Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

20 April 2021

Clarification regarding the 2014 report "Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour"

The attached report was completed in 2014 by the Environmental Sciences Group (ESG) of the Royal Military College (RMC). The report was prepared for the Cataraqui River Stakeholders Group (CRSG), which was led by Dr. Ken Reimer of ESG (now retired) with representation by Environment Canada, Fisheries and Oceans Canada, Transport Canada, CFB Kingston, Parks Canada, Ontario Ministry of Environment, Conservation and Parks, City of Kingston and Rideau Renewal Inc.

This report includes a compilation of studies on the Kingston Inner Harbour (KIH) carried out prior to 2012, as well as the results from environmental site assessments undertaken by ESG between 2006 and 2011 to map the extent of sediment contamination in the harbour and evaluate ecological risks. A detailed human health and ecological risk assessment was completed, and the results were used to identify areas of the KIH where management actions were recommended to address adverse environmental risks. The scientific approach used to assess contamination in the KIH and evaluate associated human health and ecological risks followed established frameworks and guidance for aquatic contaminated sites. The results underwent extensive peer review by technical experts within the federal government, as well as a third-party consultant.

Following release of this report in 2014, federal property owners of the KIH water lots undertook several years of follow up environmental assessments and studies, which were not completed by ESG/RMC. As of April 2021, a proposed approach for sediment management has been developed to address risks posed by contaminated sediments in the KIH. The proposed sediment management approach is based on the studies undertaken since 2014 and therefore is <u>not</u> contained in this 2014 report. This 2014 report does present some preliminary analysis of management options, but the discussion is now outdated and should be considered to be superseded by the follow up work done by others since then.

At this time, the federal property owners (Transport Canada and Parks Canada) are planning public consultation on the proposed sediment management approach for Summer 2021.

Dr. Tamsin Laing
Biologist, Aquatic Sites
Main point of contact

Dr. Iris Koch
Risk assessor

Dr. Kela Weber
ESG Director

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

February 2014
RMC-CCE-ES-14-03

STATEMENT OF LIMITATIONS

The content of this report, which includes all tables and appendices, is based on information collected during our analysis, our present understanding of the methods, and our professional judgment in light of such information available. The report provides a professional opinion on the current standing of potential hazards associated with human exposure to sediment, water and biota in the Kingston Inner Harbour (KIH). This report does not provide a legal opinion regarding compliance with applicable laws.

The services performed as described herein were conducted in a manner consistent with that level of care and skill normally exercised by other members of the science and engineering professions currently practicing under similar conditions.

The findings and conclusions are valid only as of December 22, 2013. If any conditions become apparent that differ significantly from our current understanding as presented in this report, we request that we be notified immediately to reassess the conclusion provided herein.

ACKNOWLEDGEMENTS

This report was written and produced by the Environmental Sciences Group (ESG) of the Royal Military College of Canada (RMC), under the direction of Dr. Ken Reimer. The report is the culmination of many years of work and many ESG personnel have been involved in a significant way at various stages of its development.

The sediment investigations were led by Dr. Tamsin Laing and Dr. Astrid Michels, with field assistance provided by Major David Burbridge, Esteban Estrada, Andrea Ellis, Ian Goode, Darren White, Tanya Brown, Jeremy Archer, Jeff Donald, Dean Morrow, Ryan Adams, Kristin Andruchow and Marten Devries. Laboratory analyses were carried out by the Analytical Sciences Group (ASG) at RMC and the Analytical Services Unit (ASU) of Queen's University, Kingston, ON. Logistical support for ESG field activities was provided by Kim House, Kathleen Francis and Jasmine King.

The report was written by Dr. Tamsin Laing, Dr. Iris Koch, Dr. Astrid Michels, Megan Lord-Hoyle, Dr. Guilhem Caumette, Major David Burbridge, Jennifer Joubert and Carol Luttmer. Technical review was provided by Dr. Ken Reimer, Viviane Paquin (project management) and Susie Rance (editing). Jeremy Archer and Jeffrey Donald produced the maps, while Pat Fortin performed the data compilation and data QA/QC review. Bill Duffe produced the graphic design. Financial administration of the project was overseen by Nancy Langevin and Deborah Reimer.

ESG would also like to acknowledge all those who participated in the peer review process for this report. In particular, ESG acknowledges FCSAP expert support personnel for their in-depth review and thoughtful comments.

ESG would also like to thank members of the Cataraqui River Stakeholder Group (Parks Canada, Transport Canada, City of Kingston, Ontario Ministry of the Environment, Environment Canada, Fisheries and Oceans Canada, Canadian Forces Base Kingston and Rideau Renewal Inc.) for their financial and in-kind contributions to this project.

EXECUTIVE SUMMARY

The Kingston Inner Harbour (KIH) is located at the mouth of the Great Cataraqui River where the river discharges into Lake Ontario. It comprises the final 2.5 km stretch of the river between Highway 401 to the north and the LaSalle Causeway to the south. The KIH has been part of the Rideau Canal waterway, a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage Site since 2007.

Over the past thirty years, the KIH has been the subject of many scientific investigations because of significant sediment chemical contamination caused by former industrial activities. In 1999, the Environmental Sciences Group (ESG) of the Royal Military College of Canada (RMC) in Kingston began investigating the river sediments of the KIH as a scientific project and, in 2006, ESG formed the Cataraqui River Stakeholder Group (CRSG) to address concerns about potential adverse biological effects posed by the sediment contamination.

The CRSG includes all of the key stakeholders having a direct interest in the environmental status of the Cataraqui River sediments. Current members of the CRSG are the two custodial departments, Parks Canada and Transport Canada, the City of Kingston, Environment Canada (EC), Fisheries and Oceans Canada (DFO), Health Canada (HC), the Ontario Ministry of the Environment (OMOE), Canadian Forces Base Kingston and ESG. Under the guidance of the stakeholder group, ESG has continued to conduct studies in the KIH to refine understanding of the nature and extent of the sediment contamination and the area requiring management action. Because the custodians of the KIH water lot are federal, the sediment assessment and decision-making process has followed the Federal Contaminated Sites Action Plan (FCSAP) ten-step process for addressing a contaminated site.

In addition to leading scientific studies within the KIH, ESG amalgamated the extensive amount of data that has been collected by other institutions such as the OMOE and the City of Kingston, as well as data collected in studies conducted on behalf of the custodial departments. The studies show that the sediment contamination has the potential to cause biological effects to human and ecological receptors through direct contact with the sediment and through ingestion of contaminated foods. The study results have been written up in this five-chapter report entitled "Application of the Canada-Ontario Decision-making Framework for Contaminated Sediments in the Kingston Inner Harbour." Each chapter has been extensively peer-reviewed by all three FCSAP expert support departments (EC, DFO and HC) as well as by third-party consultants contracted by the custodial departments Parks Canada and Transport Canada. Peer review comments and ESG responses to them are included in Appendix M of the report for reference.

The scientific approach used to assess contamination in the KIH and develop sediment management objectives follows established frameworks consistent with FCSAP guidance and current recommended scientific practice. As is typical for environmental investigations, an iterative process was used to assess sediment contamination, biological effects and associated human health and ecological risks. Data gaps were identified at each stage, through scientific

review and peer review from the FCSAP expert support departments as well as input from the CRSG. Additional information was collected throughout the project to address these gaps, decrease uncertainties and provide realistic exposure scenarios for the KIH. The frameworks used to guide the process include the following:

- Framework for addressing and managing aquatic contaminated sites under the FCSAP program: A ten-step approach that provides overall guidance for addressing federal aquatic contaminated sites.
- The Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment (COA). This was used to assess the sediments of the KIH under steps 2 to 6 of the FCSAP aquatic sites framework (sediment and biological assessment).
- Human health and ecological risk assessment (HHERA). An appropriate assessment methodology was used to evaluate the risks to humans and upper-trophic-level receptors from contaminant bioaccumulation in the KIH aquatic food webs. The current KIH human health risk assessment has been confirmed by Health Canada to be a detailed quantitative human health risk assessment (HHRA); the KIH ecological risk assessment is consistent with standard practice in the field.
- FCSAP Aquatic Sites Classification System (ASCS): Information from the COA assessment and the HHERA was used to classify the site.

As confirmed with the CRSG, the main risk management/remedial goal for the KIH is the protection of human health and ecological integrity. The detailed scientific investigations conducted in the KIH have provided a large amount of data that may be used confidently by site managers to make a risk management decision. The amalgamated data presented in the KIH report are comparable to and in some cases exceed the information used at other aquatic sites to make remedial decisions. While ambiguities in benthic community responses are common in aquatic projects, in cases such as the KIH where contaminant bioaccumulation in the aquatic food web poses unacceptable risks to human and ecological receptors, the benthic community responses do not preclude making remedial decisions. To this end, the results of the HHERA were used to develop the sediment quality objectives (SeQOs) for the KIH, which are presented in Chapter V of this report. This approach is consistent with the FCSAP aquatic contaminated sites framework, which strongly recommends that site-specific numeric remediation objectives be developed based on the outcomes of an HHERA to protect human health and the environment.

The five chapters in this report summarize everything that is known about the harbour. Details on past historical activities, sediment contamination patterns and biological uptake of contaminants are summarized in the first three chapters. The results of the HHERA are presented in Chapter IV and a remediation options analysis and a proposed sediment management strategy for the KIH are presented in Chapter V. A brief summary of each chapter follows.

Chapter I Summary

A historical review of all existing information, including previous scientific investigations, is summarized in Chapter I. A variety of historical industrial and commercial activities along the western shore of the KIH have resulted in contamination of sediments in the portion southwest of Belle Island. In 1832, with the completion of the Rideau Canal, Kingston became a major port on the Great Lakes and an important economic centre in Upper Canada. Industrial operations along the western shore included shipbuilding, locomotive building, a coal gasification plant, a lead smelter, a tannery, battery-manufacturing plants, a variety of mill works, fuel gas stations, a woolen mill and waste disposal sites. After the construction of the St. Lawrence Seaway, the port facilities were used less and the industries fell into the decline; the last of these was closed in the mid-1980s.

Over the past 40 years, many studies have been performed to determine the environmental status of the KIH. These investigations included surveys of physical characteristics, geology, hydrology, land use, flora and fauna, water and sediment quality, sediment pore water and biological effects. According to the literature review, major probable sources of historical contamination along the western shoreline were (1) the Frontenac Lead Smelter, contributing to aerial distribution of lead, copper and zinc; (2) the Davis Tannery, discharging chromium-contaminated wastewater into the adjacent Orchard Street Marsh, which is hydrologically connected with the river; (3) smelting operations in the area north of the former Woolen Mill, a potential source of arsenic and mercury; and (4) the former municipal landfill site at Belle Island, a suspected source for polychlorinated biphenyls (PCBs).

Most of the biological surveys performed in the KIH area were carried out in the 1970s and 1980s by the Ontario Ministry of Natural Resources (MNR). The KIH area provides fish habitat for a variety of sport and forage fish species and has been identified as an area of major importance for migratory birds in spring and fall. Endangered and threatened species and species of concern listed either provincially or federally are king rail, loggerhead shrike and Henslow's sparrow (endangered); Blanding's turtle, least bittern and stinkpot turtle (threatened); and black tern, snapping turtle and northern map turtle (species of concern).

The Cataraqui River can be characterized as a eutrophic, alkaline system, with generally good water quality that meets provincial and federal water quality objectives. Aquatic vegetation is dominated by Eurasian watermilfoil, an invasive species. The sediments are organically rich and are composed mainly of silt and clay. Previous investigations of sediment quality have identified the area south of Belle Park and along the western shoreline as an APEC (area of potential environmental concern). Concentrations of arsenic (As), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), zinc (Zn), antimony (Sb), PCBs, dichlorodiphenyltrichloroethane (DDT), chlordane and polycyclic aromatic hydrocarbons (PAHs) are the main contaminants of potential concern (CoPCs) in the APEC.

Data on biological effects suggest that benthic communities south of Belle Park may be impaired. Several studies indicate that aquatic biota collected south of Belle Island have elevated levels of PCBs. Average concentrations of PCBs in some sport fish species (bullhead, carp, pike, walleye, largemouth bass, and pumpkinseed) are in excess of the relevant fish consumption guidelines for the protection of human health. Toxicity studies are limited in spatial distribution and have been performed on a variety of test organisms and exposure times, making comparisons of the data difficult.

Overall, the historical review of the KIH confirms that the legacy of contamination from historical industrial activities persists into the present day and indicates the need to investigate in more detail the link between contaminant exposure and biological effects. Study gaps include identification of the toxicity of sediment contaminants to benthic organisms, assessment of impairment to the benthic community structure, analysis of biological uptake of contaminants into higher-trophic-level organisms and assessment of potential health risks to human and biological receptors. These data gaps were investigated by ESG under the guidance of the CRSG and are addressed in the subsequent chapters.

Chapter II Summary

The lateral and vertical extent of sediment contamination is investigated further in Chapter II. Potential reference sites for evaluating the extent of contamination in the APEC were identified based on similar physical and chemical characteristics and available information on historical activities. Studies confirmed that the area of the KIH that is upstream from Belle Island is suitable as a reference site to assess the extent of anthropogenic inputs and potential ecological impacts in the APEC.

CoPCs were identified by comparing chemical concentrations measured in sediment samples with the Canadian Council of Ministers of the Environment (CCME) aquatic sediment quality guidelines (SQGs). Contaminant plume maps were generated using interpolation software. The mean and maximum concentrations of CoPCs at sites in the APEC were compared with the means and maxima at reference sites.

Seven inorganic contaminants, two organic pesticide contaminants and two groups of organic contaminants are present at levels above guidelines in the surficial sediments of the APEC. Cr, Pb, Zn, Cu, Hg, As, total DDT, chlordane and PCBs are above the CCME probable effect level (PEL). Additionally, total PAHs are above OMOE sediment quality guidelines (lowest effect level (LEL)) and exceed the severe effect level (SEL) at several locations, and Sb is above soil quality guidelines. Some of these contaminants, such as PCBs, DDT, chlordane and organic Hg, may biomagnify. Statistical tests demonstrated that mean concentrations of Cr, Pb, Cu, As, Zn, PCBs and PAHs in the APEC are statistically different from mean concentrations at reference sites located upstream of Belle Park; means for all of these CoPCs except Zn are also more than 20 percent above the reference mean.

Subsurface Cr, Pb, Hg and PCB contamination from historical activities has been confirmed to be present. Deeper sediments generally have higher concentrations of the CoPCs. However, chromium profiles from cores collected south of Belle Island, adjacent to the former Davis Tannery property, show that Cr concentrations are relatively uniform, ranging from 500 to 1,500 ppm in the top 20 to 30 cm. The absence of lower levels of Cr in the sediments near the surface suggests that little dilution with clean sediments is occurring at the surface because of low-energy flow and continuous sediment mixing and resuspension of contaminated sediments. This conclusion is supported by radioisotopic analyses and suggests that the potential for natural recovery of surface sediments in the KIH through sediment burial and physical isolation of the contaminated layer is limited. Furthermore, continued resuspension of historical contaminated sediments and movement of these sediments into the eastern parts of the KIH is most likely occurring.

Chapter III Summary

Chapter III evaluates whether exposure to CoPCs in the APEC is having effects on biota living in or associated with the sediments. The evaluation of biological effects in the KIH was done using the three lines of evidence (LOEs) as recommended by the COA framework: (1) modelling or measurement of contaminant concentrations in the aquatic food web to assess whether biomagnification is a potential concern; (2) laboratory bioassays using several sediment-associated species to assess sediment toxicity; and (3) assessment of benthic (i.e., sediment-dwelling) invertebrate community structure.

Aquatic macrophytes, cattails, benthic invertebrates and fish sampled from the KIH show consistent evidence for bioaccumulation of contaminants such as Cr and PCBs from the southwest portion of the KIH. According to available tissue residue guidelines for assessing biota contaminant concentrations, field invertebrate and fish biota in this area of the harbour generally exceed the relevant guidelines, indicating a potential risk to wildlife consumers of aquatic biota. In contrast, aquatic biota from areas north of Belle Park and in the southeastern KIH do not appear to be accumulating contaminants to the same degree. Following the COA framework under Step 4a, the data strongly indicate that there is potential for contaminant biomagnification from the sediments through aquatic food chains in the southwest portion of the KIH. The potential risk to upper-trophic-level consumers and humans from this contaminant uptake is evaluated and presented in Chapter IV.

According to the criteria outlined in the COA framework, there is mixed evidence for benthic invertebrate toxicity in the southwestern portion of the KIH. Sediments in the vicinity of Anglin Bay and Douglas R. Fluhrer Park appear to have the greatest potential for adverse effects on benthic communities, with eight of 14 stations in this area showing evidence of minor or major toxicity effects. Although most samples showed negligible toxicity to benthic organisms, approximately one quarter of the stations sampled in the remaining southwestern KIH (Parks Canada water lot, northern Transport Canada water lot and west central KIH) had minor toxicity effects. In contrast, there is no evidence of toxicity for samples collected from other areas of the

KIH with lower concentrations of sediment contaminants, such as the area north of Belle Park or the southeastern portion of the KIH. Determining causality for the observed toxicity effects is challenging when there are multiple contaminants present, as is the case for the KIH. Toxicity identification evaluation (TIE) tests were carried out by Golder Associates for two samples collected in the vicinity of Anglin Bay which showed major toxic effects for at least one endpoint. The tests were inconclusive for one sample, but they suggested that toxicity in the other sample could be due to photoreactive PAH compounds as well as the combined effects of multiple toxicants.

Benthic communities in the KIH are dominated by organisms that are tolerant of organic (i.e., nutrient) pollution. For the studies done to date, benthic communities at 20 stations in the southern KIH were equivalent to reference condition, benthic communities at 15 stations were possibly different from reference condition and benthic communities at one station were significantly different from reference condition. Although several stations on the Parks Canada water lot and the northern portion of the Transport Canada water lot showed possible benthic community effects, most of the stations exhibiting adverse effects were located in the vicinity of Anglin Bay and the northern part of Douglas R. Fluhrer Park. Two stations in the southeastern portion of the KIH close to HMCS Cataraqui also showed potential benthic community effects. Multivariate analyses performed by ESG suggested that differences in the invertebrate community structure can be explained by environmental variables related to habitat (e.g., grain size, macrophyte abundance) and to contamination variables such as sediment Cr concentrations.

Overall, the three biological LOEs show consistent evidence of ecological effects for benthic communities in the southwestern portion of the harbour. Biological uptake studies have indicated that biota from the southwest KIH are accumulating contaminants more than those found in other areas. Through studies to evaluate sediment toxicity and benthic community structure effects, it was determined that adverse effects are likely for areas in the vicinity of Douglas R. Fluhrer Park and Anglin Bay, while potential effects were identified for the Parks Canada water lot south of Belle Park. The lack of evidence for adverse ecological effects north of Belle Island and in the central and eastern portions of the southern KIH indicates that no further action is necessary in these areas.

Chapter IV Summary

A complementary ecological and human health risk assessment to evaluate the potential risks to upper-trophic-level consumers and humans for the KIH is presented in Chapter IV of this report. The objective of the HHRA was to assess potential risks to human health during recreational use of the harbour (i.e., swimming, rowing, canoeing, walking along the shoreline, picnicking and sport fishing). The risk assessment followed standard Health Canada guidance for conducting HHRAs. Water, sediment and fish tissue contaminant concentration data for the southwest portion of the KIH were screened against available guidelines and/or concentrations at upstream reference sites to identify CoPCs for the risk assessment. Comparison of APEC water contaminant concentrations with drinking water guidelines provided by Health Canada indicated that all contaminants were below criteria, suggesting negligible risk to human health via dermal contact or incidental ingestion of water from the KIH. Sedimentary As, Cu, Cr, Hg, Pb, Zn, Sb, DDT, chlordane, PCBs and PAHs were carried forward in the risk assessment. Only PCBs were carried forward for fish tissue because concentrations of the other CoPCs in the APEC were not significantly different from concentrations at the reference site. Exposure pathways for sediment were assumed to be through dermal contact and incidental ingestion while swimming, playing along the shoreline, rowing or canoeing; the main exposure pathway for contaminated fish tissue was considered to be consumption of fish caught in the KIH.

Exposure scenarios used for the HHRA assumed that adult, child and toddler receptors would be swimming in the KIH 61 days per year. The fish ingestion rate used for calculating potential risks from fish consumption was based on OMOE's sport fish questionnaire, which identified that recreational fishers in the Great Lakes consume an average of 39 meals of 236 g each of sport fish per year.

The risk assessment outcomes indicated that all receptors face potential risks for non-cancer effects from the concentrations of PCBs, while the child and toddler receptors are also at potential risk from As, Pb, inorganic Hg and Sb. The main driver for risk to PCBs is through consumption of fish, whereas it is a combination of ingested and dermal sediment exposure for the inorganic CoPCs. When background exposures to inorganic CoPCs were included, risk for non-cancer effects was negligible for As, Pb and Hg, but background exposures alone contributed to unacceptable risk for Sb. Potential carcinogenic health risks were evident for As and PAHs. For As, the carcinogenic risk is through sediment ingestion. For PAHs, the carcinogenic risk is through dermal exposure.

The objective of the ecological risk assessment (ERA) was to evaluate the potential ecological risks to upper-trophic-level organisms for the southwest portion of the KIH, and its scope included the Orchard Street Marsh, located between the former Davis Tannery property and the southern edge of Belle Park. These two areas were considered together for the ERA because the considered ecological receptors use the entire area. The screening ERA followed Environment Canada guidance for conducting ERAs at FCSAP sites. Selected receptors for the ERA included fish (brown bullhead, yellow perch and northern pike), piscivorous mammals (mink), waterfowl (mallard duck) and piscivorous birds (osprey, great blue heron). In recognition of their importance to the ecology of the APEC, reptiles and amphibians were also included within the conceptual site model (CSM); however, it was not possible to calculate risk for these species as dose-based toxicological reference values (TRVs) are currently not available in toxicology literature. Herbivorous animals (mammal: muskrat; bird: red-winged blackbird) were also included in the CSM but were not further assessed because their habitat is limited to the Orchard Street Marsh, whose individual assessment is outside the scope of the present ERA. To calculate potential ecological risks through ingestion of contaminated food items, available data on As, Cr, Cu, Hg, Pb, Zn, Sb, DDT, chlordane, PCB and PAH concentrations in sediment were used, along with fish tissue data (all CoPCs excluding chlordane and PAHs) and macrophyte data (all CoPCs excluding Hg and pesticides). Data for invertebrates were available for Cr only; all other concentrations in biological tissue (fish and invertebrates) were modelled.

For mammal and bird receptors, risk calculations indicated that mallard ducks are potentially at risk because of dietary (invertebrate) Cr(III) ingestion. Mink are potentially at risk because of exposure to PCBs in fish tissue. For fish, field observations of the brown bullhead noted in the APEC a high frequency of morphological abnormalities (i.e., tumours and other deformities), which appeared rare at the reference site. The only apparent difference between the two sites is the presence of elevated concentrations of CoPCs in the sediments of the APEC, suggesting that the contaminated sediments pose an ecological risk for this species. Risk calculations comparing fish tissue CoPC concentrations with published fish toxicity thresholds suggest that the fish community in the APEC is not at risk; however, the available fish toxicity thresholds are not specific to brown bullheads In addition, toxicity thresholds do not account for possible additive or synergistic effects resulting from the complex mixture of contaminants in the APEC; therefore, the assessed risk may be greatly underestimated.

The KIH HHERA has identified that there are both potential human health risks and potential ecological risks from sediment and biological contamination in the southwest portion of the KIH. Management actions are needed to address unacceptable risks posed by the contaminated sediments in this area. Further work to define the extent of the area requiring management action, as well as an options analysis for the site, is presented in Chapter V of this report.

Chapter V Summary

The three prerequisites to be considered in risk management, according to FCSAP, are to determine causation for biological effects, control ongoing contaminant sources and ensure that remedial actions do not cause more environmental damage than they remedy. For the KIH, causation is demonstrated through a strength-of-evidence approach based on ecological impairments (sediment toxicity, benthic community impairment, bioaccumulation, deformities in brown bullhead and the potential for adverse health effects to human and ecological receptors) that together indicate the need for sediment management. The Emma Martin Park/Rowing Club property, the former Davis Tannery site, the Kingscourt storm sewer and the Belle Park Landfill are examined in terms of being potential ongoing sources of contaminants to the KIH. Evidence to date indicates that the legacy contamination in Cataraqui River sediments is the main source of bioavailable contaminants to the river ecosystem and that there are no significant inputs from current terrestrial sources. Storm sewers have the potential to flush urban runoff and contaminated sediments from the Orchard Street Marsh into the KIH; it is therefore recommended that the remediation of the river sediments occur in conjunction with a plan for stormwater management and cleanup of the Orchard Street Marsh. Management options must assess the potential short-term (i.e., during dredging) and long-term (i.e., post-dredging) benefits and negative impacts. Potential impacts and mitigation measures as they relate to species at risk identified in the KIH and to fish habitat are discussed; these should be addressed as part of the environmental assessment process for remedial activities.

A remedial options analysis for the KIH considered no action, institutional controls, and a comparison of three remediation approaches (monitored natural recovery (MNR), capping and dredging) based on their feasibility, effectiveness and ease of implementation. MNR was not chosen as a primary remedial option because of continual mixing and resuspension of contaminated sediments in the KIH, which means that the contaminated sediment is not isolated through burial with clean sediments fast enough to allow natural recovery. Sediment capping is not considered a suitable remedial method for the KIH because of the shallow water depths, potential erosive processes, potential for long-term maintenance requirements and unsuitability for current and anticipated use of the harbour. Dredging was determined to be the preferred remedial strategy to treat contaminated sediments in the KIH, given its feasibility and effectiveness, lack of long-term maintenance issues and general acceptance of this approach by the public.

A practical limit for vertical removal of sediment is defined by the sediment stratigraphy. For most of the harbour, the vertical depth of contamination corresponds closely with the depth of the organic gyttja. Dredging specifications may therefore specify removal of the sediments to the underlying clay layer that is present throughout much of the harbour. In the southwest corner of the harbour, at the mouth of the Kingscourt storm sewer discharge, dredging into the peat layer would possibly be required as the most elevated contaminant concentrations occur at greater depths (55 to 60 cm).

The primary objective of the KIH sediment management strategy is to reduce human and ecological risks posed by the contaminated sediments to acceptable levels. Accordingly, a risk-based approach was used to develop site-specific SeQOs for those upper-trophic-level ecological and human receptors and contaminants of concern (CoCs) determined in the KIH HHERA to pose potential risk. Risk-based SeQOs to address risks to the toddler through incidental sediment ingestion and dermal contact with sediments were calculated for As (SeQO = 6 ppm), Sb (SeQO = 6.9 ppm) and PAHs (SeQO = 0.007 to 0.1 ppm). As achievement of the PAH risk-based SeQOs is not feasible, a shoreline management area along the western shoreline was designated based on recreational use (wading and swimming) and PAH contaminant profiles.

Risk-based SeQOs for Cr (SeQO = 1160 ppm) were calculated to address potential risks to mallard ducks from food ingestion. A food web model was used to calculate risk-based SeQOs for PCBs (SeQO = 0.64 ppm) to address risks to toddler receptors and mink through fish consumption and incorporated estimates of background exposure. However, given the uncertainties inherent in the food web modelling and the relatively small risk reduction, sediment management for PCBs may not be warranted. Based on the proposed sediment management strategy the total area warranting sediment management to achieve acceptable risks to human and wildlife consumers of fish corresponds to 27 ha. The estimated total volume of sediments to be managed is 91,000 m^3.

A similar approach was presented by ESG in June 2010 at a workshop involving members of the CRSG and FCSAP expert support. The consensus by the group was that the site assessment, data analyses and approach presented by ESG were reasonable and appropriate for the KIH property, and a risk-based approach for developing remedial sediment quality objectives was endorsed at that time.

Next Steps

Early in the formation of the CRSG, stakeholder members identified some project aims to guide the assessment and sediment decision-making process for the KIH. These aims, which were endorsed at successive meetings, were to identify risks to human and ecological health, delineate areas of unacceptable risk, identify sustainable, risk-based remediation options for ensuring the protection of human and ecological health, and engage the community throughout the remediation process. It is anticipated that this finalized report, which marks the completion of the scientific investigation of the KIH sediments, will serve to facilitate discussions around the development of a public communication strategy and a remedial and risk management action plan that minimizes unacceptable risks and eventual implementation of a sediment cleanup strategy.

GLOSSARY AND ABBREVIATIONS

ºC	degrees Celsius
ηg	nanogram
ηm	nanometre
µg	microgram
95UCL	95-percent upper confidence limit
AAS	atomic absorption spectrometry
Ad	aldebaranium
Ag	silver
AI	adequate intake
Al	aluminum
ANOSIM	analysis of similarities
AO	aesthetic objective
AoC	area of concern
APEC	area of potential environmental concern
Ar	argon
As	arsenic
ASA	archaeologically sensitive area
ASCS	Aquatic Sites Classification System
ASD	Analytical Sciences Division (ESG)
ASG	Analytical Sciences Group (Royal Military College of Canada, Kingston, ON)
ASTM	American Society for Testing and Materials
ASU	Analytical Services Unit (Queen’s University, Kingston, ON)
ASWG	Aquatic Sites Working Group
Ba	barium
BEAST	Benthic Assessment of Sediment
BMF	biomagnification factor
BOD	biological oxygen demand
BSAF	biota-sediment bioaccumulation factor
BW	body weight
Ca	calcium
CABIN	Canadian Aquatic Biomonitoring Network
CALA	Canadian Association for Laboratory Accreditation Inc.
CBR	contaminant body residue
CCME	Canadian Council of Ministers of the Environment
CCREM	Canadian Council of Resource and Environment Ministers
Cd	cadmium
CEPA	Canadian Environmental Protection Act
CFB	Canadian Forces Base
CFIA	Canadian Food Inspection Agency
cm	centimetre
CN Railroad	Canadian National Railroad
COA framework	Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment
CoC	contaminant of concern
CoPC	contaminant of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
Cr	chromium
Cr_2O_3	chromium(III) oxide
CRSG	Cataraqui River Stakeholder Group
C_s	soil concentration
CSF	cancer slope factor
CSM	conceptual site model
CSO	combined sewer overflow
CSMWG	Contaminated Sites Management Working Group
Cu	copper
D_1, D_2, D_3, LE	exposure time factors
DCBP	decachlorobiphenyl
DELTs	deformities, erosions, lesions, tumours
DFO	Fisheries and Oceans Canada
DLCC	DEW Line Cleanup Criteria

DCM	dichloromethane
DCS	Decommissioning Consulting Services Ltd.
DDD	dichlorodiphenyl dichloroethane
DDE	dichlorodiphenyl dichloroethylene
DDT	dichlorodiphenyl trichloroethane
DELTs	deformities, erosions, lesions, tumours
DEW	Distant Early Warning
DGE	Directorate (or Director) General Environment
DLCU	DEW Line Cleanup
DLPCB	dioxin-like PCB
DQRA	detailed quantitative risk assessment
DSL	Domestic Substances List
dw	dry weight
EA	environmental assessment
EC	Environment Canada
ECD	electron capture detection
ED	exposure duration
EDI	estimated daily intake
EF	exposure frequency
EOX	extractable organic halides
EPA	Environmental Protection Area
EPC	exposure point concentration
EPC_{fi}	exposure point concentration of the receptor's *i*th dietary food item
EPC_{sed}	exposure point concentration of sediment
EPC_{w}	exposure point concentration of water
EPT	Ephemeroptera, Plecoptera and Trichoptera
ERA	ecological risk assessment
ESG	Environmental Sciences Group (RMC)
ESQT	Enhanced Sediment Quality Triad
ET	exposure time
ETF	viable cellular epidermal thickness factor
EWG	Environmental Working Group (DND/NTI)
F	fluoride or fluorine
F	fraction of lifetime represented
FBI	Family Biotic Index
FCSAP	Federal Contaminated Sites Action Plan
FDR	Food and Drug Regulation
Fe	iron
F_i	fraction of the receptor's diet that the *i*th food item comprises
FID	flame ionization detection
FIR	food ingestion rate
FPXRF	field portable x-ray fluorescence analyzer
F_{sed}	fraction of the receptor's diet that sediment comprises
F_{site}	fraction of the receptor's diet that is harvested from the APEC
g	gram
GC	gas chromatography
GC/ECD	gas chromatography/electron capture detection
GC/MS	gas chromatography/mass spectrometry
GIS	geographic information system
GLWQA	Great Lakes Water Quality Agreement
H_2O_2	hydrogen peroxide
ha	hectare
HC	Health Canada
HCB	hexachlorobenzene
HCH	hexachlorocyclohexane
HCl	hydrochloric acid
Hg	mercury
HG	hydride generation
HHERA	human health and ecological risk assessment
HHRA	Human health risk assessment

HI	hazard index
HMCS	Her Majesty's Canadian Ship
HMW-PAH	high-molecular-weight-PAH
HNO_3	nitric acid
HPC	heterotrophic plate count
HQ	hazard quotient
HS-1	NRC Marine Reference Standard
ICP-AES	inductively coupled plasma atomic emission spectroscopy
ID_{20}	inhibitory dose resulting in 20% reduction of an endpoint relative to a control
IDW	Inverse Distance Weighted (interpolation)
IJC	International Joint Commission
ILCR	incremental lifetime cancer risk
IMAC	interim maximum acceptable concentration
IOM	Institute of Medicine
IR_{fish}	ingestion rate — tissue
IRIS	Integrated Risk Information System
$IR_{sediment}$	ingestion rate — sediment
$IR_{suspended\ sediment}$	ingestion rate — suspended sediment
IR_{water}	ingestion rate — water
ISQG	Interim Sediment Quality Guidelines
K	potassium
KIH	Kingston Inner Harbour
L	litre
LADD	lifetime average daily dose
LaMP	Lake-wide Management Plan
leachate	substance (usually in solution) migrating from a more concentrated source
LEL	lowest effect level
LMW-PAH	low-molecular-weight-PAH
LOAEL	lowest observed adverse effects level
LOE	line of evidence
M	molar
m/s	metres per second
MAC	maximum acceptable concentration
Max_{imp}	maximum concentration from the impaired site
Max_{ref}	maximum concentration from the reference site
MDS	(non-metric) multidimensional scaling
MeHg	methylmercury
MENVIQ	Ministère de l'environnement du Québec
MESS-2	NRC Marine Reference Standard
MESS-3	NRC Marine Reference Standard
mg	milligram
Mg	magnesium
Mg	manganese
MID	multiple ion detection
mL	millilitre
mm	millimetre
Mn	manganese
MNR	monitored natural recovery
Mo	molybdenum
MS	mass spectrometry
MS	mass spectroscopy
MS_{fish}	average meal size — fish
N/A	not applicable
Na	sodium
NA	not analyzed
NAA	neutron activation analysis
$NaBH_4$	sodium borohydride
NaOH	sodium hydroxide
NBS	National Bureau of Standards (U.S.)
ND	not detected
NDR	not detected reliably
Ni	nickel
NIST	National Institute of Standards and Technology
NOAEL	no observed adverse effects level
NOL	no effect level
NRC	National Research Council
NTU	nephelometric turbidity units

OMNR — Ontario Ministry of Natural Resources
OMOE — Ontario Ministry of the Environment
P&T — purge and trap
PAH — polycyclic aromatic hydrocarbon
PAP — PCB-amended paint
Pb — lead
PCA — principal components analysis
PCB — polychlorinated biphenyl
PCDDs/PCDFs — polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans
PEF — potency equivalence factors
PEF_{PAH} — potency equivalence factors — PAHs
PEL — probable effect level
permafrost — ground remaining below zero through two or more consecutive winters and intervening summer (not necessarily frozen)
POL — petroleum, oil, lubricants
ppb — parts per billion; equivalent to ηg/g (nanograms of substance per gram of soil or sediment sample) and μg/L (micrograms of substance per litre of aqueous solution)
ppm — parts per million; equivalent to μg/g (microgram of substance per gram of soil or sediment sample) and mg/L (milligrams of substance per litre of aqueous solution)
ppt — parts per trillion; equivalent to pg/g (picograms of substance per gram of soil or sediment sample) and ηg/L (nanograms of substance per litre of aqueous solution)
PSE — pressurized solvent extractor
PSQG — Guidelines for the Protection and Management of Aquatic Sediment Quality
PVC — polyvinyl chloride
PWQMN — Provincial Water Quality Monitoring Network
PWQOs — Provincial Water Quality Objectives
RAF — relative adsorption factor
RAF_{AS} — relative retention factor for B[a]P in a soil monolayer compared to acetone
RAF_{derm} — skin adsorption of B[a]P from soil relative to acetone
RAP — remedial action plan
RDA — recommended daily allowances
RfD — reference dose
RMC — Royal Military College of Canada
ROC — receptor of concern
$SA_{arms+legs}$ — exposed surface area — other
SA_{body} — total body surface area
$SA_{body-hands}$ — exposed surface area body — hands
SA_{EXP} — surface area of exposed skin
$SAF_{arms+legs}$ — soil adherence factor - body
SA_{feet} — exposed surface area — feet
SAF_{hand} — soil adherence factor — hand
SA_{hand} — exposed surface area — hand
SARA — Species At Risk Act
$SA_{SL\ EXP}$ — surface are of skin loaded with a monolayer of soil
$SA_{ST\ EXP}$ — surface area of mouse skin dosed with B[a]P in acetone
Sb — antimony
SC — sewer core
Se — selenium
Sed-FM — sediment to fathead minnow uptake
SEL — severe effect level
SeQO — sediment remediation quality objectives
Si — silicon

SiO_2	silicon dioxide
SL	sediment loading factor
SL_{feet}	sediment loading factor — feet
SL_{hand}	sediment loading factor — hand
SM	soil monolayer loading rate
SMA	special management area
Sn	tin
$SnCl_2$	tin chloride
SPMD	semi-permeable membrane device
SQG	sediment quality guideline
SS-2	NRC Marine Reference Standard
SSTL	site-specific target level
SVOC	semi-volatile organic compound
SWAC	spatially weighted average concentration
TDI	tolerable daily intake
TDS	total dissolved solids
TEF	toxic equivalence factors
TEL	threshold effect level
TEQ	toxic equivalency
TEQ_{MAM}	toxic equivalents — mammalian
Ti	titanium
TIE	toxicity identification evaluation
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TP	total phosphorus
TPH	total petroleum hydrocarbons
TRA	tissue residue approach
TRV	toxicological reference value
TRV_{PAH}	toxicological reference value — PAHs
TSS	total suspended solids
U.S.	United States
UF	uncertainty factor
UL	tolerable upper intake level
UNESCO	United Nations Educational, Scientific and Cultural Organization
US EPA	United States Environmental Protection Agency
VEC	valued ecosystem component
VOC	volatile organic compounds
WAC	Washington Administrative Code
WESA	Water and Earth Science Associates Ltd.
WHO-IARC	World Health Organization—International Agency for Research on Cancer
WIR	water ingestion rate
WOE	weight of evidence
ww	wet weight
XRF	x-ray fluorescence (spectroscopy)
Zn	zinc

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Chapter I: Literature Review of the Environmental Status of the Kingston Inner Harbour

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT`D

LIST OF FIGURES

LIST OF TABLES

I. BACKGROUND AND OBJECTIVES

The Kingston Inner Harbour (KIH) is located at the mouth of the Great Cataraqui River, where the river discharges into Lake Ontario (Figure I-1). The river is a significant natural feature and is adjacent to the City of Kingston's downtown core. Historically, the lands were heavily industrialized, particularly on the western shore south of Belle Island (approximately 1.6 km upstream of the river's mouth). Some historical industrial operations and waste disposal practices resulted in potentially deleterious levels of contaminated sediments in portions of the Inner Harbour. Outstanding issues for the area include management strategies for the contaminated sediments and redevelopment of the previously industrialized lands along the western shore.

Sections of the Inner Harbour are under the jurisdiction of different federal agencies (Parks Canada and Transport Canada), while the adjacent lands are owned by the City of Kingston, Department of National Defence, Parks Canada and various private parties and corporations. As is shown in Figure I-2, several land parcels extend beyond the shoreline into the KIH. Parks Canada is responsible for a small water lot (Part I, Plan 13R – 13481) located immediately southwest of Belle Island, while the remaining waterway between Belle Island and the LaSalle Causeway is under the jurisdiction of Transport Canada (Figure I-2). The 2010 Draft Official Plan for the City of Kingston shows that various portions of the KIH are Provincially Significant Wetlands and Areas of Natural and Scientific Interest (see Appendix A: City of Kingston, 2010, Schedule 7-A). Parts of the Inner Harbour have also been designated as Environmental Protection Areas (EPAs), and the Rideau Canal is a UNESCO Word Heritage Site (see Appendix A: City of Kingston, 2010, Schedule 3-A). These designations are discussed in more detail in Section III.6.b.

The Cataraqui River Stakeholder Group (CRSG) was formed in 2006 to guide the sediment assessment process and facilitate a management decision for the KIH. The CRSG is composed of the site custodians (Parks Canada and Transport Canada), the federal and provincial regulators (Environment Canada, Department of Fisheries and Oceans and the Ontario Ministry of the Environment), the City of Kingston, Kingston, Frontenac and Lennox & Addington Public Health, and other stakeholders with ownership of lands adjoining the KIH (Canadian Forces Base (CFB) Kingston, Rideau Renewal Inc.). The CRSG is facilitated by the Environmental Sciences Group (ESG), an independent, multidisciplinary research group at the Royal Military College of Canada (RMC) with core expertise in site investigations, human and ecological risk assessment and innovative remediation technologies. The stakeholder group currently meets on a quarterly basis to review available scientific information for the KIH and guide the project progress.

The following list of overall project aims for the KIH has been endorsed by the CRSG:

1. Identify risks to human and ecological health.
2. Delineate areas of unacceptable risk.
3. Identify and contain all off-site sources of contaminants.
4. Identify sustainable, risk-based remediation options.
5. Engage the community throughout the remediation process.

In the past 40 years, extensive studies have been performed on the physical characteristics, land uses, natural resources and environmental quality of the KIH and its surrounding lands. Malroz (2003) performed a data compilation and gap analysis of all available studies up to 2001 to identify what additional information was required to develop a proper management strategy for the area to reach the desired states of (1) environmental quality, (2) biological diversity, productivity and beneficial uses of the ecosystem, (3) community use of the region and (4) protection of human health. Malroz (2003) notes that "jurisdiction, responsibilities, and roles of government bodies and agencies have not been addressed and significant initiatives which affect the Inner Harbour will require the establishment of an operational/administrative framework among stakeholders and regulators." It is important that stakeholders collaborate, as management strategies cannot be determined on the basis of property boundaries. Remediation of sediments in the harbour and adjacent lands is linked, and designation of different land uses within and surrounding the KIH requires different levels of environmental quality objectives. Management decisions for the Inner Harbour must take into consideration the redevelopment of properties along the shoreline as well as ecological restoration.

The purpose of this chapter is to provide an operational/administrative framework for stakeholders to develop management decisions. The approach described here and which has been adopted by the Cataraqui River Stakeholder Group to guide the assessment and remediation decision-making process for the KIH is consistent with the "Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP)" (Chapman 2010). The assessment stages of the aquatic site framework are based on the Canada–Ontario Decision-Making Framework for Assessment of Great Lakes Contaminated Sediment (COA framework) (Environment Canada and OMOE 2008). The COA framework was designed to standardize the decision-making process for sediment assessment while also being flexible enough to account for site-specific considerations. It is based explicitly on ecological risk assessment (ERA) principles (Chapman and Anderson 2005) and is consistent with many federal agencies' contaminated site classification systems. The COA framework is described in detail in Section II. The framework involves an initial historical review and analysis of all available data to identify potential contaminant sources, pathways and receptors. This is followed by comparison of contaminant concentrations in sediments with guidelines, examination of the potential biological effects through sampling, definitive evaluation of risk using a decision matrix, and a final decision outcome that addresses management action. The decision-making process is based on a weight-of-evidence approach using the best available science. Jaagumagi and Persaud (1996) note that "due to the complexity involved in evaluating contaminated sediments, it is essential that scientists with strong expertise in sediment chemistry (chemical fate, transport and speciation), sediment toxicity testing, benthic community assessment, food chain effects, and environmental statistics assist stakeholders in the interpretation of the data."

ESG has been assessing previous data and collecting new data to implement the COA framework. ESG collaborated with expert scientists, academic institutions, private consulting companies and laboratories and provincial and federal departments to ensure that the most up-to-date and scientifically valid information was used to develop management strategies for the sediments in the KIH. ESG's objectives were to

- review all the available data,
- identify data gaps,
- collect additional data as necessary,
- integrate and interpret all of the relevant data using the COA framework, and
- present the information in report format to provide an operational/ administrative framework for stakeholders.

This chapter is a literature review and gap analysis of all available data for the KIH. It corresponds to the first step of the COA framework.

Figure I-1: Study area.

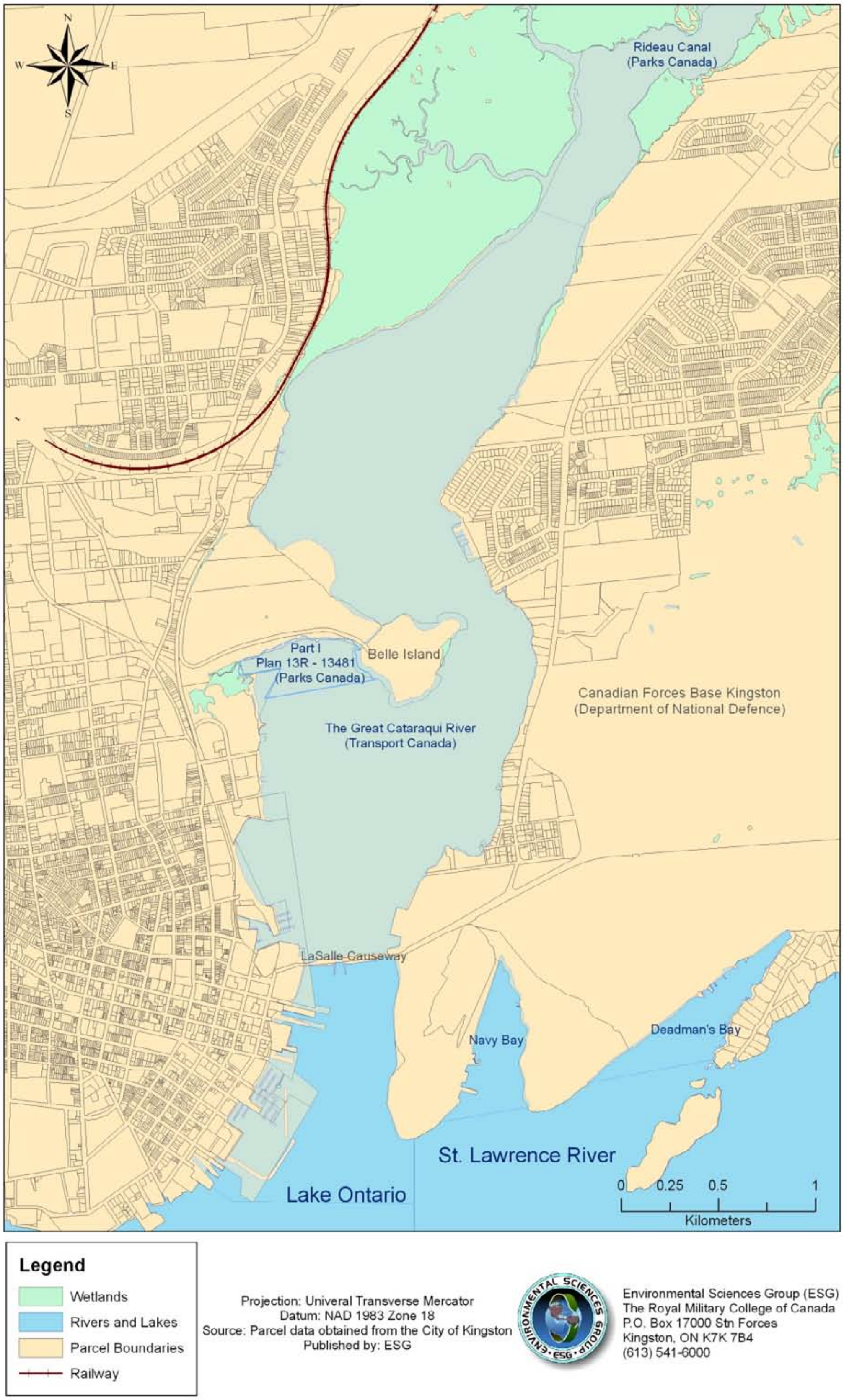


Figure I-2: Land parcel data for land and water lot.

II. The Aquatic Contaminated Sites and COA Frameworks

The “Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP)” (Chapman 2010) has been developed recently by the Aquatic Sites Working Group (ASWG), a sub-committee of the Contaminated Sites Management Working Group (CSMWG). The purpose of the framework is to provide a consistent and scientifically rigorous risk-based approach for identifying and addressing federal contaminated aquatic sites. It is closely based on the 10-step process established for the management of terrestrial contaminated sites under federal custody (CSMWG 1999), with modifications and updates relevant for aquatic sites. Scientific guidance for the assessment stages of the framework is largely based on the weight-of-evidence (WOE) approach used to address aquatic sites under the Canada–Ontario Decision-Making Framework for Assessment of Great Lakes Contaminated Sediment (Environment Canada and OMOE 2008).

The COA framework was developed recently by Peter Chapman (Golder Associates Ltd., 2011) with the COA Sediment Task Group on behalf of Environment Canada and the Ontario Ministry of the Environment (OMOE) to guide management decisions for areas of potential environmental concern (APECs) in the Great Lakes and at other aquatic sites (Environment Canada and OMOE 2008). It provides science-based step-by-step guidance to assess risks posed by contaminated sediment. The intent of the COA framework is to standardize decision-making for aquatic sites while still being flexible enough to allow for consideration of site-specific characteristics. An underlying guidance rule is that remediation alternatives will not be implemented if they cause more harm than would leaving the contaminated sediments in place. The framework uses an ecosystem approach to assess contaminated sediments, with emphasis on assessing ecological effects on sediment-dwelling organisms and other aquatic biota, as well as assessing the potential for biomagnification of contaminants throughout the aquatic food web. The framework is described in the following paragraphs and summarized schematically in Figure I-3.

Steps 1 to 3 of the COA framework (Figure I-3) correspond to a screening level ERA as defined by the Canadian Council of Ministers of the Environment (CCME) (CCME 1996). Step 1 comprises a historical review of all available data to identify potential contaminant sources, pathways and receptors. The environmental sensitivity of the site is assessed through a review of available biological information on aquatic habitats. The results of this historical review are used to guide subsequent sampling and analysis through the identification of data gaps. Step 1 of the COA framework for the KIH is summarized in Chapter I of this report.

Under Steps 2 and 3 of the COA framework (Figure I-3), chemical concentrations in surficial sediment samples are compared with aquatic sediment quality guidelines (SQGs) and with concentrations at background reference sites to determine contaminants of potential concern (CoPCs). Two decision points are reached in this section. The first decision point compares chemical concentrations with SQGs and identifies whether substances that may bioaccumulate and/or biomagnify are present in quantifiable concentrations. Bioaccumulation occurs when an organism takes up a substance faster than it can get rid of it, whereas biomagnification occurs when organisms higher on the food chain consume lower organisms that contain the chemical in question, leading to a higher chemical concentration in the consuming organism. If one or more chemicals that exceed the SQGs and/or have the potential for bioaccumulation or biomagnification are present, further assessment is undertaken. The second decision point compares chemical concentrations in site sediment samples with those from background areas (e.g., upstream reference sites). If concentrations of CoPCs and/or substances that can biomagnify are statistically higher in site samples compared with reference areas, further assessment is undertaken. Steps 2 and 3 of the COA framework for the KIH are presented in Chapter II, which summarizes contaminant concentrations and distribution patterns for sediments throughout the KIH.

Steps 4, 5 and 6 of the COA framework (Figure I-3) correspond to a quantitative ERA, in which potential ecological effects from sediment contamination are assessed through biological sampling. Three lines of evidence are examined in Step 4 as follows: modelling or measurement of contaminant concentrations in the aquatic food web to assess whether biomagnification is a potential concern; laboratory bioassays using several sediment-associated species to assess sediment toxicity; and assessment of benthic invertebrate community structure. Evidence of adverse effects for one or more of these lines of evidence prompts a decision to proceed with further assessment. Chapter III presents data on ecological effects of sediment contamination in the KIH for these three main lines of evidence.

In Step 5, a decision matrix is developed based on the weight of evidence from data collected in the assessment to date (Table I-1 and Table I-2). Evidence is generally evaluated on a station-by-station basis to define the geographic area of the site that may require management action. Expert and stakeholder groups can map the results as a tool to identify and focus on problem areas and patterns (Chapman and Anderson 2005).

Several outcomes from the decision matrix are possible: the contaminated sediments for a particular location pose a definitive environmental risk; the contaminated sediments pose a possible environmental risk but further assessment is necessary before a definitive decision can be reached; or the contaminated sediments pose a negligible environmental risk. If the second outcome arises, further detailed quantitative ecological assessment is carried out under Step 6 to provide enough data to make a definitive evaluation of environmental risk. Chapter III concludes with a decision matrix for the KIH**.** A detailed human health and ecological risk assessment (HHERA) for the KIH is presented in Chapter IV.

Step 7 examines contaminant concentrations in deeper sediments and the potential for these sediments to be exposed under reasonable circumstances. If deeper sediments contain CoPCs above the SQGs and/or one or more substances that may biomagnify and could become exposed, the COA framework from Step 1 onward is applied if necessary to assess the potential environmental risk of these sediments. Sediment contaminant concentrations at depth and their potential environmental risk are examined in Chapter II, along with the surficial sediments. In addition to examining deeper sediments, the potential for contaminant release from sediment pore water to the water column should also be investigated if sediments are likely to be disturbed. Pore water contaminant concentrations and the potential for speciation are discussed in Chapter II and the potential for remobilization of contaminants from the pore water to the water column is discussed in Chapter V as part of the remediation options analysis to evaluate whether pore water concentrations could pose an environmental risk during remediation activities.

The findings from the COA framework risk assessment are used to classify the contaminated aquatic site using the FCSAP Aquatic Sites Classification System (Appendix L) in Step 6 of the FCSAP aquatic sites framework. Sites that are classified as Class I (action required) are addressed in a risk management phase in the final four steps of the FCSAP aquatic sites framework. The results from the detailed site assessment are used to develop site-specific sediment quality guidelines or objectives for remediation and/or risk management. Chapter V presents an analysis of management options for the KIH. The results of the aquatic sites classification, as well as the extent of the area requiring management actions, are described.

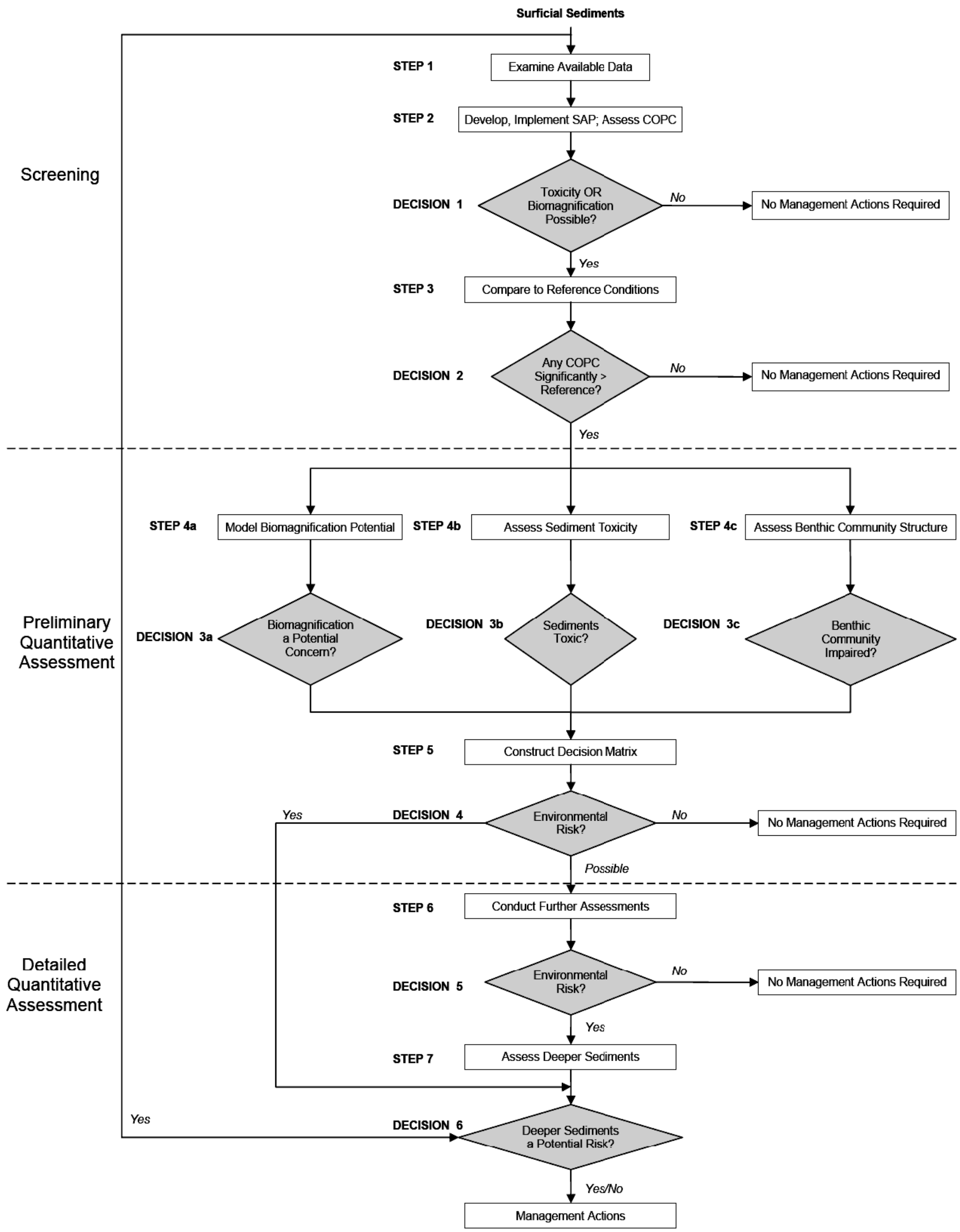


Figure I-3: Decision-making Framework for Assessment of Contaminated Sediment (EC and OMOE 2008).

Table I-1: Ordinal ranking for weight-of-evidence categorization for chemistry, toxicity, benthos and biomagnification potential as per the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment

	●	◉	○
Bulk Chemistry (compared to SQG)	Adverse Effects Likely: One or more exceedances of SQG-high	Adverse Effects May or May not Occur: One or more exceedances of SQG-low	Adverse Effects Unlikely: All contaminant concentrations below SQG-low
Toxicity Endpoints (relative to reference)	Major: Statistically significant reduction of more than 50% in one or more toxicological endpoints	Minor: Statistically significant reduction of more than 20% in one or more toxicological endpoints	Negligible: Reduction of 20% or less in all toxicological endpoints
Overall Toxicity	Significant: Multiple tests/endpoints exhibit major toxicological effects	Potential: Multiple tests/endpoints exhibit minor toxicological effects and/or one test/endpoint exhibits major effect	Negligible: Minor toxicological effects observed in no more than one endpoint
Benthos Alteration (multivariate assessment, e.g., ordination)	“different” or “very different” from reference stations	“possibly different” from reference stations	“equivalent” to reference stations
Biomagnification Potential (relative to reference)	Significant: Based on Step 6	Possible: Based on Step 4a	Negligible: Based on Steps 4a or 6
Overall WOE assessment	Significant adverse effects: elevated chemistry; greater than a 50% reduction in one or more toxicological endpoints; benthic community structure different (from reference) ; and/or significant potential for biomagnification	Potential adverse effects: elevated chemistry; greater than a 20% reduction in two or more toxicological endpoints; benthic community structure possibly different (from reference); and/or possible biomagnification potential	No significant adverse effects: minor reduction in no more than one toxicological endpoint; benthic community structure not different from reference; and negligible biomagnification potential

SQG = Sediment Quality Guideline; EC = Effective Concentration. Note that the overall definition of “No Significant Adverse Effects” is independent of sediment chemistry.

Source: Environment Canada and OMOE 2008

Table I-2: Decision matrix for weight-of-evidence categorization, as per the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment

Scenario	Bulk Sediment Chemistry	Overall Toxicity[1]	Benthos Alteration[2]	Biomagnification Potential[3]	Assessment
1	□	□	□	□	No further actions needed
2	■-◘	□	□	□	No further actions needed
3	□	□	■-◘	□	Determine reason(s) for benthos alteration (Section 5.3)
4	□	■-◘	□	□	Determine reason(s) for sediment toxicity (Section 5.3)
5	□	□	□	◘	Fully assess risk of biomagnification (Section 4.3)
6	■-◘	■-◘	□	□	Determine reason(s) for sediment toxicity (Section 5.3)
7	□	□	■-◘	◘	Determine reason(s) for benthos alteration (Section 5.3) **and** fully assess risk of biomagnification (Section 4.3)
8	■-◘	□	■-◘	□	Determine reason(s) for benthos alteration (Section 5.3)
9	■-◘	□	□	◘	Fully assess risk of biomagnification (Section 4.3)
10	■-◘	■-◘	□	◘	Determine reason(s)for sediment toxicity (Section 5.3) **and** fully assess risk of biomagnification (Section 4.3)
11	■-◘	□	■-◘	◘	Determine reason(s) for benthos alteration (Section 5.3) **and** fully assess risk of biomagnification (Section 4.3)
12	□	■-◘	□	◘	Determine reason(s) for sediment toxicity (Section 5.3) **and** fully assess risk of biomagnification (Section 4.3)

Table I-2: Decision matrix for weight-of-evidence categorization, as per the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment, cont'd.

SCENARIO	BULK SEDIMENT CHEMISTRY	OVERALL TOXICITY[1]	BENTHOS ALTERATION[2]	BIOMAGNIFICATION POTENTIAL[3]	ASSESSMENT
13	□	■-◘	■-◘	□	Determine reason(s) for sediment toxicity **and** benthos alteration[2] (Section 5.3)
14	□	■-◘	■-◘	◘	Determine reason(s) for sediment toxicity **and** benthos alteration (Section 5.3), **and** fully assess risk of biomagnification (Section 4.3)
15	■-◘	■-◘	■-◘	□	Management actions required[4]
16	■-◘	■-◘	■-◘	◘	Management actions required[4]

[1] Overall toxicity refers to the results of laboratory sediment toxicity tests conducted with a range of test organisms and toxicity endpoints. A positive finding of sediment toxicity may suggest that elevated concentrations of COPCs are adversely affecting test organisms. However, toxicity may also occur that is not related to sediment contamination as a result of laboratory error, problems with the testing protocol, or with the test organisms used.

[2] Benthos alteration may be due to other factors, either natural (e.g., competition/predation, habitat differences) or human-related (e.g., water column contamination). Benthos alteration may also be related to sediment toxicity if a substance is present that was not measured in the sediment or for which no sediment quality guidelines exist, or due to toxicity associated with the combined exposure to multiple substances.

[3] Per Table 1, significant biomagnification (■) can typically only be determined in Step 6; Step 3 only allows a determination that there either is negligible biomagnification potential or that there is possible biomagnification potential. However, there may be site-specific situations where sufficient evidence is already available from fish advisories and prior research to consider biomagnification at a site significant; this would be determined in Step 1 (examination of available data). Thus, for example, if significant biomagnification were indicated in Scenario 5, above, management actions would be required. The other three LOE do allow for definitive determinations in prior Steps of this Framework.

[4] Definitive determination possible. Ideally elevated chemistry should be shown to in fact be linked to observed biological effects (i.e., is causal), to ensure management actions address the problem(s). For example, there is no point in removing contaminated sediment if the source of contamination has not been addressed.. Ensuring causality may require additional investigations such as toxicity identification evaluation (TIE) and/or contaminant body residue (CBR) analyses (see Section 5.3). If bulk sediment chemistry, toxicity and benthos alteration all indicate that adverse effects are occurring, further assessments of biomagnification should await management actions dealing with the clearly identified problem of contaminated and toxic sediments adversely affecting the organisms living in those sediments. In other words, deal with the obvious problem, which may obviate the possible problem (e.g., dredging to deal with unacceptable contaminant-induced alterations to the benthos will effectively also address possible biomagnification issues).

Note: Ranking indicated by symbols is described in Table I-1. A dash (-) means "or." Separate endpoints can be included within each line of evidence (LOE) (e.g., metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) for Chemistry; survival, growth, reproduction for Toxicity; abundance, diversity, dominance for Benthos). For references to sections in the Assessment column, refer to the original source (Environment Canada and OMOE 2008).

III. SITE DESCRIPTION

1. Geographical Location and Physical Characteristics

The Great Cataraqui River drains an area of approximately 930 km^2 (Crysler and Lathem Ltd. 1977) in the St. Lawrence River Drainage Basin. The KIH is located at the mouth of the river, where it discharges into Lake Ontario (Figure I-1). According to the Canadian Hydrographic Service Navigational Charts (1990), the KIH extends approximately 0.5 km upstream from the LaSalle Causeway, where the Great Cataraqui River discharges into Lake Ontario (Appendix A: Canadian Hydrographic Service, 1990). This last segment of the Great Cataraqui River, south of the LaSalle Causeway, is referred to as the Outer Harbour. For the purposes of this report, the KIH study area refers to the 5 km stretch of river bounded by Highway 401 to the north and the LaSalle Causeway to the south (Figure I-1). In this report, the stretches north and south of Belle Island are referred to as the Upper and Lower Inner Harbours, respectively. Belle Island is a prominent natural landform located about 1.6 km upstream from the LaSalle Causeway. The area between Belle Island and the western shore has been infilled with dredged sediments and was subsequently used as a municipal landfill, creating an artificial peninsula.

The western shore south of Belle Island is characterized by historical industrial development, whereas north of Belle Island it is characterized primarily by the Great Cataraqui Marsh, which covers approximately 3.5 kilometres of the northwest bank of the river. There are also smaller areas of marsh along the northeastern shoreline as well as a small marsh, the Orchard Street Marsh, immediately south of Belle Island. Locations of notable geographic features and of selected former, current and proposed land uses discussed throughout this report are shown in Figure I-4.

2. Geology and Sedimentation

Surficial deposits in the area are primarily Quaternary glacial deposits and unconsolidated soils. The bedrock geology consists of Cambro-Ordovician sandstones and Precambrian basement rock of the Grenville Province, which had begun to erode before the nearly flat Ordovician limestones and shaley limestones of the Black River Group were deposited (Crysler and Lathem Ltd. 1977).

The sediments in the KIH consist primarily of mixtures of organic material and clayey silts with the organic content increasing with decreasing depth (Dalrymple and Carey 1990). A thick deposit of varved clay or clayey silt is the main overburden stratum (Geo-Canada 2001; Inspec-Sol Inc. 2002). Peat is the dominant sediment in the very shallow portions (<0.7 m) and in the marsh (Dalrymple and Carey 1990). A recent study by Asquini et al. (2007) discusses the sediment stratigraphy of eight cores collected within the Lower Inner Harbour. Peat deposits were present on the western side of the harbour, while a clay layer was present in the cores throughout the central and eastern portion of the KIH (Asquini et al. 2007). The overlying unconsolidated layer of organic gyttja sediment is formed mostly of clays and silts (Inspec-Sol Inc. 2002; Tinney 2006; Asquini et al. 2007). The overall thickness of the sediment overburden varies from west to east, with the depth to bedrock approximately 3 m on the western side of the harbour and up to 22 m on the eastern side of the harbour (Inspec-Sol Inc. 2002).

3. Hydrology and Sediment Transport

The KIH has an average depth of approximately 1.2 m and an average width of 1,000 m (Crysler and Lathem Ltd. 1977). It has been estimated that the harbour exchanges its entire volume of water 76 times each year (Paine 1983). River currents have been estimated to flow at 0.18 metres/second in the narrow areas of the harbour near the Great Cataraqui Marsh (Paine 1983) and as high as 0.4 metres/second in circulation cells west of the channel north of Belle Island (Hall1999).

Human-induced changes, including increased urbanization, water-level controls associated with the St. Lawrence Seaway and the construction of transportation corridors such as the LaSalle Causeway and Highway 401, have influenced KIH hydrology. For example, the LaSalle Causeway at the mouth of the harbour constricts the outflow of the river to Lake Ontario. The navigational channel on the eastern side of the harbour is maintained through dredging and has probably redirected flows to the middle of the river. The infilling of the marshy area between Belle Island and the western shore means that all water flowing downstream now travels around the east side of Belle Island.

Sediment transport and deposition patterns within the KIH are not well understood but are probably complex, given the hydrological flow constraints and shallow depths. Sediment resuspension from wind and wave action, boating activities and flow patterns appears to be important in redistributing sediments within the harbour. The water level controls put in place when the seaway was built virtually eliminated the periodic sediment flushing that previously extended all the way upriver to Highway 401, resulting in more rapid accumulation of sediments (personal oral communication with Dale Kristensen, Ecological Services, April 14, 2009).

4. Cultural Significance

The KIH is located northeast of Kingston's downtown core (Figure I-1). With the completion of the Rideau Canal in 1832, Kingston became a major port on Lake Ontario. The industrial and commercial development of the KIH associated with its historical use as a major port and its current uses is discussed in Section III-6. Kingston is an important tourist destination on Lake Ontario because of its rich history, its picturesque waterfront and its location as the gateway to the Rideau Canal, a UNESCO World Heritage site.

5. Archaeological Resources

Four archaeologically sensitive areas (ASAs) along the shorelines of the Great Cataraqui River have been identified (Archaeological Services Inc. 2008a). These include two pre-contact Aboriginal sites, one on Belle Island and one at the Kingston Outer Station, which is located on the western shore immediately south of the Great Cataraqui Marsh (see location 1 in Figure I-4 below). Two historical Euro-Canadian areas have also been identified on the western and eastern shores at the mouth of the Great Cataraqui River (Appendix A: Archaeological Services Inc., 2008a, Figure 1). On the western shore, the ASA consists of the Inner City Core, which includes the area around Anglin Bay. On the eastern shore it includes the Barriefield Conservation District and part of CFB Kingston. The City of Kingston Archaeological Master Plan, drafted in 2008 to address the conservation of archaeological resources, also identifies the entire shoreline on both sides of the river as having potential for pre-contact archaeological significance (Archaeological Services Inc. 2008b). The City of Kingston has amended the zoning bylaw to prevent site disturbance at the Kingston Outer Station site pending completion of further excavations, and has approved a joint ownership and stewardship agreement between First Nations and the City of Kingston for the Belle Island site (Archaeological Services Inc. 2008b).

Figure I-4: Selected geographic features and former, current and proposed land uses in southern Kingston Inner Harbour and Belle Island area. Numbering key follows.

Geographic Features

3 *Gore Road*
4 *Elliot Avenue*
5 *West Stream*
7 *Barker's point*
13 *Belle Island*
14 *Butternut Creek*
16 *South Stream*
17 *Orchard Street Marsh*
31 *Anglin Bay*

Former Uses

10 *Federal Dredged Sediments Disposal Site*
12 *Belle Park Landfill/City of Kingston Disposal Site/Cataraqui Park*
19 *Arcom Waste Disposal Facility*
20 *Former Davis Tannery*
21 *Former Frontenac Lead Smelter*
28 *Woolen Mill*
35 *Former Kingston Coal Gasification Plant*

Current Uses

1 *Music Marina (Location of Kingston Outer Station archaeological site)*
6 *Rideau Canal*
8 *Phreatophyte tree species test plot*
9 *Constructed wetland test plot*
11 *Rideau Marina*
15 *Kingscourt storm sewer*
18 *CFB Kingston*
22 *River Street Pumping Station*
23 *Emma Martin Park*
24 *Underground combined sewer overflow storage tank*
25 *Kingston Rowing Club*
26 *Buried sewage force main and water main*
29 *Douglas Fluhrer Park*
30 *Kingston Marina*
32 *HMCS Cataraqui Facility*
33 *Frontenac Village Residential Development*
34 *LaSalle Causeway*
36 *Fort Frontenac*
37 *Wolfe Island Ferry Dock*
38 *Outer Harbour*

Proposed Uses

2 *Proposed bridge crossing*

6. Land and Water Use in and around the Inner Harbour

The historical and current land use around the KIH reflects both the local physical topography and the typical industrial development associated with Euro-Canadian settlement over the past century. The low-lying water-accessible lands on the western shore have been developed extensively for industry, while the steep limestone banks of the eastern shore have largely limited development to residential and rural land uses.

a. <u>Historical Land Use</u>

1) Western Shore

With the completion of the Rideau Canal in 1832, Kingston became a major port on the Great Lakes (Osborne and Swainson 1988). Shipbuilding operations, a fuel yard and several commercial wharfs were located on Anglin Bay on the southwest shore of the KIH. In the 1850s, a branch line from the Grand Trunk Railway was extended into Kingston, with tracks running along the Inner and Outer Harbours (Figure I-5). The arrival of the railroad coincided with increased industrial and commercial development along the western shore of the KIH.

Over the past 150 years, there have been many commercial and industrial activities along the southwest shore of the Harbour. A set of figures indicating the commercial and industrial land uses in this area for the years 1880, 1947, 1963, 1984 and 1997 is presented in Malroz (Appendix A: Malroz, 1999, Figures 2.3–2.7). Over the years, the industrial operations have included a tannery, a lead smelter, two battery-manufacturing companies, a woolen mill, a grist mill, a brewery, a chemical dye company, a boat-building facility, two scrap metal dealers, a demolition yard, several coal dealers, as many as eight bulk fuel depots, a variety of mill works, welders, sheet metal fabricators, suppliers of commercial building materials and numerous fuel stations. Three waste disposal areas were also located on the shores of the Inner Harbour: the Belle Park Landfill (also known as the City of Kingston Disposal Site, later to become Cataraqui Park and Belle Park), a Federal Dredged Sediments Disposal Site on the north shore of the landfill, and the Arcom Waste Disposal Facility located within the former Davis Tannery site (Figure I-4).

A significant decrease in the number of KIH industrial and commercial operations occurred between 1963 and 1984, following the completion of the St. Lawrence Seaway in 1959. By the 1970s, the rail yards were closed because of declining traffic related to the closure of the tannery, the locomotive works and the Kingston Shipyards. The area is currently characterized by residential, institutional and light industrial and commercial activities. Several brownfield properties and closed waste disposal facilities also remain in the area as a legacy of historical industrial activities.

The following section highlights areas of probable historical sources of contamination along the western shore. Although there was extensive industrialization all along the western shore south of Belle Island, previous studies (Stokes et al. 1977; Derry et al. 2003; Malroz 2003; Manion 2007) have identified these locations as probable sources of historical contamination.

a) Frontenac Smelting Works

Located southwest of the Belle Park Landfill, the Frontenac Smelting Works operated between 1879 and 1915 (Osborne and Swainson 1988). Air emissions from the smelter represent a potential source of lead, copper, zinc and PAHs to the KIH.

b) Former Davis Tannery Property and Arcom Waste Disposal Facility

The Davis Tannery operated southwest of Belle Park Landfill from 1909 to 1973 (OMOE 1978). The tannery discharged wastewater directly into the wetland north of the site until 1967. The wastewater would have included chromium sulphate solution (used in tanning), lime and sulphide solutions (used for loosening/dissolving hide hair), enzyme solutions (used in hide treatment operations), strong arsenic solutions (to control vermin), salt acid solutions (used for hide pickling), leather dye solutions, and fat-liquoring solutions. The wastewater could have been a source of trivalent chromium, copper, lead, zinc, arsenic and salt to the KIH. Several environmental investigations on site have identified the presence of soils and sediments contaminated with metals, particularly chromium, at levels that exceed guidelines (Stokes et al. 1977; DCS 1994; ESG unpublished data).

After the Davis Tannery closed in 1973, fill material consisting of rock, brick and concrete was imported and placed across the middle of the wetland in the north portion of the site. Clay berms were also constructed along the margins of the Great Cataraqui River and the northeast site boundary to contain metal-contaminated soils and sediment. In 1985, the site was registered as the Arcom Waste Disposal Facility and was licenced for landfilling activities. Two disposal areas were created on the site for waste generated by site remediation activities (e.g., one for contaminated topsoil and one for the lead smelter foundation debris). There are indications that a third waste disposal area was created for the disposal of tanning hides. In addition, since the late 1980s, illegal dumping of construction materials and small amounts of domestic waste has occurred at several locations around the periphery of the site. The overall extent and nature of landfilling on the site is uncertain. However, the solid waste materials represent a potential source of metals and other contaminants to the KIH.

Historical industrial properties that surrounded the Davis Tannery included a gas station, several fuel depots with above- and below-ground storage tanks for oil and gas, and the Dye & Chemical Co. of Canada Ltd., which had an underground solvent storage tank (Appendix A: Malroz, 1999, Figures 2.3–2.7). Emissions from these and other nearby industrial properties represent a potential source of solvents and hydrocarbons.

c) Kingston Coal Gasification Plant

The Coal Gasification Plant operated in an area bounded by King Street, Queen Street, Ontario Street and Place d'Armes from 1848 to the early 1950s (ESG 2006). Coal and oil were carbonized to produce a gas used to fuel street lanterns. A by-product of the gas extraction process was a thick black coal tar, some of which was used as a preservative for railway ties (CH2M Hill 1991). The remaining coal tar was left on the site and has seeped into the fractured limestone bedrock, representing a potential source of PAHs to the KIH.

d) Anglin Bay Rail Yards and Shipbuilding Operations

By the early 1900s, Anglin Bay (formerly known as Cataraqui Bay) was the location of the Davis Dry Dock Company, coal and fuel storage facilities, warehouses for the trans-shipment business, and abandoned ships (ESG 2006). In 1908, the southern and western fringes of the bay were reclaimed to install multiple rail lines and commercial buildings. Sediments in the bay were dredged to a depth of 6.7 m during construction of the LaSalle Causeway (1912 to 1917), and the sediments were placed in the marshy area between the western shore of the Great Cataraqui River and Belle Island, subsequently the location of the Belle Park Landfill (Osborne and Swainson 1988). The Davis Dry Dock Company was replaced by the Canadian Dredge and Dock Company in the 1930s. The company built small boats and ships until the 1980s (ESG 2006). Large oil storage tanks that had been on the site were removed at this time, and the coal yards were covered, with the Frontenac Village residential development constructed on top of the site (Figure I-5). Subsequently, the Kingston Marina and the Metal Craft Marine Company, aluminum and steel boat manufacturer, were established at Anglin Bay in the 1980s. Historical activities at this location are a potential source of PAHs, hydrocarbons and metals to the KIH.

Figure I-5: Aerial view of the western shore of the Lower Inner Harbour in the 1920s (left photo) and in 2005 (right photo).

e) Area North of the Woolen Mill

A site investigation at the Kingston Rowing Club property, located just north of the historical Woolen Mill, revealed buried waste material containing elevated levels of cadmium, copper, molybdenum, nickel, lead, zinc, arsenic and mercury (WESA 1988). Historical activities at this site included smelting operations and are a potential source of mercury and other inorganic contaminants to the KIH (Manion 2007). The City of Kingston and OMOE are conducting a Phase II site assessment on the property to determine the extent of contaminated soil and determine whether the site is a source of fugitive emissions to the adjacent KIH.

f) Belle Park Landfill Site

The Belle Park Landfill was established in the shallow swampy area between Belle Island and the western shore of the Great Cataraqui River. The area was used as a municipal landfill from 1952 until 1974, when it was closed and redeveloped as a golf course. The area has been commonly referred to as Belle Park and Cataraqui Park. A detailed history of the landfill development and results of an extensive environmental impact study are presented in Malroz (1999). Welbourn Consulting (1999) also conducted a human health and ecological risk assessment based on existing data at that time. The landfill was a suspected source of PAHs, polychlorinated biphenyls (PCBs), metals and pesticide derivatives that have been measured in the soil of the park and sediments in the waters surrounding it (St. Lawrence College 1973; Frape 1979; Brooks et al. 1999; Cross 1999; Derry et al. 2003). A number of remedial measures have been undertaken to contain and treat the landfill leachate, which includes active groundwater pumping. Deep-rooted tree species that obtain water from a permanent ground supply or from the water table (phreatophytes) have been planted along the western site boundary to determine whether these species exert an influence on the flow of shallow groundwater across the site. In addition, an experimental wetland was constructed adjacent to the site's north shore to improve understanding of the ability of wetland vegetation to take up iron, ammonia and other nitrogen species in groundwater flowing out of the site (Rose et. al. 2004). In June 2006, an assessment of long-term management alternatives for the Belle Park Landfill was completed (CH2M Hill 2006). Ongoing groundwater monitoring suggests that the landfill is no longer a source of contamination to the KIH (City of Kingston and OMOE 2005).

g) Federal Dredged Sediment Disposal Site

The north shore of the Belle Park Landfill contains a Federal Dredged Sediment Disposal Site created in 1970 by Public Works Canada. The site consists of an area contained by a semicircular berm constructed of rubble extending to a radius of 152 m from the north shore of Belle Park (Malroz 1999). The facility was used to contain river sediments dredged during the widening of the Inner Harbour navigational channel between the LaSalle Causeway and just north of Belle Island.

h) Sewer Systems and Surface Water Drainage

Prior to the mid-1950s, Kingston did not have a wastewater treatment facility, and wastewater was allowed to flow directly into the Great Cataraqui River and Lake Ontario (St. Lawrence College 1973). In the older downtown core, the City of Kingston's municipal sewer system and storm water systems are interconnected. During periods of normal usage, the mix of stormwater runoff and sewer water is routed through a buried sewage force main under the Great Cataraqui River to the Ravensview wastewater treatment facility, located east of the city on the shore of Lake Ontario (Appendix A: Stantec Consulting Ltd., Figure 1.1). However, during periods of high usage — when the quantity of sewage and stormwater runoff exceeds the system's capacity — the excess overflows into the Great Cataraqui River. Recent upgrades to the sewer system in 2006, including the construction of combined sewer overflow holding tanks, will minimize future overflow occurrences. However, combined sewer outfalls have been identified as a significant historical source of contaminants such as nutrients (e.g., nitrogen and phosphorous) and coliform bacteria to the Great Cataraqui River.

A network of stormwater sewers also drains into the KIH along both the western and eastern shorelines (Appendix A: Malroz, 2003, Figure 2.3). These sewers collect runoff from large expanses of urban land. Contaminants associated with sewer discharge in general include PAHs, hydrocarbons, metals and bacteria. Contaminant nutrients such as nitrogen and phosphorus are commonly associated with sewage and may be discharged from sewers during combined sewer overflows. The Kingscourt storm sewer, located between the former Davis Tannery property and Belle Park Landfill, is one of the largest storm sewer outlets in the area and drains a large catchment area on the western shore.

Two small streams, the South and West Streams, drain into the KIH on either side of the Belle Park Landfill (Figure I-4). The South Stream drains the northwest corner of the former Davis Tannery property as well as lands to the south, and it joins the Kingscourt storm sewer drainage channel. Sediment cores collected in this stream contained very high levels of chromium in addition to visible oil (Wilson 1973). The West Stream drains lands to the west of the Belle Park Landfill, which were historically occupied by industrial and commercial operations such as a battery manufacturing company, railway lines and storage facilities (Malroz 1999). Some metals were detected at levels above provincial guidelines in the West Stream, upstream of the Belle Park Landfill. However, with the exception of iron, the frequency with which concentrations exceeded provincial guidelines decreased toward the mouth of the stream, and its discharge produced no influence of metals in the Great Cataraqui River (Malroz 1999).

2) Eastern Shore

In contrast to the western shore, little historical industrial and commercial development occurred on the eastern shore of the KIH. A sawmill and shingle manufacturing facility was located at Green Bay, just north of the current HMCS Cataraqui facility, from 1843 to the early 1900s (Patterson 1989). There was also a small boat-building company, which constructed small wooden skiffs, on Green Bay in the late 1800s.

During the 1800s and early 1900s, a number of barge and ferry services operated on the shore of the Great Cataraqui River, north of the current LaSalle Causeway. One of their purposes was to ferry passengers across the Great Cataraqui River at tolls lower than those charged by the Cataraqui Bridge Company for use of the former wooden bridge spanning the river at the site of the current Causeway (ESG 2006). The Barriefield Boat Company was in operation in the 1840s, and Bowman's Boathouse operated in the area in the 1930s (Patterson 1989).

In 1939, the Department of Public Works built a government wharf at the location of the HMCS Cataraqui on the east shore of the Inner Harbour. Very little information about the types of activities that occurred on and around the wharf is available, although aerial photos over the years have shown ships berthed there or at anchor to the north of the wharf. The timing of its construction and its proximity to CFB Kingston suggest that it was built to support the war effort and it may have been used to load military supplies (ESG 2006).

The remainder of the eastern shoreline of the KIH was dedicated to mainly rural and institutional land uses, with recent residential development (Malroz 2003). Butternut Creek, on the eastern shore, discharges into the Great Cataraqui River.

b. Current and Future Land Uses

A new Official Plan for the amalgamated regions of Pittsburgh Township, the Township of Kingston and the former City of Kingston came into effect on January 27th, 2010. The new City of Kingston has an area of approximately 450 square kilometres and a 2006 population of 117,000 (City of Kingston 2010). The 2010 Official Plan was created to provide planning guidance for the amalgamated City and to incorporate the 2005 Provincial Policy Statement as well as recent changes in the Provincial Planning Act.

Under the 2010 Official Plan, the KIH north of the Woolen Mill (western shore) and the HMCS Cataraqui (eastern shore) to Highway 401 is designated as a Provincially Significant Wetland (Appendix A: City of Kingston, 2010, Schedule 7-A). The Great Cataraqui Marsh, which is known to contain sensitive species, and Belle Island are identified as Areas of Natural and Scientific Interest. Most of the shoreline around the KIH north of the Belle Park Landfill is designated as an EPA (Appendix A: City of Kingston, 2010, Schedule 3-A and Schedule RC-1). This includes the Great Cataraqui Marsh on the western shore, as well as the eastern shoreline with the exception of a marina located northeast of Belle Island. Within the EPA, permitted uses include recreational and educational activities as well as wildlife and water quality management and necessary flood and erosion control measures.

The section of the Inner Harbour north of Belle Island to the northern limits of the City is also under the jurisdiction of Parks Canada. The Rideau Canada was designated as a UNESCO World Heritage site in 2007. Additional policies apply to development within this sub-area, and all applications must be reviewed by Parks Canada. All new buildings, septic systems and replacements of existing buildings must be set back a minimum of 30 m from the Rideau Canal. The 30 m setback zone is defined as an EPA, and only uses listed under the EPA designation are permitted.

The Belle Park Landfill and Belle Island, as well as land around Anglin Bay on the western shore and a small section north of the HMCS Cataraqui on the eastern shore, are designated as Open Space by the City of Kingston (Appendix A: City of Kingston, 2010, Schedule 3-A). A variety of uses are permitted under this land use designation, but in general buildings and structures are minimized. Recreational uses, landscaped areas, conservation areas and cemeteries are all included under the Open Space land use category.

The remainder of lands around the southern portion of the KIH on the western and eastern shores is a mixture of residential and institutional land uses. The River Street Pumping Station on the western shore, which pumps sewage through the distribution pipes along a utilities corridor beneath the KIH to the Ravensview Wastewater Treatment Plant (Appendix A: Stantec Consulting Ltd., Figure 1.1), is classified as Waste Management Industrial (Appendix A: City of Kingston, 2010, Schedule 3-A). An underground combined sewer overflow storage tank was built beneath Emma Martin Park, at the corner of Orchard and Cataraqui Streets, just west of the Kingston Rowing Club property. The location of a potential third bridge crossing of the KIH, which would connect Elliot Avenue on the western shore with Gore Road on the eastern shore is identified in the official plan (Appendix A: City of Kingston, 2010, Schedule 4).

Specific policies to protect waterfront areas such as the KIH are contained in the 2010 Official Plan under the Waterfront Protection land designation. Uses of these areas are defined as primarily water-oriented recreational and leisure activities, transportation services and tourist-related activities. The City has committed to improving water quality through implementing stormwater management and pollution control measures, restricting water-based activities that may be harmful to the aquatic environment and supporting the enforcement of federal and provincial abatement legislation. The City is also committed to the development and maintenance of the Waterfront Pathway. The proposed waterfront trail for the KIH shown in the official plan (Appendix A: City of Kingston, 2010, Schedule 5), includes paths along much of the eastern shore north of Belle Island as well as along the southwestern shore from Highway 2 to a point north of the Belle Park Landfill.

The City of Kingston Official plan specifically addresses the KIH under Section 3.9.A.8, as follows:

> *The Kingston Inner Harbour has been the subject of much scientific study and review to determine how the area may be remediated, where warranted, and how it can be rehabilitated to a cohesive, desirable mixed-use waterfront area. The area, shown schematically on Schedule 13, will involve a planning study, the limits and details of which will need to be determined in consultation with the Kingston Environmental Advisory Forum.*
>
> (City of Kingston 2010)

The area of the KIH designated as a "Special Policy Area" includes the western shoreline from the LaSalle Causeway to a point just north of Elliot Avenue, and includes Belle Park and Belle Island (Appendix A: City of Kingston, 2010, Schedule 13).

c. Water Uses

The Inner Harbour around and north of Belle Park is designated as a Provincially Significant Wetland (Appendix A: City of Kingston, 2010, Schedule 7-A) and is afforded special protection under the Planning Act. Trapping, hunting, commercial fishing, sport fishing, boating and nature viewing are the main resource uses permitted. The dominant use within the Great Cataraqui River is pleasure-craft boating, with three marinas operating from the KIH (Kingston Marina, Music Marina and Rideau Marina). The sheltered Inner Harbour waters also provide ideal canoeing and rowing conditions, as well as safe anchorage for larger boats. Although there are no organized bathing beaches in the Inner Harbour, the docks near the LaSalle Causeway and Anglin Bay are frequently used for swimming and other water-related recreational pursuits (Malroz 2003).

7. Flora and Fauna

The most extensive studies and biological surveys in the KIH were carried out in the 1970s and 1980s. These include an early natural resource summary of the KIH (Crysler and Lathem Ltd. 1977), a thorough study describing natural resources and management considerations for the whole river system between Kingston Mills and Belle Island and for areas of submergent vegetation south of Belle Island (Blancher 1984), and botanical surveys conducted at various times of year between 1982 and 1984 to identify species in an area of approximately 8 km^2 of open water and adjacent marshes and slopes of the lower Great Cataraqui River (Catling 1985). More recently, a biological survey was conducted of the Orchard Street Marsh, located between the former Davis Tannery property and the Belle Island Landfill (Ecological Services 2008). Weir (2008) has also published a book containing extensive information on birds of the Kingston area. Other ecological information can be drawn from various studies that have collected information for specific purposes, such as environmental evaluation of dredging projects or effects of potential contaminant sources. Natural resource information has also been collected for the Kingston area in general, with some specific references to the Inner Harbour area. All of these studies are summarized in Table I-3. Malroz (2003) provides a review and gap analysis of studies conducted from 1972 to 2001. The studies included in the Malroz (2003) compilation are highlighted in grey in Tables I-3, I-7, I-10, I-15 and I-16 in this chapter.

The Ontario Ministry of Natural Resources (MNR) maintains records of natural resources features and species of risk. In the KIH area in general, the MNR has records of occurrences of species of special concern (black tern), threatened species (Blanding's turtle, least bittern, stinkpot turtle, white wood aster) and endangered species (king rail, loggerhead shrike, Henslow's sparrow) (personal communication from Lela Pomfret, OMNR, March 24, 2009). As there is potential for other species and significant habitat features to be present, the Great Cataraqui Marsh has been identified as a Provincially Significant Wetland and the area in general as an Area of Natural and Scientific Interest. Provincially and regionally significant species for the Great Cataraqui Marsh are outlined in the MNR wetland report (Appendix A: Ontario Ministry of Natural Resources, 2009).

Table I-3: Summary of flora and fauna studies in the KIH

Study	Purpose/study area	O=Original data R=Review of previous data	Scope					
			Vegetation	Benthic fauna	Fish	Reptiles & amphibians	Mammals	Birds
Luciuk (1975)	Description of turtles in the Great Cataraqui River region.	O				√		
Crysler & Lathem (1977)	Flood plain management study for the Great Cataraqui River Basin.	O	√		√	√	√	√
Queen's University (1977)	Environmental planning study of the Great Cataraqui River Valley.	Unknown	√					
Complak (1982)	Graduate thesis on the relationship between lake type and the performance of four littoral zone fish species.				√			
Blancher (1984)	Natural resources description and management considerations for the Great Cataraqui Marsh and Rideau Canal. Comparisons made to other wetlands in southern Ontario.	O/R	√		√	√	√	√
Ecologistics and WESA (1984)	Environmental evaluation of dredging the navigational channel.	O/R	√	√	√			√

Table I-3: Summary of flora and fauna studies in the KIH, cont'd.

Study	Purpose/study area	O=Original data R=Review of previous data	Scope					
			Vegetation	Benthic fauna	Fish	Reptiles & amphibians	Mammals	Birds
Catling (1985)	Description and analysis of vascular flora of the Great Cataraqui Marsh. Study area was approximately 8 km^2 and included open water, marsh areas and shoreline slopes.	O	√					
Mudal and Krannitz (1990)	Wetland evaluation for the Great Cataraqui Marsh. Reference for the designation of the Great Cataraqui Marsh as a Provincially Significant Wetland.	R	√		√	√	√	√
Jaagumagi (1991)	Sediment and benthic community assessment of Anglin Bay and Queen Street Slip. Five samples collected to assess species composition.	O		√				
Totten Sims Hubicki Associates (1992)	Transportation study of bridge crossings of the Great Cataraqui River	R	√		√	√	√	√
Environment Canada (1993)	Environmental sensitivity atlas for Lake Ontario shoreline to aid in preparing and responding to spills of oil and other hazardous materials		√		√			√
Ecological Services for Planning (1996a, b)	Great Lakes Embayments and Harbours Investigation Program. Samples collected from one location offshore from the Kingston Rowing Club and two locations in Lake Ontario near the Olympic Harbour. Samples were composited so not specific to KIH.	O		√				

Table I-3: Summary of flora and fauna studies in the KIH, cont'd.

Study	Purpose/study area	O=Original data R=Review of previous data	Scope					
			Vegetation	Benthic fauna	Fish	Reptiles & amphibians	Mammals	Birds
Crowder et al. (1996)	Examines rates of natural and anthropogenic change in shoreline habitats in the Kingston Basin of Lake Ontario. Presents natural historic information.		√					
Crowder et al. (1997)	*Plants of the Kingston Region.* A book containing classification keys and information for identifying plants in the Kingston area.		√					
Malroz Engineering (1999)	Environmental impact study of Cataraqui Park. Included collection and analysis of land vegetation.	O	√					
ESG International (2001)	Environmental assessment for a proposed underwater sewer and water main corridor.		√		√			
ESG (2003)	ERA for sampling location south of Belle Park and a water lot near Fort Frontenac. Measurement of body burden of chemicals in zebra mussels and quantification of aquatic macrophyte and benthic invertebrate communities. See Table I-12.	O	√	√				
Benoit and Dove (2006)	Collection of benthic invertebrates and fish for analyses of contaminants. See Table I-12 for details.	O	√	√	√			
Tinney (2006)	Site investigation and ERA of the KIH. Collection of macrophytes and invertebrates. Applied several diversity indices. See Table I-12 for details.	O	√	√				

Table I-3: Summary of flora and fauna studies in the KIH, cont'd.

Study	Purpose/study area	O=Original data R=Review of previous data	Scope					
			Vegetation	Benthic fauna	Fish	Reptiles & amphibians	Mammals	Birds
Weir (2008)	*Birds of the Kingston Region*. A book containing information on birds of the Kingston area.	O						√
Ecological Services (2008)	Species inventory and ecological evaluation of the Orchard Street Marsh.	O	√	√	√	√	√	√

Note: Studies highlighted in grey are included in the Malroz (1993) review and gap analysis of studies conducted 1972–2001.

a. Vegetation

Terrestrial vegetation communities surrounding the KIH are mixed. Wooded areas are dominated by red oak and sugar maple, with pockets of eastern hemlock, eastern white pine, white cedar and remnants of red pine, hickory, white ash and beech (Blancher 1984). Thicket areas generally consist of speckled alder, winterberry, chokecherry, hawthorn, dogwood and nannyberry (Blancher 1984). Finally, open herbaceous vegetation areas are also common. These consist of pasture and meadows, open disturbed ground or open, bald ground (severely altered with new colonization).

Extensive areas of wetland vegetation are also present within the KIH. The largest marsh area is the Great Cataraqui Marsh, approximately 623 ha in size, located north of Belle Island on the west side of the harbour. It is composed mainly of cattails with some sedges and graminoids. Pockets of wetland vegetation are also present along the shoreline in other areas of the harbour, including the Orchard Street Marsh.

The botanical survey by Catling (1985) identified 596 vascular plant species from the Great Cataraqui Marsh, the Great Cataraqui River and adjacent shores (Catling 1983). This indicated relatively high diversity compared with other Lake Ontario marshes. Twenty-eight ecologically important plant species were documented in the Great Cataraqui Marsh area (Appendix A: Blancher, 1984, Table 6), with most occurring in the northern section of the marsh, where there has been less landscape and habitat alteration. A recent biological survey of plants in the Orchard Street Marsh identified 54 plant species (Ecological Services 2008). Twelve of these were invasive non-native species; no rare or uncommon species were observed. The report concluded that, on the basis of various indices of biological diversity and productivity, the Orchard Street Marsh is a degraded wetland ecosystem with limited diversity and function and there is virtually no potential for ecological recovery or for a return to high diversity without intense intervention (Ecological Services 2008).

The 1983 botanical survey of the Great Cataraqui Marsh identified a surprisingly high diversity of aquatic plants, compared with the diversity of other Great Lakes marshes (Catling 1985). Many of these plants are eaten by waterfowl, and the Cataraqui Marsh has been identified as an area with the potential to be an important feeding site for marsh birds (Blancher 1984). The 2008 Orchard Street Marsh biological survey lists white water lily (*Nymphaea odorata*), grassleaf arrowhead (*Sagittaria graminea*) and various pondweeds (*Potamogeton spp.)* as the dominant plant species at the mouth of the stormwater drainage channel (Ecological Services 2008). Aquatic vegetation communities in the harbour are dominated by Eurasian watermilfoil (*Myriophyllum spicatum*), coontail (*Ceratophyllum demersum*), pondweeds (*Potamogeton crispus, Elodea canadensis*) and eelgrass (*Vallisneria americana*) (Tinney 2006). An increase in cattails and Eurasian watermilfoil is associated with the accumulation of sediments related to human-induced hydrological changes. The dominance of the Eurasian watermilfoil, an invasive non-native species, may be a contributing factor in the accelerated eutrophication of the marsh (personal oral communication with Dale Kristensen, Ecological Services, April 14, 2009).

b. <u>Benthic Invertebrates</u>

Several studies have investigated benthic invertebrate communities within the KIH. Overall, these studies have found that the benthic invertebrate community is dominated by smaller organisms (e.g., midge larvae) in low densities, probably reflecting the nutrient-rich, fine-grained organic sediment substrate.

Ecologistics and WESA (1984) examined the density of major invertebrate groups from 10 sampling locations along the Upper Inner Harbour from just south of Belle Island to Highway 401, as part of an initial environmental evaluation of dredging. Although total numbers of organisms were low, the dominant groups were midges (*Chironomidae*), caddisflies (*Trichoptera*) and amphipods (*Amphipoda*), with the midges being dominant (Ecologistics and WESA 1984). In a more recent study, oligochaetes, midge larvae, isopods and amphipods were found to be the dominant groups at a reference site upstream of Highway 401 (Benoit and Dove 2006). Similar organisms were found at a reference site north of Belle Park, with the dominant groups being midge larvae, oligochaetes, isopods, caddisflies and snails (ESG 2003; Tinney 2006). Composition at this reference site was similar to that at other reference sites throughout the Great Lakes with comparable physical and chemical characteristics (e.g., grain size, organic content) (ESG 2003). Several studies have examined the effects of sediment contamination on benthic community structure, contaminant levels in benthic fauna and the toxicity of sediments to benthic fauna (see Section IV.D, Table I-15 and Table I-16).

c. Fish

Blancher (1984) lists 35 species of fish that have been observed or reported in the Great Cataraqui River and identifies spawning areas for various species north of Belle Island, particularly in the Great Cataraqui Marsh (Appendix A: Blancher, 1984, Table 16). Hodson (1998b) lists 24 species that are endemic to the Great Cataraqui River (Appendix A: Hodson, 1998a, Table 8). A recent biological survey of the Orchard Street Marsh south of Belle Park found eight species of fish, including northern pike, smallmouth bass, largemouth bass, rock bass and carp, with pumpkinseed, yellow perch and golden shiner being most common (Ecological Services 2008). The interior of the Great Cataraqui Marsh provides excellent spawning habitat for northern pike. Smallmouth bass nest primarily on hard substrate near Kingston Mills. Other fish, such as largemouth bass, yellow perch, bullheads, sunfish and rock bass, nest on nearshore substrate throughout the Inner Harbour, including the north side of Belle Island, where there is a small commercial fishery under licence from the MNR to catch bullheads and pan fish such as yellow perch, sunfish and crappie (Malroz 2003). Common carp have been observed spawning primarily in dense offshore weed beds near the Great Cataraqui Marsh and Belle Park (Blancher 1984; Malroz 2003). The foraging actions of the introduced carp may be contributing to the remobilization of contaminants in the upper sediments (personal oral communication with Dale Kristenesen, Ecological Services, April 14, 2009). Large numbers of young-of-the-year fish of most spawning species have been observed using inshore weed beds. Species diversity is similar to that of much larger bodies of water in Lake Ontario and may reflect the diversity of habitats and substrates available for spawning as well as the direct connection to Lake Ontario (Blancher 1984).

The majority of warm-water species identified in the Great Cataraqui Marsh are regionally common, are relatively pollution-tolerant and are reproductive generalists in terms of spawning behaviour and habitat (personal oral communication with Dale Kristensen,Ecological Services, April 14, 2009). Fish density in the Orchard Street Marsh was very low compared with that reported for adjoining waters and the Great Cataraqui

Marsh. All of the fish species encountered were considered moderately to very tolerant of poor water quality.

Sediment types and accumulation rates are important factors in determining aquatic habitat for fish. Crowder et al. (1996) have shown that there have been changes in fish communities in the wetland areas that can be attributed to increased rates of sedimentation. Over the past few decades, less economically valuable fish such as percids, ictalurids and cyprinids have replaced former communities of salmonids and other groups (personal oral communicationwith Dale Kristensen, Ecological Services, April 14, 2009). Highly invasive non-native plant species such as narrowleaf cattail (*Typha angustifolia*), purple loosestrife (*Lythrum salicaria*) and Eurasian watermilfoil are found throughout the Cataraqui River system (Ecological Services 2008). Dense growth of Eurasian watermilfoil has been known to lead to the degradation of habitats for various fish by increasing rates of organic sediment accumulation (and thus increasing biological oxygen demand (BOD), reducing open water space and causing changes to prey density and type (Engel 1995).

Several studies have examined the effect of contamination in the KIH on fish (see Section IV.D; Table I-15 and Table I-16).

d. Reptiles and Amphibians

Sixteen species of reptiles and amphibians have been observed in the KIH (Appendix A: Blancher, 1984, Table 20). Of five turtle species identified, three are listed as rare: the northern map turtle (*Graptemys geographica:* special concern), the stinkpot turtle (*Sternotherus odoratus*: threatened) and the Blanding's turtle (*Emydoidea blandingii*: threatened). The eastern milk snake (*Lampropeltis triangulum triangulum*) is also found on upland areas around the harbour, and is listed as a species of special concern. The species list of reptiles and amphibians for the KIH is probably not complete, as it is based on observations made while carrying out other studies. Most of the species were reported from the northern end of the marsh near Highway 401. However, biological surveys carried out in 2008 for the Orchard Street Marsh south of Belle Park identified the presence of midland painted turtles (*Chrysemys picta marginata*), common snapping turtles (*Chelydra serpentina*), leopard frogs (*Rana pipiens*), bullfrogs (*Rana catesbeiana*) and green frogs (*Rana clamitans*) in these areas, although their numbers and the overall amphibian species richness were extremely low (Ecological Services 2008). Map turtles and stinkpot turtles have been observed in the water lot south of Belle Park (Ecological Services 2008).

A survey of turtle nesting sites in 1983 indicated that the gravel fill at the margins of Highway 401 and the CN Railroad (Figure I-2) are the most preferred nesting areas within the Inner Harbour (Blancher 1984). Common snapping turtles and midland painted turtles were reported nesting in this area, and eastern milk snakes probably den in this habitat. Low numbers of turtle nesting sites were also found on the islands of the Great Cataraqui Marsh. Anecdotal evidence also suggests that turtles probably nest in the gravel berm adjacent to the former Davis Tannery property south of Belle Park; one snapping turtle nest was identified along the gravel bed of a railway track on the west side of the Orchard Street Marsh (Ecological Services 2008). Leopard frogs have been reported as abundant breeders throughout the marsh and along the river shores (Blancher 1984). However, there was no evidence of amphibian breeding on the Orchard Street Marsh site, probably reflecting the very low availability of insect prey and probably reflecting possible local contamination at the site (Ecological Services 2008).

e. Mammals

Available information on mammal populations within the KIH area is limited and largely anecdotal. Blancher (1984) reports a list of 25 species known to frequent the Great Cataraqui Marsh area (Appendix A: Blancher, 1984, Table 12). None of these species is listed as rare. Denning sites for red fox (*Vulpes vulpes*) and porcupine (*Erethizon dorsatum*) have been reported along the eastern shore of the KIH. Muskrat (*Ondatra zibethica*) houses have been found throughout the interior of the Great Cataraqui Marsh, with densities high enough to support muskrat trapping in the mid-1900s. A recent biological survey of the Orchard Street Marsh site observed three regionally common mammal species: raccoon (*Procyon lotor*), beaver (*Castor canadensis*) and muskrat (Ecological Services 2008). The same report concluded that the site did not appear to provide suitable habitat for other species such as river otter or mink.

f. Birds

Extensive information is available concerning avifaunal use of the KIH area, largely through observations made by the Kingston Field Naturalists club. These observations are described in a book on the birds of the Kingston region (Weir 2008). Blancher (1984) reports a list of 206 species that have been sighted in the KIH area. Of these, eight summer residents are listed as rare species: king rail (*Rallus elegans*: endangered), loggerhead shrike (*Lanius ludovicianus*: endangered), least bittern (*Ixobrychus exilis*: threatened), common nighthawk (*Chordeiles minor*: threatened), chimney swift (*Chaetura pelagica:* threatened), red-headed woodpecker (*Melanerpes erythrocephalus:* threatened), short-eared owl (*Asio flammeus*: special concern) and black tern (*Chlidonias niger*: species of concern). Four migratory or winter visitor species are also listed as rare: red knot (*Calidris canutus*: endangered), golden-winged warbler (*Vermivora chrysoptera:* threatened), hooded warbler (*Setophaga citrina, formerly Wilsonia citrina*: threatened) and peregrine falcon (*Falco peregrinus*: special concern). Most of the species observations have been reported from the north end of the Inner Harbour, near the Cataraqui Marsh. During the biological survey of the Orchard Street Marsh, black terns were sighted (Ecological Services 2008).

Large numbers of red-winged blackbirds (*Agelaius phoeniceus*), marsh wrens (*Cistothorus palustris*), swamp sparrows (*Melospiza georgiana*) and mallards (*Anas platyrhynchos*) have been reported nesting in the Great Cataraqui Marsh (Blancher 1984). Several rare species are also known to nest here, including black terns and least bitterns. A 1983 biological survey of marsh-nesting birds in Great Cataraqui Marsh also identified 15 other bird species that were nesting within the marsh (Blancher 1984). Little information on nesting birds is available for other areas of the KIH. However, red-winged blackbirds, marsh wrens, and swamp sparrows were reported nesting in the Orchard Street Marsh south of Belle Park in 2008, and a pair of ospreys (*Pandion haliaetus*) was observed nesting on a platform at the south edge of Belle Park (Ecological Services 2008).

The Great Cataraqui River has been identified as an area of major importance in the spring and fall migrations for both waterfowl and terrestrial bird species (Crysler and Lathem Ltd. 1977). Large numbers and a high diversity of waterfowl are found on the river during the spring migration, while gulls are found in fall, winter and early spring (Blancher 1984). Migrating warblers are also found on the river shores during the spring. The Great Cataraqui Marsh is a highly significant tree swallow (*Tachycineta bicolor*) migration area, with tens of thousands of swallows using the marsh as a roost in July and August (Weir 2008; Environment Canada 1993).

IV. PREVIOUS STUDIES ON ENVIRONMENTAL QUALITY

Many studies have been conducted over the past 40 years to investigate the environmental quality of the KIH. These include various environmental consulting studies undertaken to assess projects such as utility and transportation crossings of the harbour, fugitive emissions from bordering contaminated sites, and dredging of the Rideau Canal waterway; undergraduate and postgraduate environmental quality studies carried out by Queen's University, Royal Military College of Canada and St. Lawrence College students; and environmental investigations by Environment Canada and the OMOE to locate possible sources of contaminants entering the Great Lakes under the Canada–United States (U.S.) Lake Ontario Lakewide Management Plan (LaMP).

Past studies have addressed various aspects of surface water quality, sediment quality and sediment pore water quality and their biological effects. In this report, all previous studies, including those conducted up to 2006, are summarized, in table format, for ease of reference. The study descriptions and results are intended not to be a thorough summary but to give the reader an indication of the scope and purpose of each study. For more detailed information on specific studies, the reader should refer to Malroz (2003), which provides summaries and selected figures for the studies conducted up to 2001, or to the original sources. Relevant data from all previous reports have been reviewed and, if applicable, have been combined with additional data collected by the Environmental Sciences Group (ESG) in 2006, 2007 and 2008 to provide a thorough analysis of the spatial distribution of contaminants (Chapter II) and the ecological effects of the sediment contamination (Chapter III).

A. Water Quality

1. Water Quality Guidelines

Provincial and federal guidelines for assessing surface water quality exist. Most studies within the KIH have compared water quality parameters with the Provincial Water Quality Objectives (PWQOs), which are designed to assess ambient surface water quality (OMOE 1994). Two sets of federal (CCME) guidelines are available: freshwater guidelines for the protection of aquatic life (CCME 2007), and agricultural guidelines, which include different values for livestock and for irrigation water (CCME 1999a). The guidelines for protection of aquatic life tend to be more stringent than the agricultural guidelines and are more appropriate for assessing water quality in the KIH. Several KIH studies have used the CCME freshwater guidelines for the protection of aquatic life to assess surface water quality. The City of Kingston also provides guidelines for the discharge of liquids into the sanitary and storm sewer systems (City of Kingston 2002). One study compared surface water quality and pore water analyses to these guidelines to assess disposal options for a sediment remediation project (Inspec-Sol 2003c). The CCME and OMOE surface water guidelines for inorganic elements and for organic elements and the City of Kingston sanitary, combined and storm sewers discharge criteria are summarized in Table I-4, Table I-5 and Table I-6 respectively.

Table I-4: CCME and OMOE water quality guidelines for inorganic elements

Element	**Water quality guidelines (mg/L)**	
	CCME Guidelines for Protection of Aquatic Life[a]	**OMOE PWQOs**[b]
Aluminum	0.005–0.10	0.075
Arsenic	0.005	0.10
Boron		0.20
Cadmium	0.000017	0.0002
Chromium (total)		
Chromium (III)	0.0089	0.0089
Chromium (VI)	0.001	0.001
Cobalt		0.0009
Copper	0.002–0.004	0.005
Iron	0.003	0.003
Lead	0.001–0.007	0.005–0.025
Mercury	0.000026	0.0002
Molybdenum	0.073	0.04
Nickel	0.025–0.15	0.025
Selenium	0.001	0.001
Silver	0.0001	0.0001
Uranium		0.005
Vanadium		0.006
Zinc	0.03	0.03

[a]CCME 2007
[b]OMOE 1994

Cells are left blank where no values are available.

Table I-5: CCME and OMOE water quality guidelines for organic contaminants

Organic contaminants	Water quality guidelines (µg/L)	
	CCME Guidelines for Protection of Aquatic Life[a]	OMOE PWQOs[b]
Naphthalene	1.1	7
Acenaphthylene		
Acenaphthene	5.8	
Fluorene	3	0.2
Phenanthrene	0.4	0.03
Anthracene	0.012	0.0008
Fluoranthene	0.04	0.0008
Pyrene	0.025	
Benzo[a]fluoranthene	0.018	0.0004
Chrysene		0.0001
Benzo[b]fluoranthene		
Benzo[k]fluoranthene		0.0002
Benzo[a]pyrene	0.015	
Indeno(1,2,3-cd)pyrene		
Dibenz[a,h]anthracene		0.002
Benzo[g,h,i]perylene		0.00002
PCBs		
Aroclor 1254		
Aroclor 1260		
Total PCBs		0.001

[a]CCME 2007
[b]OMOE1994

Cells are left blank where no values are available.

Table I-6: City of Kingston sanitary, combined and storm sewer discharge limits as per Bylaw No. 2000-263

Parameter	Discharge limits (mg/L)		Parameter	Discharge limits (mg/L)	
	Sanitary & combined sewers	Storm sewer		Sanitary & combined sewers	Storm sewer
Biochemical oxygen demand	300	15	Benzene	0.01	0.002
Cyanide (total)	2	0.02	Chloroform	0.04	
Fluoride	10		1,2-Dichlorobenzene	0.05	0.0056
Total Kjeldahl nitrogen (TKN)	100		1,4-Dichlorobenzene	0.08	0.0068
Oil and grease (animal and vegetable)	150		Cis-1,2-dichloroethylene	4	0.0056
Oil and grease (mineral and synthetic)	15		Trans-1,3-dichloropropene	0.14	0.0056
Phenolics (4AAP)	1	0.008	Ethylbenzene	0.16	0.002
Phosphorus (total)	10	0.4	Methylene chloride	0.21	0.0052
Suspended solids (total)	350	15	1,1,2,2-Tetrachloroethane	0.04	0.017
Aluminum (total)	50		Tetrachloroethylene	0.05	0.0044
Antimony (total)	5		Toluene	0.016	0.002
Arsenic (total)	1	0.02	Trichloroethylene	0.07	0.0076
Cadmium (total)	0.7	0.008	Xylenes (total)	0.94	0.0044
Chromium (total)	4	0.08	Di-n-butyl phthalate	0.08	0.015
Chromium (hexavalent)	2		Bis(2-ethylhexyl)phthalate	0.012	0.0088
Cobalt (total)	5		Nonylphenols	0.001	0.001
Copper (total)	2	0.04	Nonylphenol ethoxylates	0.01	0.01
Lead (total)	1	0.12	Aldrin/Dieldrin	0.0002	0.00008
Manganese (total)	5	0.05	Chlordane	0.1	0.04
Mercury (total)	0.01	0.0004	Dichlorodiphenyl-trichloroethane (DDT)	0.0001	0.00004
Molybdenum (total)	5		Hexachlorobenzene	0.0001	0.00004
Nickel (total)	2	0.08	Mirex	0.1	0.04
Selenium (total)	1	0.02	PCBs	0.001	0.0004
Silver (total)	5	0.12	3,3'-Dichlorobenzidine	0.002	0.0008
Tin (total)	5		Hexachlorocyclohexane	0.1	0.04
Titanium (total)	5		Pentachlorophenol	0.005	0.002
Zinc (total)	2	0.04	Total PAHs	0.005	0.002
Vinyl chloride	0.04	0.04			

Bylaw: City of Kingston 2002

2. Summary of Previous Studies

Under OMOE's Provincial Water Quality Monitoring Network (PWQMN), water quality for the Great Cataraqui River at Kingston Mills and the LaSalle Causeway is monitored monthly, with data coverage from the 1960s to present. Other water quality data for KIH have been collected in the context of environmental investigations, with limited temporal and spatial data coverage. Malroz (2003) identified and reviewed a total of 13 water quality studies. The 2003 data compilation indicated that surface water quality in the Inner Harbour generally meets the PWQOs and Ontario's body-contact water recreation bacteriological guidelines (Malroz 2003). Seven recent additional studies investigating water quality in the Inner Harbour (ESG 2003; Inspec-Sol Inc. 2003c; Derry et al. 2003; City of Kingston and OMOE 2005; Tinney 2006; Conestoga-Rovers and Associates 2006; Manion 2007) have been identified since the 2003 data compilation. All of the studies examining water quality are summarized in Table I-7.

The Great Cataraqui River may be characterized as a eutrophic system with a relatively high pH. Overall, the available studies indicate that the water quality of the KIH is generally good with respect to provincial and federal guidelines. This is probably partly a reflection of rate at which water is flushed through the Cataraqui River system. The flushing rate is high, which would facilitate dilution of any water-borne contaminants. Comparison with older studies suggests that some aspects of water quality, such as nutrient concentrations, have improved since the 1970s. Recent groundwater monitoring following remedial measures at the Belle Park Landfill and groundwater monitoring in the vicinity of Emma Martin Park suggests that these sites are not current contaminant sources to the KIH through groundwater flow (City of Kingston and OMOE 2005; Benoit and Dove 2006). Ongoing work assessing groundwater and surface water quality at the former Davis Tannery property is being used to determine whether there are fugitive emissions associated with this area. Relevant data from these studies is discussed in Chapter V of the report.

Table I-7: Summary of studies examining water quality

Study	Purpose/methods	Parameters assessed	Results
Westerby (1971)	Unpublished BSc thesis on geochemistry in the Great Cataraqui River.	• Conventional water quality parameters	Generally elevated concentrations of alkalinity, hardness, chloride, Na, Ca and nitrates along the north shore of Cataraqui Park.
St. Lawrence College (1973)	Study by St. Lawrence College students on contamination in the Great Cataraqui River from the Kingston Waste Disposal Site near Belle Island. Water samples collected around the landfill site and in adjacent steams.	• Conventional water quality parameters • Pb, Zn, Cu, Cr, V and Hg	No significant evidence of water quality impairment attributable to the landfill site. Water quality impacts attributed to surface water drainage located immediately north and south of the landfill.
Underhill, (1975)	Unpublished BSc thesis on the water quality of the landfill site in Cataraqui Park. Water samples collected from on-shore test pits and nearshore surface waters at Cataraqui Park.	• Conventional water quality parameters	Elevated levels of alkalinity, hardness, chloride, sulphate and Fe at southwest corner of Federal Dredged Sediments Disposal Site. Malroz (2003) notes results may be suspect because of sampling and analysis procedures.
Stokes et al. (1977)	Investigation of former Davis Tannery and Frontenac Smelting Works property.	• Metals	Elevated levels of As, Cd, Co, Cr, Pb and Zn
OMOE (1986)	Two-year study of surface water quality in vicinity of Cataraqui Park. Report provides summary of analytical data reported as mean concentrations.	• Conventional water quality parameters • Metals	Some evidence of diffuse impairment of surface water quality associated with the landfill. Significant impact from storm sewer discharges.
CH2M Hill (1992)	Evaluation of the influence of stormwater inputs and combined sewer overflows by collecting water samples during wet and dry weather conditions. Samples collected between Highway 401 and LaSalle Causeway, including stormwater outfalls, sites off Belle Island and River Street Pumping Station.	• Conventional water quality parameters	No evidence of water quality impairment.

Table I-7: Summary of studies examining water quality (cont'd.)

Study	**Purpose/methods**	**Parameters assessed**	**Results**
CH2M Hill (1994)	Final report on closed waste disposal site assessment at the Belle Island Landfill site.	• Conventional water quality parameters	
Ecological Services for Planning (1996a;b)	Great Lakes Embayments and Harbours Investigation Program. Samples collected in triplicate from one location offshore from Kingston Rowing Club and two locations in Lake Ontario near Olympic Harbour. Samples collected three times in each of 1993 and 1994.	• Conventional water quality parameters • Metals • PCBs • DDT • VOCs • Bacteria	Phosphorous levels exceeded the PWQO. Other parameters were below the PWQOs. No significant difference between water quality at the Inner Harbour and Olympic Harbour sampling locations.
Staples (1996)	Unpublished BSc thesis investigating impact of contaminated groundwater seepage on southern shoreline of Belle Island peninsula. Sampling of five mini-piezometers and surface waters along southern shoreline of Cataraqui Park.		No adverse effects associated with landfill site were reported. Chloride levels were higher in surface water samples than in mini-piezometers and highest in discharge from the storm sewer.
OMOE (1997)	Monthly monitoring data collected by OMOE at Kingston Mills and LaSalle Causeway. Routine monitoring carried out continuously since mid-1960s.		In a review of the data, Malroz (1999) reported that OMOE data were remarkably similar in quality at upstream (Kingston Mills) and downstream (LaSalle Causeway) locations. Marginally higher mean Fe and chloride concentrations at downstream location.
Malroz (1999)	Assessment of surface water quality in the vicinity of Cataraqui Park. Sampling conducted over two years, including locations upstream and downstream.	• Landfill leachate indicator parameters • Metals • PCBs • PAHs	Confirmed findings of previous investigations that concentrations of some water quality parameters are elevated in vicinity of landfill but concentrations are below PWQOs. PWQOs exceeded for several metals in samples taken from West Stream, upstream of Cataraqui Park (Belle Island Landfill).
Malroz (2003)	Summary and gap analysis of previous studies.		

Table I-7: Summary of studies examining water quality (cont'd.)

Study	**Purpose/methods**	**Parameters assessed**	**Results**
ESG (2003)	Collection of water samples from two locations in KIH (upstream and downstream of the Belle Park Landfill) and two locations in Outer Harbour (Fort Frontenac water lot and near Wolfe Island Ferry Dock) as part of an ecological risk assessment of contamination effects.	• Inorganic elements • PAHs • PCBs	Inorganic element, PAH and PCB concentrations were mostly below analytical detection limits, Cu concentrations were marginally above CCME water quality guidelines at the upstream reference site.
Inspec-Sol (2003c)	Environmental assessment of a potential utilities crossing. Collected three samples of river water for analysis. Results were compared to City of Kingston Sewer Bylaw guidelines for waste discharges to municipal sewers.	• SVOCs • PCBs • Inorganic elements	The majority of parameters were below field blank samples, suggesting results may not be valid.
Derry et al. (2003)	Collection of integrated large volume water samples from six storm sewer outflows on the western side of the KIH and three draw-down wells on the Belle Island Landfill.	• PCB congeners • PAHs • Limited suite of organo-chlorine pesticides.	PCB concentrations in all of the storm sewer water samples were below the PWQO. PCB concentrations for leachate samples from the three wells at Belle Island Landfill exceeded the guidelines. All samples exceeded the PWQOs and CCME water quality guidelines for a variety of PAHs. Concentrations were several orders of magnitude below levels at which acute toxicity is observed in aquatic life such as *Daphnia magna*. Concentrations reported for four organochlorine pesticides in the leachate and selected storm sewer samples did not exceed the relevant PWQOs.
City of Kingston and OMOE (2005)	Groundwater monitoring to quantify PCB concentrations and congener patterns in groundwater leaving the Belle Island Landfill and at other locations along the western shore south of Belle Island.	• PCB congeners	The results of the study suggested no evidence of ongoing sources of contamination from groundwater.

Table I-7: Summary of studies examining water quality (cont'd.)

Study	**Purpose/methods**	**Parameters assessed**	**Results**
Tinney (2006)	Collection of water samples from 13 locations (including three reference sites) throughout the KIH at three different sampling periods: November 2004; June 2005 and September 2005.	• Conventional water quality parameters • PCBs • PAHs • Inorganic elements	Water profiles at all locations were alkaline with slightly elevated conductivities. Temperature and dissolved oxygen profiles indicated that water column was typically unstratified. Nutrient (TKN and total phosphorus, TP) and BOD concentrations indicate a typical eutrophic system, but samples were within PWQOs and federal guidelines. PAH and PCB results were below the analytical detection limits. Of the 30 inorganic elements for which analysis was done, relevant guidelines were exceeded for Al (seven locations), Fe (three locations) and total Cr (one location). All samples from upstream reference sites were within guidelines.
Manion (2007)	Collection of surface runoff samples during three rainfall events (September 2006, March 2007 and June 2007) from the northern section of Douglas Fluhrer Park and the Kingston Rowing Club property, as well as of water samples from three nearby storm sewers.	• Total Hg	Total Hg results in all storm sewer samples were below analytical detection limits. Total Hg results in surface runoff samples were significantly higher and exceeded relevant guidelines; however, comparisons of unfiltered and filtered samples indicated that the Hg was bound primarily to particulate matter.

Table I-7: Summary of studies examining water quality (cont'd.)

Study	Purpose/methods	Parameters assessed	Results
Benoit and Burniston (2010)	Collection of water samples from seven stations located mostly in southwest portion of the KIH south of Belle Park, and from one upstream reference location. Grab samples were collected on August 2, 2006 and August 30, 2006.	• PCB congeners • Total suspended solids • Organo-chlorines • PAHs • Inorganic elements	Most chemicals were present in trace quantities or below relevant analytical detection limits and PWQO and CCME guidelines. Elevated chemical concentrations in several samples were correlated with suspended solid concentrations, suggesting that the chemicals were primarily bound to particulates. Elevated PCBs (35 ng/L) in one sample from southeast arm of Belle Island Landfill were not correlated with higher suspended solids and may indicate a nearby input.

B. Sediment Quality

1. Sediment Quality Guidelines

Most previous studies assessing contaminants in KIH sediments have compared concentrations with the Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (PSQGs), while some recent studies have also used the federal CCME sediment quality guidelines. Given that ownership of the KIH sediments is primarily federal (Parks Canada and Transport Canada), the federal CCME sediment quality guidelines are the most appropriate to use as benchmarks in assessing sediment quality. These guidelines and the provincial guidelines (calculated using a maximum total organic carbon (TOC) of 10 percent) are summarized in Table I-8 and Table I-9 (CCME 1999b; OMOE 1993).

Both federal and provincial guidelines use a two-tiered system as follows:

- The federal Interim Sediment Quality Guidelines (ISQGs) include a set of contaminant concentrations that were derived based on the threshold effect level (TEL). This value represents the concentration below which adverse biological effects are rarely expected. The federal guidelines also specify a probable effect level (PEL), which defines the level above which adverse effects in biota are expected to occur frequently.

- The provincial guidelines list typical background concentrations as well as no effect level (NOL), lowest effect level (LEL) and severe effect level (SEL) for specified contaminants. The SEL is calculated for the study site based on TOC levels in the sediments, with a maximum TOC of 10 percent used for organic-rich areas such as the KIH. If concentrations are above the LEL, it is expected that sediments may have adverse effects on some benthic organisms. The provincial LEL tends to be slightly more conservative than the federal ISQG. If values are above the SEL, sediment is considered to be contaminated and is likely to have a significant effect on benthic organisms. Provincial SEL values tend to be higher than federal PEL levels.

Table I-8: CCME sediment quality guidelines for the protection of aquatic life and OMOE provincial sediment quality guidelines for inorganic elements and nutrients

Element/ nutrient	CCME[1] [µg/g]		OMOE[2] [µg/g]	
	ISQG	PEL	LEL	SEL[3]
Arsenic	5.9	17	6	33
Cadmium	0.6	4	1	10
Chromium	37.3	90	26	110
Copper	35.7	197	16	110
Iron			2	4
Lead	35	91.3	31	250
Manganese			460	1,100
H	0.17	0.49	0	2
Nickel			16	75
Zinc	123	315	120	820
TOC (%)			1	10
TKN			550	4,800
Total phosphorus			600	2,000

[1]CCME 1999b
[2]OMOE 1993
[3]SEL for organic compounds has been corrected for 10 percent organic carbon.
Cells are left blank where no values are available.

Table I-9: CCME sediment quality guidelines for the protection of aquatic life and OMOE provincial sediment quality guidelines for organic contaminants

PAHs	CCME[1] [µg/g]		OMOE[2] [µg/g]	
	ISQG	PEL	LEL	SEL
Naphthalene	0.035	0.391		
Acenaphthylene	0.006	0.128		
Acenaphthene	0.007	0.089		
Fluorene	0.021	0.144	0.190	16
Phenanthrene	0.042	0.515	0.560	95
Anthracene	0.047	0.245	0.220	37
Fluoranthene	0.111	2.355	0.750	102
Pyrene	0.053	0.875	0.490	85
Benzo[a]fluoranthene	0.032	0.385	0.320	148
Chrysene	0.057	0.862	0.340	46
Benzo[b]fluoranthene				
Benzo[k]fluoranthene			0.240	134
Benzo[a]pyrene	0.032	0.782	0.370	144
Indeno[1,2,3-cd]pyrene			0.200	32
Dibenz[a,h]anthracene	0.006	0.135	0.060	13
Benzo[ghi]perylene			0.170	32
Total PAHs			4	1,000
PCBs				
Aroclor 1254	0.060	0.340	0.060	3.4
Aroclor 1260			0.005	2.4
Total PCBs	0.034	0.277	0.070	53

[1]CCME 1999b
[2]OMOE 1993
Cells are left blank where no values are available.

2. Summary of Previous Studies

There have been extensive studies on sediment quality in the KIH. In the review of all studies up to 2001, Malroz (2003) identified that (1) sediment quality assessments comparing sediment concentrations to federal guidelines are limited in scope, (2) contaminant sources and loadings are not fully identified, (3) the spatial distribution, depth of burial and temporal trends with respect to sediment impacts due to contaminants are not known; and (4) the fate and transport of contaminants within the KIH ecosystem are not well understood. Since 2001, several additional studies have been conducted (Inspec-Sol 2003b, c, d; ESG 2003; Derry et al. 2003; Benoit and Dove 2006; Tinney

2006; Goodberry et al. 2006; Asquini et al. 2007; Manion 2007; Benoit and Burniston 2010). A summary of sediment quality studies for areas in and around the KIH is presented in Table I-10.

In summary, surface sediments throughout the KIH are composed mostly of fine-grained organic gyttja, with large percentages of clays and fine silts. The sediments are rich in organic material, with many reported TOC concentrations in excess of 10 percent. Nutrient concentrations such as TKN and TP are also high within the sediments, with several studies reporting TKN values exceeding the provincial SEL (e.g., Inspec-Sol 2003d; Tinney 2006). As contaminants tend to bind tightly to fine-grained sediments with high organic content, it is likely that the main processes influencing the fate and transport of contaminants in the KIH would be associated with sediment resuspension and redistribution caused by turbulent water flow generated by river currents, wind and boat activity. Studies assessing the biological effects of sedimentary contaminants are also important in determining whether contaminants bound to the sediments are bioavailable. This is discussed further in Section D.

Numerous studies have found surface sediment contamination exceeding the provincial and federal guidelines in the southwestern portion of the KIH, reflecting the historical legacy of industrial activities in this area. In contrast, little sediment contamination is found north of Belle Park or along the eastern shoreline of the harbour. The main sedimentary contaminants of concern are arsenic, chromium, copper, lead, mercury, zinc, PCBs and PAHs, with chromium being the most widespread and abundant contaminant. There is limited information on organochlorine pesticide concentrations, although some studies have reported elevated levels of DDT and metabolites immediately south of the Belle Island Landfill (e.g., Cross 1999; Benoit and Dove 2006).

Available data on spatial coverage of sediment contaminant concentrations relative to depth for the KIH are limited. The data suggest that contaminant concentrations at depth are generally highest on the western side of the KIH, reflecting historical industrial activities in this area. Inorganic element concentrations at a depth of approximately 30 cm appear to be elevated in comparison with surface sediments, except in areas of highest concentration close to the former Davis Tannery site (Benoit and Dove 2006; Goodberry et al. 2006; Asquini et al. 2007). Little information is available on sediment depth profiles of organic contaminants.

Collectively, the data give an indication of the types and distribution of the contaminants, but the different studies in isolation are not sufficient for drawing definitive conclusions for management action. A compilation of the data and thorough analysis of sediment contamination are presented in Chapter II.

Table I-10: Summary of sediment quality studies

Study	Purpose/sediment sampling plan	Parameters assessed
Johnston (1972)	Unpublished MSc thesis on the sediment geochemistry in Deadman Bay (a reference area in Lake Ontario outside of the Inner Harbour). Sediment cores collected.	• Cu, Pb, Zn, Co, Ni, Mn, Fe, Ca, Mg, Na, K, Ti, Al, Si • Radioactive dating
Hudson (1973)	Unpublished BSc thesis on the sediment quality. Surface samples collected along the shorelines south (14 samples) and north (four samples) of Cataraqui Park.	• Al, Ca, Cr, Cu, Fe, K , Mg, Mn, Na, Pb, SiO_2, Sn, Sr, Ti, Zn
St. Lawrence College (1973)	Sediment quality survey by college students prepared for OMOE. Surface samples collected throughout the KIH. No data presented. Figures show metals distribution.	
Stokes et al. (1977)	Investigation of former Davis Tannery and Frontenac Smelting Works properties. Two sediment samples collected from the shoreline near the former Davis Tannery.	• Cd, Cr, Cu, Pb, Hg, Ni, Zn
Stokes (1977)	Follow-up investigation of Davis Tannery to assess chemical form and mobility of chromium. Three different types of extraction conducted on two sediment samples from the shoreline near the former Davis Tannery and also other surface soil samples.	• Cr and leaching tests
OMOE (1978)	Remedial Action Plan for Davis Tannery. No new data. References previous studies.	
Frape (1979)	Unpublished PhD thesis on interstitial waters and sediment geochemistry as indicators of groundwater seepage. Samples collected from 25 sediment cores around outer margins of Federal Contaminated Sediment Disposal Area located on north shore of Belle Park.	• pH, organic carbon, % loss on ignition • Fe, Mn, Cu, Zn, Pb, Co, Ni, and Cd
Ecologistics and WESA (1984)	Environmental evaluation of dredging the navigational channel. Samples collected at 10 locations extending from Belle Island to Highway 401. Report does not specify the fractions of the cores analyzed.	• % moisture, % loss on ignition, % Ni, % P • Hg, Pb, Zn, Co, Ni, Cr, Cd, Fe • PCB, DDT (two samples)
OMOE (1985)	Unpublished data from OMOE from 19 sampling locations on lower half of KIH. Sampling methodology and analytical protocols not known.	• PCBs • Fe, Ar, Ad, Co, Cr, Cu, Hg, Ni, Pb, Zn

Table I-10: Summary of sediment quality studies, cont'd.

Study	Purpose/sediment sampling plan	Parameters assessed
CH2M Hill (1991)	Investigation of extent of PAH contamination in Anglin Bay and the Outer Harbour. Cores collected at 13 locations in Anglin Bay and KIH and at 13 locations in Outer Harbour. No analysis of surficial sediments.	• Visual or olfactory evidence of coal tar. • PAHs
Jaagumagi (1991)	Follow-up to CH2M Hill (1991) to investigate surficial sediments from Anglin Bay and Queen Street Slip.	• PAHs • PCBs • Organochlorine pesticides • Nutrients • TOCs • Metals
Totten Sims Hubicki Associates (1992)	Transportation study of bridge crossings of the Great Cataraqui River, including implementation strategy for the construction of new river crossing(s). No new sediment data collected. Report presents the MOE (1985) unpublished data.	
Groundtrax (1996)	Evaluation of the potential impact of a closed waste disposal site within the Deadman Bay watershed. Cores collected at 13 sampling stations in Deadman Bay. Data from core samples representing a composite of natural and anthropogenic sediment quality conditions.	
UMA Engineering (1996)	Property transfer assessment of Crawford Dock. Sediment collected from three locations near Crawford Dock, Outer Harbour. Used a Pionjar rock drill to vibrate a split spoon sampling device to 1 m.	• As, Cd, Cr, Cu, Ni, Zn (detected)
Ecological Services for Planning (1996a)	Great Lakes Embayments and Harbours Investigation Program. Samples collected at one location south of Woolen Mill and two locations along Kingston waterfront near Olympic Harbour. Data for all locations combined, so provide no meaningful sediment chemistry data for KIH.	
Ecological Services for Planning (1996b)	Provides the KIH data for the Ecological Services for Planning Limited (1996a) study. One sampling location south of the Woolen Mill.	• PCBs • Cr, Pb, Cu, Zn, Mn, Hg, Cd
Aqua Terre Solutions (1997)	Sediment sampling program prepared for Transport Canada. Nine sampling locations in Outer Harbour (Crawford Dock) and one reference site (Frederick's point).	• Metals • Particle grain size • Oil and grease, PCBs, PAHs
Environment Canada (1997)	Sediment characterization at Department of National Defence water lots. Surface sediment samples collected in Deadman Bay (seven locations) and Navy Bay (18 locations).	• Metals • PAHs • PCBs

Table I-10: Summary of sediment quality studies, cont'd.

Study	Purpose/sediment sampling plan	Parameters assessed
J.L. Richards Acres & Associates and Acres and Associates Environmental Limited (1997)	Letter report to the City of Kingston and Kingston Public Utilities Commission on condition assessment work for the sewage force main and water main crossings. Surface sediments collected at nine locations along the sewer and water main crossing of the KIH.	• PCBs • Metals (10) • Nutrients
Sierra Legal Defence Fund (1998)	Unpublished data for samples from five locations near northwest corner of Belle Island Landfill and four locations along south shore of landfill. Data reported in Malroz (1999).	• PCBs
Brooks et al. (1999)	Unpublished thesis on an environmental evaluation of river sediments surrounding Belle Island. Surface sediment samples collected at 41 locations.	• PAHs • Organochlorine pesticides • PCB Aroclors • PCB congeners • Fe, Mn, Cu, Cd, Pb, Zn
Cross (1999)	Undergraduate thesis investigating organochlorines around Belle Island. Provides PCB Aroclor, PCB congener and pesticide data for 11 surface samples collected in Brooks et al. (1999). Examines differences among PCB Aroclor and congener compositions between upstream and downstream sediments. References PCB and DDT values from locations around Lake Ontario for comparative purposes.	• PCB Aroclors • PCB congeners • Organochlorine pesticides
Malroz Engineering (1999)	Environmental impact study for the Cataraqui Park. Original data for one sample collected from north shore of Cataraqui Park. Compilation of previous data (OMOE 1985; Ecological Services for Planning 1996a; Sierra Legal Defence Fund 1998; Brooks et al. 1999; Cross 1999).	• PCBs
Environmental Sciences Group (2000)	Report prepared for CFB Kingston. Three sediment cores taken from the Outer Harbour adjacent to Fort Frontenac.	• PAHs
Kennedy et al. (2000)	Undergraduate sediment quality study of stormwater runoff from CFB Kingston. Samples taken off shore from Butternut Creek and at three storm sewer outlets surrounding HMCS Cataraqui.	• As, Cd, Cr, Co, Cu, Pb, Ni, Zn • Petroleum hydrocarbons • PAHs • PCBs (Aroclors)
Environmental Sciences Group (2001)	Characterization of sediment contaminant levels in Deadman Bay. Four sediment cores taken in Deadman Bay.	• 20 inorganic elements • Total petroleum hydrocarbons • PAHs • PCBs (Aroclors)

Table I-10: Summary of sediment quality studies, cont'd.

Study	Purpose/sediment sampling plan	Parameters assessed
Geo-Canada (2001)	Assessment of alternatives for replacement of two existing service crossings between River St. Pumping Station and Green Bay and evaluation of feasibility of additional services within new utility conduit(s). Nine sediment cores collected parallel to and approximately 20 m downstream (south) of existing utilities crossing. Four additional surface samples collected near east side of river.	• TKN • TOC • Phosphorus • Inorganic elements • PCBs • PAHs • Leachate testing for inorganics and PCBs
Malroz Engineering (2003)	Summary and gap analysis of previous studies.	
Inspec-Sol (2002)	Environmental assessment for a proposed new utility crossing approximately 15 m north of existing crossing between River St. Pumping Station and Green Bay. Variety of surface and depth samples (42 total) from 22 boreholes.	• SVOCs • Pesticides • PCBs • Inorganic elements • pH, conductivity • Na absorption ratios • Free cyanide • TOC, TKN • Leachate testing for metals (As, Ba, Bo, Cd, Cr, Pb, Hg, Se, Ag)
Inspec-Sol (2003b, c)	Supplementary environmental assessment report for utilities crossing at proposed docking area on east shoreline and nearshore area of west shoreline. Two boreholes in the nearshore area on each side of river, as well as three additional sediment cores along the utility crossing corridor.	• SVOCs • Pesticides • PCBs • Inorganic elements • pH, conductivity • Na adsorption ratios • Free cyanide • TOC, TKN
Environmental Sciences Group (2003)	Collection of surface sediment samples from two locations in KIH (up- and downstream of Belle Park Landfill) and two locations in Outer Harbour (Fort Frontenac water lot and near the Wolfe Island ferry dock) as part of an ecological risk assessment of contamination effects.	• % moisture • % organic matter • Grain size distribution • TKN • Total phosphorus • PAHs • PCBs • 31 elements
Derry et al. (2003)	Pilot project for Canada-U.S. Lake Ontario LaMP conducted in 2001. Quantification of extent and concentrations of PCB contamination, identification of ongoing PCB sources, determination of bioavailability of PCBs. Various surface and sediment cores collected from 55 locations, primarily south of Belle Park and at storm sewer discharge points.	• PCBs • TOC • Cd, Cr, Cu, Fe, Pb, Ni, Zn, Al • Organochlorine compounds

Table I-10: Summary of sediment quality studies, cont'd.

Study	Purpose/sediment sampling plan	Parameters assessed
Benoit and Dove (2006)	Supplemental study to Derry et al. (2003). Presents results of 2002 and 2003 monitoring programs for the LaMP. Fifty-two sediment samples collected from 36 locations, primarily near western shoreline of KIH in the vicinity of River St. Pumping Station, Rowing Club, Emma Martin Park and Woolen Mill. Three cores collected at each of eight stations along shoreline to Emma Martin Park and City of Kingston's sewage pumping station and an additional set of three cores were taken at Rowing Club docks.	• PCBs • PAHs • TOC • Grain size • 30 inorganic elements
Tinney (2006)	Unpublished MSc thesis on site investigation and ecological risk assessment of KIH. Sampling locations chosen to provide information for areas of the KIH for which information from previous studies was lacking. Various surface sediment samples and cores collected over three seasons: November 2004, June 2005 and September 2005.	• PCBs • PAHs • TOC, TKN, TP • Grain size • 30 inorganic elements • Sediment dating using Pb-210
Goodberry et al. (2006)	Undergraduate thesis on environmental and economic impacts of sediment contamination in the Great Cataraqui River. Eight sediment cores collected throughout southern portion of the KIH.	• Cr, Cu, Pb, Zn
Asquini et al. (2007)	Undergraduate thesis on the remediation of sediment contamination in the Great Cataraqui River. Eight sediment cores collected, mostly southwest of Belle Park.	• Cr, Cu, Pb, Zn
Manion (2007)	Unpublished MSc thesis on distribution and fate of mercury in sediments of the Great Cataraqui River. Twenty-one sediment cores sampled throughout the KIH, with most sampling locations in western portion of harbour south of Belle Island.	• Total Hg
Benoit and Burniston (2010)	Results from a 2006 follow-up study on success of remediation efforts in the Cataraqui River under the LaMP. Surface 1–2 cm of sediment was collected from 26 sampling locations, mostly south of Belle Park and adjacent to Emma Martin Park and Woolen Mill. Sediment cores collected from two locations southwest of Belle Park.	• PCB congeners • TOC • Grain size • Organochlorines • PAHs • As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn
Golder Associates Ltd. (2011)	Sediment chemistry investigation focused on the portion fo the KIH that is managed by Transport Canada which includes sediments that lie south of Belle island.	• As, Cr, Cu, Pb, Hg, Zn • PCBs • PAHs • Dioxins and furans • Organochlorines

C. Sediment Pore Water Quality

Contaminants in interstitial waters may contribute to ecological effects, may provide an indication of the possible flux of contaminants upward into the water column and may become mobile if the sediments are disturbed. These effects must be taken into account when designing a remediation strategy. Additionally, pore water contaminant concentrations often correlate more closely with ecological effects than do bulk sediment concentrations, as pore water concentrations may provide an indication of bioavailability.

Only a small number of studies have investigated pore water contaminant concentrations in the KIH (Table I-11). The available studies suggest that chemical concentrations in pore water are generally present at trace levels or below the analytical detection limits or the relevant water quality guidelines. Although PCBs in contaminated sediment southwest of the Belle Park Landfill appear to be bioavailable, the relationship between PCB concentrations in the semi-permeable membrane devices (SPMDs) that are used to provide a measure of bioavailable contaminants and concentrations in the environment is unclear. With the exception of mercury, very little information is available on inorganic element concentrations in sediment pore water. Recent work has been completed to assess chromium speciation in sediment pore water samples from KIH; these results are presented in Chapter II**.**

Table I-11: Summary of studies investigating potential contaminants in pore water

Study	Purpose/pore water sampling plan	Parameters assessed	Results
Inspec-Sol (2003c)	Environmental assessment for the Great Cataraqui River utilities crossing. Samples of supernatant fluid were collected at three sediment coring sites. Results were compared to City of Kingston sewer bylaw guidelines for discharges (Table I-6).	• SVOCs • VOCs • PCBs • Inorganic elements	Majority of parameters were below analytical detection limits. Concentrations of bis(2-ethylhexyl) phthalate, methylene chloride and Zn exceeded storm sewer discharge criteria. These chemicals were also elevated in field blank samples, suggesting samples or analytical methods may have been compromised.
Benoit and Dove (2006)	Presents results of 2002 and 2003 monitoring programs for the LaMP. Employed semi-permeable membrane devices (SPMDs) in sediments at eight locations in the KIH to monitor distribution of hydrophobic organic contaminants present in water at relatively low concentrations.	• PCBs	With exception of one station downstream of Kingscourt Sewer, PCB concentrations in SPMDs after 28 days were elevated at all sites south of Belle Park compared with sites north of Belle Park, suggesting that PCBs in sediments are bioavailable at these locations. Highest PCB concentrations were found at a station immediately south of Belle Park Landfill. PCB congener patterns for SPMDs at sites south of Belle Park (except downstream of Kingscourt Sewer) were similar, suggesting exposure to a similar source of PCBs.
Manion (2007)	MSc thesis on distribution and fate of Hg in sediments. Pore water samples collected throughout KIH.	• Hg	Concentrations for all pore water samples were well below relevant water quality guidelines.
Benoit and Burniston (2010)	Presents results of 2006 remediation follow-up study for LaMP. Employed SPMDs in sediments at eight locations in the KIH to monitor distribution of hydrophobic organic contaminants present in water at relatively low concentrations.	• PCBs	PCB concentrations in SPMDs similar to those in 2002 study. However, highest concentrations were found at Emma Martin Park site, with second-highest concentration at southeast arm of Belle Island Landfill.

D. Biological Effects

Biological effects in the KIH have been assessed through examination of community structures, direct measurements of contaminants in biota and toxicity testing. Much of the data on macrophytes (aquatic plants) and community structure is based on taxonomic identification of samples that were also used for analyses of contaminant concentrations.

1. Macrophyte and Benthic Community Structure

Benthic invertebrates are good indicators of the health of an aquatic ecosystem because they cover a broad cross-section of trophic groups; they are associated closely with the sediments and entrained contaminants, their life cycles are of an appropriate temporal scale, their taxonomy is well understood and there is much scientific literature on their use in biomonitoring (Reynoldson and Rodriguez 1999). They are the most widely used organisms in investigations of sediment contamination (Rosenberg and Resh 1993; Resh et al. 1995). However, data comparisons become difficult when the processing and taxonomic identification approach varies between studies. Despite this, the data can provide information on environmental quality and the effects of contaminated sediments. Aquatic macrophytes tend to reflect, by their presence or absence, the environmental status of their environment and therefore serve as useful bioindicators (Melzer 1999).

Only a small number of studies have examined benthic community and macrophyte structure in the KIH (Table I-12). Based on the limited data available, benthic invertebrate communities appear to be largely dominated by taxa that are tolerant of the fine-grained organic-rich sediments found throughout the harbour, such as oligochaetes and chironomids. Overall, the spatial coverage of benthic community analyses is limited and assessment of sedimentary contaminant effects is hampered by the different processing and taxonomic approaches used by each study. Given the predominance of smaller-bodied organisms noted in several studies (e.g., ESG 2003), it appears that processing sediments with larger sieve sizes (>250 µm) may not permit researchers to capture an accurate assessment of benthic community structure. Processing the sediments with a smaller sieve size (250 µm) also enables use of Environment Canada’s BEAST (BEnthic Assessment of SedimenT)/Canadian Aquatic Biomonitoring Network (CABIN) statistical package to compare potentially impacted sites with Great Lakes reference sites, consistent with the approach used for assessing benthic communities in other Great Lakes APECs (Environment Canada 1998, 2006). This approach uses multivariate statistics to compare the benthic assemblages with those at similar reference sites in the Great Lakes, which are identified based on a suite of sediment and water characteristics not likely to be affected by anthropogenic activities. Sufficient taxonomic resolution (generally to species and genus level) should also be attempted in benthic community studies if the BEAST/CABIN approach is to be applied.

Despite these limitations, the available data suggest that sedimentary contaminants south of Belle Park and possibly those in Anglin Bay may be impacting benthic communities at these locations. Recent work has been carried out to assess benthic invertebrate assemblages to evaluate ecological effects of contaminated sediments in the southwestern portion of the KIH; these results are presented in Chapter III.

Table I-12: Summary of studies on macrophyte and benthic community structures

Study	**Purpose/sampling plan**	**Results**
Macrophyte community structure		
ESG (2003)	Collection of macrophyte samples in June and September 2002 from two locations in KIH (upstream and downstream of Belle Park Landfill) and two locations in Outer Harbour (Fort Frontenac water lot and near Wolfe Island ferry dock) as part of an ecological risk assessment of contamination effects.	*Myriophyllum spicatum* (an invasive species common throughout the Great Lakes that flourishes in nutrient-rich environments) was common at all sites.
Tinney (2006)	Collection of macrophytes at various sites in the KIH at three different times: November 2004, June 2005 and September 2005.	Macrophyte communities in KIH dominated by *Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton crispus, Elodea canadensis* and *Vallisneria americana*. Multivariate statistical analysis indicated that variables related to nutrient concentrations (e.g., TKN, TP) were most important influences on macrophyte community structure. Macrophyte community structure did not appear to be related to contaminant concentrations within sediments.
Benthic community structure		
Ecologistics and WESA (1984)	Examination of benthic invertebrate community structure at 10 stations along navigational channel upstream of Belle Park.	Samples revealed impoverished benthic communities dominated by low densities of midge larvae.
Jaagumagi (1991)	Benthic community assessment of sediments for three locations in Anglin Bay contaminated with PAHs, Cu, Cr and Pb. Samples were processed using a 595 µm sieve and identified to lowest practical taxonomic level (genus and species).	Assemblages dominated by *Tubificidae* (oligochaetes), common in organic-enriched sediments. Benthic organism density correlated with TOC and negatively correlated with metal concentrations. Benthic organism density did not appear to be related to sediment PAH concentrations.

Table I-12: Summary of studies on macrophyte and benthic community structures, cont'd.

Study	Purpose/sampling plan	Results
ESG (2003)	Analyzed benthic community structure in sediment samples from two locations in KIH (upstream and downstream of Belle Park Landfill) and two locations in Outer Harbour (Fort Frontenac water lot and near Wolfe Island ferry dock). Samples sieved to 125 µm and identified to lowest practical taxonomic level (generally species level). Benthic invertebrate assemblages were compared with a data set of non-impacted sites throughout Great Lakes using BEAST model (Environment Canada 1998).	Gastropods (snails), caddisflies, oligochaetes and chironomids were main groups identified, with a more diverse assemblage noted for upstream reference site. Results indicate that benthic community structure at upstream reference site was similar to those at reference sites in Great Lakes. Benthic community structure at Belle Park site was significantly different, suggesting that sedimentary contaminants may be affecting benthic assemblages at this site.
Tinney (2006)	Investigation of benthic assemblages for 13 locations in the KIH, including three upstream reference sites over three sampling periods (November 2004, June 2005 and September 2005). Samples were sieved to 500 µm and identified to lowest practical taxonomic level (genus and species).	Benthic invertebrate abundances and diversity generally low. Chironomids, caddisflies, oligochaetes, isopods and gastropods were dominant benthic invertebrate groups. Impoverished benthic community and species assemblages may be considered characteristic of eutrophic, fine-grained organic-rich sediments. Diversity and pollution indices did not show any consistent relationship with contaminated sites in KIH, perhaps not surprisingly given larger sieve processing size and fact that these indices generally do not distinguish between organic enrichment and chemical contamination.
Benoit and Dove (2006)	Coarse-resolution benthic community analysis conducted as part of a study investigating benthic invertebrate uptake of dioxins, furans and dioxin-like polychlorinated biphenyls (DLPCBs) from seven sites, located mostly south of Belle Park. Samples were sieved to 500 µm and identified to taxonomic order level.	No benthic invertebrates found at one location (near Davis Tannery); this could be due to metal toxicity or elevated TOC levels. Crustaceans were dominant group at most locations. Annelids found at all stations but one. Insects found only at one station.
Golder Associates (2011)	Analysis of benthic community structure was conducted in the water lot south of Belle Park as part of the implementation of the COA framework.	Benthic communities along the western shoreline were moderately impaired compared to reference communities north of Belle Island.

2. Contaminant Uptake in Biota

Several persistent organic contaminants, such as PCBs and DDT, tend to bioaccumulate in biological tissue because of their physical and chemical characteristics. For organisms at higher trophic levels in the aquatic food web, the main pathway of exposure to these contaminants is through consumption of contaminated aquatic biota such as fish, invertebrates or plants. Tissue residue guidelines are provided by a number of jurisdictions to address those substances that have a strong tendency to bioaccumulate in biota and to biomagnify to higher concentrations at successive trophic levels of the aquatic food web.

a. <u>Tissue Residue Guidelines</u>

Fish consumption guidelines for the protection of human health are provided by Health Canada and the OMOE. The Guide to Eating Ontario Sport Fish provides recommendations for human consumption based on fish species, size and habitat location and consumer characteristics (i.e., adults, children, women of childbearing age) (OMOE 2013). The CCME provides tissue residue guidelines for the protection of ecological receptors feeding on aquatic life (Table I-13). These guidelines have been developed for PCBs, dioxins, DDT, methylmercury and toxaphene, with several of these derived for different receptors (e.g., mammalian vs. avian). The International Joint Commission (IJC) also provides guidelines for various parameters (Table I-14).

Table I-13: Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota

Parameter		**CCME TRG[1]**
DDT (total)		14 µg/kg diet on a wet weight basis
Methylmercury		33 µg/kg diet on a wet weight basis
PCBs	Mammalian	0.79 ng TEQ·kg-1 diet ww
	Avian	2.4 ng TEQ•kg-1 diet ww
Polychlorinated dibenzo-*p*-dioxins/ polychlorinated dibenzofurans	Mammalian	0.71 ng TEQ•kg-1 diet ww
	Avian	4.75 ng TEQ•kg-1 diet ww
Toxaphene		6.3 µg/kg diet on a wet weight basis

[1]CCME 2001b

Table I-14: IJC tissue residue guidelines for selected parameters

Parameter	Purpose	IJC TRG[1]
Mercury	Protection of aquatic life and fish-consuming birds	0.5 µg/g ww (whole fish)
Total PCBs	Protection of aquatic life and fish-consuming birds	100 ng/g ww (whole fish)
Heptachlor	Protection of human consumers of fish	300 ng/g ww (heptachlor and heptachlor epoxide in edible portions of fish)
Aldrin/Dieldrin	Protection of human consumers of fish	300 ng/g ww (sum of Aldrin and Dieldrin in edible portions of fish)
Mirex	Protection of aquatic organisms and fish-consuming birds and animals	Concentrations of mirex and its degradation products should be lower than the detection limits using the best available technology.
DDT and metabolites	Protection of fish-consuming aquatic birds	1,000 ng/g ww (sum of DDT and its metabolites for whole fish)

[1]IJC 1989

b. Summary of Previous Studies

A number of KIH studies have investigated contaminant concentrations in biological tissue, including aquatic plants, invertebrates and fish (Table I-15). In summary, a number of lines of evidence suggest that aquatic biota in the southwest portion of the KIH contain elevated levels of PCBs, sometimes in excess of the relevant fish consumption and aquatic life protection tissue guidelines. Fish monitoring studies carried out by the OMOE over the past 25 years have shown consistent patterns, with fish from locations immediately south of the Belle Park Landfill and near Emma Martin Park having the highest PCB uptake relative to uptake in fish from other sites throughout the KIH. A similar spatial distribution was found for invertebrate uptake studies and lab bioaccumulation tests. Invertebrate and fish PCB uptake appears to be related to sedimentary PCB concentrations, with higher biological uptake evident at sites with higher PCB contamination in the sediments. In contrast, PCB concentrations in aquatic plants do not show the same spatial pattern, suggesting that uptake from the water column may be the dominant pathway of exposure for macrophytes. Overall, the data consistently indicate that forage fish at sites south of Belle Park are accumulating PCBs in concentrations that may present a risk to wildlife consumers of aquatic biota.

Little information is available for biological uptake of other contaminants, such as DDT and inorganic elements. There is some evidence to suggest that dichlorodiphenyl-dichloroethylene (DDE) concentrations are elevated in biota collected in the vicinity of the Belle Park Landfill; however, limited spatial coverage of sediment and biota data throughout the KIH hampers interpretation of the data. Ongoing studies are investigating invertebrate bioaccumulation of chromium and other inorganic elements; these data are discussed in Chapter III.

Table I-15: Summary of studies examining contaminant uptake in aquatic plants, invertebrates and fish

Study	Purpose	Conclusions
Aquatic plants		
Tinney (2006)	Examination of uptake of PAHs, PCBs and inorganic elements into Eurasian watermilfoil (*Myriophyllum spicatum*) collected from 12 locations throughout the KIH. Analyses of inorganic element in macrophytes from nine locations throughout the KIH.	Uptake of PAHs was negligible at all locations. PCB levels were similar to those collected from the St. Lawrence River. Low uptake of metals such as Cr, Cu, Pb and Zn at most sites, with the exception of a site southwest of Belle Park, where sediments contained high concentrations of Cr and Pb. A significant positive correlation was found between the concentration of Cr in the sediments and its uptake into macrophytes.
Invertebrates		
ESG (2003)	Analysis of burdens of chemicals in zebra mussel samples from two locations in KIH (upstream and downstream of Belle Park Landfill) and two locations in Outer Harbour (Fort Frontenac water lot and near Wolfe Island ferry dock) as part of an ecological risk assessment of contamination effects.	Only samples from the Fort Frontenac water lot contained enough zebra mussels for chemical analyses. Levels of contaminants were low, analogous to those found throughout the Great Lakes.

Table I-15: Summary of studies examining contaminant uptake in aquatic plants, invertebrates, and fish, cont'd.

Study	**Purpose**	**Conclusions**
Derry et al. (2003)	Caged mussel study conducted over 10 weeks at nine locations in the KIH to investigate potential uptake of PCBs. Benthic invertebrate samples also collected for tissue analysis of DLPCBs, dioxins, and furans from seven locations in the KIH, most located south of Belle Park. The benthic invertebrates were combined into three categories: annelida (worms), crustacea and insecta.	Highest PCB uptake and concentrations of concentrations of DLPCBs, dioxins, and furans found at locations immediately south of Belle Park Landfill and near Emma Martin Park. PCB concentrations were generally below or near analytical detection limits for stations north of Belle Park, with exception of one station located on northeast arm of landfill. Calculated totals of PCB congener toxic equivalents (TEQs) well below CCME PCB tissue residue guideline. Principal component analysis of PCB congeners suggested multiple potential PCB sources. Crustaceans were most widely collected invertebrate and showed greatest accumulation of DLPCBs and dioxins and furans. Concentrations at all sites except upstream reference site exceeded CCME tissue residue guidelines for mammalian consumers of aquatic biota for DLPCBs and dioxins and furans.
Benoit and Dove (2006)	Collection of benthic invertebrates for analysis of DLPCB concentrations in tissues. Eight samples collected, mostly south of Belle Park near shore of former Davis Tannery property.	At six sites, enough biomass was collected for chemical analyses. With exception of upstream reference site, all sites exceeded CCME DLPCB tissue residue guideline for mammalian consumers of aquatic biota. All sites exceeded CCME dioxin and furan tissue residue guideline for mammalian consumers. Dioxin and furan tissue concentrations were within range of TEQ (toxic equivalent) levels observed elsewhere in Canadian environment. Levels of TEQ_{mam} for several Canadian species of freshwater fish and invertebrates range from less than detection limit to 112 ng·kg-1 ww, with 34% of values below the mammalian TEQ. This indicates that elevated dioxin and furan tissue values in benthic invertebrate tissue may be due to distribution by long-range transport rather than local sources.

Table I-15: Summary of studies examining contaminant uptake in aquatic plants, invertebrates, and fish, cont'd.

Study	Purpose	Conclusions
Tinney (2006)	Analysis of mussel tissue samples from various locations throughout the KIH for PAHs and inorganic elements. Mussels were collected from macrophytes in the water column and were not living on the sediment substrate.	PAH concentrations were below the analytical limits of detection for all four locations analyzed. Inorganic element concentrations in mussels from eight locations were very low, especially in comparison with levels found in mussels from other contaminated sites in the Great Lakes. Lack of exposure to contaminated sediment probably explains the low biological uptake seen in this study but supports the observation that water quality is generally good with respect to these parameters.
Fish		
Hodson (1998a)	Statistical review of contaminant concentrations in fish sampled by OMOE (1998) from south of Belle Island and from Colonel By Lake (a reference site upstream). Carp, largemouth bass, yellow perch, pumpkinseed and bluegill were found at both sites. All of these would be considered locally resident with the exception of carp, which migrates widely throughout Lake Ontario.	Of 46 fish analyzed, four carp from KIH exceeded OMOE PCB human consumption guideline of 0.5 ppm and one largemouth bass from KIH exceeded Health Canada Hg human consumption guideline of 0.5 ppm. Of 44 chemicals measured, Hg, Cu, Zn, Pb, Cd, total PCB and pp-DDE were above detection limits often enough to be analyzed statistically. Concentrations of Cd in carp, bass and bullhead, PCBs in carp and bullhead and DDE in carp were significantly higher in fish collected near Belle Island than in those from Colonel By Lake. Traces of mirex/photomirex were present only in carp. As mirex is a contaminant unique to Lake Ontario, PCBs present in large carp probably originated from outside KIH.
Hodson (1998b)	Summary of concentrations of Hg, PCBs, total DDT and mirex in yellow perch, black crappie, sunfish and bullhead collected south of Belle Island in 1997 by Canadian Food Inspection Agency (CFIA) (n=1 for all species) and concentrations of Hg, PCBs and total DDT in dogfish (n=1) and catfish (mean of four to six fish) collected by in 1998 by OMOE south of Belle Island.	All contaminant concentrations were below the OMOE 1993 guideline for human consumption. Concentrations of PCBs, total DDT and mirex in the CFIA samples were below detection limits.

Table I-15: Summary of studies examining contaminant uptake in aquatic plants, invertebrates, and fish, cont'd.

Study	**Purpose**	**Conclusions**
Hayton (2000)	Summary of PCB concentrations in juvenile yellow perch collected in 1999 from five locations throughout KIH: upstream reference site, north of Belle Park Landfill, immediately south of Belle Park Landfill, near Kingston Rowing Club, and in Outer Harbour. Compares data with monitoring data on forage fish collected by OMOE in 1978, 1982, 1990 and 1991 in lower Great Cataraqui River at various sample sites.	Mean fish sample concentrations for sites south of the Belle Park Landfill consistently exceeded the IJC guideline for PCBs. PCB concentrations in fish appear to have declined downstream of the landfill: mean concentrations in 1978 and 1990 exceeded 800 ppb ww, while the highest mean concentration at a station in 1999 was 432 ppb ww.
Derry et al. (2003)	Summary of PCB concentrations in juvenile yellow perch collected in 2000 from five locations throughout the KIH: an upstream reference site, north of Belle Park Landfill, immediately south of Belle Park Landfill, near Kingston Rowing Club, and at Outer Harbour.	Fish sampled from sites south of Belle Park contained significantly higher PCB levels in comparison with those from sites north of Belle Park, with highest concentrations measured in yellow perch from Rowing Club location. Mean fish sample concentrations in 1999 and 2000 for all sites south of Belle Park Landfill exceeded IJC guideline for PCBs.
Benoit and Dove (2006)	Summary of young-of-the-year and yearling yellow perch data for the same monitoring locations as Derry et al. (2003), as well as an additional upstream reference site near Highway 401. Fish samples were analyzed for Hg and a suite of 20 organochlorine chemicals. Minimum, average and maximum PCB concentrations determined for six species of sport fish (northern pike, carp, brown bullhead, bluegill, largemouth bass and yellow perch) collected around Belle Island in 2002. Sample size for each species ranged from four to 11 fish.	Only Hg, PCBs and pp-DDE were above analytical detection limits. Sites south of Belle Park had significantly higher PCB uptake than sites north of Belle Park; average fish PCB concentrations exceeded IJC guideline for PCBs at all southern sites. Highest PCB concentrations reported for Rowing Club location and site immediately south of Belle Park Landfill. Hg concentrations exceeded CCME tissue residue guideline for some of fish samples collected from sites south of Belle Park Landfill but also for several samples collected at upstream reference sites near Highway 401. Concentrations of pp-DDE detected for fish samples collected throughout KIH and exceeded CCME tissue residue guidelines in some samples collected immediately north and south of Belle Island Landfill and near Rowing Club. Average and median PCB concentrations for northern pike, carp, and brown bullhead exceeded IJC guideline for PCBs. Maximum PCB concentrations for bluegill and yellow perch also exceeded IJC guideline.

Table I-15: Summary of studies examining contaminant uptake in aquatic plants, invertebrates, and fish, cont'd.

Study	Purpose	Conclusions
OMOE (2013)	2013–14 Guide to Eating Ontario Sport Fish contains entry for Great Cataraqui River in Belle Island area. Fish consumption guidelines included for northern pike, largemouth bass, yellow perch, black crappie, pumpkinseed, bluegill, brown bullhead, white sucker, and carp.	Brown bullhead with a length greater than 30 cm and carp with a length greater than 55 cm are listed as unsafe for consumption by women of childbearing age and children under the age of 15.
Golder Associates (2011)	Collected forage fish from four areas within the KIH to supplement existing data on concentrations of contaminants in fish tissue. Fish were analyzed for lipid content, moisture, speciated Cr, speciated As, MeHg and total PCBs, and results compared to threshold values for adverse effects.	Results confirmed that fish are accumulating PCBs from the sediment within the KIH. The report concluded that risks to humans from PCBs and Hg via fish ingestion is generally low for typical consumers of fish but would increase for individuals with higher consumption.

3. Toxicity Tests

A number of KIH studies have employed toxicity testing to determine whether surface water, sediments or leachate from surrounding lands are toxic to fish and benthic organisms. Several different categories of tests, such as Microtox, benthic invertebrate survival and growth studies and fish toxicity tests have been implemented within KIH studies.

Microtox utilizes the luminescent marine bacterium *Vibrio fischeri* to determine toxicity of sediment and water samples. Microtox analyses of sediments have been shown to be highly correlated to sediment contamination, by both metals (Rönnpagel et al.1995; Environment Canada 2002) and organic substances (Doherty 2001). Although the sensitivity of the Microtox method has also been shown to compare well with other tests (Becerro et al. 1995; Din and Abu 1993; Kaiser 1993), more recently its suitability has been questioned because of conflicting results, and caution should be exercised when drawing conclusions from these tests.

Benthic invertebrate survival and growth studies are commonly used to assess toxicity of sediments, as these organisms are directly exposed to contaminated media. A number of different organisms may be used to assess toxicity, with each organism differing in sensitivity to various contaminants. The exposure time of the test is also important: shorter exposures are likely to measure acute toxicity, while longer exposures give an indication of chronic toxicity effects. Studies within the KIH have employed a variety of benthic organisms and exposure times.

Fish toxicity tests are similar to the benthic invertebrate survival and growth studies, where a live bioassay involves exposing a sensitive species to a contaminated medium (water or sediment) and observing adverse effects. Three methods typically employed include *in situ* tests (using caged fish), controlled laboratory tests and a combination of the two. Hamilton and Hodson (2003) suggest that *in situ* toxicity tests are not sufficiently developed or reliable and that toxicity is assessed more reliably using lab methods. However, standard laboratory tests have several limitations, including evaluation of the true extent of their ecological relevance (Baudo et al. 2002). Laboratory conditions are rarely identical to exposure conditions in the field, as sediments in laboratory tests are altered during collection and storage (Tinney 2006). For fish, toxicity test durations vary from a few hours for acute toxicity to days and weeks for chronic toxicity. In general, the literature suggests that longer-term tests (i.e., greater than 10 days) that measure growth are more sensitive than shorter-term tests (e.g., Ingersoll et al. 1995). Ideally, several species from a single location should be evaluated for toxicity, as different species show varying sensitivities to different contaminants.

In the KIH, several acute toxicity tests of rainbow trout and benthic invertebrate *Daphnia magna* exposed to groundwater seepage from Belle Park were conducted in relation to charges by the Sierra Legal Defence Fund and the OMOE against the City of Kingston under the Fisheries Act (OMOE 1997b). These studies and reviews of these studies (Beak International Inc. 1997; OMOE 1997a; Sierra Legal Defence Fund 1997; Hodson 1998a, 1998b; Malroz 1999) are summarized in Malroz (2003). Other toxicity tests conducted on sediments and water from the KIH include Microtox toxicity tests (ESG 2003; Tinney 2006) and various other benthic invertebrate and fish toxicity tests (ESG 2003; Tinney 2006; Benoit and Dove 2006) (Table I-16).

In summary, toxicity studies for the Inner Harbour are limited in spatial distribution and have used a variety of test organisms and exposure times, making comparisons of the data difficult. However, some general trends are evident. There is no evidence of toxicity from studies investigating river water samples collected throughout the KIH or sediment samples collected north of Belle Park. There are mixed results for toxicity of sediments in the bay southwest of Belle Park, with effects dependent on the type of organism tested and the exposure time of the test. Further work that has been being carried out to assess the toxicity of sediments in the area south of Belle Island is discussed in detail in Chapter III.

Table I-16: Summary of toxicity studies

Study	Microtox	Benthic fauna	Fish	Sediments	Water	Purpose/method	Results
Sierra Legal Defence Fund (1997)			√		√	Toxicity tests on groundwater seepage from Belle Park using rainbow trout.	Mortalities occurred in all of the tests.
Beak International (1997)		√	√		√	Toxicity tests on groundwater seepage from Belle Park using rainbow trout and *Daphnia magna*.	Tests identified ammonia as the only component in the seepage water that is toxic to aquatic organisms.
OMOE (1997a)		√	√		√	Toxicity tests on groundwater seepage from Belle Park using rainbow trout and *Daphnia magna*.	Mortalities occurred in all of the tests.
Malroz (1999)		√	√		√	Toxicity tests on groundwater seepage from Belle Park using rainbow trout and *Daphnia magna*.	Mortalities occurred in all but one test. Report provides interpretation of all previous toxicity data from other studies. Report indicates that samples were non-toxic at the time of collection and that toxicity was generated within laboratory during sample preparation process.
Hodson (1998b)		√	√		√	Review of toxicity to fish and invertebrates of groundwater discharged from Belle Island Landfill site, 1996/1997.	Conclusions corroborate those of Malroz (1999) that toxicity was generated in the samples after they reached the laboratory.
Malroz (2003)						Summary of previous tests.	
ESG (2003)	√			√	√	Conducted Microtox analyses on sediment and water samples from seven locations in the Outer Harbour, seven locations south of Belle Park and in the bay south of the peninsula and two locations northeast of Belle Park.	Water and sediments were considered toxic if they exceeded Environment Canada's criterion of an EC_{50} (concentration producing a 50% reduction in light). All water samples were non-toxic. All sediment samples from the Outer Harbour and three of seven samples from south of Belle Island were toxic. Both sediment samples northeast of Belle Park were non-toxic.

Table I-16: Summary of toxicity studies, cont'd.

Study	**Microtox**	**Benthic fauna**	**Fish**	**Sediments**	**Water**	**Purpose/method**	**Results**
Jackman and Doe (2002) in ESG (2003)	√	√		√		Portion of sediment samples from ESG (2003) sent to Environment Canada for toxicological testing. Conducted a14-day exposure test with freshwater amphipod *Hyalella azteca* on two samples from Outer Harbour, one southeast of Belle Island and one northeast of Belle Island. Conducted Microtox tests on three samples: one from Outer Harbour, one from southeast of Belle Island and one from northeast of Belle Island.	No statistically significant effects on *Hyalella azteca* were observed. None of the sediments were toxic to *Hyalella azteca*. The Microtox study indicated the sediment sample from the Outer Harbour was toxic to the bacterium *Vibrio fischeri* using the Interim Guideline for Environment Canada's Ocean Disposal Program. The other two samples were not considered toxic.
Hamilton and Hodson (2003) in ESG (2003)			√	√	√	Toxicity studies examining bioavailability of PAHs to fish. Rainbow trout were exposed to sediments and water in a variety of field (caged fish) and lab bioassays. Fifteen sites sampled in five areas: three in Outer Harbour, one near foot of Elliott Ave. north of Belle Island and one area north of Highway 401.	The results indicated that PAH contamination in the Outer Harbour sites showed evidence of toxicity to fish, while no evidence of PAH toxicity was found for the northern KIH sites.

Table I-16: Summary of toxicity studies, cont'd.

Study	Microtox	Benthic fauna	Fish	Sediments	Water	Purpose/method	Results
Tinney (2006) and Environment Canada (2005)		√		√		ESG conducted Microtox toxicity analysis of 17 water and 20 sediment samples from a variety of locations throughout KIH to test toxicity to *Vibrio fischeri*. Environment Canada also tested two sediment samples for txocity to Vibrio fischeri using Microtox methods. Environment Canada conducted a 14-day exposure bioassay for survival and growth effects with freshwater amphipod *Hyalella azteca* for sediments from five KIH locations: two near HMCS Cataraqui property on eastern shore, two immediately south of Belle Park and an upstream reference site.	None of water samples was toxic to *Vibrio fischeri*. None of sediment samples analyzed by ESG was toxic to *V. fischeri*, but results indicated that sediments near HMCS Cataraqui exert some degree of toxicity. Environment Canada results for Microtox tests carried out on two sediment samples indicate that samples taken from south end of HMCS Cataraqui were toxic to *V. fischeri*, while sample from south side of Belle Park was not. No toxic effects on survival or growth of *H. azteca* observed in any test sediments. However, test animals exposed to sediments from very close to south shore of Belle Park showed lowest growth. Review of results and comparisons to ESG (2003) data shows that toxicity of sediments varies temporally and spatially.

Table I-16: Summary of toxicity studies, cont'd.

Study	Microtox	Benthic fauna	Fish	Sediments	Water	Purpose/method	Results
Benoit and Dove (2006)		√	√	√		A 21 -day lab bioaccumulation test with juvenile fathead minnows (*Pimephales promelas*) for lead and PCBs in sediment from eight locations throughout the KIH, most collected southwest of Belle Park. Two benthic invertebrate tests for survival and growth effects: a 10-day exposure test with the midge larvae *Chironomus tentans* and a 21-day exposure test with the mayfly nymph *Hexagenia* sp. for eight sediment samples, most collected south of Belle Park.	No mortality was observed in any of the tests. Tests indicated that Pb and PCBs may be bioaccumulating at all exposure sites. PCB tissue concentrations in the minnow samples were 4–11 times higher for sediment samples collected south of Belle Park than for reference sediment. For *Chironomus tentans*, no statistically significant survival or growth effects were noted. However high variability in replicates may have reduced ability of a statistical test to detect a significant impairment. For *Hexagenia*, statistically significant reduced survival and growth effects were evident for sediments from an active seep on south side of Belle Park adjacent to Kingscourt storm sewer. Decreased growth effects were also noted for *Hexagenia* for sediments from a location in the bay southwest of Belle Park near outlet of Kingscourt sewer drainage.
Golder Associates		√				Laboratory chronic toxicity tests were performed using sensitive organisms (20-day *Chironomous tentans* and 28-day *Hyalella azteca*) to assess survival, growth and reproduction responses.	Results were interpreted using the COA framework decision matrix. Sediment samples collected from the western portion of the KIH showed mixed evidence of toxicity with two of seven sampling stations showing significant toxicity.

V. Data Application and Data Gaps for Implementing the COA Framework

The COA framework is based on the integration of available data and the collection of new data where necessary. The historical review provided the following information that is being used in the application of the COA framework:

- Concentrations of arsenic, chromium, copper, lead, mercury, zinc, PCBs, PAHs and DDT in sediments exceeded the federal SQGs for some samples, indicating that these are CoPCs that require further investigation.
- Concentrations of contaminants upstream from Belle Island were significantly different from those downstream from Belle Island, indicating that the upstream sites could be used as "reference sites."
- The receptors of concern include benthic communities in direct contact with the sediments, as well as organisms at higher trophic levels, as some of the CoPCs are known to biomagnify and/or bioaccumulate.
- Potential historical sources of contamination are concentrated along the western shore, particularly in the area of the former Davis Tannery property and the Orchard Street Marsh, and at the sewer discharge locations.
- The hydrology of the KIH is altered from its natural state, affecting sedimentation rates and sediment transport patterns, which in turn affect many components of the ecosystem.

Data gaps that must be addressed to apply the COA framework include:

- integration of all available data,
- information on sediment contamination at depth and on pore water chemistry,
- information on the link between exposure and biological effects, which includes data on biological uptake, benthic community impairment and bioaccumulation/ biomagnification, and
- information to allow identification of site boundaries, such as temporal and spatial distribution of contaminants and their biological effects.

ESG has compiled the data and created a geographic information system (GIS) that integrates analytical results from previous studies. Only data that are scientifically defensible (having undergone appropriate quality assurance and quality control) and comparable (produced using a consistent methodology) were incorporated into the database. This work is described in Chapter II**.**

The GIS and mapping applications were used to analyze the spatial distribution of contaminants (Chapter II) and were then used in combination with the historical review to select additional sites for sampling. The analysis of spatial distribution and selection of of additional sites was conducted by ESG from 2006 to 2008 (Table I-17) to fill in data gaps and ensure thorough spatial representation. To address the lack of information about sediment quality at depth, ESG collected additional sediment cores in 2006 and 2008, primarily in the area of concern south of Belle Island and Cataraqui Park.

The historical review presented in this report indicates the need for more data to improve our understanding of the link between exposure and biological effects, including data on biological uptake, benthic community impairment and bioaccumulation/ biomagnification. The spatial coverage of existing benthic community structure data is very limited. In addition, these studies use different processing and taxonomic approaches, hindering data comparisons. A number of studies examine water and sediment toxicity in the KIH, also with somewhat limited spatial coverage. The variety of test organisms and exposure times used hampers comparisons among study locations. To overcome these limitations, ESG has conducted additional assessments of bioaccumulation of inorganic contaminants in invertebrate body tissue, analysis of additional sampling locations for sediment toxicity using a consistent indicator approach, and analysis of additional sampling locations for benthic community structure analysis using the CABIN approach (Environment Canada 2006) to further assess the ecological effects of the sediment contamination (Table I-17). The results of this work are presented in Chapter III.

Table I-17: Previously unpublished studies conducted by ESG from 2006 to 2008

Study	Purpose/sampling plan	Parameters assessed
ESG (unpublished) samples collected September and December 2006	Ten surface sediment samples collected to determine spatial extent of contamination, eight sediment cores (max. length 102.5 cm) taken to determine vertical distribution of contamination and three toxicity test samples using *Hyalella azteca* and *Chironomus tentans* performed in area south of Cataraqui Park and Belle Island. Sampling locations chosen to provide information for areas of KIH where information was lacking from previous studies and for areas of concern requiring more sampling.	• TOC • Grain size • Suite of 30 inorganic elements • Toxicity tests (*Chironomus* and *Hyalella*) • Bioaccumulation studies (*Hyalella*)
ESG (unpublished) samples collected in November 2007	Five sediment toxicity evaluations in area south of Cataraqui Park performed using *Hyalella azteca* and *Chironomus tentans*. Chromium uptake in *Hyalella* test individuals investigated. Sampling locations chosen to provide information for areas of KIH where information was lacking from previous studies, such as areas along eastern shoreline and areas of concern requiring more sampling. Benthic invertebrates collected at five locations to determine their abundance and diversity.	• TOC • Grain size • Suite of 30 inorganic elements • Toxicity tests (*Chironomus* and *Hyalella*) • Bioaccumulation studies (*Hyalella*) • Benthic community structure analysis
ESG (unpublished) samples collected in May 2008	Five sediment toxicity evaluations in the area south of Cataraqui Park performed using *Hyalella azteca, Chironomus riparius, Tubifex tubifex* and *Hexagenia* spp. Chromium uptake in test individuals investigated. Sampling locations chosen to provide information for areas of KIH where information was lacking from previous studies.	• TOC • Grain size • Suite of 30 inorganic elements • Toxicity tests (four species) • Bioaccumulation studies on toxicity test species
ESG (unpublished) samples collected in October/ November 2008	Five sediment cores taken to determine vertical distribution of contaminants; five cattail samples, nine macrophytes samples and four benthic invertebrate samples collected to investigate contaminant uptake in biota. Benthic invertebrate samples collected at four locations to determine their abundance and diversity. Sampling locations chosen along shoreline at and south of Cataraqui Park.	• PCBs • PAHs • TOC • Grain size • Suite of 30 inorganic elements • Inorganic uptake in benthic invertebrates and macrophytes • Toxicity tests with two species • Benthic community

Table I-17: Previously unpublished studies conducted by ESG from 2006 to 2010, cont'd.

Study	Purpose/sampling plan	Parameters assessed
ESG (Burbridge Master's thesis 2010) August 2009 porewater sampling	Five peeper sampling devices with 18 peepers per housing were deployed into sediments adjacent to former Davis Tannery property in August 2009 for 20 days to measure chromium concentrations in porewater. Locations of peepers were selected based on proximity to area where effluent-contaminated marsh discharges into Great Cataraqui River and where groundwater flow suspected to emanate from below former tannery property discharges into the river.	Total Cr, Cr III and Cr VI in porewater
ESG (unpublished) October 2009 fish sampling	Fish samples were collected in October 2009 from a test site immediately south of Belle Park and from an upstream reference location to investigate bioaccumulation of inorganic elements and PCBs. Three species of fish were collected: brown bullhead, yellow perch and northern pike. Whole body (brown bullhead) or whole body minus one fillet (yellow perch and northern pike) was analyzed for CoPCs.	• PCBs • As • Cr • Pb • Zn • Cu • Ni • Co • Cd • Lipids • % moisture • Fish age determination
ESG September 2010 sediment sampling	Total of four sediment cores and 25 sediment samples were collected in the area south of Belle Park in fall 2009 to refine PCB and Hg delineation.	• PCBs • Hg

VI. References

Aqua Terre Solutions Inc. 1997. Sediment Sampling Program — Crawford Dock Waterfront, Kingston. Prepared for Transport Canada. Toronto, ON.

Archaeological Services Inc. 2008a. Planning for the Conservation of Archaeological Resources in the City of Kingston. Submitted to Culture and Heritage, City of Kingston, August 2008.

Archaeological Services Inc. 2008b. Master Plan of Archaeological Resources — City of Kingston Technical Report. Submitted to Culture and Heritage, City of Kingston, August 2008.

Asquini, A., M. McLeod and C. Sollows. 2007. "Remediation of Sediment Contamination in the Cataraqui River, Kingston Inner Harbour." Undergraduate thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Baudo, R., D. Rossi, and M. Beltrami, 2002. "*In situ* toxicity testing of Lake Orta sediments." *Journal of Limnology* 60: 277–284.

Beak International Inc. 1997. Toxicity Identification/Evaluation of Sample 97W36. Prepared for Malroz Engineering Inc., Kingston, ON.

Becerro, M.A., M.J. Uriz and X. Turon (Becerro et at.). 1995. "Measuring toxicity in marine environments: Critical appraisal of three commonly used methods." *Experientia* 51: 414–418.

Benoit, N. and D. Burniston. 2010. Cataraqui River Project Trackdown: Follow-up Study on Success of Remediation Efforts in the Cataraqui River 2006. Technical Report. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Benoit, N. and A. Dove. 2006. Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 monitoring programs. Technical Report. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Blancher, P. 1984. Natural Resource Description and Management Considerations, Cataraqui Marsh — Rideau Canal. Prepared for Parks Canada, Ottawa, ON.

Brooks, K., J.P.F. Fleury, J.G.Y. Raymond and A.M. Reinhardt (Brooks et al.). 1999. "An environmental evaluation of the river sediments surrounding the Belle Island Landfill, Kingston, Ontario." Undergraduate thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Canadian Council of Ministers of the Environment (CCME). 1996. A Framework for Ecological Risk Assessment: General Guidance. EN 108-4-101996E. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999a. Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999b. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 2001. Canadian Tissue Residue Guidelines for the Protection of Wildlife Consumers of Aquatic Biota. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Environmental Quality Guidelines for the Protection of Aquatic Life. Winnipeg, MB.

Canadian Hydrographic Service. 1990. Canada, Ontario, St. Lawrence River, Kingston Harbour and Approaches — Chart 2017, Scale 1:15,000. Ministry of Fisheries and Oceans Canada, Ottawa, ON.

Catling, P. 1985. Description and Analysis of Vascular Flora of the Cataraqui Marsh. Kingston, ON.

CH2M Hill Engineering Ltd. 1991. Final Report for Phase I of the Investigation to Determine the Presence/Absence of Coal Tar Contamination in Anglin Bay and Lake Ontario in the City of Kingston. Submitted to the Kingston Public Utilities Commission.

CH2M Hill Engineering Ltd. 1992. City of Kingston Pollution Control Planning Study. Prepared for the City of Kingston.

CH2M Hill Engineering Ltd. 1994. Final Report: Closed Waste Disposal Site Assessment at the Belle Island Landfill Site in Kingston, Ontario. Prepared for the Ministry of Environment and Energy.

CH2M Hill Engineering Ltd. 2006. Belle Park Landfill Assessment of Long-term Management Alternatives — Final Draft Report. Prepared for the City of Kingston, June 2006.

Chapman, P.M. 2011. Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP). Final Report. Prepared by Golder Associates Ltd., Burnaby, BC, for Fisheries and Oceans Canada.

Chapman, P.M. and J. Anderson. 2005. “A Decision-making Framework for Sediment Contamination.” *Integrated Environmental Assessment and Management* 1, no. 3 (July 2005): 163–173.

City of Kingston. 2002. By-law No. 2000-263: By-law To Control Waste Discharges to Municipal Sewers, Passed October 10, 2000, as Amended by By-Law No. 2002-125 — 2002, Passed June 4, 2002.

City of Kingston. 2010. City of Kingston Official Plan. Approved January 27, 2010. Consolidated as of February 12, 2010. Kingston, ON.

City of Kingston and Ontario Ministry of Environment (OMOE). 2005. Project Trackdown Cataraqui River, Kingston, Ontario: Assessment of PCBs in Nearshore Groundwater. Final Report. February 2005.

Complak, J.A. 1982. "Relationship between lake type and the performance (growth, body condition, feeding patterns) of four littoral zone fish species." MSc thesis, Department of Biology, Queen's University, Kingston, ON.

Conestoga Rovers and Associates. 2006. Phase II Environmental Site Assessment: Former Davis Tannery Property, Orchard Street, Kingston, Ontario.

Contaminated Sites Management Working Group (CSMWG). 1999. A Federal Approach to the Management of Contaminated Sites.

Cross, K. 1999. "An investigation of organochlorines in freshwater sediment: A case study of Belle Island, Kingston, Ontario." Unpublished BSc thesis, Department of Biology, Queen's University, Kingston, ON.

Crowder, A.A., J.P. Smol, R. Dalrymple, R. Gilbert, A. Mathers and J. Price. 1996. "Rates of natural and anthropogenic change in shoreline habitats in the Kingston Basin, Lake Ontario." *Canadian Journal of Fisheries and Aquatic Sciences* 53 (suppl. 1): 121–135.

Crowder, A.A., K.E.J. Topping and J.C. Topping. 1997. *Plants of the Kingston Region: 1996*. Fowler Herbarium, Department of Biology, Queen's University, Kingston, ON.

Crysler and Lathem Ltd. 1977. Cataraqui River Basin — Flood Plain Management Study. Prepared for the Cataraqui Region Conservation Authority, Kingston, ON.

Dalrymple, R.W. and J.S. Carey. 1990. "Water-level fluctuations in Lake Ontario over the last 4,000 years as recorded in the Cataraqui River lagoon, Kingston, Ontario." *Canadian Journal of Earth Sciences* 27: 1330–1338.

Decommissioning Consulting Services Ltd. 1994. Report to Miller Thomson on Phase II Environmental Investigation: Former Davis Tannery and Ancillary Properties, Kingston, ON.

Derry, A., A. Dove, R. Fletcher, and N. Benoit. 2003. PCB Source Trackdown in the Cataraqui River: 2001 Findings. Technical Memorandum. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Din, Z.B. and A.B. Abu. 1993. “Toxicity of produced water from crude oil terminals to *Photobacterium phosphoreum*, *Chaetoceros* sp. and *Donax faba*.” *Bulletin of Environmental Contamination and Toxicology* 50: 413–436.

Doherty, F.G. 2001. “A review of the Microtox® toxicity test system for assessing the toxicity of sediments and soils.” *Water Quality Research Journal of Canada* 36: 475–518.

Ecological Services. 2008. Species Inventory and Ecological Evaluation: Orchard St. Marsh, Kingston, Ontario. Prepared for the Environmental Sciences Group, Kingston, ON.

Ecological Services for Planning Ltd. 1996a. Great Lakes Embayments and Harbours Investigation Program Phase II: Lake Ontario. Prepared for the Ontario Ministry of the Environment, Kingston, ON.

Ecological Services for Planning Ltd. 1996b. Great Lakes Embayments and Harbours Investigation Program Phase II: Technical Appendix. Prepared for the Ontario Ministry of the Environment, Kingston, ON.

Ecologistics Limited and Water and Earth Science Associates Limited (WESA). 1984. Initial Environmental Evaluation of General Dredging, Rideau Canal. Prepared for Parks Canada, Kingston, ON.

Engel, S. 1995. “Eurasion watermilfoil as fishery management tool.” *Fisheries* 20, no. 3 (March 1995): 20–27.

Environment Canada. 1993. Environmental Sensitivity Atlas for Lake Ontario’s Canadian Shoreline.

Environment Canada. 1997. Sediment Characterization at Department of National Defence Waterlots in Deadman Bay and Navy Bay, CFB Kingston. Prepared by Environment Canada Remediation Technologies Program for Canadian Forces Base Kingston, Kingston, ON.

Environment Canada. 1998. Benthic Assessment of Sediment Software, Version 1.8. Canadian Centre for Inland Waters, Burlington, ON.

Environment Canada. 2002. Biological Test Method for Determining the Toxicity of Sediment Using Luminescent Bacteria in a Solid-Phase Test, EPS 1/RM/42. April 2002.

Environment Canada. 2005. Results of Toxicological Testing of Sediment Samples from Cataraqui River — Environment Canada Toxicology Lab, Moncton, NB. Report ID: T641, November 17, 2005.

Environment Canada. 2006. Canadian Aquatic Biomonitoring Network (CABIN). Accessed at http://www.ec.gc.ca/rcba-cabin/

Environment Canada and Ontario Ministry of the Environment (OMOE). 2008. Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment. Prepared by Peter Chapman (Golder Associates Ltd.) with the COA Sediment Task Group on behalf of Environment Canada and the Ontario Ministry of the Environment under the Canada-Ontario Agreement (COA 2002), March 2008.

Environmental Sciences Group (ESG). 2000. PAH Aanalysis of Sediment Samples Collected Offshore of Fort Frontenac, Kingston, Ontario. RMC-CCE-00-09.

Environmental Sciences Group (ESG). 2001. Characterization of Sediment Contaminant Levels — Deadman Bay, Kingston, Ontario. Prepared for Base Environmental Officer, Canadian Forces Base Kingston, Kingston, ON.

Environmental Sciences Group (ESG). 2003. Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour. Royal Military College of Canada, Kingston, ON. October 2003.

Environmental Sciences Group (ESG). 2006. History of Anthropogenic Inputs into Kingston Inner and Outer Harbour. RMC-CCE-ES-06-13. May 2006.

ESG International Inc. 2001. Evaluation of Water and Wastewater Alternative Routes: Description of Existing Environmental Conditions — Great Cataraqui River Utilities Crossing Environmental Assessment. Prepared for R. Anderson Association Limited.

Frape, S.K. 1979. “Interstitial waters and bottom sediment geochemistry as indicators of groundwater seepage.” Unpublished PhD thesis, Department of Geological Sciences, Queen’s University, Kingston, ON.

Geo-Canada Ltd. 2001. Report on Geotechnical and Environmental Investigation for Proposed Sanitary Sewer, Water and Other Utility Crossings of the Great Cataraqui River Inner Harbour, Kingston, Ontario. Ref. No. G-20.0703. March 2001.

Golder Associates. 2011. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment: Kingston Inner Harbour — Framework Steps 4 and 5 (Preliminary Quantitative Risk Assessment).

Golder Associates. 2012. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment: Kingston Inner Harbour — Framework Step 6 (Detailed Quantitative Assessment).

Goodberry, C., A. Mather, R. Snyder and J. Suchan (Goodberry et al.). 2006. “Environmental and economic impacts of sediment contamination in the Cataraqui River, Kingston Inner Harbour.” Undergraduate thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Groundtrax Inc. 1996. Sediment Analysis at Arrowhead Beach. Prepared for Canadian Forces Base Kingston, Kingston, ON.

Hall, K. 1999. Hydrodynamics and Sedimentation in the Cataraqui River Basin, Kingston, Ontario. Report prepared for the City of Kingston.

Hamilton, T.K. and P.V. Hodson. 2003. "Research to evaluate the potential risk to fish of Kingston Harbour sediments, as indicated by bioassays of exposure and toxicity." In: Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour.

Hayton, A. 2000. Juvenile Fish Monitoring Study, Belle Island Landfill, Lower Cataraqui River. Prepared for Kingston District Office, Biomonitoring Section, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment.

Hodson, P. 1998a. Review of Data on Chemicals Reported in Fish Muscle Samples from the Great Cataraqui River by Mr. A. Hayton, Coordinator, Sport Fish Contaminant Monitoring Program, June 2, 1998. Technical Memorandum prepared for Malroz Engineering Inc.

Hodson, P. 1998b. Review of the Toxicity to Fish and Invertebrates of Ground Water Discharged from the Belle Island Landfill Site, 1996/1997. Prepared for Malroz Engineering Inc.

Hudson, R.B. 1973. "A geochemical study of recent sediments in Cataraqui Bay." Unpublished BSc thesis, Department of Geological Sciences, Queen's University, Kingston, ON.

Ingersoll, C.G., G.T. Ankley, D.A. Benoit, G.A. Burton, F.J. Dwyer, I.F. Greer, T.J. Norberg-King and P.V. Winger. 1995. "Toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates: A review of methods and applications." *Environmental Toxicology and Chemistry* 14: 1885–1894.

Inspec-Sol Inc. 2002. Environmental and Geotechnical Investigation: Great Cataraqui River Utilities Crossing, Kingston Inner Harbour, Kingston, Ontario. Prepared for Utilities Kingston.

Inspec-Sol Inc. 2003a. Supplemental Environmental Assessment Volume 1: Proposed Utility Services Approaches, Great Cataraqui River Utilities Crossing, Kingston, Ontario. Prepared for Utilities Kingston.

Inspec-Sol Inc. 2003b. Supplemental Environmental Assessment Volume 2: In Waterworks Docking Area & Near West Shore, Great Cataraqui River Utilities Crossing, Kingston, Ontario. Prepared for Utilities Kingston.

Inspec-Sol Inc. 2003c. Supplemental Environmental Assessment Volume 3: Supernatant Fluid and Sediment Testing, Great Cataraqui River Utilities Crossing, Kingston, Ontario. Prepared for Utilities Kingston.

Inspec-Sol Inc. 2003d. Supplemental Geotechnical Assessment Volume 4: Clay and Sediment Analysis, Great Cataraqui River Utilities Crossing Kingston, Ontario. Prepared for Utilities Kingston.

International Joint Commission (IJC). 1989. Great Lakes Water Quality Agreement of 1978: Agreement, with Annexes and Terms of Reference, between the United States and Canada, signed at Ottawa November 22, 1978, and Phosphorus Load Reduction Supplement, signed October 16, 1983, as amended by Protocol signed November 18, 1987 — Annex 1: Specific Objectives. International Joint Commission — United States and Canada. September 1989.

Jaagumagi, R. 1991. Sediment and Benthic Community Assessment of the Kingston Waterfront at Anglin Bay and the Queen Street Slip, September 1990. Prepared for the Ontario Ministry of Environment.

Jaagumagi, R. and D. Persaud. 1996. An Integrated Approach to the Evaluation and Management of Contaminated Sediment. Prepared for the Ontario Ministry of Environment.

Jackman, P. and K.G. Doe. 2002. Results of Toxicological Testing of Sediment Samples from Joseph Bennett of the Royal Military College. Prepared by Environment Canada, ECB, Environmental Science Centre. Moncton, NB. November 28, 2002.

J.L. Richards Acres & Associates Limited/Acres and Associates Environmental Limited. 1997. The City and Public Utilities Commission of the City of Kingston, Great Cataraqui River, Sewage Force Main and Water Main Crossings — Condition Assessment Work. Letter report to the City of Kingston. July 31, 1997.

Johnston, L.M. 1972. “A geochemical study of Deadman Bay Near Kingston, eastern Lake Ontario.” Unpublished BSc thesis, Department of Geological Sciences, Queen’s University, Kingston, ON.

Kaiser, K.L.E. 1993. “Qualitative and quantitative relationships of Microtox® data with toxicity data for other aquatic species,” in *Ecotoxicology Monitoring*, M.L. Richardson (ed.), pp. 197–211. VCH Publishers, Weinheim, Germany, 1993.

Kennedy, J.D., M.K. McGrath, A.N. Moore and E.E. Smith. 2000. “Environmental investigation of CFB Kingston stormwater runoff.” Undergraduate thesis, Royal Military College of Canada, Kingston, ON.

Luciuk, L. 1975. Turtles of the Cataraqui Region, in *The Blue Bill* 22, no. 2 (1975). Kingston Field Naturalists, Kingston, ON.

Malroz Engineering Inc. 1999. Environmental Impact Study — Cataraqui Park, Kingston, Ontario. Prepared for the Corporation of the City of Kingston. 990903-218/733.

Malroz Engineering Inc. 2003. Kingston Inner Harbour Data Compilation and Gap Analysis — Great Cataraqui River, Kingston, Ontario. File 384.00, Doc. 101R. Prepared for Kingston Environmental Advisory Forum, February 21, 2003.

Manion, N. 2007. "Determining the distribution and fate of mercury in sediment of the Cataraqui River at Kingston, Ontario." Unpublished MSc thesis, Department of Biology, Queen's University, Kingston, ON.

Melzer, A. 1999. "Aquatic macrophytes as tools for lake management." *Hydrobiologia* 395/396: 181–190.

Mudal, S. and P. Krannitz. 1990. Wetland Evaluation — Great Cataraqui Marsh. File report prepared by TKN Environmental Consultants for Ontario Ministry of Natural Resources, Kingston, ON.

Ontario Ministry of Natural Resources (OMNR). 2009. Peterborough District Wetland Report for Greater Cataraqui Marsh (Wetland FMF ID: 1251547458), third edition. February 10, 2009.

Ontario Ministry of the Environment (OMOE). 1978. Davis Tannery Site — City of Kingston Site Contamination Evaluation Report. May 1978.

Ontario Ministry of the Environment (OMOE). 1985. Unpublished sediment quality data. Original data collected by D. Poulton.

Ontario Ministry of the Environment (OMOE). 1986. Belle Island Landfill Site, Kingston Cataraqui River — 1985 Survey. File report.

Ontario Ministry of the Environment (OMOE). 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Queen's Printer for Ontario. August 1993.

Ontario Ministry of the Environment (OMOE). 1994. Water Management Policies, Guidelines: Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen's Printer for Ontario. July 1994.

Ontario Ministry of the Environment (OMOE). 1997a. Unpublished provincial water quality monitoring data for Stations #12-0004-002-02 (Kingston Mills) and #12-0004-001-02 (Highway #2).

Ontario Ministry of the Environment (OMOE). 1997b. Belle Island Landfill Site Prosecution Brief.

Ontario Ministry of the Environment (OMOE). 2013. Guide to Eating Ontario Sport Fish, 2013–2014 — 27th Edition, revised. Queen's Printer for Ontario.

Osborne, B.S. and D. Swainson. 1988. *Kingston: Building on the Past*. Butternut Press, Westport, ON.

Paine, J. 1983. "Cataraqui Marsh Hydrodynamics and Hydrology." Appendix E to Blancher, P.J., Natural Resource Description and Management Considerations, Cataraqui Marsh — Rideau Canal. Report prepared for Parks Canada, 1984.

Patterson, W.J. 1989. *Lilacs and Limestone: An Illustrated History of Pittsburgh Township 1787–1987*. Pittsburgh Historical Society.

Queen's University, School of Regional and Urban Planning. 1977. The Great Cataraqui River Valley Environmental Planning Study.

Resh, V.H., R.H. Norris and M.T. Barbour (Resh et al.). 1995. "Design and implementation of rapid assessment approaches for freshwater resource monitoring using benthic macroinvertebrates." *Australian Journal of Ecology* 20, no. 1 (March 1995): 108–121.

Reynoldson, T.B., and P. Rodriguez. 1999. "Field methods and interpretation for sediment bioassessment." In: *Manual of Bioassessment of Aquatic Sediment Quality*, A. Mudroch, J.M. Azcue and P.Mudroch (eds.), pp. 135–176. Lewis Publishers, Boca Raton, FL.

Rönnpagel, W., W. Liβ and W. Ahlf. 1995. "Microbial bioassays to assess the toxicity of solid-associated contaminants." *Ecotoxicology and Environmental Safety* 31: 99–103.

Rose, S., P. MacLatchy, G. Bickerton and D. VanStempvoort. 2004. Strategies for Mitigation of Environmental Impacts from a Closed Municipal Landfill. Presentation at NATO/CCMS Pilot Study Meeting, Cardiff, Wales, May 23–26, 2004.

Rosenberg, D.M. and V.H. Resh (eds.). 1993. *Freshwater Biomonitoring and Benthic Macroinvertebrates*. Chapman and Hall, New York.

Sierra Legal Defence Fund. 1997. Belle Island Landfill Site Prosecution Brief.

Sierra Legal Defence Fund. 1998. Unpublished sediment quality data. Letter provided to Malroz Engineering Inc.

Staples, J.W. 1996. "An investigation of the impact of contaminated groundwater seepage on the southern shoreline of Belle Island Peninsula." Unpublished BSc thesis, Department of Geological Sciences, Queen's University, Kingston, ON.

St. Lawrence College. 1973. Report on Contamination in the Cataraqui River from the Kingston Waste Disposal Site near Belle Island. November 1973.

Stokes, P. 1977. A Further Study of the Chromium Content of Soils and Sediments from Selected Sites on the Davis Tannery, Kingston, Ontario. Prepared for Arcom Developments Ltd.

Stokes, P., G. Moselhy, G. Spence and M. Liang (Stokes et al.). 1977. A Survey of Heavy Metals in Soils, Water, and Vegetation from the Davis Tannery, Kingston, Ontario. Prepared for Arcom Developments Ltd.

Tinney, M. 2006. "Site investigation and ecological risk assessment of the Kingston Inner Harbour." Unpublished MSc thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Totten Sims Hubicki Associates. 1992. Transportation Study: Bridge Crossings of the Cataraqui River. Prepared for City of Kingston, Township of Pittsburgh, County of Frontenac and Ministry of Transportation of Ontario. June 1992.

UMA Engineering Limited. 1996. Soil and Groundwater Investigation at Crawford Dock. Prepared for Public Works and Government Services Canada.

Underhill, J.A. 1975. "Water quality of the abandoned landfill site on the Cataraqui River." Unpublished BSc thesis, Department of Geological Sciences, Queen's University, Kingston, ON.

Water and Earth Science Associates Ltd. (WESA). 1988. Hydrogeological Investigation of Subsurface Conditions Beneath Proposed Extension of Kingston Rowing Club Storage Building, Kingston, Ontario. Prepared for the Kingston Rowing Club.

Weir, R.D. 2008. *Birds of the Kingston Region*, 2nd edition. Quarry Press, Kingston, ON.

Welbourn Consulting. 1999. Report on Belle Island Landfill (Cataraqui Park) in the City of Kingston — Human and Ecological Risk Assessments.

Westerby, G. 1971. "Geochemistry of the Cataraqui River near Kingston, Ontario." Unpublished BSc thesis, Department of Geological Sciences, Queen's University, Kingston, ON.

Wilson, B.C. 1973. "The Distribution of Chromium in Recent Polluted Stream Sediments." Unpublished BSc thesis, Department of Geological Sciences, Queen's University, Kingston, ON.

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Chapter II: Spatial Distribution of Contaminants in Sediments of the Kingston Inner Harbour

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

TABLE OF CONTENTS

List of Tables

List of Figures

I. INTRODUCTION

Sediments are an important component of aquatic ecosystems, providing essential habitat for many aquatic organisms. Pollutants that are released into the environment from various sources, such as industrial effluents, wastewater and solid waste disposal, may accumulate in bed sediments over time, particularly in sediments characterized by fine-grained particles with high organic content. Bottom sediments can act as long-term contaminant sinks and are an important route of exposure to aquatic, terrestrial and human receptors. A wide variety of aquatic organisms, which are potentially important food web components, live in direct contact with sediments. By ingesting the sediments or interstitial or overlying water, they are exposed to the contaminants present.

The degree of environmental risk posed by exposure to sediment contamination is dependent on the contaminant type and concentration, its bioavailability (i.e., the percentage of a chemical contaminant that can potentially be absorbed by an organism), and the potential for redistribution of sediment particles. Persistent organic contaminants such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT) and organic mercury can accumulate through the aquatic food web into organisms of higher trophic level, such as fish. As a result, a primary step in aquatic assessment is to evaluate the extent and distribution of sediment contamination at sites of concern.

Under Steps 2 and 3 of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment (COA framework) (see Chapter I, Figure I-3; Environment Canada and OMOE 2008), CoPCs and their potential to biomagnify and affect the health of other organisms higher up the food chain are identified.

The CoPCs are identified by comparing chemical concentrations found in sediment samples with aquatic sediment quality guidelines (SQGs). Because the custodians of the Kingston Inner Harbour (KIH) water lot are federal (Transport Canada and Parks Canada), this study uses federal CCME guidelines (see Chapter I, section IV-A, CCME 1999a) for comparison to sediment chemical concentrations. These guidelines provide a useful benchmark for identifying CoPCs and evaluating their potential for adverse biological effects in aquatic systems; they are derived using highly conservative assumptions. However, analytical data exceeding guidelines are not conclusive evidence of ecological degradation (Grapentine et al. 2002), and exceedance of guidelines may also be indicative of naturally elevated background site conditions. Therefore, potential CoPCs are identified by determining whether there is a statistically significant difference

($p<0.05$) between the CoPC concentrations at impacted sites and those at reference sites. Under the COA framework, the mean of the CoPC concentration at impacted sites must be at least 20% higher to be considered significantly different from the mean at reference sites.

Typically, reference areas are sites that have been minimally impacted by human activities and are ecologically similar to test sites. The presence of sediments with mean concentrations that exceed reference area mean concentrations by 20 percent or more suggests that anthropogenic exposure has occurred.

Reference areas for assessing impacted sediments are typically located in a drainage basin similar to the impacted site (Whittier et al. 2007). For the KIH, an appropriate reference area for the impacted area south of Belle Park was identified based on available information on historical industrial activities which are the primary source of the sediment contamination in the KIH. The upper portion of the KIH, upstream of Belle Island, has been minimally impacted by past industrial activities and can be considered representative of the KIH basin in terms of characteristics such as substrate composition, discharge rates, stream type and habitat features. Studies conducted in the upper and lower portions of the river have confirmed that the sediments north of Belle Island are a suitable reference site for evaluating impacts associated with historic contamination in the lower portion of the KIH, south of Belle Island.

The following sections summarize the extent and distribution of sediment chemical concentrations for each CoPC that was identified through an extensive historical review of the site (summarized in KIH report Chapter I). The sediment data has been compiled from both existing and new studies into a geo database to facilitate interpretation of the data. Only data meeting strict quality control standards were included in the database.

II. METHODOLOGY

A. Sample Collection

The majority of samples whose locations are indicated on the surface sediment contaminant maps (Appendix B) were collected by the Environmental Sciences Group (ESG), the Ontario Ministry of the Environment (OMOE) or Environment Canada following standard practice. The sampling methodology used by ESG is presented here in more detail, while collection methods used by OMOE and Environment Canada are described in their respective reports which are referenced to throughout the chapter.

ESG personnel collected surface sediments using a Ponar grab sampler. Because there is typically high heterogeneity in sediment contaminant concentrations, ESG staff collected three sediment grabs at each sampling location. A composite sample of the three grabs was homogenized at each location at the time of sample collection, then packed in a hermetically closed Whirl-Pak bag and a 125 mL amber glass wide-mouth jar using a stainless steel scoop. ESG's sampling methods are described in Appendix C.

Cores were collected using either a Kajak-Brinkhurst (KB) gravity corer, which retrieves the top layer of the sediment with minimum disturbance, or a percussion corer, which allows retrieval of cores of up to 1.5 m in depth. Cores were subsampled at 5 cm intervals and the subsamples were placed in sterile Whirl-Pak bags for laboratory analysis. Samples were kept at 4°C until analysis, which was performed using standard laboratory methods. Sampling location coordinates were collected using a GPS.

B. Sediment Physico-chemical Analyses

Sediment samples collected for the various studies were analyzed for a suite of inorganic elements, including mercury; a smaller number of samples were also analyzed for organic contaminants such as PCBs, PAHs and organochlorine pesticides. All analyses were conducted by the Analytical Services Unit at Queen's University and/or the Analytical Sciences Group at the Royal Military College of Canada, both located in Kingston, ON. The analytical methods used are presented in Appendix C. Some sediments were analyzed at ESG by x-ray fluorescence (XRF) spectroscopy.

Samples were analyzed for inorganic elements using inductively coupled plasma atomic emission spectroscopy (ICP AES). All organic analyses involved solvent extraction and analysis by gas chromatography (GC), coupled with either electron capture detection (ECD) or mass spectrometry (MS). Wet-dry analyses were also conducted, and results were reported based on dry weight.

C. Data Compilation and Mapping Techniques

ESG established a database that contains information on sediment chemistry, sediment toxicity and biological tissue concentrations for the KIH. A list of the studies incorporated into the surface sediment contamination maps is included in Table II-1. Only studies conducted after 1990 were incorporated into the database, because sediment dynamics in highly productive systems such as the Cataraqui River system can change contamination patterns on a decadal scale or less (Smol 2002). Before data were entered into the database, a thorough analysis of data quality was carried out for each data set to ensure that similar analytical methods had been used and that analytical results were reliable. Using a base map provided by the City of Kingston, information from the database was incorporated into an ESRI ArcGIS, which presents the data graphically and can reveal patterns, relationships and trends that are not readily apparent in tabular data. Results below their respective detection limits were replaced with a value equal to half of that detection limit.

Table II-1: List of studies used for mapping the spatial extent of CoPCs in the KIH

Study	**Number of sample locations with physical and chemical data**
Brooks et al. 1998	14
Benoit and Berniston 2010	30
Benoit and Dove 2006	34
CH2M Hill 1991	13
Cross 1999	9
ESG 2003	2
Derry et al. 2003	48
Golder Associates 2011, 2012	20
Jaagumagi 1991	3
Manion 2007	20
Scheider 2009	5
Tinney 2006	54
Totten Sims Hubicki Associates 1992	19
ESG unpublished data 2006–2008	27

The interpolation maps were developed based on several rounds of sampling, allowing for identification of areas where more surface samples were needed in order to refine contaminant distribution patterns. Recent sampling efforts carried out by ESG have focused on the collection of surface samples to fill in these identified gaps in spatial coverage. The resulting contaminant plume maps presented in this report are based on a grid of surface sediment sample points showing good spatial coverage throughout the KIH.

ArcGIS Version 10 was used to create the plume maps. Inverse Distance Weighted (IDW) interpolation was applied on the log-transformed data to estimate sediment concentrations at unsampled locations. IDW is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points. Contaminant plume maps were created using log-transformed data, which is standard practice and allows for non-linear distribution of concentration between concentrations at known points. It should be noted that these plume maps are hypothesized and provide an approximation of the spatial extent of current contamination.

These maps were then used to examine the spatial distribution of the main CoPCs in surficial sediments of the KIH following Steps 2 and 3 of the COA framework (Environment Canada and OMOE 2008). The spatial distribution of contaminants with respect to potential historical sources of contamination is also discussed. Surface sediment contamination maps for the KIH sediments were produced for the main contaminants of concern exceeding the SQGs and the concentrations at the reference sites.

III. Results and Discussion

In this section, the physical and chemical characteristics of the sediments are described in detail and the spatial extent of the CoPCs is visually depicted in a series of plume maps (Appendix B). Map B-II-1 (Appendix B) highlights the geographical features as well as current and past land uses that are referred to when describing the spatial extent of the CoPCs within the harbour. Table II-1 lists the studies that have been used to create the plume maps as well as the number of sampling locations per study that provided physical and chemical data for inclusion in the KIH geodatabase.

A. Sediment Stratigraphy and Sediment Particle Size

Knowledge of sediment grain size composition is essential because contaminants often bind preferentially to fine-grained organic sediments (Baird and Cann 2005). The grain size composition for the lower KIH is shown in Appendix B, Map B-II-4. Sediment samples were analyzed for the proportions of sand-, silt- and clay-sized particles. For the sediment grain size distribution map, the Shepard's sediment classification was used to describe the types of sediment within the bay. Shepard's classification is based on percentages of sand, silt and clay within the sediment and is represented by a ternary diagram (Shepard 1954). For the lower KIH the majority of samples fell into the clayey-silt field of the Shepard diagram. The grain size data indicate that gravel is present in small proportions, between 5 and 20 percent, in the sediments immediately adjacent to the Davis Tannery and the Belle Island Landfill Further off shore, small grain sizes predominate, with clayey silt and silty clay making up almost 90 percent of the total. The area south of the Woolen Mill is represented by a limited number of samples and hence there is a limited certainty with the interpolated grain size results for this portion of the harbour

The fraction of total organic carbon (TOC) in surface sediments is mapped in Appendix B, Map B-II-5. The surface sediments in the KIH have a TOC content of 20–30 percent and are considered organic-rich. The sediments in the Inner Harbour are also nutrient -rich, which is indicative of a eutrophic system. The macronutrients nitrogen and phosphorus are high contributing to the heavy growth of macrophytes throughout the harbour. The decay of the aquatic plant material in the autumn leads to high organic carbon content in the sediments which in turn increases biological oxygen demand in the water. However, relatively high levels of dissolved oxygen in the water column indicate that the TOC is not affecting oxygen levels adversely.

Both the fine-grained sediments and the high levels of organic content provide large amounts of organic material onto which contaminants can bind tightly potentially making contaminants less bioavailable to receptors than they would be in coarse-grained sediments with low TOC. The organic content increases with water depth (Dalrymple, R.W. and J.S. Carey 1990).

Asquini et al. (2007) studied sediment stratigraphy in several cores collected from the southwest portion of the KIH. Three different types of sediments are distinguishable: medium-grained silt (gyttja), clay and peat. The top layer of sediment is composed of gyttja, which extends to a depth of 25–40 cm. In the western part of the harbour, a peat layer is present under the gyttja. The fibrous peat usually consists of 70–75 percent organic detritus. In the eastern and central part of the Inner Harbour, a clay layer is present under the gyttja. Because of the relatively low levels of organic matter in clay, metals and other contaminants cannot easily bind to this type of sediment. Clay often acts as a barrier to prevent downward movement of water and contaminants.

B. Contaminants of Potential Concern

Chemical analysis of the sediments in the KIH has confirmed the presence of several of the CoPCs that were identified during the historical review. The CoPCs that exceeded applicable sediment guidelines – CCME Interim Sediment Quality Guidelines (ISQG) or OMOE lowest effect level (LEL) – are: Cr, Pb, Zn, Cu, As, Hg, PAHs, PCBs, chlordane and total DDT (tDDT). No sediment guidelines were available for Sb but concentrations exceeded CCME and OMOE soil quality guidelines.

In the sections that follow, each of the CoPCs identified above is described briefly in terms of the potential toxicity of the CoPC to aquatic biota and the spatial extent of the CoPC in the KIH. Concentrations at reference locations are compared with concentrations in the impacted area and analyzed statistically to determine if the mean of contaminant levels at the impacted sites is significantly higher than the mean at reference sites. In cases where statistical results were ambiguous, contaminants are screened using methodology described in Chapter IV. Specifically, maximum values in the APEC are compared with maximum values from the reference area. Although this procedure is not part of the COA framework, it is consistent with Health Canada guidelines for screening potential contaminants for human health risk assessment (HHRA) (Health Canada 2012). This is also consistent with our approach of carrying CoPCs identified in this chapter forward for human health and ecological risk assessment (HHERA) in Chapter IV. Table II-2 presents the mean, maximum and minimum values and statistics for each CoPC.

Table II-2: Average concentrations and statistics for each CoPC in KIH sediments at APEC and reference locations

		Inorganics (ppm)							PAH (ppm)		PCB (ppb)	Pesticides (ppb)	
		Cu	**Pb**	**Zn**	**Cr**	**As**	**Hg**	**Sb**	**All samples**	**Without Anglin Bay depth samples**		**tDDT**	**Chlordane**
APEC	Number of samples	456	454	444	449	195	156	131	142	130	242	51	49
	min	11	5.9	6.2	31	1.7	0.0035	0.1	0.13	0.13	<0.1	2.2	0.5
	max	780	3,246	2,460	42,737	742	11	894	20,605	175	12,000	145	41
	mean	49	176	190	1,564	26	1.1	14	189	10	628	15	4.3
	95 upper confidence level (UCL)	53	196	205	2,457	49	1.7	45	823	18	964	20	9.0
	n non-detects	21	1	5	58	4	5	55	5	5	18	14	13
Background	Number of samples	45	44	46	38	35	12	16	19	19	28	4	4
	min	17	13	53	<20	<1	0.04	0.2	0.1	0.1	<3	6	<2
	max	58	290	2,200	240	16	0.2	0.4	5.9	5.9	580	36	<2
	mean	30	53	160	63	2.6	0.1	0.3	1.6	1.6	59	16	n/a
	95 UCL	35	83	361	94	2.9	0.1	0.5	2.9	2.9	105	n/a	n/a
	n non-detects	1	0	0	3	2	0	14	0	0	9	0	4
Statistics	Guidelines (ISQG)	35.7[a]	35[a]	123[a]	37[a]	5.9[a]	0.17[a]	1[c]	4[b]	4[b]	34[a]	1.2[a]	4.5[a]
	Guidelines (PEL)	197[a]	91.3[a]	315[a]	90[a]	17[a]	0.49[a]	20[d]	920[b]	920[b]	277[a]	4.8[a]	8.8[a]
	APEC mean > ref mean	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no	yes
	APEC max > ref max	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
	% APEC higher	62	233	18	2,421	908	1,076	4,800	>10,000	525	951	n/a	n/a
	t-test p	6.6×10^{-7}	7.9×10^{-13}	9.2×10^{-10}	2.2×10^{-15}	0.018	0.3	0.12	8.2×10^{-7}	2.6×10^{-6}	1.6×10^{-8}	0.69	0.28
	t-test conclusion	Site > ref	Site > ref	Site > ref	Site > ref	Site > ref	Site <= ref	Site <= ref	Site > ref	Site > ref	Site > ref	Site <= ref	Site <= ref

[a]CCME sediment guidelines. [b]OMOE sediment guidelines: LEL is in ISQG cell, and SEL, corrected for organic carbon, is in PEL cell. [c]OMOE soil guideline: agricultural/other land use for site standard with 30 m of water body. [d]CCME soil guideline for residential/agricultural land use.

1. Chromium

a. <u>Fate and Sources of Chromium in the Environment</u>

Chromium (Cr) is a trace element that can be toxic to aquatic biota at elevated concentrations (CCME 1999c). Chromium can exist in two oxidation states in aquatic systems: hexavalent Cr (Cr(VI)) and trivalent Cr (Cr(III)). Cr(III) is an essential element and is minimally toxic; Cr(VI) compounds are relatively mobile and can be acutely toxic. Cr(VI)is the dominant form in the dissolved phase, while nearly all of the chromium in sediments (below the sediment-water interface) is Cr(III) (CCME 1999b). Chromium (III) is associated with particulate matter and enters aquatic systems through aerial deposition and runoff, ultimately residing in bed sediments.

Toxicological information on chromium in aquatic ecosystems is relatively limited. There is clear evidence that exposure to certain levels of Cr(VI) can result in significant human health and ecological risks. Toxicity appears to depend on factors intrinsic to the receiving organisms; however, Cr(VI) is generally considered to be more toxic than the Cr(III) form (Eisler 1986). Known effects on benthic organisms include increased mortality and reduced diversity and abundance, as well as behavioural changes (CCME 1999b). These effects depend on species sensitivity, physicochemical characteristics (e.g., pH, redox potential and chemical speciation), geochemical characteristics (e.g., particle size and organic and metal oxide content) and biological characteristics (e.g., feeding patterns and rates of uptake). Epidemiological studies have also shown chromium to be a human carcinogen, usually through exposure by inhalation (Foulkes 1990). Biomagnification of chromium in aquatic and terrestrial food chains probably does not occur (Eisler 1986).

Elevated sedimentary chromium levels are usually associated with industries that produce or use chromium products. These include metal plating and finishing, paints and pigments, leather tanning, wood preservatives, corrosion inhibitors and the manufacture of common household and office supplies (e.g., cosmetics, fertilizers, soaps and cleaning products) (CCME 1999b). One of the primary sources of chromium at the KIH was the former Davis Tannery, which operated from 1903 to 1973. The tannery used chromium tanning agents, especially Cr(III) sulfates (ESG 2009).

While concentrations of chromium in freshwater and marine sediments vary significantly throughout Canada, a variety of studies indicate that the mean background concentration in Canadian lake sediments is 47 ppm and the mean concentration in Canadian stream sediments is 81 ppm. The CCME ISQG, however, is 37.3 ppm (CCME

1999b). The ISQG is lower than the national background concentration because a weaker acid digestion, which provides a measure of the bioavailable fraction only, was used to derive the ISQG. The methods used in determining the background concentrations employed strong acid digestion, which removes both the bioavailable and the residual chromium fractions (CCME 1999b). The PEL for chromium is 90 ppm.

b. Spatial Extent of Chromium in Surface Sediments of the KIH

The chromium plume illustrated in Appendix B, Map B-II-6 shows that sediment contamination in the KIH is prevalent along the western shore of the lower Cataraqui River. The highest chromium concentrations were measured in the discharge area of the South Stream and the Kingscourt storm sewer, in the southwest corner of the Belle Park Landfill. Concentrations in sediments range from 30 ppm to 43,000 ppm, the highest being almost 500 times above federal guidelines. The chromium concentrations in this area are probably the highest reported from any site in the Great Lakes. The widespread chromium contamination is probably related to the historical discharge of tannery effluents into the KIH. The chromium plume map reflects the area of historical discharge until 1967; all of the tannery's liquid wastes were discharged into the Orchard Street Marsh without treatment (CRA 2006). Orchard Street Marsh is drained by the South Stream, which merges with the Kingscourt storm sewer before it discharges into the harbour southwest of Belle Island. The high levels of chromium found in the discharge area indicate rapid precipitation of the metal upon contact with the water.

Chromium is present throughout the Inner Harbour in its Cr(III) form; analytical results reveal no detectable concentrations of Cr(VI). The plume map shows that chromium concentrations decrease from west to east. In the zone between the River Street Pump Station and Belle Park, concentrations range from 900–1,350 ppm; in the zone between the Rowing Club and the western edge of Belle Island, levels range from 450–900 ppm; and along the eastern shore, concentrations are generally below the PEL of 90 ppm. Similarly, sampling locations north of Belle Park have levels of chromium below the PEL, and some are even below the ISQG.

Chromium concentrations at reference locations were compared with concentrations at locations within the APEC using box-whisker plots (Figure II-1). The majority of the affected sites have concentrations above the 90 ppm PEL. The mean concentration at APEC sites, 1,564 ppm, is more than 20 percent higher than the mean of 63 ppm at reference sites. The t-test results ($p < 0.05$, Table II-2) show that the mean of chromium levels at the APEC sites is significantly higher than the mean at reference sites.

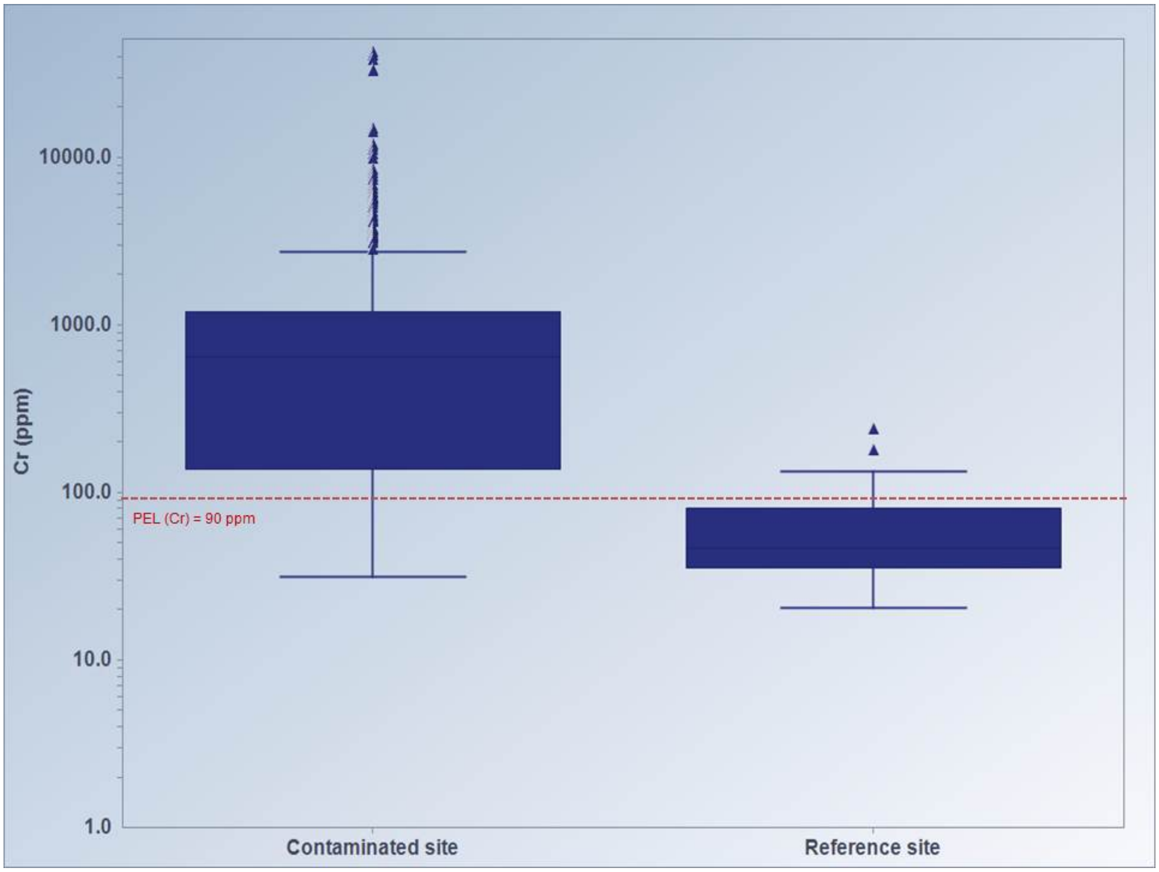


Figure II-1: Boxplot of chromium levels at sites within the APEC (n=441) and at reference sites (n=38).

c. <u>Extent of Chromium in Deeper Sediments of the KIH</u>

Figure II-2 summarizes the contaminant depth profiles of chromium concentrations in selected cores collected in the bay where the South Stream and the Kingscourt storm sewer discharge into the lower KIH.

Chromium concentrations at depth were highest in the sewer core (SC) retrieved in the South Stream, 100 m downstream from the Kingscourt storm sewer. Here, chromium was measured at 43,000 ppm at a depth of 20–25 cm. Because this core was located in the discharge channel, the variations in chromium concentrations in surface and depth sediments may reflect differences in effluent composition and the amount of tannery waste discharged over time. In a core retrieved further downstream, close to the mouth of the South Stream (Core 8), chromium concentrations in excess of 40,000 ppm were measured at a depth of 30–55 cm. Chromium levels at depth in Core 8 are at least one order of magnitude higher than those in surface sediments, suggesting that significant chromium deposition occurred in the past. Chromium concentrations decrease to less than 300 ppm at a depth of 65 cm.

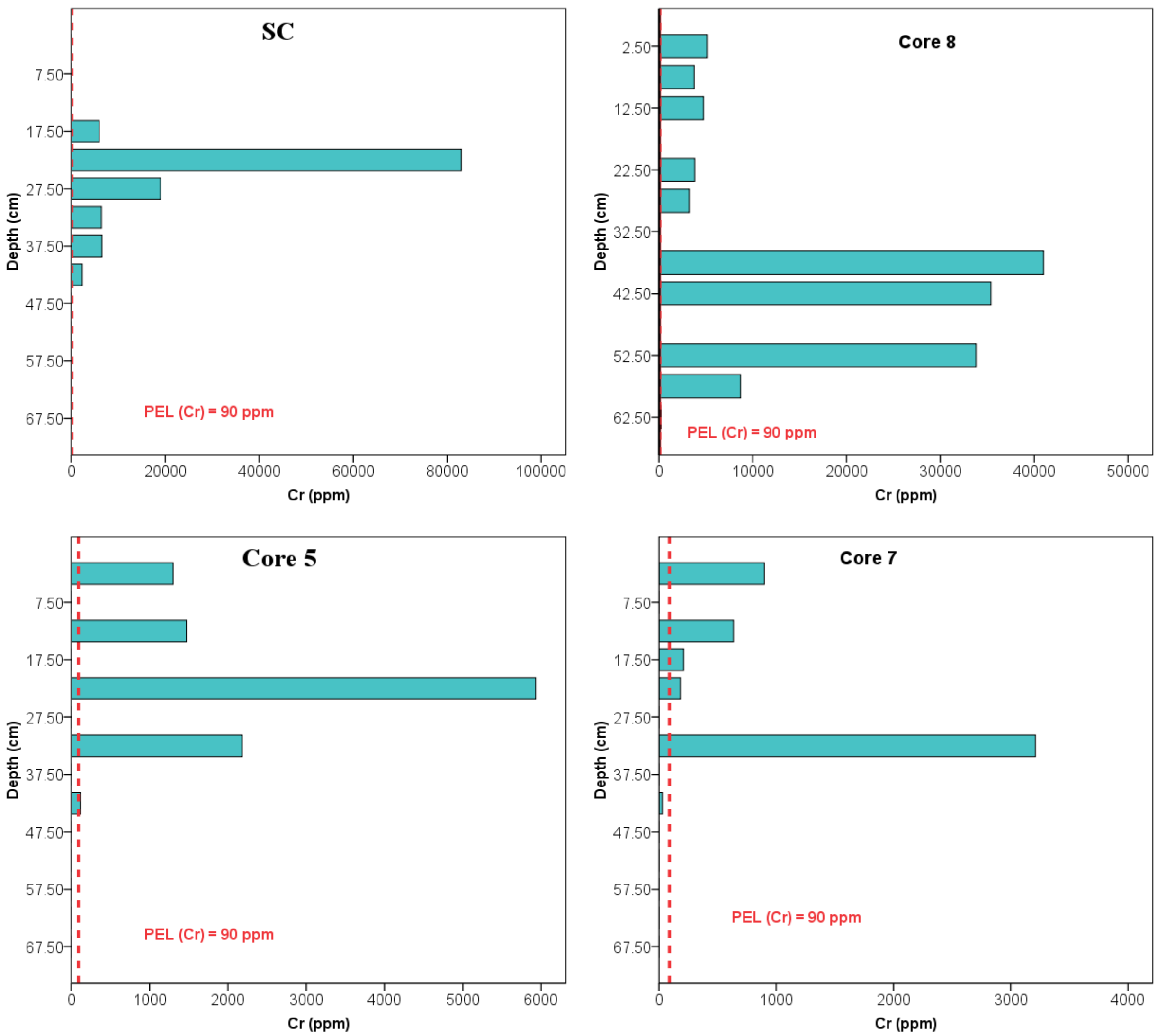


Figure II-2: Chromium depth profiles for selected cores retrieved from the KIH (ESG 2006).

A trend emerged in which maximum chromium concentrations were found at a depth of 20–60 cm in all cores. Chromium concentrations at depth decrease with increasing distance from the outlet. In Cores 5 and 7, for example, peak concentrations of 3,500–7,000 ppm were measured, while Core 3 and Core 6, collected at exterior stations, had chromium concentrations of 1,500–1,800 ppm.

The chromium depth profiles suggest that sediment deposition rates vary across the lower KIH and are highest in the discharge area of the South Stream, as would be expected. The chromium profiles suggest a mixed sediment zone near the surface that is isolated from the zone of greatest chromium contamination. In the top 20 cm, chromium concentrations are relatively uniform, ranging from 500–1,500 ppm. The absence of sediments containing lower levels of chromium near the surface suggests that little dilution with clean sediments occurs because of limited sediment input and continual mixing and resuspension of contaminated sediments. The spatial extent of chromium in the sediments indicates limited dilution of chromium concentrations in surface sediments as the result of limited sediment input and upstream flow. As groundwater is discharging from the nearshore area, the possibility that chromium may be mobilized from deeper layers and transported to the surface has to be considered.

In the summer of 2009, ESG carried out *in situ* experiments to directly measure contaminants in entry points to sediments, such as groundwater or surface water. ESG installed mini-piezometers and *in situ* peeper samplers along the western shore of the KIH, adjacent to the former Davis Tannery property, to monitor groundwater conditions and to assess chromium speciation. No chromium was detected in groundwater collected near the former Davis Tannery property shore, demonstrating that the former tannery site does not act as a continuing source of contamination. In addition, no Cr(VI) was detected in pore water, indicating no potential for chromium oxidation. Cr(III) is geochemically stable in KIH sediments under ambient conditions and is expected to remain so under severe weather conditions or during any remedial actions.

2. Lead

a. <u>Fate and Sources of Lead in the Environment</u>

Lead (Pb) is toxic to biological organisms at elevated concentrations and exists in the environment as a non-essential trace element. While the elemental state of lead (Pb(0)) rarely occurs in nature, lead is most commonly seen in its divalent (Pb(II)) state, although its monovalent (Pb(I)) and tetravalent (Pb(IV)) states also occur frequently. Lead is typically deposited, aerially or through runoff, in bed sediments in association with iron and manganese oxides, and it has a greater relative affinity than other trace metals, such as copper, zinc, cadmium and nickel. It can also precipitate out of solution with carbonate or sulfide (CCME 1999d).

Before 1990, the most prominent source of lead was the petroleum industry, in which tetraethyl lead was used as an antiknock additive in gasoline (CCME 1999d). Historically, lead has also been used in pottery glazes, art and paint pigments, coins and water pipes and as an insecticide in the form of lead arsenate. Other major sources of lead include the mining, smelting and refining industries as well as battery manufacturing.

The Canadian Environmental Protection Act (CEPA) lists lead as a toxic substance, when it enters the environment "in quantities or concentrations, or under conditions, that are having or may have a harmful effect in the environment" (CCME 1999e). The adverse biological effects associated with lead include increased mortality, abnormal development and decreased abundance and diversity of benthic invertebrates (CCME 1999d). Organic lead compounds, which are primarily anthropogenic, are generally more toxic than inorganic lead but are usually less prevalent in the environment (CCME 1999d).

While concentrations of lead in freshwater and marine sediments vary significantly throughout Canada, the mean background concentration in Canadian lake sediments is 6 ppm and the mean concentration in Canadian stream sediments is 12.7 ppm. The ISQG in freshwater sediments is 35.0 ppm, and the PEL is 91.3 ppm (CCME 1999d).

b. Spatial Extent of Lead in Surface Sediments of the KIH

The lead plume map (Appendix B, Map B-II-7) shows that, similar to the chromium plume, the highest levels of lead were measured near the mouth of the South Stream, in the area south of Belle Park and east of the former Davis Tannery property. The highest concentration, 3,246 ppm was measured at a sampling station close to Belle Park. Levels in this area were up to 35 times higher than the PEL of 91.3 ppm. The source for the lead contamination was probably the operation of the Frontenac Smelting Works between 1879 and 1916.

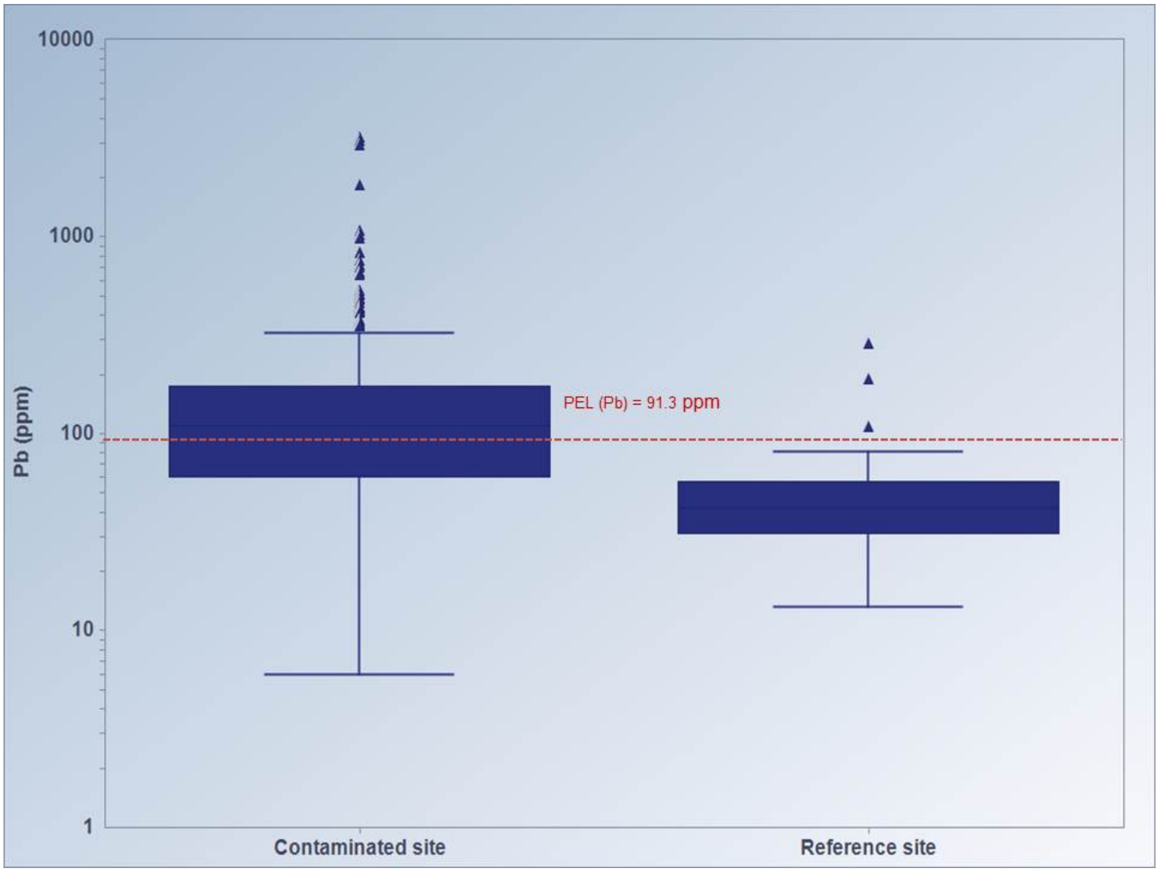


Figure II-3: Boxplot of lead levels at sites within the APEC (n=446) and at reference sites (n=44).

A second lead-contaminated area, with concentrations three times higher than the PEL, is located on the western shore, between the Rowing Club and Anglin Bay. Lead at levels above the PEL is widespread on the western shore of the KIH, south of the Belle Park Landfill down to the LaSalle Causeway, with concentrations decreasing to the east.

The boxplots (Figure II-3) indicate that lead concentrations in the APEC range from 6 ppm to 3,246 ppm and are generally above the PEL of 91.3 ppm. At reference locations, levels from 13 to 290 ppm were measured. The mean at sites within the APEC, 176 ppm, is more than 20 percent higher than the reference site mean of 53 ppm. The t-test results showed that lead levels in the APEC are significantly higher than they are at reference sites ($p<0.001$).

c. Extent of Lead in Deeper Sediments of the KIH

Figure II-4 shows the lead profile in Core 8. Concentrations at depth in Core 8 range from 280–3,560 ppm and are highest at between 40 and 55 cm. The zone of highest lead contamination coincides with the zone of greatest chromium contamination, indicating that the depth of maximum concentration represents the period of maximum contaminant loading to the harbour in the past.

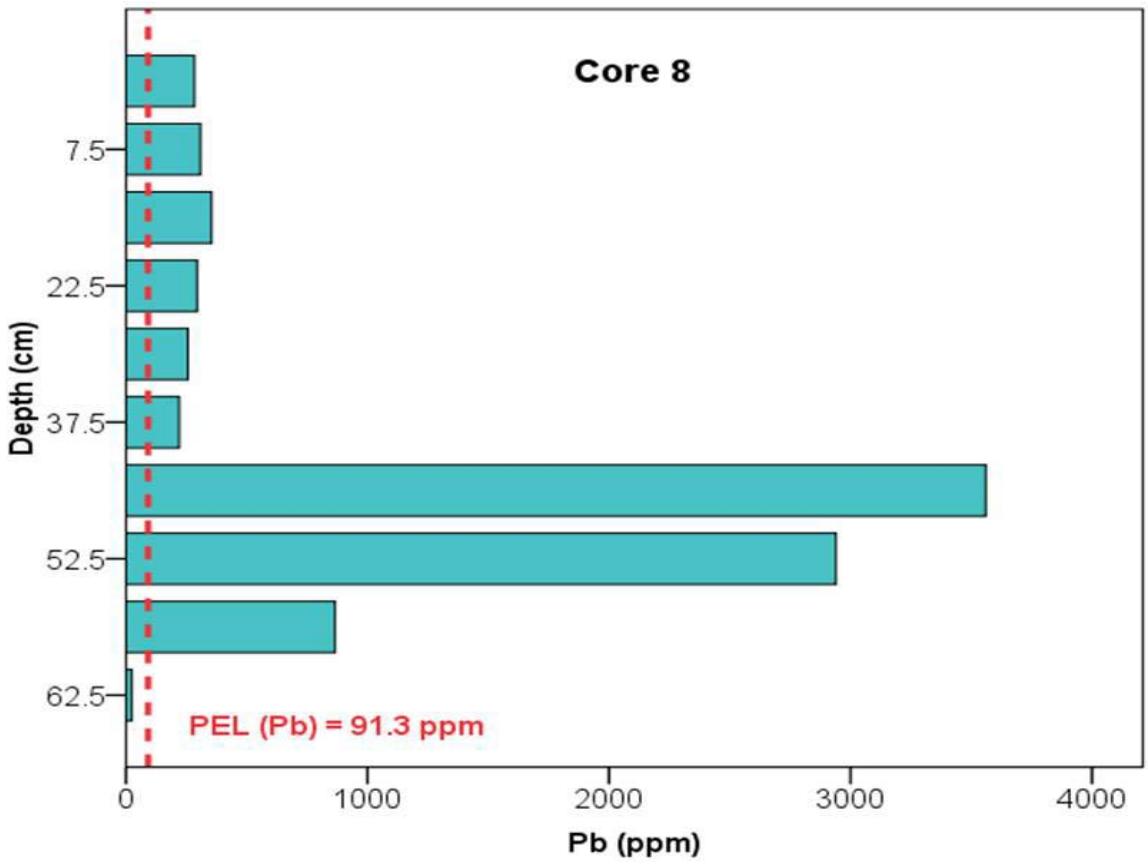


Figure II-4: Lead depth profile for C8 percussion, collected in the bay where the South Stream discharges into the KIH (ESG 2006).

3. Zinc

a. Fate and Sources of Zinc in the Environment

Zinc (Zn) is the fourth most commonly used metal worldwide, after iron, aluminum and copper (BCMoE 1999). It is used to prevent iron and steel products from rusting, in the manufacture of brass and bronze die-casts, in many household items (including utensils, cosmetics, paints and rubber), in the manufacture of glass, automobile tires, television screens, dry cell batteries, insecticides and adhesives, in metallurgic operations, in wood preservatives, and in fire-fighting operations (BCMoE 1999).

Zinc can be toxic to aquatic organisms when present at elevated concentrations (CCME 1999f). As an essential trace element, however, certain levels are necessary to prevent the harmful effects of zinc deficiency (CCME 1999f; BCMoE 1999). It is typically deposited into bed sediments of aquatic systems aerially and through surface runoff, creating an important route of exposure for these aquatic organisms. It has a high affinity to particles in the aquatic environment, especially iron and manganese oxides, as well as to organic matter (BCMoE 1999).

Benthic organisms are exposed to dissolved zinc in interstitial waters and to particulate zinc through contact with and ingestion of sediment. The dissolved forms demonstrate higher bioavailability (CCME 1999f). The bioavailability and toxicity of zinc are influenced largely by changes in pH, redox potential, turbidity, water hardness, salinity, temperature and the presence of co-contaminants (CCME 1999f; BCMoE 1999). Adverse effects include increased mortality, changes in behaviour and decreased diversity and abundance, particularly of invertebrates (CCME 1999f). The toxicity of zinc is often reduced by organic matter and sulfides (CCME 1999f).

While concentrations of zinc in freshwater and marine sediments vary significantly throughout Canada, the mean background concentration in Canadian lake sediments is 104 ppm and the mean concentration in Canadian stream sediments is 107 ppm. The ISQG in freshwater sediments is 123 ppm, and the PEL is 315 ppm (CCME 1999f).

b. Spatial Extent of Zinc in Surface Sediments of the KIH

The zinc plume map (Appendix B, Map B-II-8), shows that concentrations in the APEC are generally higher than the ISQG of 123 ppm. The highest concentrations were measured near the mouth of the South Stream, in the area south of Belle Park and east of the former Davis Tannery property, where a maximum concentration of 2,460 ppm (8 times the PEL) was observed. The high concentrations may be related to historical lead smelting operations, as zinc is usually associated with lead production.

Surface sediments in the area adjacent to the former Kingston Cotton Manufacturing Company, now referred to as the Woolen Mill, and in the area north of Anglin Bay also had zinc levels above the PEL. The boxplot in Figure II-5 indicates that zinc concentrations range from 6.2 ppm to 2,460 ppm at sites within the APEC and from 53 to 2,200 ppm at reference sites. The mean at sites within the APEC, 190 ppm, is only

18% higher than the reference site mean of 160 ppm. However, because the t-test results showed that Zn levels in the APEC are significantly higher than they are at reference sites ($p<0.001$), and because the mean within the APEC exceeded the ISQG value, Zn was retained as a CoPC.

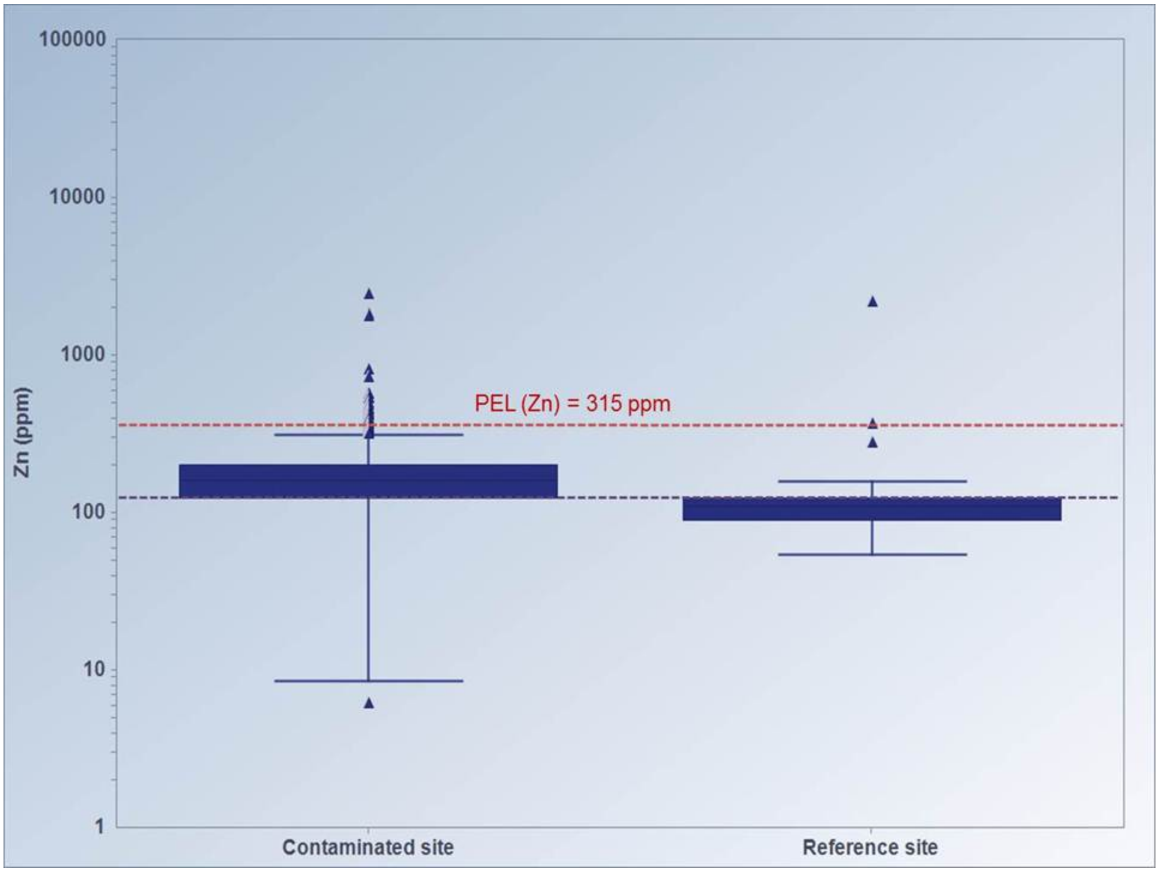


Figure II-5: Boxplot of zinc levels within APEC sites (n=436) and at reference sites (n=46).

4. Copper

a. Fate and Sources of Copper in the Environment

Copper (Cu), an essential trace element, can be toxic to aquatic biota when present at elevated concentrations (CCME 1999g). Its presence in aquatic systems is due largely to aerial transport and surface runoff, and it tends to accumulate in sediments because of its affinity to particulate matter, especially iron, manganese and organic matter. Copper occurs in a wide range of mineral deposits, mostly in the form of sulphide minerals.

Adverse biological effects of copper include decreased benthic invertebrate diversity and abundance, increased mortality, and behavioural changes (CCME 1999g). As with other metals, the effects are mitigated by the sensitivity of individual species, as well as by physiochemical, biological and geochemical factors that affect its bioavailability. The presence of organic matter is thought to decrease copper's toxicity to benthic organisms (CCME 1999g).

Copper is used in the manufacture of textiles, antifouling marine paints, electrical conductors, plumbing fixtures and pipes, coins and cooking utensils. It is also an active ingredient in wood preservatives, pesticides and fungicides, and is a micronutrient used in agricultural fertilizers in the form of copper sulphate (CCME 1999g). Potential sources of copper in the KIH include stormwater sewer discharges, the Belle Island Landfill and various industries on the western shoreline.

While concentrations of copper in freshwater and marine sediments vary significantly throughout Canada, the mean background concentration in Canadian lake sediments is 31 ppm and the mean concentration in Canadian stream sediments is 32 ppm. The ISQG for freshwater sediments is 35.7 ppm, and the PEL is 197 ppm (CCME 1999g).

b. Spatial Extent of Copper in Surface Sediments of the KIH

The plume map for copper (Appendix B, Map B-II-9) shows that concentrations range from 11 ppm to 780 ppm at sites within the APEC but rarely exceed the PEL. Concentrations at reference sites north of Belle Island range from 17 to 58 ppm.

The mean concentration at sites within the APEC (Figure II-6) is 49 ppm, which is more than 20 percent higher than the mean concentration at reference sites, which is 30 ppm. The t-test results indicated that the mean of copper levels in the APEC is significantly higher than at reference sites ($p<0.001$).

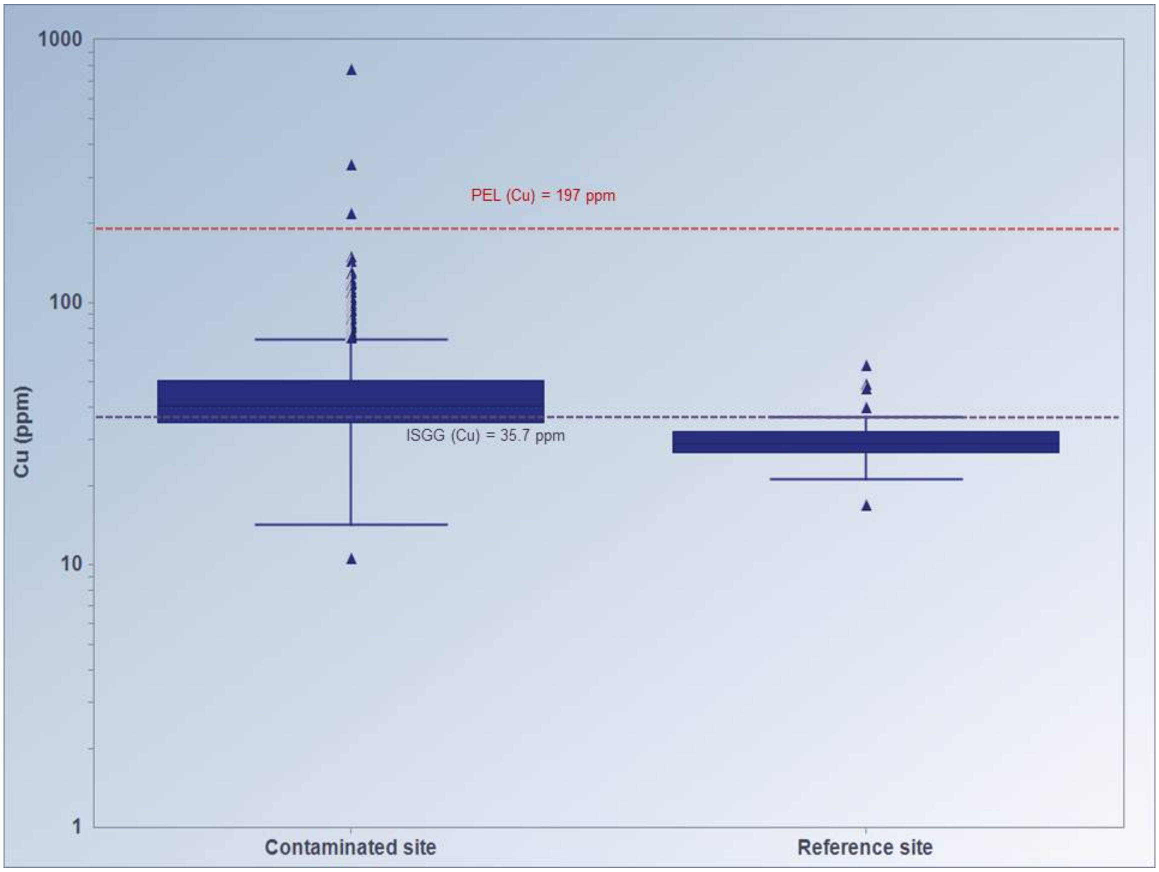


Figure II-6: Boxplot of copper levels at APEC sites (n=448) and at reference sites (n= 45).

5. Arsenic

a. <u>Fate and Sources of Arsenic in the Environment</u>

Arsenic (As) is a metalloid that occasionally occurs in nature as a solid in the elemental state but is most often found in compounds with sulphur, either alone or in combination with various metals (Boyle and Jonasson 1973). Arsenic can occur in the gaseous state or in the dissolved phase, as inorganic As(III) and As(V) species, as well as in various methylated compounds (Cullen and Reimer 1989).

Arsenic has a strong affinity for particles that can be suspended in aquatic systems, especially iron and manganese oxides, which contributes to its deposition in bed sediments in association with these materials (CCME 1999h). The toxicity to aquatic organisms is dependent on the form of arsenic present. Arsenic can exist in the +3 and +5 oxidation states (Cullen and Reimer 1989). The toxic inorganic forms of arsenite ($As(OH)_3$, As(III)) and arsenate ($H_2AsO_4^-$, As(V)) can exist simultaneously in aquatic environments, depending on redox and pH conditions (Cullen and Reimer 1989).

Adverse biological effects of arsenic exposure include decreased abundance of benthic invertebrates, increased mortality and changed behaviour (CCME 1999h). The likelihood of such adverse effects depends on the sensitivity of the species as well as on a variety of physiochemical (e.g., pH and redox potential), geochemical (e.g., particle size, phosphorus concentrations and presence of metal oxides) and biological (e.g., feeding behaviour and rates of uptake) factors that affect bioavailability (CCME 1999h).

Arsenic's inorganic form is of primary toxicological concern to humans. Numerous studies have demonstrated that inorganic arsenic compounds can cause cancer in humans, both by inhalation and ingestion (CCME 1999h). The current concentrations of inorganic arsenic in Canadian drinking water, soil, air and, especially, food may pose a risk to both the environment and human health. Therefore, under Section 11 of CEPA, arsenic and its associated compounds are considered to be "toxic" (Government of Canada, Health Canada and Environment Canada 1993). Research assessing the bioavailability and toxicity of individual arsenic compounds is ongoing.

Natural weathering and anthropogenic activities contribute to the presence of arsenic in aquatic and terrestrial environments. Anthropogenic sources include gold and base-metal processing, arsenical pesticides, power generation from coal burning and domestic and industrial waste disposal (Government of Canada, Health Canada and Environment Canada 1993). The presence of arsenic in sediments of the KIH is likely to have been associated with activities at the Woolen Mill.

While concentrations of arsenic in freshwater and marine sediments vary significantly throughout Canada, the mean background concentration in Canadian lake sediments is 2.5 ppm and the mean concentration in Canadian stream sediments is 10.7 ppm. The ISQG for arsenic in freshwater sediments is 5.9 ppm, and the PEL is 17 ppm (CCME 1999h).

b. <u>Spatial Extent of Arsenic in Surface Sediments of the KIH</u>

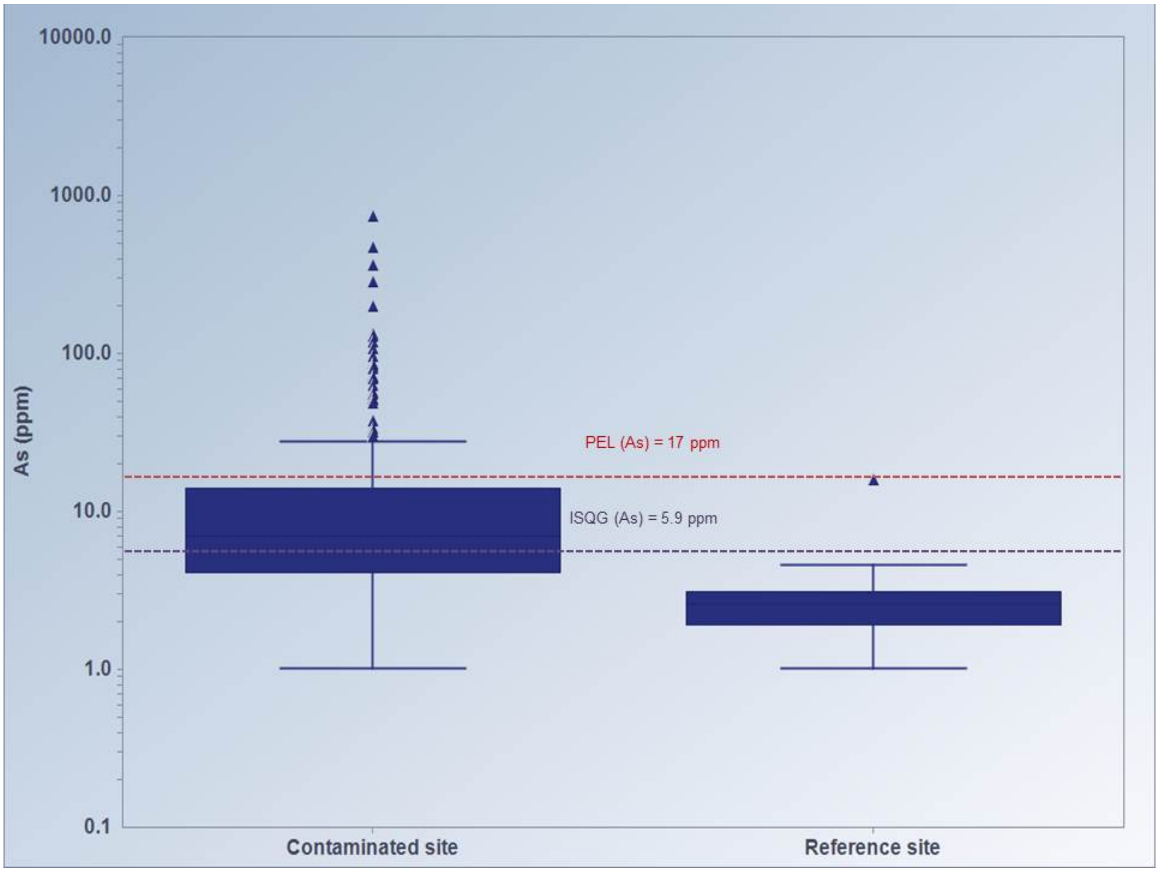


Figure II-7: Boxplot of arsenic levels at APEC sites (n=187) and at reference sites (n=35).

The plume map for arsenic (Appendix B, Map B-II-10) shows that concentrations of up to 742 ppm were measured adjacent to the western shoreline between the former Frontenac Lead Smelter and the former Woolen Mill. While the PEL of 17 ppm was exceeded by 40 times in this area, it appears that arsenic contamination remains localized in a relatively small stretch along the western shore and has not extended far into the KIH. Surface sediment concentrations for arsenic decrease with increasing distance from the shoreline, to levels below the PEL but remain above the ISQG. Arsenic concentrations continue to decrease towards Belle Island and the navigational channel to background levels below the ISQG. The plume map suggests that the arsenic source is local and terrestrial, located in the area of the Rowing Club and the former Woolen Mill.

The mean concentration at sites within the APEC (Figure II-7) is 26 ppm, more than 20 percent higher than the mean of 2.6 ppm at reference sites. The t-test results indicated that arsenic levels in the APEC are significantly higher than those at reference sites ($p<0.05$).

6. Mercury

a. Fate and Sources of Mercury in the Environment

Mercury (Hg), a non-essential trace element, is present in the environment in a number of organic and inorganic forms. It exhibits three stable valence states: elemental (Hg(0)), mercurous (Hg_2(II)) and mercuric (Hg(II)) (CCME 1999i). Elemental mercury is a liquid at room temperature and evaporates easily. Ionic inorganic mercury chelates easily with organic matter to form stable complexes and is also often found in association with sulphides, which render it unreactive in anoxic conditions. It has a high affinity for any organic ligands present on particles and colloids, so it is easily transported to and deposited in bed sediments (CCME 1999i).

The presence of mercury in the environment is of great concern because of its toxicity and its tendency, under certain environmental conditions, to accumulate in biota as methylmercury (MeHg). Inorganic mercury can be methylated by sulphur-reducing bacteria indigenous to sediment, with anaerobic conditions favouring their activity (Regnell and Tunlid 1991). Because MeHg can magnify through food webs, particularly in aquatic systems, humans can be exposed to this neurotoxic metal through consumption of aquatic food.

Mercury is transported easily across cell membranes, resulting in toxicity to biota. As detailed by Carty and Malone (1979), methylmercury in the diet is absorbed in the vertebrate digestive tract with high efficiency, and it associates rapidly with sulfhydryl-containing molecules in blood. These mobile complexes transport methylmercury to tissues and organs and facilitate its movement across cell membranes. The adverse effects on benthic organisms include death, reduced fertility and impairment of early development (CCME 1999i).

Mercury has been used historically in alchemy and the occult arts, as well as in medicine, science and technology (Environment Canada 2004a). It is used in the extraction of gold from ore because of its ability to form amalgams (metal solutions). Until the 1980s, the largest anthropogenic source in Canada was a consequence of the production of chlorine and sodium hydroxide (Environment Canada 2004b). Mercury is also present in a number of consumer products, including fluorescent light bulbs and dental amalgam (Environment Canada 2004b). Natural sources of mercury in the environment include volcanic eruptions, soil and rock weathering and evaporation from the ocean (Environment Canada 2004a). The source of mercury in the Kingston Inner Harbour appears to be associated with the old Woolen Mill.

While concentrations of mercury in freshwater and marine sediments vary significantly throughout Canada, concentrations tend to be highest in industrial areas and harbours (CCME 1999i). The mean background concentration in Canadian lake sediments is 0.074 ppm and the mean concentration in Canadian stream sediments is 0.075 ppm. The ISQG for freshwater sediments is 0.17 ppm, and the PEL is 0.49 ppm (CCME 1999i).

b. Spatial Extent of Mercury in Surface Sediments of the KIH

The plume map for mercury (Appendix B, Map B-II-11) indicates that mercury was present in concentrations above the PEL of 0.49 ppm along the western shoreline, between the Rowing Club and the Woolen Mill, in the same areas in which arsenic exceeded the PEL. The highest concentrations, up to 11 ppm and 20 times the PEL, were measured in surface sediment collected next to the Woolen Mill. The pattern suggests that arsenic and mercury may have had a similar local terrestrial source. In a study completed by Water and Earth Science Associates Ltd. (WESA) (1988), buried wastes containing mercury and arsenic in elevated concentrations were found next to the Rowing Club property, suggesting that mercury was used in processes employed at the Woolen Mill. Mercury was used for dyeing cotton, while both arsenic and mercury were used as biocides to prevent the degradation of natural fibres. The concentrations of mercury in surface sediments decrease with increasing distance from shore, to levels below the PEL.

The mean at sites within the APEC (Figure II-8) is 1.1 ppm; this is more than 20 percent higher than the mean of 0.1 ppm at reference sites. The t-test results indicate that mercury levels in the APEC are not significantly higher than the levels at reference sites ($p=0.3$). However, because there was a difference of more than 20 percent between the means, and because the mean within the APEC exceeded both ISQG and PEL values, mercury was retained as a CoPC.

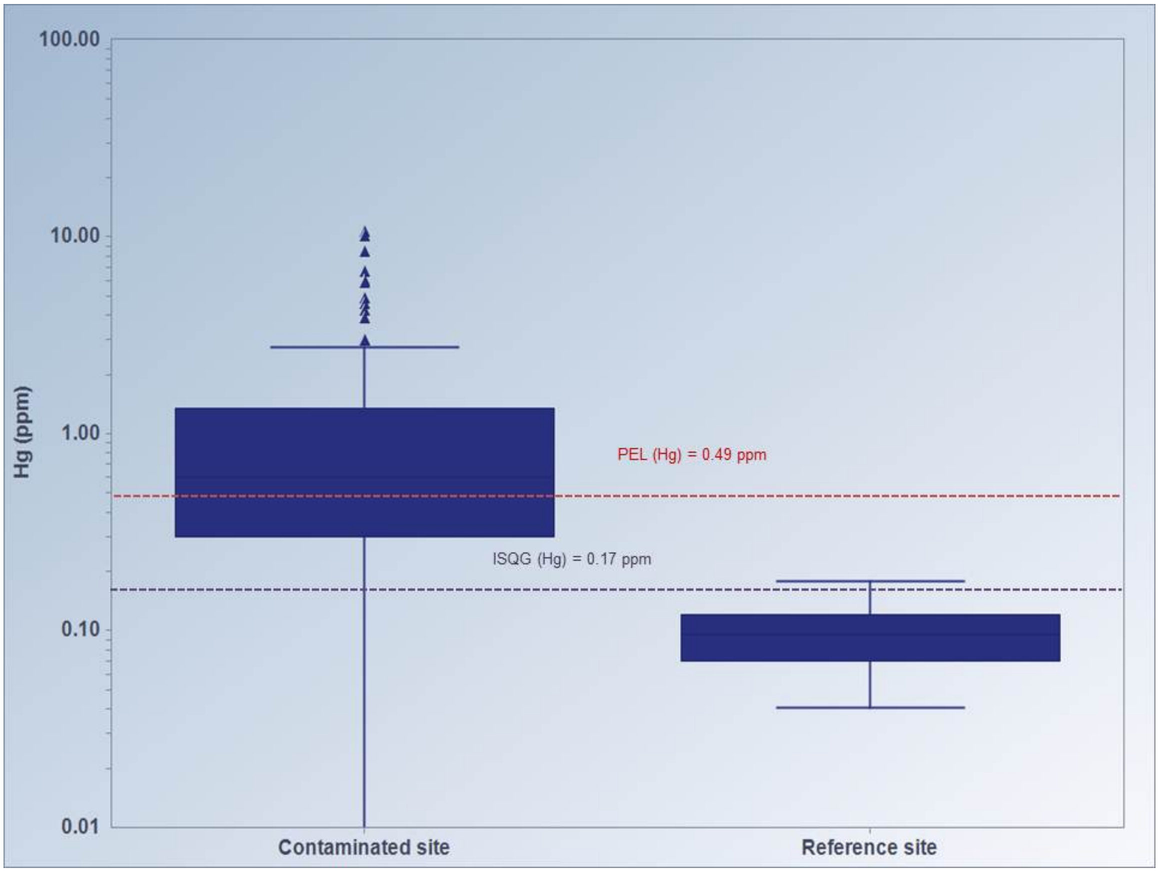


Figure II-8: Boxplot of mercury levels at APEC sites (n=148) and at reference sites (n=12).

c. Mercury in Deeper Sediments

Depth profiles of mercury in sediment cores are shown in Figure II-9. As a general trend, mercury extends further into the harbour at depth than it does at surface, suggesting that mercury loading to sediments was higher in the past. Concentrations range from 0.03 to 11 ppm.

The highest concentrations of mercury were measured in cores 14 and 6 collected adjacent to the Woolen Mill and the Rowing Club with the contamination plume following the directional flow of the river.

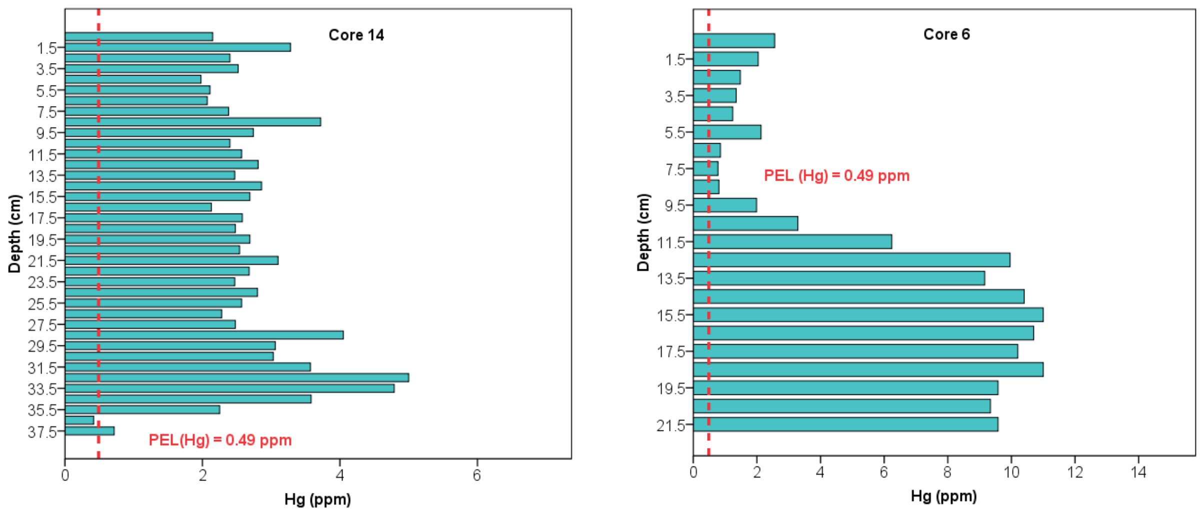


Figure II-9: Mercury depth profile for Core 14 and Core 6, collected in the KIH in the vicinity of the Woolen Mill and the Rowing Club.

7. Antimony

a. Fate and Sources of Antimony in the Environment

Antimony (Sb) is a metalloid that easily combines with other elements, usually sulfur, to form other minerals. Its compounds are used primarily as flame retardants in plastics such as polyethylene and polyvinylchloride, as well as in textiles, carpeting, furniture and rubber. It is found in myriad products like electrical equipment, automotive parts, building materials and others (Environment Canada and Health Canada 2010). It is often used as a replacement for lead in pipe solder and in many other metal applications (e.g., batteries) (Health Canada 1997).

Antimony and its compounds are considered pollutants of priority interest by the Environmental Protection Agency of the United States (US EPA 1979) and the European Union (CEC 1976). Additionally, one of its compounds, antimony trioxide, has been identified in the categorization of the Domestic Substances List (DSL) as a high priority for action but does not meet the criteria set out in section 64 of CEPA 1999 (Environment Canada and Health Canada 2010). This compound has been classified by other agencies on the basis of carcinogenicity. The Health Canada, OMOE and US EPA (United States Environmental Protection Agency) drinking water standard is 6 ppb, and the European Union established a maximum admissible concentration of antimony in drinking water of 5 ppb. Antimony has no known biological function and is toxic. Trivalent species are reported to be more toxic than pentavalent forms (Bencze 1994).

Background concentrations in Canadian lake sediments with low anthropogenic influence have been reported to range from <0.1–60 ppm, with a 90th percentile value of 0.5 ppm (Environment Canada and Health Canada 2010). No guidelines are available for sediment quality. The CCME guidelines for soil quality are 20 ppm for residential and agricultural lands and 40 ppm for commercial and industrial lands. OMOE has set soil standards for background site conditions, which are the same as site conditions within 30 m of a water body (both potable and non-potable water scenarios), for agricultural/other land use (1 mg/kg) and for residential/ parkland/ institutional/ industrial/ commercial/ community property use (1.3 mg/kg).

b. Spatial Extent of Antimony in Surface Sediments of the KIH

The plume map for antimony (Appendix B, Map B-II-12) indicates that antimony levels are highest at the outlet of the Orchard Street Marsh directly below Belle Island. A maximum concentration of 894 ppm, 45 times the CCME soil quality guideline (SQG) (used in the absence of available sediment guidelines) was observed near the shore. The concentration of antimony in surface sediments decreases with increasing distance from shore, to levels below the soil guideline. The mean concentration of the contaminated area is 14 ppm (Figure II-10). The mean concentration at the contaminated area, although below CCME SQG and not statistically different from the reference area mean, is 60 times higher than the background mean of 0.3 ppm, and is also substantially higher than the OMOE soil guidelines. Although the t-test results indicate that antimony levels in the APEC are not significantly higher than the levels at reference sites (p=0.12), this element was retained as a CoPC because of the lack of information about guidelines in sediments for this contaminant, and because it met the screening criteria for HHRA (mean and maximum values in the APEC exceeded guideline values and the maximum value in the APEC exceeded the maximum value in the reference area).

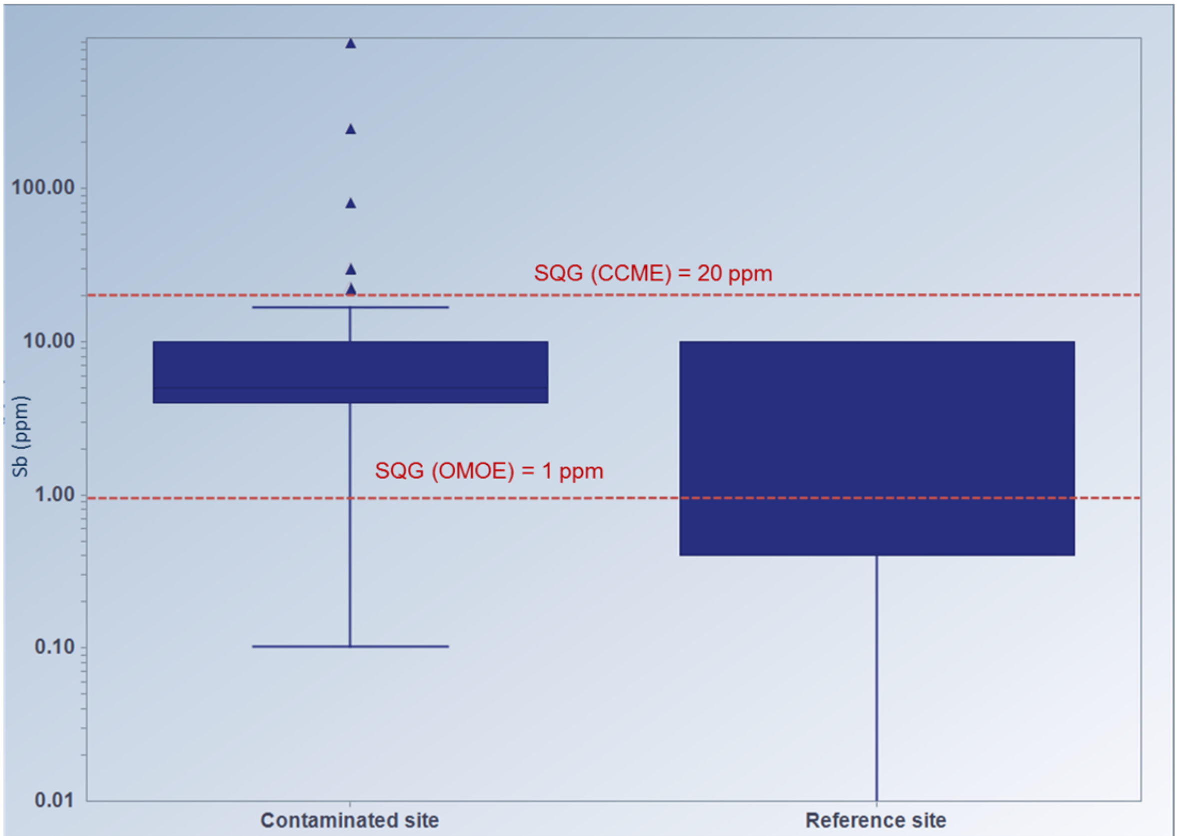


Figure II-10: Boxplot of antimony levels at APEC sites (n=93) and at reference sites (n=16). Soil quality guidelines (SQGs) are shown: CCME SQG is for residential and agricultural lands, and OMOE SQG is for background site condition and for within 30 m of a water body.

8. Polychlorinated Biphenyls (PCBs)

a. <u>Fate and Sources of PCBs in the Environment</u>

PCBs are a class of manufactured chlorinated organic compounds comprising 209 different congeners, each of which consists of a biphenyl molecule (two bonded benzene rings) with between one and 10 chlorine atoms substituted in varying arrangements (UNEP 1999). In North America, PCBs were manufactured commercially as complex mixtures of congeners and sold under the trade name Aroclor (CCME 2001). Approximately 130 congeners are found in commercial PCB mixtures. While PCBs were not manufactured in Canada, an estimated 40,000 tonnes were imported into the country and used between 1929 and 1977. PCB imports were banned in 1980. PCBs are known to be extremely stable compounds with high lipid solubility, which makes them difficult to destroy and allows them to bioaccumulate in the fatty tissues of organisms (Foulkes 1990). They are considered "CEPA-toxic" under CEPA (CCME 2001). PCBs are also known to produce toxic dioxins and furans when they burn at low temperatures (Loock et al. 2001).

Because of their thermal and chemical stability, PCBs were commonly used as dielectric fluids in electrical transformers and capacitors, but they were also used in heat transfer fluids and hydraulic fluids and as a plasticizer in paints, adhesives and caulking compounds (UNEP 1999). The primary sources to aquatic environments include leaks and spills, municipal and industrial discharge, runoff from contaminated sites and landfill leachate, as well as long-range transport and aerial deposition (CCME 2001). Most PCBs that cycle through the environment are ultimately incorporated into bed sediments (CCME 2001). Potential sources in the KIH include the Belle Park Landfill and municipal stormwater effluent.

The adverse effects of PCBs on benthic invertebrates include changes in species richness and abundance and, to a lesser degree, density, diversity and integrity. The effects on higher-order species (mammals and birds) include reduced growth rates, liver enlargement, impaired reproduction and death (CCME 2001). The likelihood of an adverse effect, however, depends on the sensitivity of individual species, as well as on the physicochemical (e.g., lipophilicity and individual congener size and weathering), geochemical (e.g., organic matter content, clay content and sediment particle size) and biological (e.g., feeding behaviour and uptake rates) factors that affect bioavailability (CCME 2001). In addition, PCBs appear to accumulate more readily in organisms that reside in coarser-grained sediments. Uptake is believed to be limited in finer-grained sediments because they have a larger surface area and higher clay content, which reduces PCB availability. The more highly chlorinated congeners tend to bioaccumulate more in benthic organisms than the less-chlorinated congeners. Maximum bioavailability, however, appears to be highest in the moderately chlorinated congeners (CCME 2001).

The CCME recommends that congener-specific analyses of total PCBs be used for weathered or historically contaminated sediment samples, rather than Aroclor-based analyses. This is because diagenesis (rock formation) of sediments and PCB dechlorination may change the Aroclor profile. This can make it extremely difficult to match Aroclor patterns, resulting in significant errors in the estimation of PCB concentrations (CCME 2001).

PCBs have been detected in the sediments of various sites across Canada. Concentrations tend to be low, with elevated concentrations near historical sources such as those listed above (CCME 2001). The mean concentration in freshwater sediments varies widely, and the CCME does not report a single mean background concentration. The ISQG for total PCBs in freshwater sediments is 34.1 ppb and the PEL is 277 ppb.

b. Spatial Extent of PCBs in Surface Sediments of the KIH

The PCB plume map (Appendix B, Map B-II-13) shows that sediments with PCB levels exceeding the PEL of 277 ppb are found throughout the lower KIH, particularly south of Belle Park, east of the western shoreline up to the navigational channel and in front of Douglas Fuhrer Park, which is located between Emma Martin Park and Anglin Bay. PCB concentrations gradually decrease downstream from Belle Park to the south. The highest concentrations, which were up to 12,000 ppb, were measured in sediments collected immediately next to the former Belle Park Landfill. The Belle Park Landfill site operated as a municipal landfill from 1952 to 1974. During this time, landfill material and debris was deposited over approximately 44 hectares of marshland extending into the KIH from the west bank of the Great Cataraqui River. The former landfill at Belle Park was a potential contaminant source to the sediments, and it was suspected to be leaching PCBs into the Cataraqui River. In 1997, the City of Kingston took measures to assess the risks at the site and to address leachate seepage into the Cataraqui River. Seep management measures have been implemented and expanded since then: drawdown wells were placed in the northwest and southwest areas of the landfill to collect and divert any point-source leachate into the sanitary sewer system (CH2M Hill 2006). Other actions taken included wetland development and poplar tree plantings along the perimeter of the landfill. Recent studies conducted by the City of Kingston (2011) have confirmed that there are no ongoing source of PCBs due to discharge of shallow groundwater from the Southern shore of Belle Park to the Cataraqui River.

Although the landfill at Belle Island was a primary suspected source of PCB contaminants, there are other possible sources located along the western shore of the Great Cataraqui River. The OMOE and Environment Canada initiated three projects to track down sources of PCBs to Lake Ontario. The Great Cataraqui River was selected as one site, because studies indicated that PCBs were present in sediments (Derry et al. 2003). As part of the project, principal component analysis (PCA) analysis on congener-specific PCB sediment data from the KIH was conducted to determine potential PCB sources (Benoit and Dove 2006). The results suggested that potential sources along the western shoreline near Emma Martin Park may be different from the source in the vicinity of the landfill, and the Kingscourt storm sewer also may have been a source of PCBs to the river.

Sediments to the east of the Rowing Club and south of Belle Island show elevated levels of PCBs, with concentrations of up to 1,700 ppb. Elevated levels of PCBs were measured in sediments adjacent to the Rowing Club before 2004. This contamination probably resulted from a historical discharge or spill. It was assumed that resuspension of these sediments caused by activity at the Kingston Rowing Club was enough to result in bioaccumulation in area biota. Sediments around the Rowing Club and its docks were consequently dredged in the fall of 2004, and at present their PCB levels are below the ISQG.

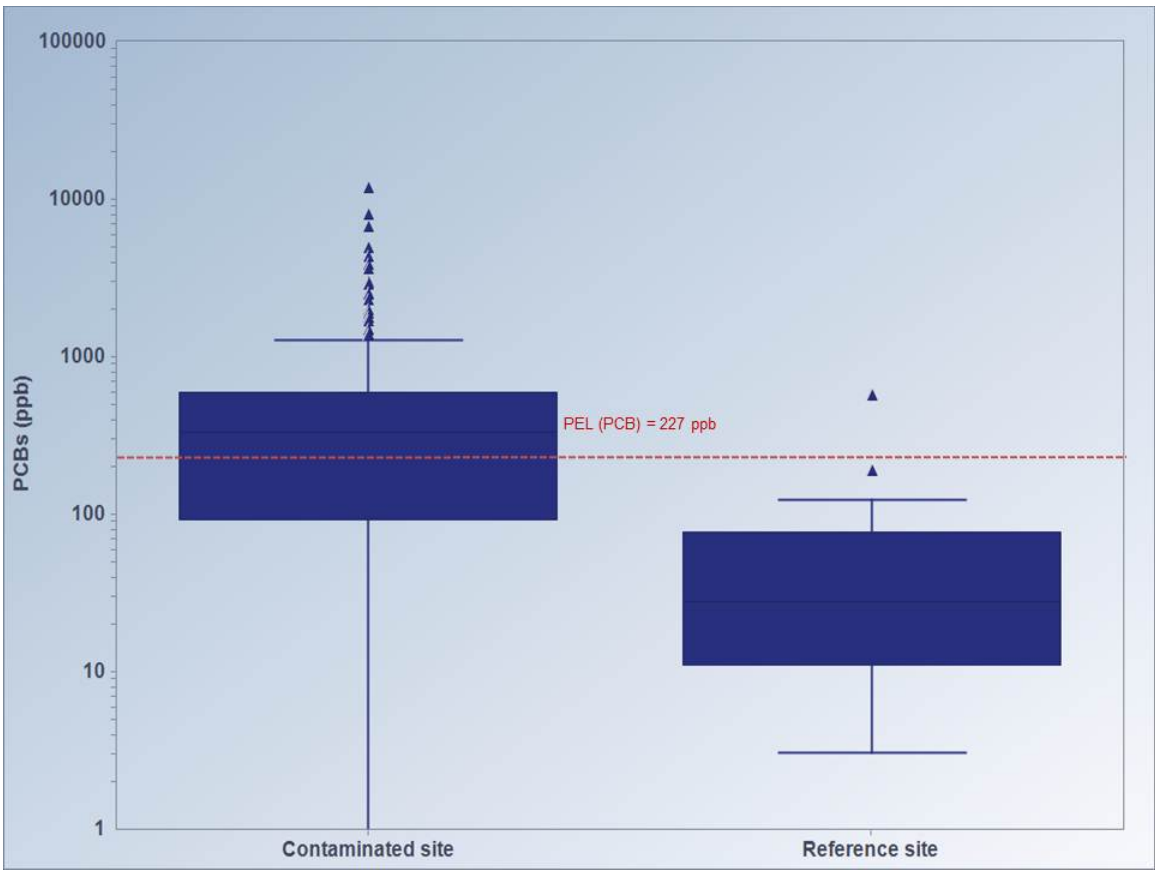


Figure II-11: Boxplot of PCB levels within APEC (n= 234) and at reference sites (n=28).

Another area with PCB concentrations exceeding the PEL is located adjacent to Douglas Fluhrer Park, between Emma Martin Park and Anglin Bay. The highest levels in this area were 1,180 ppb.

The mean concentration at sites within the APEC (Figure II-11) is 625 ppb; this is more than 20 percent higher than the mean concentration of 59 ppb at reference sites. The t-test results indicated that PCB levels in the APEC are significantly higher than levels at reference sites ($p<0.001$).

c. Extent of PCBs in Deeper Sediments of the KIH

In a core retrieved close to the mouth of the South Stream (Core 8), PCB concentrations were higher at depth than at surface, suggesting historical input. The highest concentration was measured at 57 cm, and was above the ISQG but below the PEL (Figure II-12). Overlying the subsurface sediment was a layer of cleaner sand, gravel and cobble that was approximately 3 to 5 cm thick. PCB profiles from four shallow sediment cores also showed higher concentrations at depth compared with surface sediment, indicating that current sources, if they exist, are emitting fewer PCBs than were emitted in the past (Benoit and Dove 2006). The highest total PCB concentration (3,000 ppb), reported by Derry et al. (2003), was obtained from a subsurface sediment layer within the channel downstream of the Kingscourt storm sewer, southwest of the Belle Island Landfill. This sediment was black and oily and had a hydrocarbon odour.

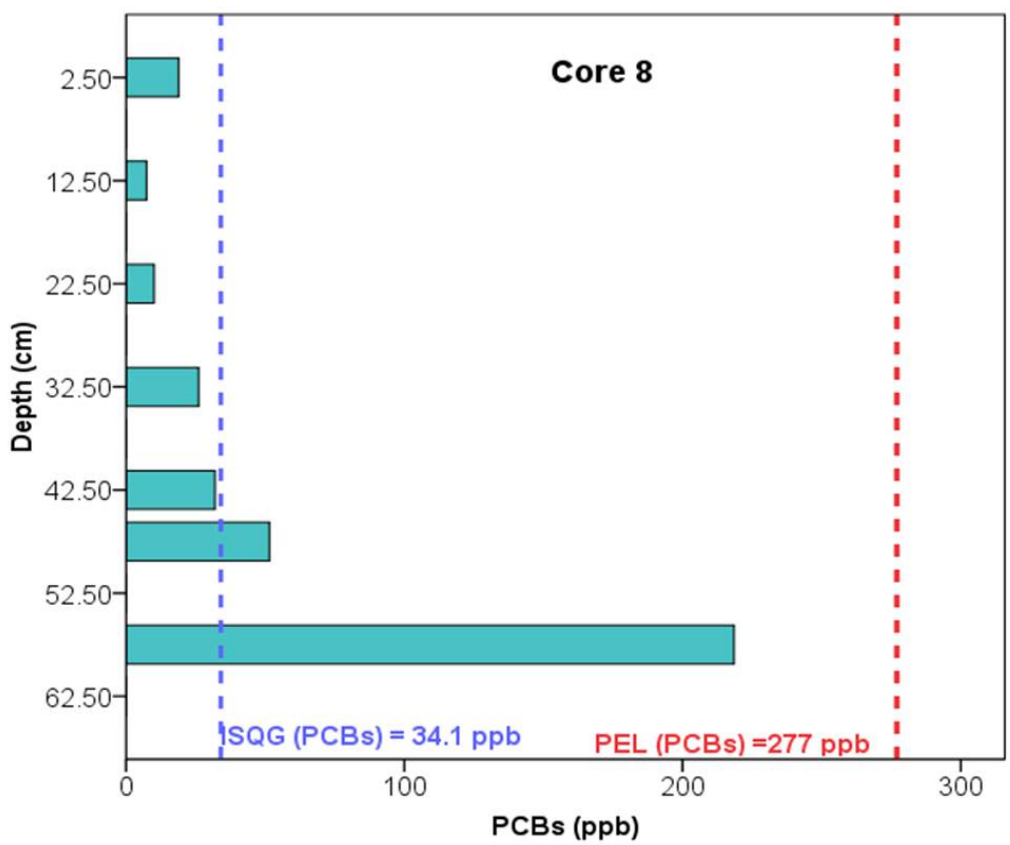


Figure II-12: PCB depth profiles for selected cores retrieved from the KIH (ESG 2006).

9. Polycyclic Aromatic Hydrocarbons (PAHs)

a. Fate and Sources of PAHs in the Environment

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds that contain two or more bonded benzene rings with substitutions of nitrogen, sulphur or oxygen within the rings and/or substitutions of hydrogen for alkyl groups (CCME 1999j). PAHs are further classified into two groups on the basis of their structure: those with three or fewer aromatic rings are considered to be “low-molecular-weight (LMW) PAHs” while those with four or more rings are considered “high-molecular-weight (HMW) PAHs” (CCME 1999j). The variations in size and structure account for the variability in the physical and chemical properties of individual PAHs. In addition, the position of the substituted alkyl groups plays a significant role in the carcinogenicity of a particular PAH compound (CCME 1999j).

When present at elevated concentrations, PAHs can be toxic to aquatic biota (CCME 1999j). In general, LMW-PAHs are considered to be acutely toxic but non-carcinogenic to aquatic organisms, while HMW-PAHs are not acutely toxic but some are carcinogenic (CCME 1999j). The adverse effects on benthic organisms associated with PAHs include decreased abundance, diversity and growth, as well as changes in behaviour and physiology (CCME 1999j). The bioavailability of PAHs in sediment is dependent on the physicochemical properties (e.g., molecular weight) of the individual compound as well as the geochemical (e.g., total organic matter and particle size) and biological (e.g., feeding patterns and life stage) factors (CCME 1999j).

PAHs are released into the environment through natural events, such as forest fires and volcanic eruptions, as well as by anthropogenic sources, such as industry, fossil fuel burning and waste incineration (CCME 1999j). Aerial deposition is considered to be the primary source of aquatic environment contamination because Canadian emissions are almost exclusively atmospheric (CCME 1999j). Potential local sources of PAHs to the Kingston Inner Harbour include the Belle Park Landfill, storm sewer effluent and the former coal gasification plant, where coal tar was left on the site and has seeped into the fractured limestone bedrock. Anglin Bay, which housed coal and fuel storage facilities, is also a potential source, as are the warehouses and abandoned ships from the shipping industry. Various other industrial and combustion activities might also have contributed.

PAHs tend to be hydrophobic and therefore are likely to adsorb to particles in air and water (CCME 1999j). This leads to their deposition in bed sediments. Physical processes such as photooxidation, hydrolysis, biodegradation and mineralization play a role in the cycling of PAHs through the aquatic environment.

The CCME does not report mean background concentrations of PAHs in Canadian lake and river sediments, probably because of the broad range of compounds and their characteristics. Instead, cases studies are described for both marine and freshwater environments that are in close proximity to a variety of anthropogenic sources. The CCME does note, however, that reported concentrations of PAHs tend to be lower in freshwater sediments than in marine sediments. The published ISQGs, in µg/kg (ppm), for LMW-PAHs in freshwater environments are as follows: naphthalene – 34.6; 2-methylnaphthalene – 20.2; acenaphthylene – 5.87; acenaphthene – 6.71; fluorene – 21.2; phenanthrene – 41.9; and anthracene – 46.9. The corresponding guidelines for HMW-PAHs, in µg/kg, are as follows: fluoranthene – 111; pyrene – 53.0; benz(*a*)anthracene – 31.7; chrysene – 57.1; benzo(*a*)pyrene – 31.9; and dibenz(*a*,*h*)anthracene – 6.22 (CCME 1999j).

b. Spatial Extent of PAHs in Surface Sediments of the KIH

The value for total PAHs, which corresponded closely to the levels of all individual PAHs, was used for creating Map B-II-14 (Appendix B). The Ontario LEL of 4 ppm and SEL of 1,000 ppm (which assumes 10 percent TOC in sediments) were used for comparison, as no CCME guidelines exist for total PAHs. The highest concentration, 20,650 ppm, was found in a depth sample (103 cm) from Anglin Bay, close to the King Street storm sewer outlet; other samples at this depth and similar location ranged to as low as 18.6 ppm, and the average concentration was 2,300 ppm (CH2M Hill 1991). In samples collected at depths as little as 50 cm in Anglin Bay and the rest of the KIH, the total PAH concentrations ranged from 0.13 to 175 ppm. PAHs are generally localized along the shore and decrease off shore.

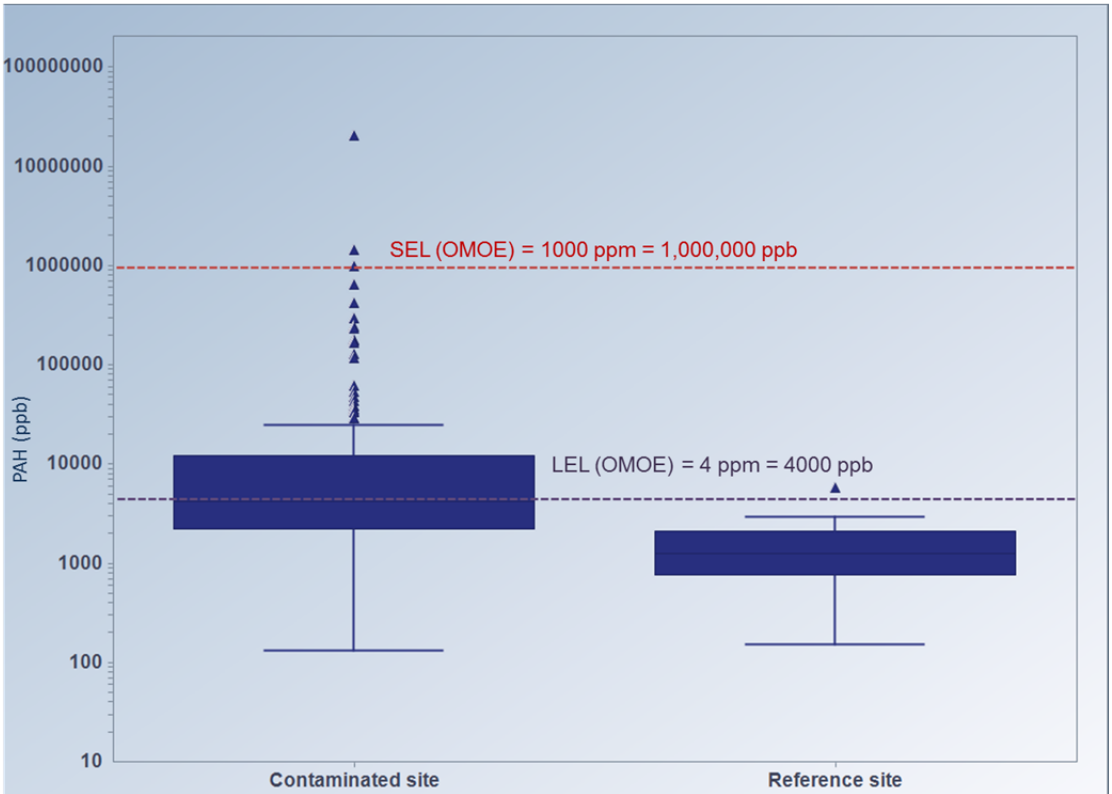


Figure II-13: Boxplot of PAH levels at sites within the APEC (n= 134) and at reference sites (n=19). Anglin Bay depth samples are included.

The mean concentration at sites within the APEC (Figure II-13) is 199 ppm, which is substantially more than 20 percent higher than the mean of 1.6 ppm at reference sites. The t-test results indicated that PAH levels in the APEC are significantly higher than they are at reference sites ($p<0.001$). When the depth samples from Anglin Bay are removed from the data set, the mean PAH concentration for the APEC (10 ppm) is still above the reference mean (1.6 ppm) by more than 20 percent, and the mean for the APEC and mean for the references sites are significantly different ($p<0.001$).

10. DDT and Chlordane

a. <u>Fate and Sources of Total DDT and Chlordane in the Environment</u>

DDT is a chlorinated hydrocarbon that was used worldwide as a broad-spectrum commercial insecticide and pesticide (CCME 1999k). It comprises a number of isomers and is often transformed in the environment to dichloro-diphenyl-dichloroethylene (DDE) and sometimes to dichloro-diphenyl-dichloroethane (DDD). It is considered "CEPA-toxic." DDT's use was restricted severely in 1970 and then ultimately banned in 1985 because of concerns that it could bioaccumulate and because of evidence of adverse effects on a number of wildlife species (CCME 1999k). DDT enters aquatic environments through direct application to surface water and by aerial deposition. The latter is the most important source in Canadian waterways and sediments (CCME 1999k). The most likely sources of DDT to the KIH are the Belle Island Landfill and the storm sewers. DDT is chemically stable under normal conditions, with low water solubility and high lipid solubility. As a result, it has a high affinity for bed sediments, where it can be taken up by aquatic organisms, accumulating in fatty tissues of higher-order organisms (CCME 1999k).

The adverse effects of DDT exposure on benthic invertebrates include decreased abundance and diversity, increased mortality and changes in behaviour (CCME 1999k). Acute toxicological exposure commonly leads to death, while chronic exposure is more likely to lead to changes in growth, reproduction and behaviour.

While DDT has been detected in freshwater sediments at various Canadian locations, the data are limited and the CCME does not report mean background concentrations for Canadian lakes and rivers. The ISQG and PEL for DDT are 1.19 ppb and 4.77 ppb respectively (CCME 1999k).

Chlordane is a pesticide that was sold in North America from 1948 to 1988, as both a dust and an emulsified solution. Because of concern about damage to the environment and harm to human health, the US EPA banned all uses of chlordane in 1988 and set a limit in drinking water of 2 ppb. Chlordane is very persistent in the environment because it does not break down easily. Being hydrophobic, chlordane adheres to soil particles and enters groundwater slowly, owing to its low solubility (0.009 ppm). Chlordane bioaccumulates in animals and is highly toxic to fish, with an LD50 (the amount of the substance that kills 50% of the test population) of 0.022–0.095 mg/kg (oral). The PEL for chlordane is 8.87 ppb (CCME 1999k).

b. Spatial Extent of DDT and Chlordane in Surface Sediments of the KIH

Sampling locations for total DDT (including DDT and its isomers DDD and DDE) locations in which tDDT exceeds the PEL are shown in Appendix B, Map B-II-15. Interpretation of the data is complicated, as detection limits for a number of locations are higher than the guidelines. Total DDT is present at levels above the PEL in several hotspot areas along the south shore of the Belle Island Landfill and in sediments along the outflow of the Kingscourt storm sewer. These hotspots, however, remain localized, and concentrations decrease to levels below the PEL in off-shore areas.

The mean for chlordane concentrations in the APEC is 4.3 ppb, which is below the PEL of 8.87 ppb, although the 95% UCL (9.0 ppb) is above it. However, some sites contain chlordane concentrations of up to 41 ppb, which is five times the PEL (Appendix B, Map B-II-16).

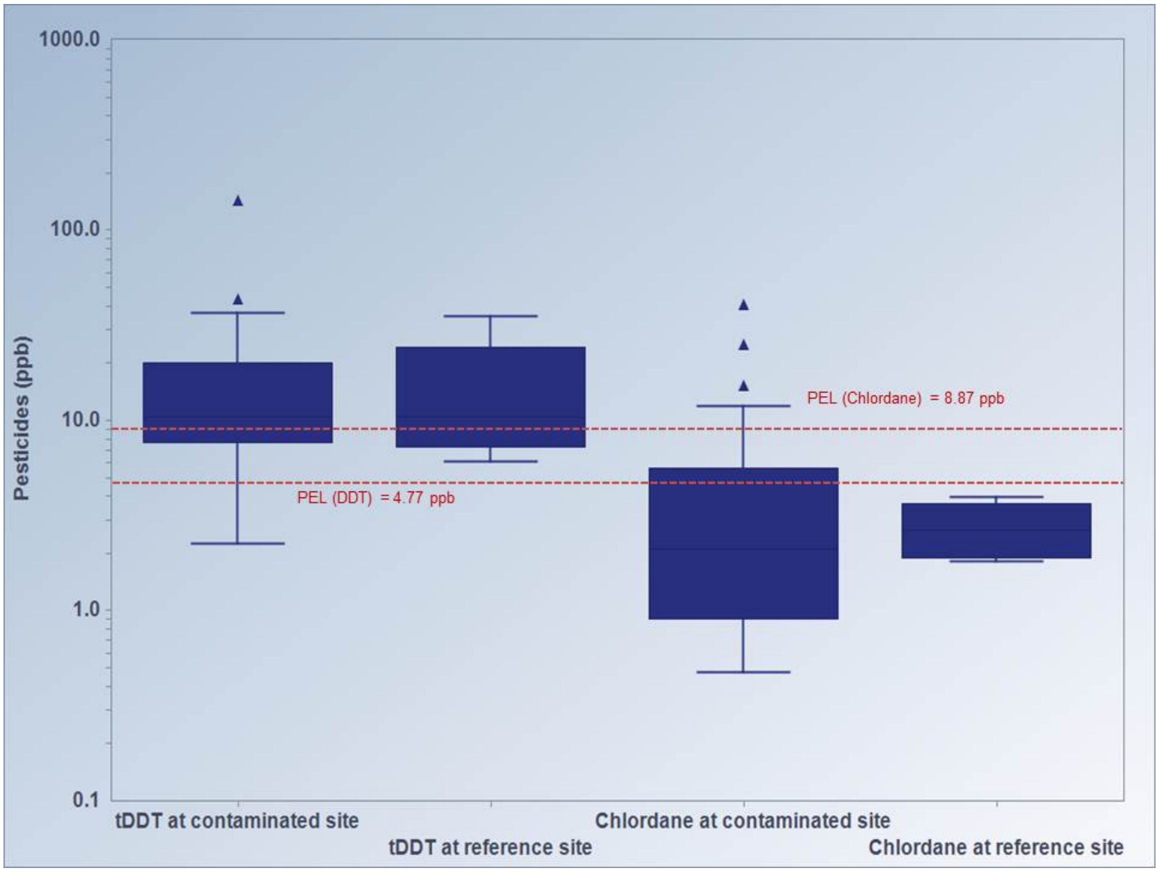


Figure II-14: Boxplot of DDT levels and chlordane levels within the APEC (n=46 and (n=44 respectively) and at reference sites (n=4 and n=4 respectively).

Figure II-14 shows that the mean of DDT at sites within the APEC is above the guideline of 4.77 ppb, while chlordane levels are below the PEL of 8.87 ppb. The mean concentrations of both contaminants at sites within the APEC is not significantly different from the mean for the reference sites ($p>0.05$). Nevertheless, both DDT and chlordane were carried forward as CoPCs because they met the screening criteria for HHRA (APEC concentrations exceeded guidelines, and maximum APEC values were greater than maximum reference values).

IV. Decision-making Framework for Sediment Contamination

The physical-chemical characteristics of the sediments of the KIH have been assessed according to the COA decision-making framework. The surface sediments of the lower KIH are organically rich and are composed mainly of silt and clays. Several inorganic and organic contaminants (i.e., Cr, Pb, Zn, Cu, Hg, As, Sb, PCBs, PAHs, chlordane, and DDT) are present at levels above guidelines in the surficial sediments of the APEC. Some of these contaminants, such as PCBs, pesticides and organic Hg, are substances that may biomagnify. Mean concentrations of Cr, Pb, Cu, As, Zn, PCBs and PAHs are significantly higher ($p<0.05$) in the APEC than mean concentrations at reference sites located upstream from Belle Park. In addition, concentrations of these CoPCs, with the exception of Zn, are at least 20 percent above the concentrations of those same CoPCs in reference sites. While a statistical difference was not noted for Hg, its mean APEC concentration was more than 20% higher than the mean reference site concentrations. Hg also met HHRA screening criteria along with the other contaminants that exceed guidelines (Sb, DDT and chlordane): their maximum values in the APEC exceeded maximum values in the reference site.

Studies of subsurface contamination have confirmed that deeper sediments have been impacted by historical activities. Chromium profiles from cores collected south of Belle Island show that deeper sediments generally have higher Cr concentrations. The cores also indicate that Cr concentrations in the top 0-15 cm of sediment are generally much higher than the CCME PEL. Furthermore, radioisotope dating analyses indicate that the top layers of sediment are mixed (Tinney, 2006). These findings suggest that there is little dilution with clean sediments due to continual mixing and resuspension of contaminated sediment. As a result, physical isolation of the contaminants through burial with clean sediments is not occurring at rates high enough to permit natural recovery.

V. CONCLUSIONS

The evaluation of sediment contamination in the KIH confirmed the presence of a number of chemicals that exceed the federal sediment quality guidelines in the southwestern portion of the harbour. In addition, several substances that biomagnify-specifically PCBs, organochlorine pesticides (e.g., DDT) and mercury, are present at levels that may affect the health of biological communities at higher trophic levels. However sediment quality guidelines are based on highly conservative assumptions; therefore, guideline exceedances do not necessarily mean that the contamination is causing adverse biological effects. The next step in the aquatic assessment under the COA framework is an evaluation of ecological effects through biological sampling. Chapter III summarizes biological data for the KIH and assesses the data using the COA assessment decision-making framework to determine if management action is required.

VI. REFERENCES

Asquini, A., M. McLeod and C. Sollows. 2007. Remediation of Sediment Contamination in the Cataraqui River, Kingston Inner Harbour. Undergraduate thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Baird, C. and M. Cann. 2005. *Environmental Chemistry*. W. H. Freeman and Company, New York.

Bencze, K., 1994. Antimony. In: Seiler, H.G., Sigel, A., Sigel, H. (Eds.), Handbook on Metals in Clinical and Analytical Chemistry. Marcel Dekker, New York, pp. 227 - 236.

Benoit, N. and A. Dove. 2006. Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 Monitoring Programs. Technical Report. Prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Benoit, N. and D. Berniston. 2010. Cataraqui River Project Trackdown: Follow-up Study on Success of Remediation Efforts in the Cataraqui River 2006. Prepared for Ontario Ministry of the Environment, Eastern Region.

Boyle, R.W. and I.R. Jonasson. 1973. "The geochemistry of antimony and its use as an indicator element in geochemical prospecting." *Journal of Geochemical Exploration* 2: 251–296.

British Columbia Ministry of the Environment (BCMoE). 1999. Water Quality: Ambient Water Quality Guidelines for Zinc. Available from www.env.gov.bc.ca/wat/wq/BCguidelines/zinc/zinc.html. Accessed September 14, 2009.

Brooks, K., J.P.F. Fleury, J.G.Y. Raymond and A.M. Reinhardt. 1998. An environmental evaluation of the river sediments surrounding the Belle Island Landfill Kingston Ontario. Prepared for Environmental Sciences Group, Kingston, ON.

Canadian Council of Ministers of the Environment (CCME). 1999a. Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. CCME EPB-98E. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999b. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Chromium. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg. MB.

Canadian Council of Ministers of the Environment (CCME). 1999c. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Chromium. In: Canadian

Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999d. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Lead. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999e. Canadian Environmental Quality Guidelines. Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999f. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Zinc. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999g. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Copper. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999h. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Arsenic. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999i. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Mercury. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999j. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Polycyclic Aromatic Hydrocarbons (PAHs). In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999k. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: DDT, DDE and DDD. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 2001. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Polychlorinated Biphenyls (PCBs). In: Canadian Environmental Quality Guidelines, 2001. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Carty, A.J. and S.F. Malone. 1979. “The Chemistry of Mercury in Biological Systems.” In: J.O. Nriagu, ed., *The Biogeochemistry of Mercury in the Environment*. Elsevier/North-Holland Biomedical Press, Amsterdam, pp. 433–479.

CH2M Hill Engineering Ltd. 1991. Final Report for Phase I of the Investigation to Determine Presence/Absence of Coal Tar Contamination in Anglin Bay and Lake Ontario in the City of Kingston. Report submitted to the Kingston Public Utilities Commission.

CH2M Hill Engineering Ltd. 2006. Belle Park Landfill Assessment of Long-term Management Alternatives — Final Draft Report. Prepared for the City of Kingston. 109 pp.

City of Kingston. 2011. Belle Park South Shore Shallow Groundwater Monitoring Program – Interoffice Memorandum to Paul MacLatchy form David Matheson

Conestoga Rovers and Associates (CRA). 2006. Phase II Environmental Site Assessment: Former Davis Tannery property, Orchard Street, Kingston, Ontario

Council of the European Communities (CEC). 1976.

Cross, K. 1999. “An Investigation of Organochlorines in Freshwater Sediment: A Case Study of Belle Island, Kingston, Ontario.” Unpublished BSc thesis, Department of Biology, Queen’s University, Kingston, ON.

Cullen, W.R. and K.J. Reimer. 1989. “Environmental Arsenic Chemistry.” *Chemical Reviews* 89: 713–764.

Dalrymple, R.W. and J.S. Carey. 1990. Water-level Fluctuations in Lake Ontario over the Last 4000 years as Recorded in the Cataraqui River Lagoon, Kingston, Ontario.” *Canadian Journal of Earth Sciences* 27: 1330–1338.

Derry, A., A. Dove, R. Fletcher and N. Benoit. 2003. PCB Source Trackdown in the Cataraqui River: 2001 Findings. Technical Memorandum. Prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Eisler, R. 1986. “Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.” U.S. Fish and Wildlife Service Biological Report 85 (1.6).

Environment Canada (EC). 2004a. Mercury and the Environment: Basic Facts. Available from http://www.ec.gc.ca/MERCURY/EN/bf.cfm. Accessed September 30, 2009. Ottawa, ON.

Environment Canada (EC). 2004b. Mercury and the Environment: Sources of Mercury. Available at http://www.ec.gc.ca/MERCURY/SM/EN/sm-i.cfm?SELECT=SM. Accessed September 30, 2009. Ottawa, ON.

Environment Canada and Health Canada. 2010. Screening Assessment for the Challenge: Antimony trioxide (Antimony oxide). Accessed from http://www.ec.gc.ca/ese-ees/9889ABB5-3396-435B-8428-F270074EA2A7/batch9_1309-64-4_en.pdf. 86 pages.

Environment Canada and Ontario Ministry of the Environment (Environment Canada and OMOE). 2008. Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediments. Prepared by Peter Chapman (Golder Associates Ltd.) with the COA Sediment Task Group on behalf of Environment Canada and the Ontario Ministry of the Environment under the Canada–Ontario Agreement (COA 2002), March 2008.

Environmental Sciences Group (ESG). 2003. Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour. Royal Military College of Canada, Kingston, ON, October, 2003.

Environmental Sciences Group (ESG). 2009. Application of the Canada-Ontario Decision-making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 1: Literature Review.

Foulkes, E.C. 1990. *Biological Effects of Heavy Metals*. CRC Press, Boca Raton, FL.

Golder Associates. 2011. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment — Kingston Inner Harbour: Framework Steps 4 and 5 (PQRA). Submitted to Public Works and Government Services Canada. Report number 10-1421-0039. 469 pp.

Golder Associates. 2012. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment — Kingston Inner Harbour: Framework Step 6 (detailed quantitative assessment). Submitted to Public Works and Government Services Canada. Report number 11-1122-0154. 497 pp.

Government of Canada, Health Canada and Environment Canada. 1993. Canadian Environmental Protection Act, Priority Substances List Assessment Report: Arsenic and its Compounds. Available from http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl1-lsp1/index-eng.php.

Grapentine, L., J. Anderson, J., 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, no. 7: 1641-1655.

Health Canada. 1997. Guidelines for Canadian Drinking Water Quality — Supporting Documentation: Antimony. Revised 1999.

Health Canada. 2012. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. September 2010; revised 2012. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Jaagumagi, R. 1991. Sediment and Benthic Community Assessment of the Kingston Waterfront at Anglin Bay and the Queen Street Slip. Prepared for the Ontario Ministry of the Environment. September 1990.

Library of Parliament, Research Branch. 1994. *Environmental Health: Risks Posed by PCBs* (BP-392E). Prepared by W. Murray, Science and Technology Division, November, 1994. Available from http://dsp-psd.pwgsc.gc.ca/Collection-R/LoPBdP/BP/bp392-e.htm. Accessed July 23, 2009.

Loock, D., A. Dumoulin-Jeromel and W. Ingham. 2001. "PCDF/PCDD Formation from Uncontrolled Combustion: The Lady Franklin Point Fire in Historical Context." *Proceedings of the Second Biennial Workshop on Assessment and Remediation of Contaminated Sites in Arctic and Cold Climates (ARCSACC), May 2001*, pp. 281–94. Edmonton, AB.

Manion, N. 2007. "Determining the Distribution and Fate of Mercury in Sediment of the Cataraqui River at Kingston, Ontario." Unpublished MSc thesis, Department of Biology, Queen's University, Kingston, ON.

Regnell, O. and A. Tunlid. 1991. "Laboratory Study of Chemical Speciation of Mercury in Lake Sediment and Water under Aerobic and Anaerobic Conditions." *Applied and Environmental Microbiology* 57 (1991): 789–795.

Scheider, W. 2009. Methylmercury Study in the Kingston Inner Harbour — Technical Memorandum. Prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Shepard, F.P. 1954. "Nomenclature Based on Sand-silt-clay Ratios." *Journal of Sedimentary Petrology* 24: 151–158.

Smol, J. 2002. *Pollution of Lakes and Rivers: A Paleo-environmental Perspective*. Oxford University Press, New York, NY. 280 pp.

Tinney, M. 2006. Site Investigation and Ecological Risk Assessment of the Kingston Inner Harbour. Unpublished MSc thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Totten Sims Hubicki Associates. 1992. Transportation Study: Bridge Crossings of the Cataraqui River. Prepared for City of Kingston, Township of Pittsburgh, County of Frontenac and Ministry of Transportation of Ontario. June 1992.

United Nations Environment Programme (UNEP). 1999. Guidelines for the Identification of PCBs and Materials Containing PCBs, First Issue. Prepared by United Nations Environment Programme — Chemicals, Geneva, CH. August 1999. Available from http://www.chem.unep.ch/pops/pdf/PCBident/pcbid1.pdf. Accessed September 23, 2009.

United States Environmental Protection Agency (US EPA). 1979.

Water and Earth Science Associates Ltd. (WESA). 1988. Hydrogeological Investigation of Subsurface Conditions beneath Proposed Extension of Kingston Rowing Club Storage Building, Kingston, Ontario. Prepared for the Kingston Rowing Club.

Whittier, T.R., J.L. Stoddard, D.P. Larsen and A.T. Herlihy. 2007. "Selecting Reference Sites for Stream Biological Assessments: Best Professional Judgment or Objective Criteria." *Journal of the North American Benthological Society* 26, no. 2: 349–360.

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Chapter III: Ecological effects: Evaluation of Bioaccumulation of Contaminants in Biota, Sediment Toxicity and Benthic Community Structure

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

EXECUTIVE SUMMARY

The Environmental Sciences Group (ESG) of the Royal Military College of Canada (RMC) assessed the ecological effects of sediment contamination in the Kingston Inner Harbour (KIH) using the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment (COA framework). This chapter integrates existing data on biological effects in the KIH using the three lines of evidence (LOEs) examined under the COA framework: (i) modelling or measurement of contaminant concentrations in the aquatic food web to assess whether biomagnification is a potential concern; (ii) laboratory bioassays using several sediment-associated species to assess sediment toxicity; and (iii) assessment of benthic (i.e., sediment-dwelling) invertebrate community structure. A complementary ecological and human health risk assessment for the KIH is presented in Chapter IV of this report.

Aquatic macrophytes, cattails, benthic invertebrates and fish sampled from the KIH show consistent evidence for bioaccumulation of contaminants such as chromium (Cr), polychlorinated biphenyls (PCBs) and mercury (Hg) from the southwest portion of the KIH. According to available tissue residue guidelines for assessing biota contaminant concentrations, field invertebrate and fish biota in this area of the harbour generally exceed the relevant guidelines, indicating a potential risk to wildlife consumers of aquatic biota. In contrast, aquatic biota in other areas of the KIH do not appear to have accumulated contaminants to the same degree. Following the COA framework under Step 4a, the data strongly indicate that there is potential for contaminant biomagnification from the sediments through aquatic food chains in the southwest portion of the KIH.

According to the criteria outlined in the COA framework, there is mixed evidence for benthic invertebrate toxicity in the southwestern portion of the KIH (Appendix A, Golder Associates 2012, Figures B-1 to B-3). Sediments in the vicinity of Anglin Bay and Douglas R. Fluhrer Park appear to have the greatest potential for adverse effects on benthic communities, with eight of 14 stations in this area showing evidence of minor or major toxicity effects. Although most samples showed negligible toxicity to benthic organisms, approximately one quarter of the stations sampled in the remaining southwestern KIH (Parks Canada water lot, northern Transport Canada water lot and west central KIH) had minor toxicity effects. In contrast, there is no evidence of toxicity for samples collected from other areas of the KIH with lower concentrations of sedimentary contaminants, such as the area north of Belle Park or the southeastern portion of the KIH. Determining causality for the observed toxicity effects is challenging when there are multiple contaminants present, as is the case for the KIH. Toxicity identification evaluation (TIE) tests were carried out for two samples in the KIH, collected in the

vicinity of Anglin Bay, that showed major toxic effects for at least one endpoint (Golder 2012). The tests were inconclusive for one sample, but they suggested that toxicity in the other sample could be due to photoreactive PAH compounds as well as the combined effects of multiple toxicants.

Benthic communities in the KIH are dominated by organisms that are tolerant of organic (i.e., nutrient) pollution. For the studies done to date, benthic communities at 20 stations in the southern KIH were equivalent to reference condition, 15 stations were possibly different from reference condition and benthic communities at one station were significantly different from reference condition (Appendix A, Golder Associates 2012, Figure B-8). Although several stations on the Parks Canada water lot and the northern portion of the TC water lot showed possible benthic community effects, most of the stations exhibiting adverse effects were located in the vicinity of Anglin Bay and the northern part of Douglas R. Fluhrer Park. Two stations in the southeastern portion of the KIH close to HMCS Cataraqui also showed potential benthic community effects. Multivariate analyses performed by ESG suggested that differences in the invertebrate community structure can be explained by environmental variables related to habitat (e.g., grain size, macrophyte abundance) and to contamination variables such as sediment Cr concentrations.

Overall, the three biological LOEs show consistent evidence of ecological effects for benthic communities in the southwestern portion of the harbour. Investigations of sediment quality have indicated that concentrations of Cr, lead (Pb), zinc (Zn), copper (Cu), Hg, arsenic (As), antimony (Sb), PCBs, polycyclic aromatic hydrocarbons (PAHs) and dichlorodiphenyltrichloroethane (DDT) exceed the probable effect level (PEL) in the surficial sediments of this area and are significantly higher than those at upstream reference sites (see Chapter II). Using the COA framework to evaluate sediment toxicity and benthic community structure effects, it was determined that adverse effects are likely for areas in the vicinity of Douglas R. Fluhrer Park and Anglin Bay, while potential effects were identified for the Parks Canada water lot south of Belle Park (see Appendix A, Golder Associates 2012, Figures B-3 and B-8). The lack of evidence for adverse ecological effects north of Belle Island and in the central and eastern portions of the southern KIH indicates that no further action is necessary in these areas. The potential risk to upper-trophic-level consumers and humans using the area is evaluated and presented in Chapter IV. Further work to define the extent of the area requiring management, as well as an options analysis for the site, is presented in Chapter V of this report.

Table of Contents

Table of Contents, cont'd

LIST OF FIGURES

LIST OF FIGURES, CONT'D

LIST OF TABLES

I. INTRODUCTION

The evaluation of sediment contamination in the Kingston Inner Harbour (KIH) identified a number of contaminants of potential concern (CoPCs) at concentrations that exceed the federal sediment quality guidelines, particularly in the lower portion of the harbour southwest of Belle Island. The presence of several substances that biomagnify, such as PCBs, DDT and organic mercury, was also confirmed. Concentrations of the main CoPCs (Cr, Pb, Cu, As, Hg, PCBs, PAHs and DDT) are significantly higher in the southwest portion of the KIH compared with concentrations at reference sites upstream of Belle Park. Chromium is the most widespread contaminant in the KIH; however, because sediment quality guidelines are based on highly conservative assumptions, exceedance of these guidelines does not necessarily lead to ecological effects. Under the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment (COA framework) (see Figure 3, Chapter I; Environment Canada and OMOE 2008), the next phase in aquatic assessment is an evaluation of ecological effects through biological sampling. This chapter summarizes existing biological data from the KIH in the context of the COA assessment scheme.

Assessment of ecological effects resulting from sediment contamination is particularly important at aquatic sites, as remediation can alter sensitive habitats and have a long-term effect on receptors dependent on those habitats. Accordingly, much attention has been focused in the scientific literature on the assessment of aquatic ecological effects (e.g., Chapman and Long 1983; Long and Chapman 1985; Reynoldson et al. 1995; Chapman 2000; Borgmann et al. 2001). Typically, a weight-of-evidence (WOE) approach, in which several lines of biological evidence are assessed and compared to determine whether ecological effects are occurring, is used. The widely used Sediment Quality Triad (Chapman and Long 1983) focuses on sediment assessment through the measurement of sediment chemical concentrations, assessment of sediment toxicity to test organisms, and evidence of modified resident sediment-dwelling macroinvertebrates. Recently, measures of contaminant bioaccumulation in biological tissue of resident organisms have been added as a line of evidence (Chapman 2000; Borgmann et al. 2001). This is referred to as the Enhanced Sediment Quality Triad (ESQT). The COA framework is based closely on the ESQT, which provides a rigorous, scientifically defensible foundation for the assessment of aquatic ecological effects.

The potential ecological effects from sediment contaminants are assessed under Step 4 of the COA framework. Three lines of evidence are examined as follows: (i) modelling or measurement of contaminant concentrations in the aquatic food web to assess whether biomagnification is a potential concern; (ii) laboratory bioassays using several sediment-associated species to assess sediment toxicity; and (iii) assessment of benthic invertebrate community structure. Integration of these three lines of evidence enables identification of the area showing biological effects and leads to a determination of whether management actions are required to address sediment contaminant concerns.

A summary of previous studies documenting biological effects for the KIH was presented in Chapter I. Several gaps were identified through the literature review and have been addressed through additional sampling. These include

- bioaccumulation of inorganic contaminants in invertebrate body tissue;
- bioaccumulation of inorganic and organic contaminants in fish sampled from the Parks Canada water lot;
- analysis of additional sampling locations for sediment toxicity using a consistent indicator approach; and
- analysis of additional sampling locations for benthic community structure using the BEAST (BEnthic Assessment of SedimenT)/CABIN (Canadian Aquatic Biomonitoring Network) approach.

The sections that follow integrate previous findings with the new results for each of the three lines of biological evidence examined under the COA framework. This chapter compiles data on ecological effects for the KIH and applies the COA framework to assess the potential environmental risk of sedimentary contaminants.

II. BIOACCUMULATION AND BIOMAGNIFICATION OF CONTAMINANTS IN KIH FOOD CHAINS

Hydrophobic persistent organic pollutants such as PCBs, organochlorine pesticides, and methylmercury (MeHg) tend to accumulate in the tissue of aquatic organisms. Because organisms have limited mechanisms for eliminating these contaminants, they can accumulate to high concentrations in biological tissue over the lifetime of an organism (termed bioaccumulation). Through ingestion of contaminated prey, organisms in the higher trophic levels in aquatic food webs may concentrate these contaminants to a high degree (termed biomagnification). In this way, sedimentary contaminants can magnify up the aquatic food chain to levels much higher than in the original contaminated media. Persistent organic pollutants such as DDT are known to cause ecological effects (e.g., reproductive failure) in organisms such as fish and birds. Therefore, it is important to assess whether bioaccumulative contaminants in sediments can biomagnify to an extent at which ecological effects may occur.

Step 4a of the COA framework assesses whether biomagnification is a potential concern for the contaminated site of interest. This may be done either through modelling, which employs conservative assumptions about contaminant exposure and uptake and biomagnification factors to calculate potential contaminant concentrations in receptors at higher trophic levels, or through actual measurement of body tissue contaminant concentrations in aquatic biota. For the KIH, extensive data are available on PCB and Hg concentrations in invertebrate and fish tissue at the various sampling locations throughout the harbour studied by the Ontario Ministry of the Environment (OMOE) and Environment (see detailed review of studies in Chapter I), allowing for a quantitative evaluation of ecological effects. An ecological risk assessment has been performed at the KIH to evaluate risks to receptors such as piscivorous fish, birds and other wildlife through modelling. The risk assessment is presented in Chapter IV of this report.

Sampling for biological uptake in the KIH has focused on four receptor groups: macrophytes (aquatic plants), cattails, benthic invertebrates and fish. Comparisons were made between concentrations in biota collected from the test area and those in biota collected from upstream reference areas, which were selected to represent sites anticipated to be ecologically similar to the test area but without contaminated sediments. Detailed results are presented below.

A. Aquatic macrophytes

Eurasian watermilfoil (*Myriophyllum spicatum*) is an invasive macrophyte (aquatic weed) that is abundant and widespread throughout the KIH. It can tolerate a wide range of environmental conditions and typically grows rooted in water depths from 1 to 10 m (Washington State Department of Ecology 2010). Carbohydrate storage is provided by overwintering shoots and roots. The high tannin content of Eurasian watermilfoil renders it unpalatable to most grazers, although it may be eaten by carp and muskrat.

Samples of Eurasian watermilfoil were collected in the autumn of 2008 from six locations throughout the KIH (Appendix B, Map B-III-1). The samples were separated into root (rhizome) and shoot (stem and leaves), rinsed thoroughly in distilled water and then analyzed for inorganic elements. Detailed analytical results are presented in Appendix D, Table D-III-1.

A significant positive correlation was noted between the concentration of Cr in the sediment and the concentration of Cr in the macrophytes for the sampled sites (Appendix F, Figure F-III-1), indicating Cr uptake. Cr concentrations were generally higher in the rhizome than the stem, with the maximum Cr uptake noted at the site with the highest sediment Cr concentration (Figure III-1). Similar trends were noted for Pb, although the maximum macrophyte Pb concentration was an order of magnitude lower than the maximum macrophyte concentration for Cr, reflecting the lower Pb sediment concentrations (Figure III-2). These data corroborate earlier work completed by Tinney (2006), who noted uptake of Cr and Pb into *Myriophyllum spicatum* at sampling site ERA5, where sediments contained elevated concentrations of Cr and Pb, but low uptake at other sample sites throughout the KIH where sediment concentrations were moderate or low (Appendix B, Map B-III-1). Although there are no guidelines for evaluating Cr or Pb concentrations in plants, the data indicate that uptake of these elements into KIH macrophytes is occurring in the most contaminated sediment locations, which are southwest of Belle Island.

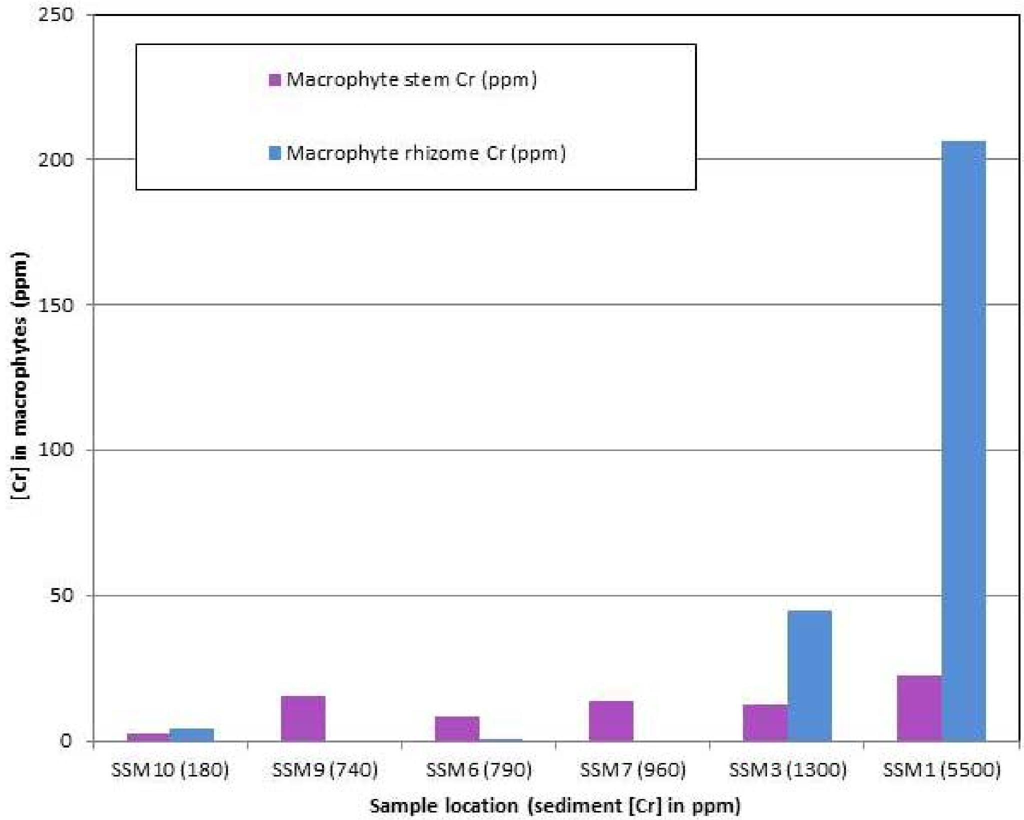


Figure III-1: Cr concentrations in macrophytes from KIH sites.

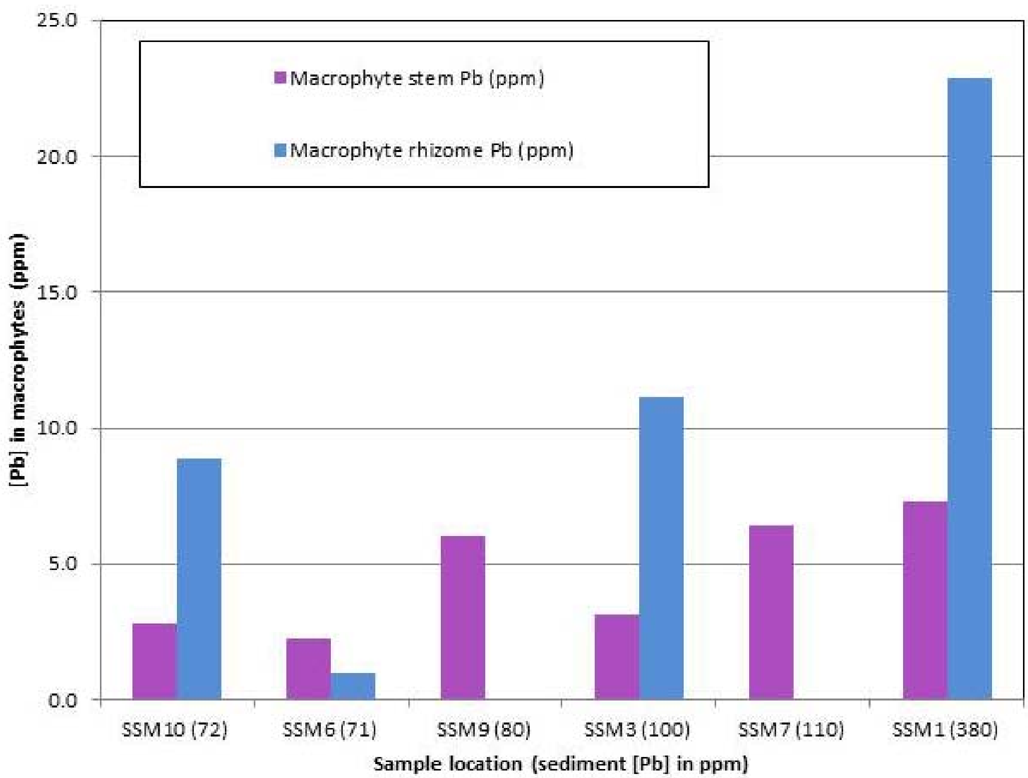


Figure III-2: Pb concentrations in macrophytes from KIH sites.

B. Cattails

Cattails (*Typha latifolia* and *Typha angustifolia*) are the dominant plant within the Great Cataraqui Marsh, and are also found in marshy patches throughout the KIH, as well as around the shoreline where the water depth permits growth. They grow in soil that remains wet, saturated or flooded throughout the growing season where water depths do not exceed 1 m (Rook 2002). Their extensive underground rhizomes are an important food for muskrats and for waterfowl such as geese. Red-winged blackbirds, yellow-headed blackbirds and marsh wrens commonly nest in cattail stands, while waterfowl nest in areas with open water interspersed with cattail cover. Frogs and fish also lay their eggs in the water between cattail stems and may use these areas as habitat.

To evaluate potential contaminant uptake into cattails in the KIH, samples were collected from four locations in November 2008: three locations along the shoreline south of Belle Park and one reference location in the Great Cataraqui Marsh (Appendix B, Map B-III-2). The samples were separated into root (rhizome) and shoot (stem and leaves), rinsed thoroughly in distilled water and then analyzed for inorganic elements and PCBs. Detailed results are presented in Appendix D, Table D-III-2. Although the sample size is small, Cr, Pb, and PCB concentrations in the sediments correlated with concentrations in the rhizome (Appendix F, Figures F-III-2 to F-III-4). Contaminant concentrations were below the analytical detection limits or present at trace levels in cattails at the reference site, while concentrations were elevated at the test sites, particularly those with higher sediment contamination (Figures III-3 to III-5). Translocation of contaminants to the cattail shoot appears to be low, as contaminant concentrations are much higher in the cattail rhizome. Although there are no guidelines for evaluating Cr, Pb or PCB concentrations in plants, the data suggest that uptake of Cr, Pb and PCBs into cattails is occurring immediately south of Belle Park.

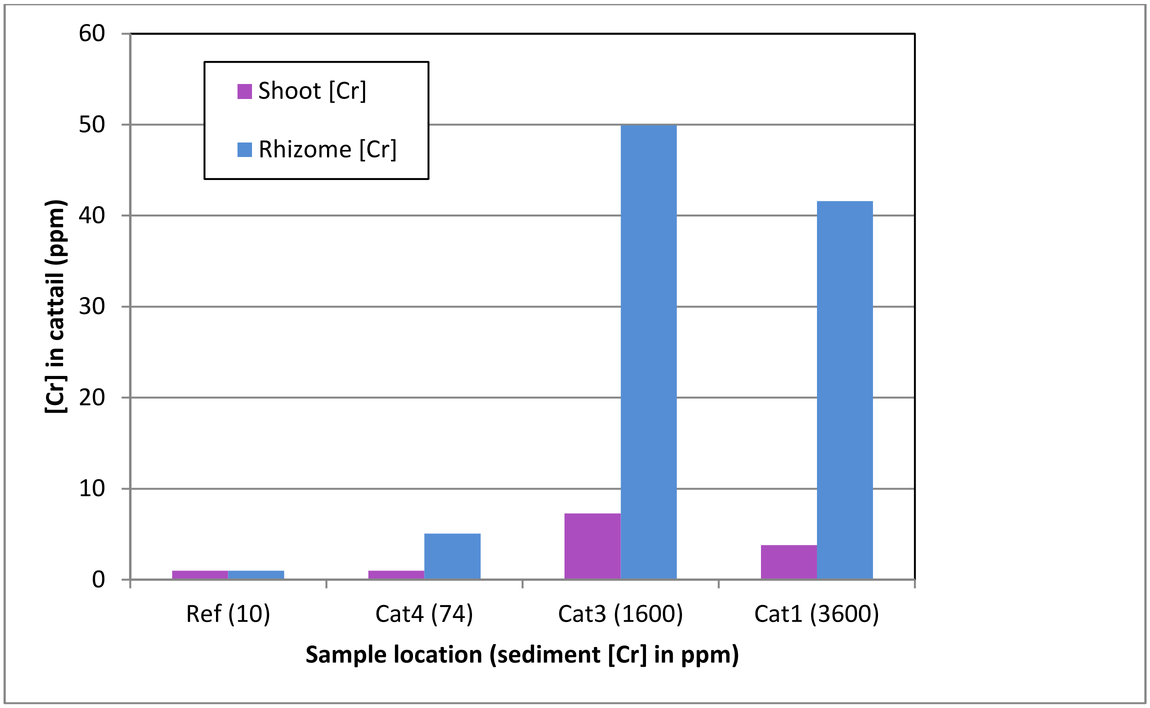


Figure III-3: Cr concentrations in cattails from KIH sites.

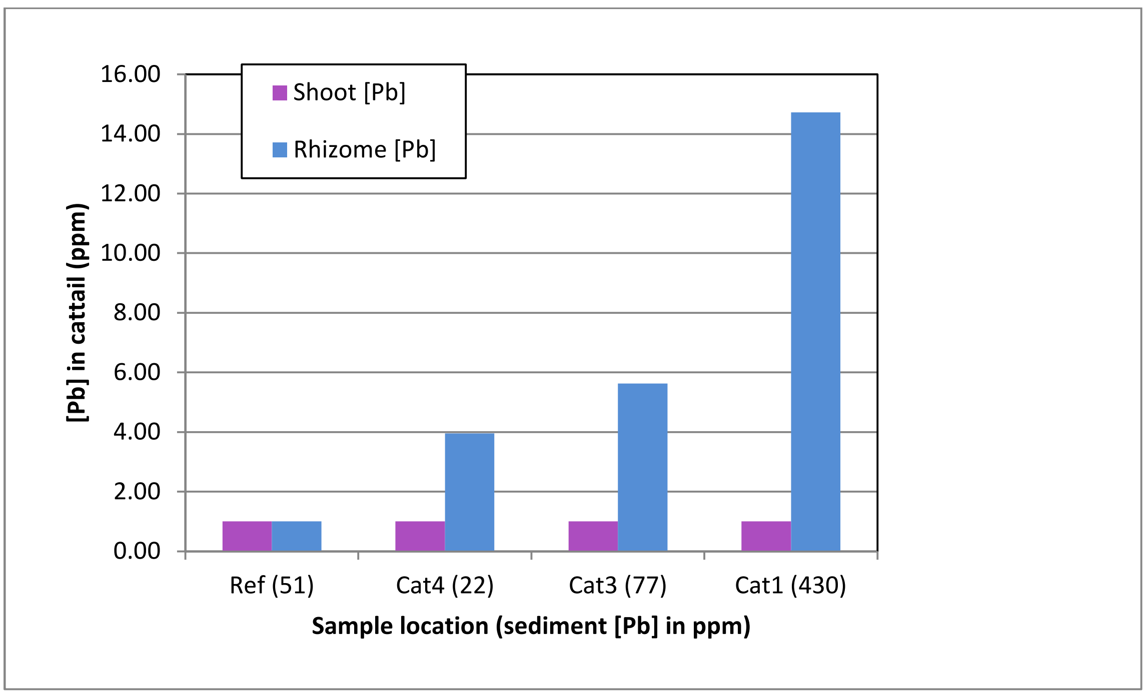


Figure III-4: Pb concentrations in cattails from KIH sites.

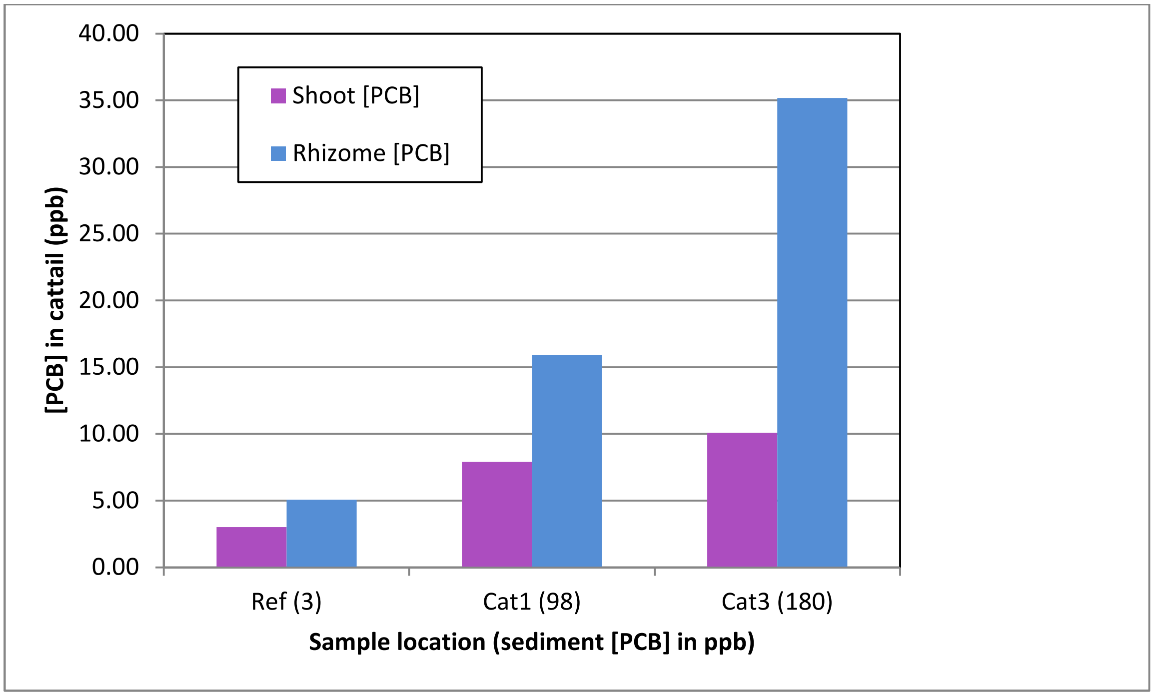


Figure III-5: Total PCB concentrations in cattails from KIH sites.

C. Invertebrates

Benthic invertebrates are widely used as indicators of sediment contamination because of their close association with contaminated sediments and their relatively short life cycles and because they represent a variety of trophic levels and contaminant exposure pathways. They are also an important food item for many aquatic species, including fish, birds, amphibians and reptiles.

Two approaches were used to investigate Cr uptake into invertebrates from KIH sites. In November 2008, invertebrates were collected in surface sediment grabs from four locations: three test sites located south of Belle Park and one reference site upstream (Appendix B, Map B-III-3). The samples were sieved using a 500 µm sieve, separated into major taxonomic groups (Crustaceans and Other), rinsed in distilled water, frozen and then analyzed for Cr. Detailed results are presented in Appendix D, Table D-III-3. There were insufficient sample masses to allow analysis of the same taxonomic group at all sites. Contaminant body burdens differ among taxonomic groups from the same site because of varied exposure to the contaminated sediment; however, comparisons of the benthic invertebrate body burdens among sites is likely to be sufficient to indicate general spatial trends in contaminant uptake. The field benthic invertebrate data indicate that invertebrate Cr concentrations are higher at all of the test sites than at the reference site

(Figure III-6; Appendix B, Map B-III-4). Although the sample size is small, Cr concentrations in the sediments correlated with the Cr concentration in the invertebrates (Appendix F, Figure F-III-5).

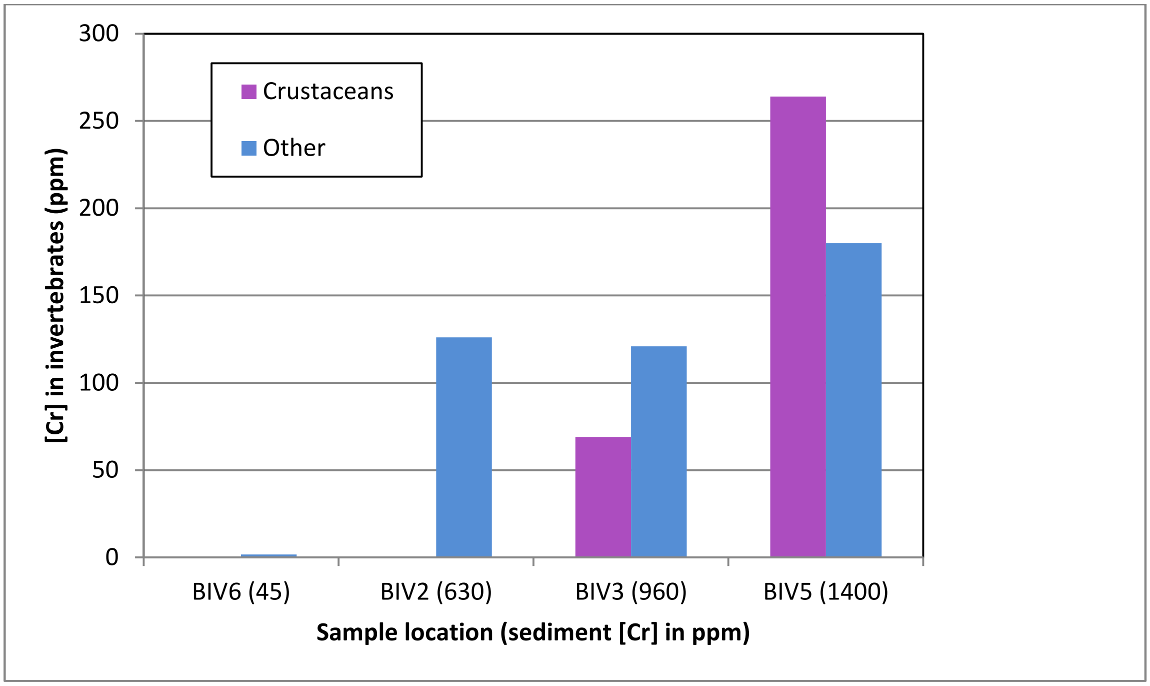


Figure III-6: Cr concentrations in benthic invertebrates collected from KIH sites.

Similar trends were noted for lab tests, which investigated Cr uptake for *Hyalella azteca* during 28-day toxicity tests using sediment from four upstream reference sites and 10 test sites in the KIH (Appendix B, Map B-III-5). Six replicates were carried out for sediments from each site. After the test period, the organisms were sieved from the sediment, rinsed with deionized water, dried and analyzed for Cr. Detailed results are presented in Appendix D, Table D-III-4. Cr uptake at the upstream reference sites was very low and not significantly different from organisms exposed to sediments from control sites (i.e., uncontaminated sites from another geographic location); however, higher uptake was generally seen for organisms exposed to sediments from test sites (Figure III-7). Invertebrate Cr concentrations were at least one order of magnitude lower than those observed for invertebrates collected *in situ*, probably reflecting the shorter exposure times. A highly significant positive correlation was noted between the Cr concentration in the sediments and the Cr concentration in *Hyalella azteca* organisms (Appendix F, Figure F-III-6). Although there are no guidelines to evaluate Cr concentrations in biological tissue, the data indicate uptake of Cr into invertebrates, particularly at sites southwest of Belle Park (Appendix B, Map B-III-5).

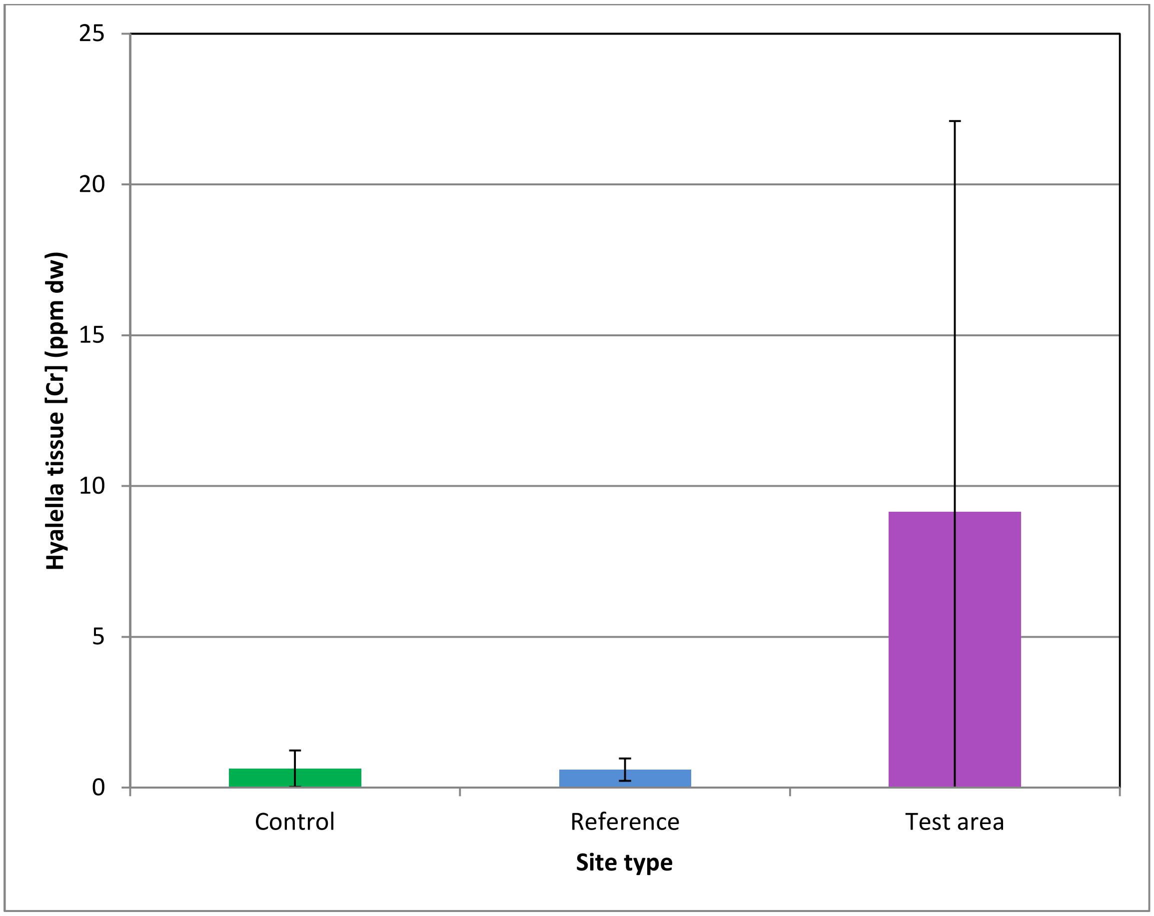


Figure III-7: Average Cr concentrations in *Hyalella azteca* following a 28-day lab bioassay with sediments from KIH sites.

Environment Canada and OMOE have completed a number of studies investigating the uptake of PCBs and Hg into invertebrates within the KIH (Derry et al. 2003; Benoit and Dove 2006; Scheider 2009). There is clear evidence for bioaccumulation of PCBs in invertebrates collected south of Belle Park in contrast to reference sites north of Belle Park where there is little evidence of bioaccumulation. Caged mussel studies indicated that the highest uptake of PCBs occurred at stations immediately south of Belle Park and near Emma Martin Park (caged mussel stations 182 and 183 on Appendix B, Map B-III-3; Figures 9 and 11 in Derry et al. 2003), although the tissue concentrations were below the Canadian Council of Ministers of the Environment (CCME) and International Joint Commission (IJC) tissue residue guidelines (see Chapter I) after a10-week test period. Similar spatial trends were noted for field collections of benthic invertebrates: the highest concentrations of dioxin-like PCBs (DLPCBs), dioxins and furans were found in invertebrates collected at a station immediately south of the Belle Park Landfill and a station close to Emma Martin Park (Appendix B, Map B-III-6; Figure 10 in Benoit and Dove 2006). Invertebrate tissue concentrations for all sampling locations except the upstream reference site exceeded the CCME tissue residue guidelines for mammalian consumers of aquatic biota for DLPCBs (0.79 picogram(pg) toxic equivalency (TEQ)/g wet weight (ww)), as well as for dioxins and furans (0.71 pg TEQ/g ww; Benoit and Dove 2006). Similarly, a recent MeHg study in the KIH using caged mussels also found evidence for bioaccumulation of MeHg (Scheider 2009), with the highest concentrations from stations located near the Kingston Rowing Club and Emma Martin Park as well as immediately south of the Belle Park Landfill (King 3, King 4 and King 5 on Appendix B, Map B-III-3; Figure 2, Scheider 2009). MeHg concentrations in the mussels were below the CCME MeHg tissue residue guidelines (33 ng/g) for all sites after the 21-day test period (Scheider 2009). It is not known whether organisms *in situ* are accumulating levels of these contaminants above the guidelines, but this is a possibility given the longer exposure times of field organisms.

D. Fish

Fish are important bioindicators of aquatic contamination because they bioaccumulate contaminants such as organochlorines and metals; they represent a variety of aquatic trophic levels, and they have ecological and socioeconomic importance. Bottom-feeding fish such as the brown bullhead (*Ictalurus nebulosus*) and the common carp (*Cyprinus carpio*) are directly exposed to contaminated sediments and also ingest benthic invertebrate prey (Scott and Crossman 1973). Juvenile forage fish, such as yellow perch (*Perca flavescens*), are commonly used in biomonitoring programs because of their importance as prey for other fish and their limited ranges in the first year of life, allowing identification of spatial and temporal contaminant trends (Hayton 2000). Higher-trophic-level fish, such as northern pike (*Esox lucius*), may accumulate greater amounts of contaminants through biomagnification, and they are often prized as sport fish. Fish are eaten both by higher-level aquatic wildlife consumers and by humans and therefore are a key component of ecological and human health risk assessment for aquatic sites.

To investigate bioaccumulation of inorganic elements and PCBs into fish from the KIH, ESG staff collected fish from two locations in the autumn of 2009: a test site immediately south of Belle Park and an upstream reference location (Appendix B, Map B-III-7). Three species of fish were collected: brown bullhead, yellow perch and northern pike. The whole body (brown bullhead) or the whole body minus one fillet (yellow perch and northern pike) was analyzed for a suite of inorganic elements and Aroclor PCBs as well as for percent lipids and percent moisture. Otoliths from the fish were used to determine age for each sample. Detailed results are presented in Appendix D, Table D-III-5.

No significant relationship was noted between fish age and tissue contaminant concentration (Appendix F, Figures F-III-7 and F- III-8), which is not surprising given the small age range (three to six years) of the fish samples. However, the narrow age range allows for good comparability between fish sampled from the test site and fish from the reference area. Cr concentrations were significantly higher ($p<0.05$) for brown bullhead collected from the test area, but this was not the case for yellow perch or northern pike (Figure III-8). These data are expected given the close association of brown bullhead with sediments compared with the other two species. Total PCB concentrations (mg/g ww) in all three species of fish (brown bullhead, yellow perch and northern pike) collected from the test area were significantly higher than those in the fish collected from the reference area (Figure III-9), and total PCBs exceeded the IJC tissue residue guideline (0.1 mg/g ww) for all three groups at the test site. Lipid-normalized total PCB concentrations (mg/g lipid ww) indicate that northern pike from the test area showed the highest PCB bioaccumulation of the three fish species (Figure III-10), probably reflecting the elevated trophic status of this fish (a piscivore). The data indicate that biomagnification of PCBs into fish is occurring in the area south of Belle Park.

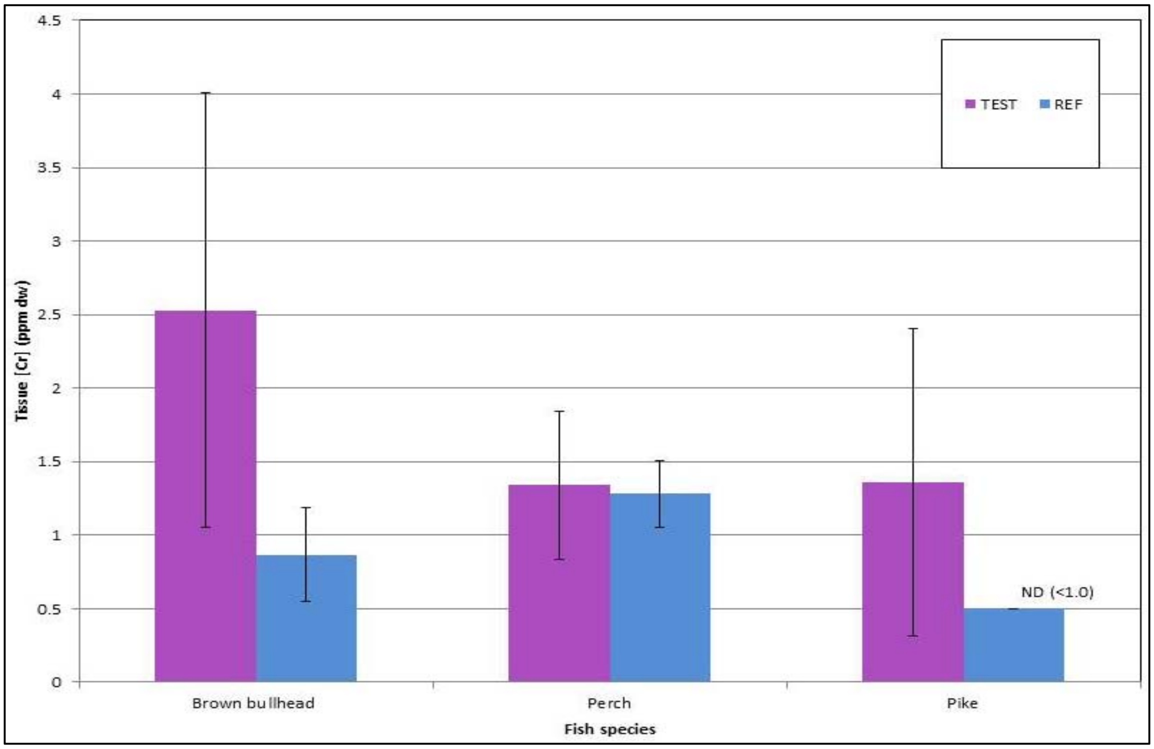


Figure III-8: Average Cr concentrations in three fish species collected from the KIH.

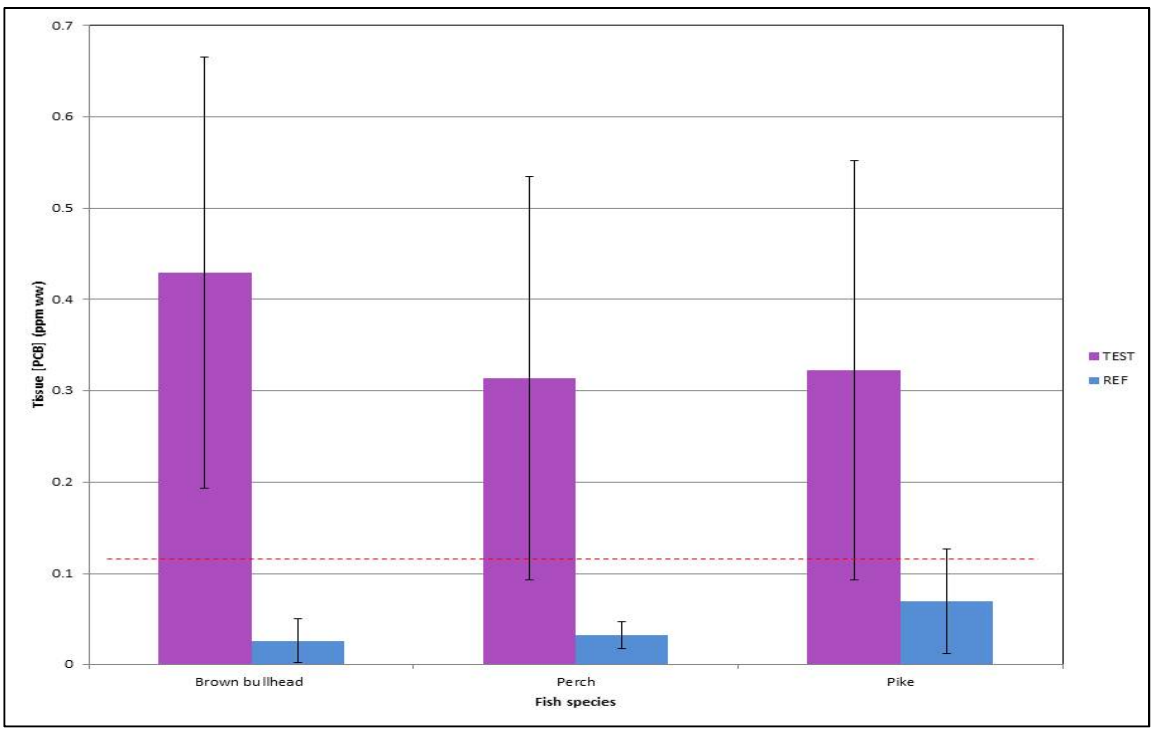


Figure III-9: Average total PCB concentrations in three fish species (Brown Bullhead, Yellow Perch and Northern Pike) collected from the KIH, reported on a wet weight basis. Red dashed line indicates the IJC Tissue Residue guideline for the protection of aquatic wildlife consumers.

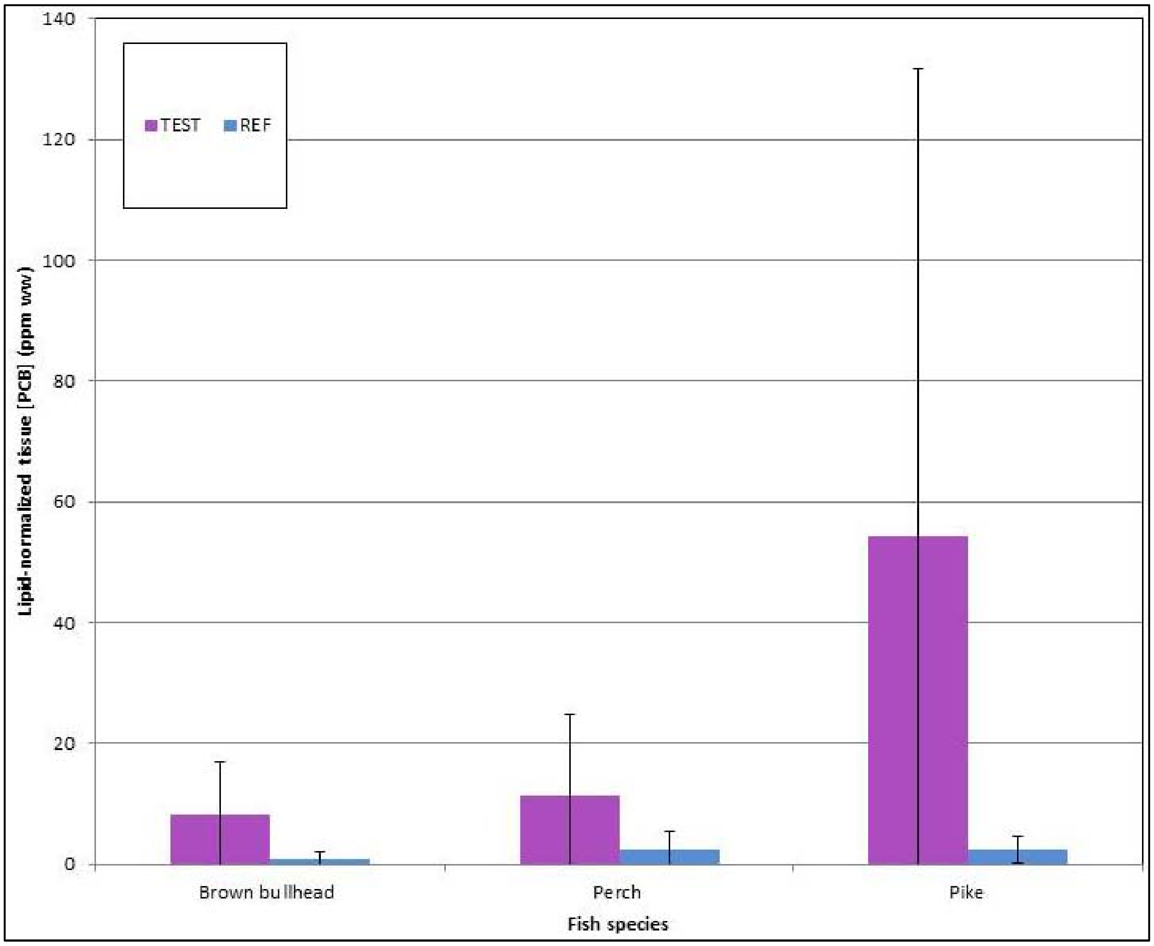


Figure III-10: Average lipid-normalized total PCB concentrations in three fish species (Brown Bullhead, Yellow Perch and Northern Pike) collected from the KIH, reported on a wet weight basis.

These data are corroborated by extensive fish biomonitoring studies carried out by the OMOE for sites in the KIH over the past 25 years. There is more evidence for bioaccumulation of PCBs in forage fish and sport fish collected south of Belle Park compared with reference sites north of Belle Park. Biomonitoring studies of young-of-the-year and juvenile yellow perch carried out by the OMOE over the past 25 years have consistently noted the highest PCB uptake at sites immediately south of the Belle Park Landfill and near Emma Martin Park (Table 1 in Hayton 2000; Figure 1 in Derry et al. 2003; Figures 9a–9b and Table 6 in Benoit and Dove 2006; Table 4 in Scheider 2009). There is some evidence to suggest that PCB concentrations in forage fish downstream from the landfill have declined since the early 1990s (Hayton 2000), although monitoring locations were not consistent until the late 1990s, complicating the identification of temporal trends. The average fish PCB concentration from the most recent monitoring data available for each monitoring station (2002 or 2008) is plotted on Appendix B, Map B-III-8; the geometric mean was plotted for Kingston Marina fish to minimize the effect of an extreme outlier for this site collected in 2008 (2,700 ppb). Comparisons of PCB concentrations in sediment and biota for both field sampling locations and lab bioassays with juvenile fathead minnows provide clear evidence for biomagnification of PCBs, as levels in biota are typically higher than those found in associated sediments (Benoit and Dove 2006).

Comparison of PCB biota tissue concentrations with the relevant tissue residue guidelines (see Chapter I, Tables 13 and 14) suggests that PCBs are biomagnifying in the southern KIH to a degree that may cause ecological effects. Mean PCB concentrations for forage fish (juvenile and young-of-the-year yellow perch) collected at sites south of the Belle Park Landfill have consistently exceeded the IJC aquatic life guideline for PCBs (100 ppb ww; Hayton 2000; Derry et al. 2003; Benoit and Dove 2006; Scheider 2009; Appendix B, Map B-III-8), indicating a potential risk for wildlife consumers of aquatic biota. Similarly, average and median PCB concentrations for three species of sport fish collected by the OMOE in the vicinity of Belle Park (northern pike, carp and brown bullhead) exceeded the IJC aquatic life guideline for PCBs (100 ppb ww), with the highest maximum PCB concentrations reported for northern pike (1,400 ppb) and carp (1,900 ppb; Benoit and Dove 2006; Scheider 2009). The 2013–2014 Guide to Eating Ontario Sport Fish (OMOE 2013) lists brown bullhead longer than 30 cm and carp longer than 55 cm from the Belle Park area as being unsafe for consumption by women of childbearing age and children under the age of 15. Although the guideline comparisons are conservative, these data suggest potential risk for ecological and human health effects from biomagnification of PCBs in KIH biota. An ecological and human health risk assessment has been performed for the KIH and is presented in Chapter IV of this report.

Recent fish monitoring studies (1999 to 2008) have provided evidence for the bioaccumulation of Hg in fish tissue throughout the KIH, especially in the vicinity of the Kingston Rowing Club and Emma Martin Park (Scheider 2009). The average fish Hg concentration from the most recent monitoring data (2002 or 2008) available for each monitoring station is plotted on Map B-III-9 (Appendix B). Juvenile yellow perch collected from the Kingston Rowing Club consistently contained Hg concentrations exceeding the CCME tissue residue guideline for protection of wildlife consumers of aquatic biota (33 ppb ww). Fish Hg concentrations were significantly higher at this site compared with others in the KIH, suggesting a local source of Hg. Several juvenile yellow perch samples collected south of the Belle Island Landfill in 2002 also exceeded the CCME Hg guidelines, while samples collected near Highway 401 were close to the guideline in 2002 and 2008. Fish Hg concentrations appear to have increased over time at these three sites, when compared with results from sampling periods in 1999 and 2000. Mercury concentrations in sport fish collected by the OMOE near Belle Island consistently exceeded the CCME tissue residue guidelines for carp, largemouth bass, northern pike and yellow perch, with some instances of bluegill and brown bullhead also exceeding the guideline (Scheider 2009). However, the concentrations were comparable to those measured in sport fish from the upstream Colonel By Lake and were not high enough to limit human fish consumption. The CCME tissue residue guidelines are derived using very conservative assumptions, and a site-specific ecological risk assessment as presented in Chapter IV provides a more realistic measure of probable risk.

There is limited evidence for uptake of other organic contaminants into KIH fish. Pesticides such as DDT have generally been below analytical detection limits or at trace levels for juvenile yellow perch, with the exception of eight fish samples collected in 2002 (Benoit and Dove 2006; Scheider 2009). At this time, several samples collected immediately north and south of the Belle Island Landfill and near the Kingston Rowing Club exceeded the CCME tissue residue guidelines for protection of wildlife consumers of aquatic biota for total DDT and metabolites (14 ppb ww). Similarly, most sport fish samples collected by the OMOE near Belle Island contained trace levels of DDT and its metabolites. A total of 11 fish samples from three species (brown bullhead, carp and northern pike) exceeded the CCME tissue residue guidelines for total DDT and metabolites, with a maximum reported total DDT concentration of 400 ppb ww for carp (Scheider 2009). These data suggest that some uptake of DDT may be occurring in the KIH, but the biological uptake of mercury and especially PCBs is more consistent and widespread.

E. Summary

Overall, the available data on tissue contaminant concentrations for KIH biota show consistent evidence for bioaccumulation of contaminants such as Cr, PCBs and Hg from the southwest portion of the KIH. Where tissue residue guidelines are available to assess biota contaminant concentrations, field invertebrate and fish biota from this area of the harbour are consistently above the relevant guidelines, indicating potential risk to wildlife consumers of aquatic biota. In contrast, aquatic biota from other areas of the KIH do not appear to have accumulated contaminants to the same degree. Following the COA framework under Step 4a, the data strongly indicate that there is potential for contaminant biomagnification from the sediments through aquatic food chains in the southwest portion of the KIH. An evaluation of the potential human health and ecological risks to higher-trophic-level consumers is presented in Chapter IV of this report.

III. SEDIMENT TOXICITY

Lab sediment bioassays, in which sensitive test organisms are exposed to contaminated sediments from the site of concern, are commonly used to assess sediment toxicity. Because different species show different degrees of sensitivity to contaminants, the choice of test organism can affect the results obtained. It is generally recommended that lab bioassays be carried out with several sensitive sediment-dwelling or sediment-associated test organisms that are reasonably similar to those that would be found at the study site. Typical test organisms for the assessment of freshwater sediments include mayflies (*Hexagenia*), freshwater amphipods (*Hyalella azteca*), midges (*Chironomus tentans* or *C. riparius*) and oligochaetes (e.g., *Tubifex tubifex*). The use of multiple test organisms accounts for the varying sensitivity and exposure pathways of different organisms to different contaminants, and also provides a weight-of-evidence approach to evaluating sediment toxicity at a particular site.

The choice of measurement endpoints can also influence the conclusions to be drawn from sediment toxicity tests. Lab bioassays that evaluate test organism growth and reproductive effects are generally considered more sensitive than those that evaluate only survival rates, since the former endpoints can be indicative of chronic effects of sediment contamination. A rigorous QA/QC program is essential to ensure that effects detected are caused by the test sediments and are not a result of toxicity generated by test conditions.

Step 4b of the COA framework assesses whether sediments are toxic, using lab sediment bioassays. Statistical differences in sediment toxicity endpoints between lab bioassay control samples and test/reference samples are evaluated. Based on the scientific literature, a difference of less than 20 percent between the control sample endpoints and test/reference endpoints is not considered to indicate sediment toxicity under the COA framework. However, if one or more of the sediment toxicity endpoints for the test samples has more than a 20 percent difference from the reference samples and is statistically significantly different from the reference sample, the COA framework assumes that there is a potential environmental risk and further assessment is undertaken. Toxicological effects are considered major under the COA framework when a statistically significant reduction of more than 50 percent in at least one of the toxicological endpoints occurs.

A number of studies investigating sediment toxicity have been performed for the KIH and are summarized in Table I-16 in Chapter I of this report. Because previous studies showed limited spatial coverage and differed in methodology, additional surface sediment sampling for toxicity testing was carried out for the KIH between 2006 and 2009. Subsequent to this, additional toxicity analyses were carried out in 2010 and 2011 for two reference locations upstream of Belle Park and 20 test sites in the southern KIH on the Transport Canada water lot; these previously unreported data are summarized in the sections that follow.

A. 2006 to 2009 Studies

Sample locations for the 2006–2009 studies were chosen to provide good spatial coverage of the area of interest southwest of Belle Park, with upstream reference sites selected from ecologically similar locations with low sediment contaminant concentrations. At each station, a minimum of three 8.2 L Ponar grab samples of surface sediments were retrieved and homogenized in a plastic container. Upon return of the samples to the laboratory, the sediment was stored in the dark at 4°C until toxicity testing was initiated. The samples were stored for a maximum of six weeks before being analyzed, in accordance with accepted lab protocols.

The 2006–2009 toxicity testing evaluated potential effects on the survival, reproduction and growth of test benthic invertebrate organisms. Toxicity testing was performed for a total of 22 test sites in the southwest KIH (Appendix B, Map B-III-10). To evaluate the statistical difference between test and reference locations as outlined in the COA approach, sediments from upstream reference sites were included for each toxicity test run. Reference sites were selected from areas north of Belle Park with grain sizes and organic content comparable to test locations but with trace levels of sediment contaminants. A total of seven upstream reference locations were sampled for sediment toxicity (Appendix B, Map B-III-10). The reference site used for statistical comparisons for each toxicity text run is shown in the “reference” column of Table III-1.

Specific methodologies for the 2006–2009 sediment toxicity tests, as conducted by Cantest Ltd. and Environment Canada, are outlined below.

B. Cantest Ltd.

From 2007 to 2009, Cantest Ltd. of Burnaby, BC, performed sediment toxicity testing using *Chironomus tentans* and *Hyalella azteca*. The tests were conducted with guidance from the United States Environmental Protection Agency (US EPA) Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (US EPA 2000; EPA/600/R-99/064). Sediment toxicity results for 12 test locations in the KIH (T3, T4, T5, T6, T7, T8, T21, T22, T23, T24, PC13 and PC14) were compared with results for samples from five upstream reference locations (T1, T2, T19, T20 and PC12), as well as with results for control sediment obtained from Mackenzie Bay, British Columbia. Test organisms were exposed to sediments in 300 mL tall-form beakers with controlled flow-through water renewal (two volume additions daily), photoperiod (16 hours light to eight hours darkness), temperature (23±1ºC) and feed (1.5 mL/day Tetrafin for *Chironomus tentans* and 1 mL/day YCT for *Hyalella azteca*). Each sample was tested with 10 organisms per test vessel in either six replicates (most samples) or 12 replicates (PC12, PC13 and PC14). Water quality parameters (dissolved oxygen, temperature, pH, hardness, alkalinity, conductivity and ammonia) were logged at the beginning and end of each test. Additional measurements of dissolved oxygen, temperature and pH were collected three times per week, while conductivity was measured weekly.

1. *Chironomus tentans*

The *Chironomus tentans* tests were conducted for 20 days using freshly hatched larvae (<24 h). At the test endpoint, vessel contents were sieved using a 500 µm mesh screen and surviving larvae and pupae were counted. Surviving larvae were dried and weighed to determine growth. *Chironomus tentans* tests were considered valid if the average size in control organisms was greater than or equal to 0.6 mg/larvae as dry weight or 0.48 mg/larvae as ash-free dry weight at the endpoint.

2. *Hyalella azteca*

Hyalella azteca tests were conducted for 28 days using three- to five-day-old organisms. On day 28, vessel contents were poured into a glass baking dish and amphipods were recorded and removed. The remaining sediment was passed through a 500 µm sieve and surviving adults were collected, counted and weighed. *Hyalella azteca* tests were considered valid if 80 percent or more control organisms had survived at the endpoint. Tissue analysis for Cr was performed after determining survival and growth parameters.

C. Environment Canada

Four benthic invertebrate toxicity tests were performed on sediment samples from the KIH: *Hyalella azteca* 28-day survival and growth test; *Chironomus riparius* 10-day survival and growth test; *Hexagenia* spp. 21-day survival and growth test; and *Tubifex tubifex* 28-day survival, growth and reproduction test. Sediment toxicity results for 10 test locations (T15, T16, T17, T18, T25, T26, T28, T29, T30, T31) were compared with results for samples from two upstream reference locations (T11 and T27) and for a control sample (i.e., uncontaminated sediment from another geographic location). Tests were conducted in beakers under static water conditions. Four replicates were used for each test and reference sample, and five replicates were used for the control sample. Water quality parameters (dissolved oxygen, temperature, pH, conductivity and ammonia) were measured at the start and end of each test. Temperature was maintained at 23±1ºC. Daily lighting was controlled at 16 hours light to eight hours darkness for all tests, except for *Tubifex tubifex*, which was run with 24-hour darkness.

1. Hyalella azteca

Hyalella azteca tests were conducted for 28 days with two- to 10-day-old organisms. At the test endpoint, organisms were sieved and surviving amphipods were counted. Growth was measured by dry weight. *Hyalella azteca* tests were considered valid if 80 percent or more control organisms had survived at the endpoint for reference sediments.

2. Chironomus riparius

Chironomus riparius tests were performed for 10 days with freshly hatched larvae (<24 h). At the test endpoint, organisms were sieved using a 250 µm screen and surviving adults were counted. Growth was measured by dry weight. *Chironomus riparius* tests were considered valid if 70 percent or more control organisms had survived at the endpoint for reference sediments.

3. Hexagenia spp

Hexagenia spp. tests were conducted for 21 days using nymphs. At the test endpoint, organisms were sieved through a 500 µm screen and surviving nymphs were counted. Growth was measured by dry weight. *Hexagenia* spp tests were considered valid if 80 percent or more control organisms had survived at the endpoint for reference sediments.

4. Tubifex tubifex

Tubifex tubifex tests were performed for 28 days with sexually mature worms. At the test endpoint, vessel contents were sieved sequentially through 500 µm and 250 µm screens to separate surviving adults from small, immature worms. Survival percentages were measured by counting the number of surviving adults. Reproduction parameters were obtained by determining the total number of cocoons per adult, the percentage of hatched cocoons and the total number of immature worms per adult. *Tubifex tubifex* tests were considered valid if 75 percent or more control organisms had survived at the endpoint for reference sediments.

D. Statistical Analyses

Statistical analyses of toxicity data were performed using the SPSS 17.0 software package. For each test run, differences in survival, growth and reproduction data were assessed using a one-way ANOVA. Post-hoc pairwise comparisons with a Dunnett's test were used to determine statistical differences ($p<0.05$) between test sites and the control and reference samples. The statistical software package PC-ORD was used for principal components analysis (PCA) of the toxicity endpoint data.

E. Sediment Toxicity Results and Discussion

Sediment toxicity results for survival, growth, and reproduction for the KIH sediment samples are presented in Appendix G, Figures G-III-1 to G-III-11, and summarized in Table III-1; detailed results are compiled in Appendix D, Table D-III-6. Toxicity was assessed using the COA framework: if one or more of the sediment toxicity endpoints for the test samples had a difference from the reference sample of greater than 20 percent and was statistically significantly different from the control sample and the reference sample, the location was classified as showing potential risk. Using these criteria, lab bioassays performed by Cantest identified five locations within the KIH that showed evidence of toxicity to benthic organisms: T3, T4, T7, T8a and T8b. However, sediment samples collected in 2009 very close to two locations (T28 and T29; Appendix B, Map B-III-10) were tested by Environment Canada and did not show any evidence of toxicity. Organisms grown on sediments from some test sites were noted to have higher growth than organisms grown on sediments from reference locations; this may be because of higher nutrient concentrations in the sediments as a result of sewer overflows in the test area.

Table III-1. Summary of benthic invertebrate toxicity testing for sediments collected from test locations in the KIH.

Location	Laboratory	Control	Reference	Cr in sediments [ppm]	Chironomus tentans Survival (%)	Chironomus tentans growth (mg/ind)	Hyalella azteca survival (%)	Hyalella azteca growth (mg/ind)	Chironomus riparius survival (%)	Chironomus riparius growth (mg/ind)	Hexagenia survival (%)	Hexagenia growth (mg/ind)	Tubifex survival (%)	Tubifex Coc/Adult (#)	Tubifex hatch (%)	Tubifex Young/Adult (#)
T1	Cantest	C1		47	N	N	N	N								
T3	Cantest	C1	T1	1,000	Y	N	N	N								
T4	Cantest	C1	T1	1,000	N	N	Y	N								
T2	Cantest	C2		50	N	N	N	N								
T5	Cantest	C2	T2	780	N	N	N	N								
T6	Cantest	C2	T2	1,200	N	N	N	N								
T7a	Cantest	C2	T2	850	N	Y										
T8a	Cantest	C2	T2	600	Y	Y										
T19	Cantest	C3		37			N	N								
T7b	Cantest	C3	T19	1,000			N	N								
T8b	Cantest	C3	T19	820			Y	N								
T11	Env Canada	C4		37			N	N	N	N	N	N	N	N	N	N
T15	Env Canada	C4	T11	1,100			N	N	N	N	N	N	N	N	N	N
T16	Env Canada	C4	T11	660			N	N	N	N	N	N	N	N	N	N
T17	Env Canada	C4	T11	1,100			N	N	N	N	N	N	N	N	N	N
T18	Env Canada	C4	T11	760			N	N	N	N	N	N	N	N	N	N
T20	Cantest	C5		38	N	N	N	N								
T21	Cantest	C5	T20	990	N	N	N	N								
T22	Cantest	C5	T20	850	N	N	N	N								
T23	Cantest	C5	T20	7,500	N	N	N	N								
T24	Cantest	C5	T20	430	N	N	N	N								
T25	Env Canada	C7	T27	2,300			N	N	N	N	N	N	N	N	N	N
T26	Env Canada	C7	T27	560			N	N	N	N	N	N	N	N	N	N
T27	Env Canada	C7		40			N	N	N	N	N	N	N	N	N	N
T28	Env Canada	C7	T27	930			N	N	N	N	N	N	N	N	N	N
T29	Env Canada	C8	T27	990			N	N	N	N	N	N	N	N	N	N
T30	Env Canada	C8	T27	720			N	N	N	N	N	N	N	N	N	N
T31	Env Canada	C8	T27	860			N	N	N	N	N	N	N	N	Y*	Y*
T32	Cantest	C9		30	N	N										
T33	Cantest	C9	T32	5,700	N	N										
T34	Cantest	C9	T32	11,000	N	N										

Y = minor toxicity effects (statistically different from control and reference and >20% difference from reference sample)

Y = major toxicity effects (statistically different from control and reference and >50% difference from reference sample)

*based on Principle Components Analysis

As an alternative approach to assessing toxicity, PCA was performed on the KIH toxicity endpoint data from Cantest and Environment Canada. The use of a multivariate approach allows the integration of all of the toxicity endpoints into one statistical analysis, and it may also be useful for detecting patterns in the data when the survival or growth in the control and reference samples is low. The resulting ordination plots are presented in Appendix G, Figures G-III-12 to G-III-16; sites that plot close together on the diagram are more similar to each other than sites that are distant. Results from the multivariate analysis corroborated those found using the COA approach: the same five test locations (T3, T4, T7, T8a and T8b) were identified as showing toxic effects. In addition, evidence for sublethal toxicity effects was found at site T31, indicated by reduced *Tubifex* reproduction (Grapentine, unpublished data). Toxicity showed little relationship to measured Cr concentrations in the test sediment (Table III-1). However, the presence of multiple contaminants in the sediments complicates the definition of causal relationships for the observed toxicity effects.

The results from the 2006–2009 toxicity tests were integrated with those from previous studies for the overall toxicity assessment for the KIH. Sample locations, test organisms and toxicity effects noted for all toxicity test locations in the KIH used in the overall assessment are shown in Appendix A, Golder Associates 2012, Figures B-1 to B-3. Previous tests using Microtox analyses were excluded from the overall toxicity assessment for the KIH because of concerns about the suitability of this approach (see Chapter I for further discussion).

Previous studies in the KIH assessing sediment toxicity using benthic organisms have also noted mixed results for the KIH southwest of Belle Island. As part of OMOE's and Environment Canada's "Project Trackdown," toxicity tests were performed for sediments from eight test sites within this area (Appendix B, Map B-III-10; Watson-Leung 2004, reported as an appendix in Derry et al. 2003). Three sediment bioassays were conducted: a 21-day test for survival and growth effects using mayflies (*Hexagenia* spp.); a 10-day test for survival and growth effects using midges (*Chironomus tentans*); and a 21-day test for survival effects using fathead minnows (*Pimephales promelas*). Using the COA criteria, two locations (one at an active seep immediately south of the Belle Island Landfill and another on the north shore of the former Davis Tannery property) showed toxic effects for *Hexagenia* survival and growth (Appendix A, Golder Associates 2012, Figures B-1 to B-3). However, no toxicity studies to date have found toxic effects to benthic invertebrates for any upstream reference sites or for stations located on the eastern side of the KIH.

The assessment of toxicity in the southwestern KIH is complicated by conflicting results between co-located sediment samples tested by Cantest and Environment Canada for some test locations. Cantest uses testing methodology very similar to that used by Environment Canada, with closely related test organisms and test duration times. Interlaboratory comparisons of short- and long-term toxicity tests with the two test organisms (*Chironomus tentans* and *Hyalella azteca*) have shown generally good reproducibility, with the variability in results dependent on the toxicity endpoint (Norberg-King et al. 2006). It is possible that the toxicity noted in the Cantest samples reflects heterogeneity in sediment chemical concentrations or a transient toxicity effect from an influence that was not present in 2009, such as storm runoff or a sewer overflow event. Confounding factors such as high total organic carbon (TOC) or sediment grain sizes may also affect toxicity to benthic invertebrates (Ankley et al. 1994; Ristola et al. 1999). However, the TOC and grain size measurements for the Cantest sites are within the range of reported values for the KIH, suggesting that they do not exert an undue influence at these sites. The lower number of replicates used by Environment Canada (four compared with six used by Cantest) may also have affected the ability to detect statistical differences between stations.

F. 2010–2011 Sediment Toxicity Studies

Additional toxicity analyses were carried out in 2010 and 2011 for two reference locations upstream of Belle Park and 20 test sites in the southern KIH on the Transport Canada water lot ((Appendix A, Golder Associates 2012, Figures B-1 to B-3). The toxicity tests used chironomid larvae (*Chironomus tentans*: 20-day test in 2010; *Chironomus dilutus*: 20-day test in 2011) and amphipods (*Hyalella azteca*: 28-day test) as test organisms and examined survival and growth endpoints for five replicates per location. Using the COA criteria, six of the 20 test locations had at least one endpoint with major toxic effects and eight test locations had at least one endpoint with minor toxic effects (Appendix A, Golder Associates 2012, Figures B-1 to B-2). Most of the test sites exhibiting minor and major toxic effects were located in the vicinity of Anglin Bay and Douglas R. Fluhrer Park on the southwestern shore of the KIH.

G. Integration of Toxicity Test Results from All Studies

Toxicity test results compiled from all available studies are shown in Appendix A, Golder Associates 2012, Figures B-1 to B-3. Overall, the available studies indicate negligible toxicity for areas north of Belle Park and for the central and eastern portions of the southern KIH. There is mixed evidence for benthic invertebrate toxicity in the southwestern portion of the KIH. The results for this area of the KIH can be summarized as follows (Appendix A, Golder Associates 2012, Figure B-3):

- *Parks Canada water lot:* Most test sites (10 of 14) had negligible toxicity, while three sites exhibited minor toxicity effects and one site had major toxicity effects.
- *Northern Transport Canada water lot (NF-3):* Most test sites (13 of 16) had negligible toxicity, while three test sites showed minor toxicity effects.
- *West Central KIH (NF-1, NF-2, MF-2, MF-3):* Most test sites (five of seven) had negligible toxicity, while two test sites showed minor toxicity effects.
- *Southwestern KIH (MF-1, FF-0, FF-1)*: Five test sites in this area exhibited negligible toxicity, five test sites showed minor toxicity effects and two sites showed major toxicity effects.

Based on these results, sediments in the southwestern KIH in the vicinity of Anglin Bay and Douglas R. Fluhrer Park appear to have the greatest potential for adverse effects on benthic communities.

Determining causality for the observed toxicity effects can be difficult when there are multiple contaminants present as for the KIH. There appears to be little relationship between measured Cr concentrations and toxicity test results (Table III-1). Chromium toxicity is strongly influenced by oxygen concentrations in the sediments, with little toxicity evident when anoxic conditions are present (Berry et al. 2004; Becker et al. 2006). This is probably the case for KIH sediments, where the main form of sedimentary Cr was Cr(III) and pore water studies did not find detectable Cr(VI), suggesting limited Cr mobility (see Chapter II of this report). Toxicity identification evaluation (TIE) tests aim to characterize and identify which chemicals or chemical classes cause observed toxicity effects through physical and chemical manipulations of test sediments combined with toxicity testing. TIE tests were carried out for two samples in the KIH collected in the vicinity of Anglin Bay showing major toxic effects for at least one endpoint (Golder 2012). The tests were inconclusive for one sample but suggested that toxicity in the other sample could be due to photo-reactive PAH compounds as well as the combined effects of multiple toxicants. Given the small sample size and the fact that photo-oxidation of PAHs generally occurs in the water column at depths where light penetrates and not in buried sediments, caution should be used in interpreting the results as conclusive evidence that PAHs are causing the observed sediment toxicity effects in the KIH.

IV. BENTHIC INVERTEBRATE COMMUNITY ANALYSIS

Benthic organisms are deemed to be the most sensitive aquatic receptors for sedimentary contaminants, as they are continuously exposed to contaminants through dermal contact and the ingestion of sediment particles and contaminated prey. Different species show varying sensitivities to contaminant concentrations, with some species considered pollution-tolerant while others are highly sensitive and will not be found in contaminated sediments. A benthic invertebrate community analysis can identify whether ecological effects are occurring at a particular site through comparison of the species assemblages to those that would typically be expected given natural physical and chemical habitat characteristics (e.g., organic content, alkalinity).

Study design considerations such as sediment processing techniques can have an important effect on the resolution and conclusions drawn from benthic community studies. Sieving and sorting of bulk sediment samples is required to separate the benthic invertebrates from the sediments for species identification. The selection of the minimum sieve size for processing affects the benthic community analysis, as smaller invertebrates will not be retained if a coarse sieve (e.g., 500 µm) is used for sediment processing. Given the predominance of smaller-bodied organisms noted in several studies of KIH sediments (e.g., ESG 2003; ESG unpublished data, 2006), it would appear that processing sediments with sieve sizes >250 µm may not present an accurate assessment of benthic community structure.

Both univariate and multivariate statistical approaches may be used for analyzing the benthic invertebrate community and associated environmental data. In the univariate approach, measures have been developed to simplify the benthic community information into a single metric to assess community structure. Typical measures include the total number of taxa and the dominant taxa, as well as diversity and biotic indices. However, environmental data usually involve many variables and therefore the multivariate approach may be more appropriate because it searches for patterns in the data matrix, usually on a species-by-site matrix. The advantage of this approach is that it allows for the examination of spatial and temporal trends in benthic communities influenced by several environmental variables (Clarke and Ainsworth 1993). The COA framework strongly recommends the use of a multivariate approach to analyze benthic community structure.

Use of a consistent taxonomic identification scheme for the reference sites and potentially impacted sites is crucial for the accurate detection of differences. The taxonomic specialist contracted for the benthic community analysis of KIH sediment samples collected in 2007 and 2008 also completed the taxonomic identifications for the Great Lakes reference sites.

Step 4c of the COA framework assesses whether the benthic community is impaired. The framework first asks whether it is appropriate or realistic to assess the benthic community structure, as regions of high bed scour or shallow areas with a large amount of propeller wash would not be deemed appropriate for these types of analyses. In the case of the Kingston Inner Harbour, samples were collected away from the Rideau Canal navigational channel to avoid areas in which high amounts of boat traffic would be expected to disturb sediment communities. An earlier benthic community analysis of two KIH locations indicated that the technique appears to be useful in assessing ecological effects (ESG 2003). The second part of the COA framework then asks whether the benthic community at the site is significantly different from that in appropriate reference areas.

The main objective in this study is to use benthic invertebrates as an indicator of ecosystem conditions in the Kingston Inner Harbour and to determine whether the benthic community structure differs significantly from reference sites. Benthic community structure is described in terms of univariate metrics and also involves multivariate analysis for full characterization. This section summarizes those findings, with particular attention to defining the magnitude and spatial extent of any impairment observed.

A. Methodology

1. Sample Collection

In 2007 (November 9) and 2008 (November 4), nine locations within the KIH were sampled and assessed for benthic invertebrate community structure. Sample collection took place in late fall, after most species had mated and the larval stages had had the opportunity to develop throughout the summer in preparation for overwintering. Seven stations were in the area south of Belle Island and the Kingston Rowing Club; two were upstream of Belle Island and represent potential reference sites (Appendix B, Map B-III-11).

At each sample location, samples were collected for chemical and physical analyses of sediment and overlying water as well as for benthic community analyses. Environmental variables measured are listed in Table III-2. Details on sampling techniques and methods for sample collection follow the sampling methodology described in Reynoldson et al. (2000). Before sediment collection, water samples were obtained 0.5 m from the lake bottom using a van Dorn sampler. Temperature, conductivity, pH and dissolved oxygen were measured at each station using a YSI 600QS water quality instrument. Samples for alkalinity, total phosphorus, total Kjeldahl nitrogen, nitrites/nitrates (NO_3/NO_2), total ammonia (NH_4^+) and TOC were dispensed to appropriate containers and stored at 4°C for later analysis.

At each station a minimum of three 8.2 L Ponar grabs of surface sediments were retrieved and homogenized in plastic containers. The sediments were stirred for several minutes using a stainless steel scoop, and three 500 mL subsamples were collected and preserved in 5 percent formalin for later identification. Benthic community samples were transferred to 70 percent ethanol after a minimum of 72 hours in formalin.

Table III-2: Environmental variables at stations BC 1 to BC 9

Environmental variables	Test sites							Reference sites	
	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9
Cu (ppm)	45	41	43	47	55	32	43	29	27
Ni (ppm)	30	28	31	32	35	24	29	25	21
Co (ppm)	20	15	15	17	35	13	15	13	11
Pb (ppm)	115	108	108	141	152	71	105	32	48
Zn (ppm)	178	161	170	190	184	119	155	104	110
Cr (ppm)	653	826	777	1199	1360	933	879	50	42
As (ppm	17	5	5	6	32	4	5	2	2
Alkalinity	105	98	86	91	98	104	117	80	97
TOC %	9.2	8.1	7.5	5.6	8.9	4.2	4.1	8.4	19.2
Hg (ppm)	0.17	0.97	0.33	0.33	0.73	0.17	0.33	0.17	0.33
PAHs (ppm)	700	2	2	6	2	2	6	2	6
PCBs (ppm)	0.42	0.03	0.69	0.06	0.42	0.18	0.00	0.03	0.00
Phosphorus—total (ppm)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Oxygen (%)	107	108	106	108	120	103	97	104	109
pH	8.7	8.6	8.6	8.7	9.2	8.3	8.0	8.5	9.1
Temperature (C)	8.5	7.9	5.4	5.2	8.2	4.2	4.0	4.7	6.4
Depth (lake) (m)	1.0	1.3	1.5	1.4	1.2	0.7	0.6	0.7	1.0
Clay (%)	41.7	56.7	36.2	36.3	57.2	32.8	37.8	24.6	53.5
Silt (%)	48.8	39.6	50.2	52.9	40.7	54.6	54.2	55.2	42.2
Sand (%)	9.3	3.7	13.6	10.8	2.2	12.5	8.0	20.1	4.3

2. Taxonomic Identification

Each benthic community sample was sieved though a 250 µm mesh, then subsampled according to CABIN procedures (Reynoldson et al. 2000) using a Marchant box subsampling device (Marchant 1989), which consists of a box divided into 100 cells. The objective of subsampling is to recover macroinvertebrates in relation to their abundance in the sample and provide a statistically robust estimate for their representation at the site. The taxa Porifera, Nemata, Copepoda, Cladocera, Plathelminthes and Ostracoda are not included in the 300-organism subsample count because they are not considered part of the macroinvertebrate community (Reynoldson et al. 2000). The organisms in these taxa were counted separately and recorded in a spreadsheet.

Invertebrates in the benthic community samples were sorted, identified to the family level, and enumerated by a certified taxonomist. Slide mounts were made for Oligochaeta and Chironomidae and identified to family using high-power microscopy.

3. Quality Assurance/Quality Control

a. <u>Benthic community sorting efficiency</u>

To evaluate control measures for benthic invertebrate enumeration, randomly selected samples that had already been sorted were re-sorted, and the number of new organisms found was counted. The percent of organisms missed (%OM) was calculated using the equation:

%OM = # organisms missed/total organisms found × 100

Sorting efficiency for this study was determined by re-sorting four replicate samples (or 15 percent of all replicate samples) using two separate sorters. The average %OM for the community samples was 1.2, which is an acceptable low level, indicating that there was good recovery (>95%) of organisms in the sample.

4. Data Analysis

a. <u>Univariate measures of community structure</u>

1) Taxa Richness

This measure is the total number of taxa present across the samples.

2) Shannon-Wiener Diversity Index (H)

The Shannon-Wiener Diversity Index (H) is commonly used to assess the number and distribution of taxa (biodiversity). As the biotic diversity within the community increases, so does the value of "H" (Barbour et al. 1999).

3) Pielou's Evenness

Evenness or equitability expresses how evenly the individuals are distributed among taxa. Low evenness indicates that the sample is dominated by one species.

4) Family Biotic Index (FBI, Metric 2)

The Family Biotic Index was originally developed by Hilsenhoff (1982) to provide a tolerance value for organic nutrient pollution, which is the average of the tolerance values assigned to all species within the benthic community. The Biotic Index was subsequently modified to the family level with tolerance values ranging from zero (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution, creating the Family Biotic Index (FBI). The FBI is calculated by multiplying the tolerance value for each family of species by the quantity of that species found in the sample, summing the results for all the different species and dividing the result by the total number of taxa in the sample. The tolerance numbers used in this study were obtained from Mandaville (2002).

5) Percent Shredders

The Shredder index is independent of taxonomy, since some families may represent several functional feeding groups (Plafkin et al. 1989). When compared with a reference site, shifts in the dominance of a particular feeding group correspond to the abundance of a particular food source, which reflects a specific type of impact on the community (Plafkin et al. 1989).

6) Ephemeroptera, Plecoptera, and Trichoptera (EPT) Index

The EPT index represents the taxa richness of species of mayflies, stoneflies and caddisflies, which are considered to be sensitive to pollution and therefore should increase with improved water quality. Initially developed for species-level identifications, this index is valid for use at the family level (Plafkin et al. 1989). The EPT Index is equal to the total number of families represented within these three orders in the sample. Numbers above 10 are indicative of excellent water quality, 6 to 10 represent good water quality, 2 to 5 represent fair water quality, and values less than 2 are typical of poor water quality (Watershed Science Institute 2008).

b. Multivariate analysis

The COA framework strongly recommends the use of multivariate approaches in benthic community data interpretation. The advantage of multivariate analyses is that they are able to integrate many variables into one analysis, and are particularly useful in identifying patterns in matrices of environmental data such as benthic community species composition. A number of multivariate analyses were used to evaluate the benthic community composition at sampling stations throughout the KIH. Descriptions of these approaches follow.

1) CABIN/BEAST analysis

The benthic data were entered into the Canadian Aquatic Biomonitoring Network (CABIN) online database (http://ec.gc.ca/rcba-cabin) and evaluated using the BEnthic Assessment of SedimenT or BEAST approach, developed by Environment Canada (Reynoldson and Day 1998; Reynoldson et al. 2000). CABIN is maintained by Environment Canada and has been developed in response to the need for a national standardized method to assess the ecological conditions of Canada's freshwater environments. As part of the BEAST methodology, benthic community composition is compared with a large data set of Great Lakes reference sites. Selection of reference sites is intended to establish baseline conditions for selected endpoints and to determine what constitutes a "normal" range of biological variability. Test sites are matched to predefined groups of reference sites based on habitat characteristics related to geographic location, water depth, TOC and alkalinity. In general, a test site is considered a good match to a reference group if its probability of belonging to the group is at least 60 percent.

The BEAST model predicts the invertebrate community group that should occur at a test site based on natural environmental conditions. Benthic community assessments were conducted at the family level, as this taxonomic detail has been shown to be sensitive for the determination of stress (Reynoldson et al. 2000). Community data for the test sites were merged with the reference site invertebrate data of the matched reference group (the group to which the test site has the highest probability of belonging) only and were ordinated using hybrid multidimensional scaling, with Bray-Curtis distance site × site association matrices calculated from raw data.

2) Multivariate analyses

Multivariate analyses were conducted on biotic and abiotic KIH samples alone to complement the BEAST analyses and evaluate benthos-habitat relationships. For most analyses, nonparametric multivariate techniques were used. Multivariate analyses were carried out using PRIMER (Plymouth Routines In Multivariate Ecological Research, developed at the Plymouth Marine Laboratory, Plymouth, UK, cited in Clarke and Warwick 2001). The statistic chosen to examine relationships between similarity and distance was a Spearman rank correlation coefficient, ρ.

Relative species abundances were log-transformed (log(x+1)) to adjust for the influence of numerically dominant species on inter-sample similarities. Similarity matrices for log-transformed species relative abundances were calculated using the Bray-Curtis similarity coefficient (Bray and Curtis 1957), which has many properties amenable to ecological data, such as independence from scale of measurement and joined absences (Clarke and Warwick 2001).

Similarity matrices were then subjected to cluster analysis and ordination. Clustering was by hierarchical, agglomerative method, employing group-average-linking; the results are displayed in a dendrogram.

Ordination of biotic and environmental data was by non-metric multidimensional scaling (MDS). MDS is the most robust ordination technique using only rank order information. Ordination constructs a "map" of samples, usually in two dimensions, in which the location of the samples reflects the similarity of their biological communities. Distances between samples match the corresponding dissimilarities in community structure: nearby sites have very similar communities, while samples that are far apart have few species in common. The stress coefficient is the extent to which the relations can be adequately represented in a two-dimensional map. Stress values above 0.3 have to be treated with caution, because they indicate that sample points are close to being arbitrarily placed in the two-dimensional ordination space. Environmental data were normalized and a resemblance matrix based on Euclidean Distance was calculated. Significance tests for differences between test and reference sites were performed using the ANOSIM (analysis of similarities) permutation test (Clarke and Green 1988).

The relationships between community structure and environmental variables were examined using the BIOENV procedure (Clarke and Ainsworth 1993), which calculates rank correlations between a similarity matrix derived from biotic data and matrices derived from the environmental variables. This procedure is used to define subsets of environmental variables that best explain the biotic structure. PCA analysis on the normalized environmental variables was performed using Canoco version 4.5 (ter Braak and Smilauer 2002).

B. Results

1. Benthic Invertebrate Community

A total of 114 benthic invertebrate taxa were identified in the benthic community samples collected in the Kingston Inner Harbour. The most taxa-rich families were the chironomids (46) and the oligochaetes (naidids, 11). Caddisflies (Leptoceridae), amphipods (*Hyalella*, *Gammarus*) and gastropods (Planorbidae, *Pyrgulopsis*, *Valvata*) were also represented in the samples. A detailed list of benthic species and families is presented in Appendix D, Table D-III-7.

The number of taxa per station ranged from 13 to 59 (Figure III-11). The highest number of taxa (n=59) were found at stations BC1 and BC2, located east of the Kingston Rowing Club. The lowest number of taxa were identified at the reference station BC8, west of the Rideau Marina. It is difficult to compare taxa richness with other studies because they use different sample procedures (i.e., sieving through a 500 µm mesh in the 2004/2005 study and a 125 µm mesh in 2001 versus a 250 µm mesh in this study).

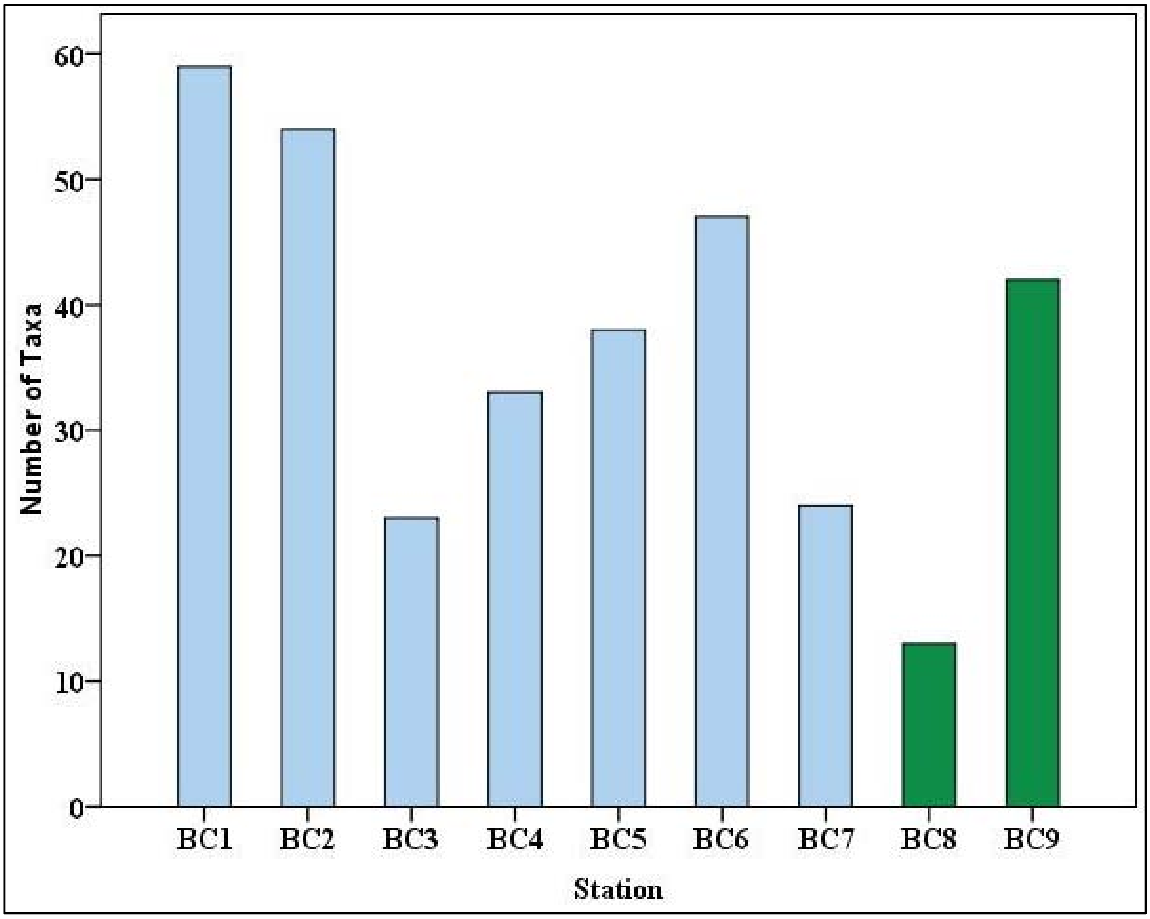


Figure III-11: Number of taxa in benthic community samples collected in the KIH. Green bars are reference sites.

The mean relative abundances of the predominant invertebrate groups are shown in Figure III-12. Chironomids were present at all stations in greatest abundances, comprising 30 percent (BC7) to 85 percent (BC8) of the macroinvertebrate community. The most abundant genera within the chironomids were, in order of importance, *Orthocladius*, *Paratanytarsus*, *Glyptotentipes*, *Ablabesmyia*, *Psectrocaldius*, *Polypedium* and *Tanytarsus*. All of these genera are tolerant to organic (nutrient) enrichment, with the latter two genera also found in less organically enriched environments. Additional important taxonomic groups were caddisflies, oligochaetes and amphipods.

Caddisflies accounted for up to 44 percent of the relative abundance, with highest abundances at the two stations close to the southern shoreline of Belle Park, BC6 and BC7. At station BC4, further south, relative abundances of up to 15 percent were recorded. The caddisfly group was comprised almost entirely of the species *Leptocerus americanus*, a species that grazes on plants or scrapes algae from surfaces.

The oligochaete community consisted of species from two families, Naididae and Enchytraeidae, with the naidids being the most abundant. Highest oligochaete abundances (>10 percent) were found at BC7, the station closest to the discharge area of the South Stream and the Kingscourt storm sewer in the southwest corner of the KIH.

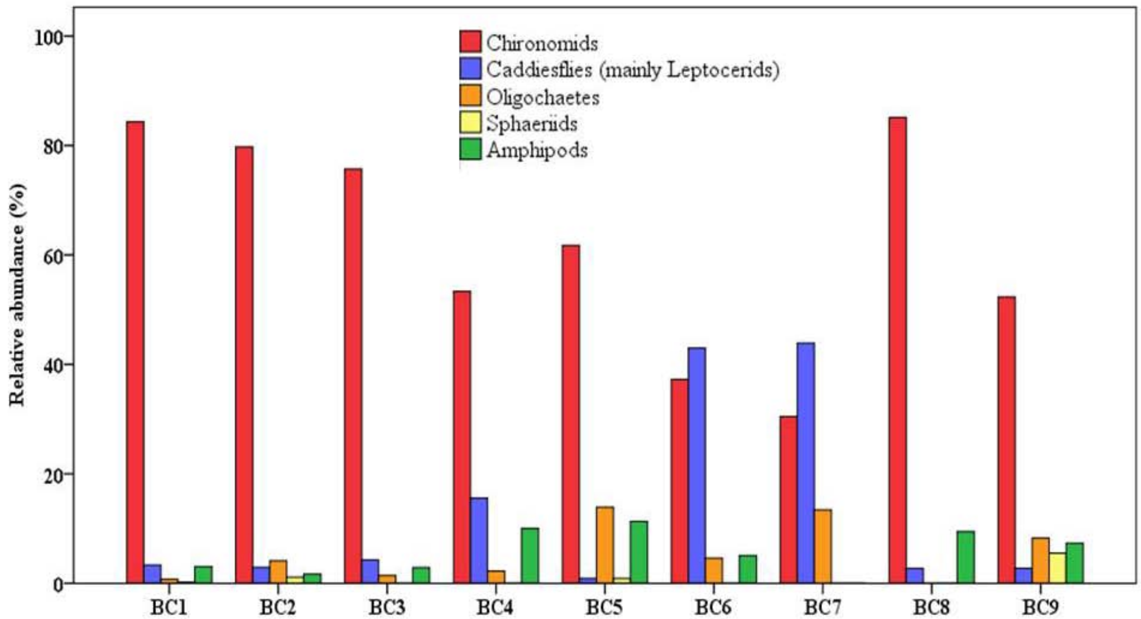


Figure III-12: Mean relative abundances of the major taxonomic groups in benthic community samples collected in the KIH.

Amphipods were present in abundances higher than 10% at BC4 and BC5 as well as at reference sites BC8 and BC9. Mayflies occurred only in very low relative abundances (<1.5%), and stoneflies were absent.

Similar to previous studies (ESG 2003; Tinney 2006), all stations were dominated by taxa that are tolerant to organic (i.e., nutrient) pollution. Tinney (2006) collected benthic invertebrate data at 10 stations within the KIH in support of a benthic community assessment in 2004 and 2005. During the three sampling seasons undertaken by Tinney (2006), pollution-tolerant tubificids, chironomids, Asselidae and Hirudinea were identified in the KIH. Bivalves, caddisflies and amphipods were also found in the sediments.

2. Evenness

Evenness of the benthic communities at stations BC1 to BC9 is shown in Figure III-13. Evenness measures the relative distribution of abundances across the taxonomic categories: an evenness of 1 means that the abundances are distributed equally among taxonomic groups, while an evenness of 0 means that one species is dominant. Evenness among the stations ranged from 0.7 to 0.9, indicating that the benthic community structure is dominated not by only one family but by several. There were no significant differences in evenness between test sites (BC1–BC7) and reference sites (BC 8 and BC9) (ANOVA, F=0.74, p<0.42).

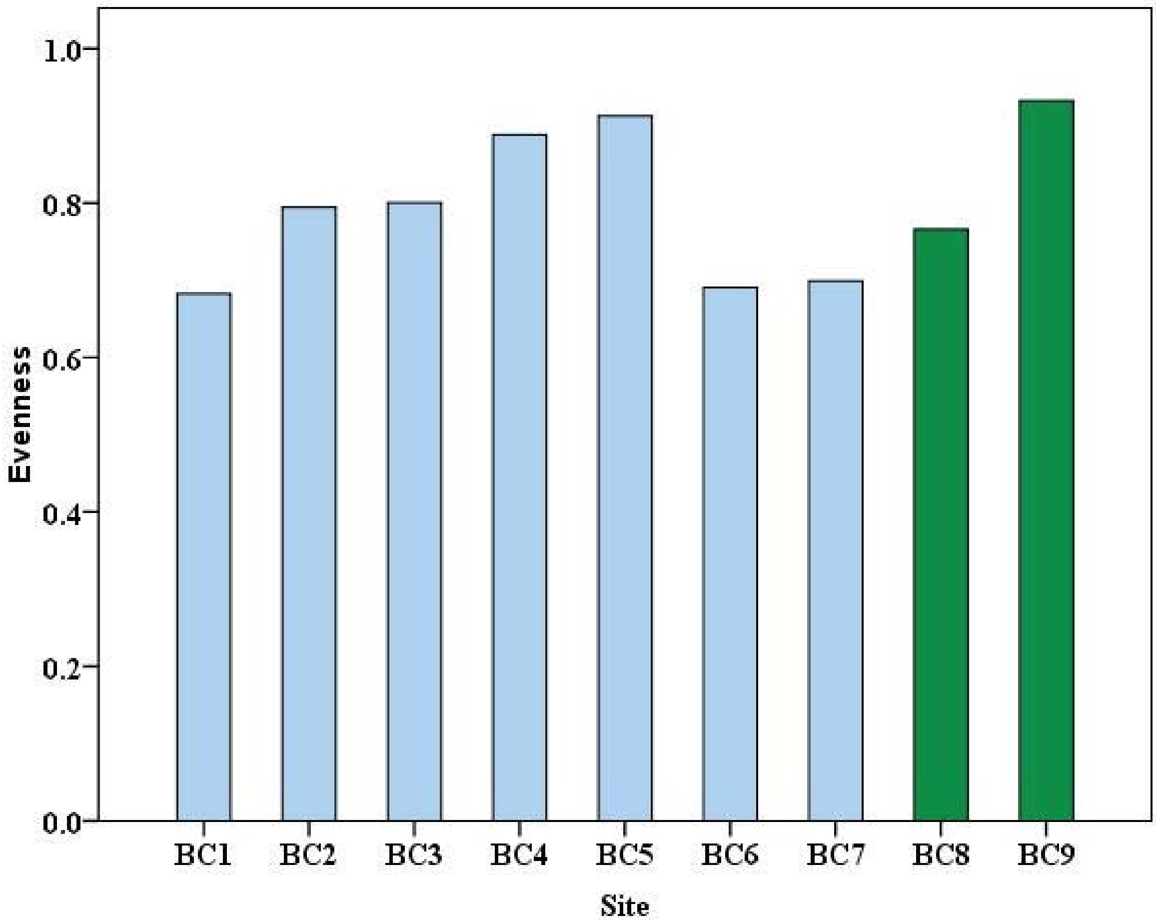


Figure III-13: Evenness of benthic communities in samples collected in the KIH. Green bars represent reference sites.

3. Shannon-Wiener Diversity

Shannon-Wiener diversity at stations BC1 to BC9 is shown in Figure III-14; higher values indicate higher biodiversity. Shannon-Wiener diversity ranged from 1.9 at BC8 to 3.6 at BC9, with the lowest and highest biodiversity encountered at the two reference sites. Shannon-Wiener diversity is highest at BC9, the reference site north of Belle Island, and at BC5.

Biodiversity of the samples collected in 2007 and 2008 is slightly higher than values reported in previous studies: Shannon-Wiener diversity ranged from 0.7 to 3.3 in samples collected in 2001 (ESG 2003) and from 0.5 to 2.2 for samples collected in 2005 (Tinney 2006). The differences in Shannon-Wiener diversity between sampling events may be explained by the use of different sieving techniques, when more or fewer species may be retained. There were no significant differences in Shannon-Wiener diversity between test sites (BC1–BC7) and reference sites (BC 8 and BC9) (ANOVA, F=0.05, p=0.82)

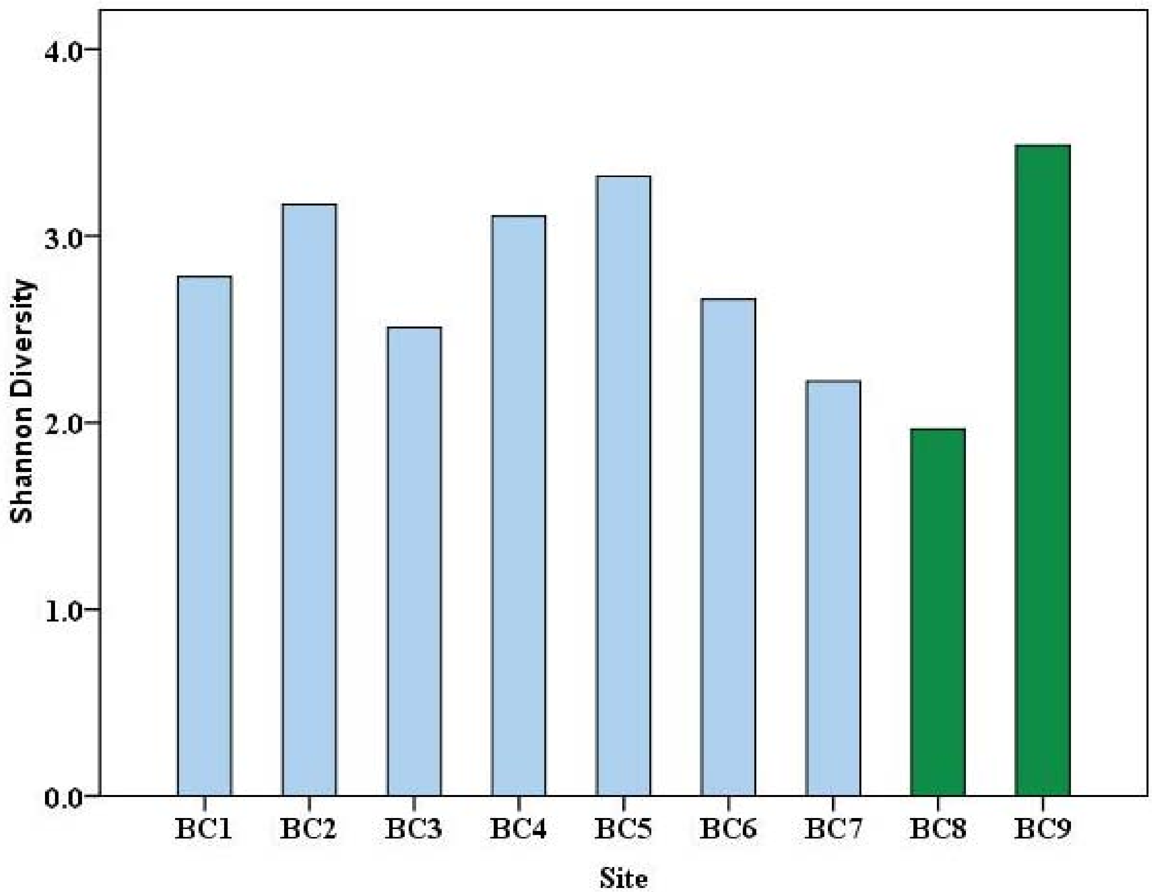


Figure III-14: Shannon-Wiener diversity in benthic communities at stations collected in the KIH. Green bars represent reference sites.

4. Family Biotic Index

The FBI provides an indication of tolerance values for a community as a whole. Higher numbers indicate higher tolerance to organic enrichment, which is an indicator that the habitat may be degraded. One of the limitations of the FBI is that tolerance indices represent only tolerance to eutrophication and not tolerance to other contaminants, such as metals, pesticides and acidity. The FBI scores for stations BC1 to BC9 are shown in Figure III-15. The FBI for test and potential reference stations ranged from 6.1 to 6.9, indicating substantial to very substantial organic enrichment. There were no significant differences in FBI scores between test sites (BC1–BC7) and reference sites (BC 8 and BC9) (ANOVA, F= 0.202, p<0.66).

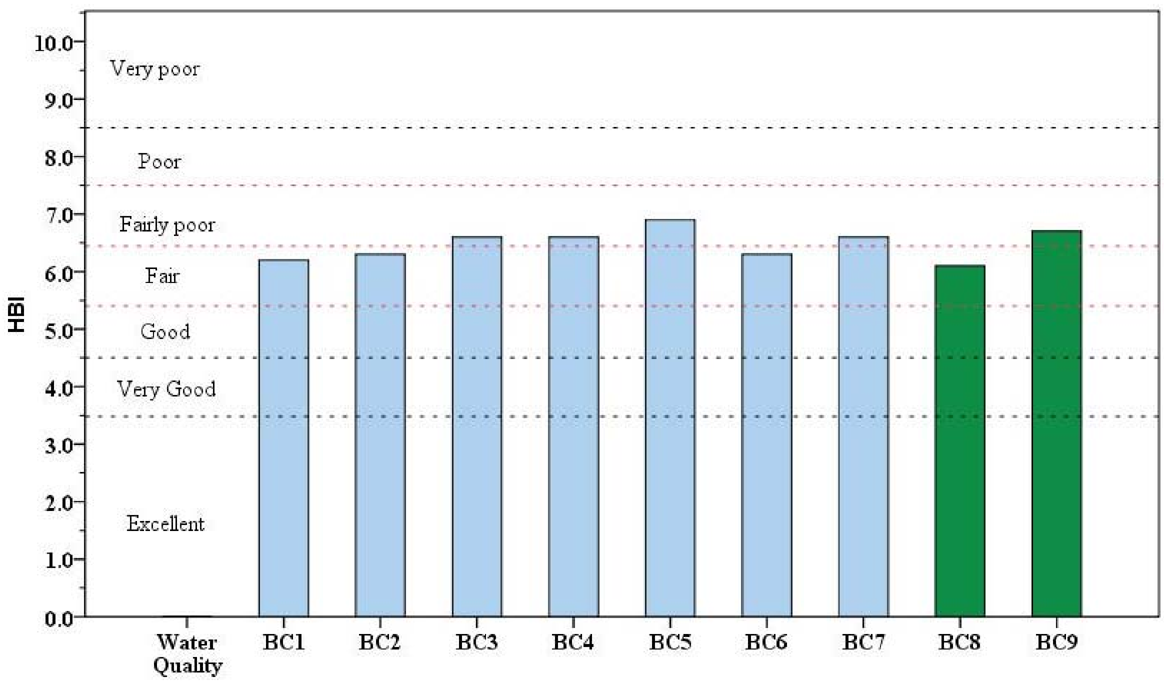


Figure III-15: FBI for benthic invertebrate communities in the KIH. Green bars represent reference sites.

5. Number of EPT taxa

The number of Ephemeroptera, Plecoptera and Trichoptera taxa (Figure III-16) ranged from 1 to 4 at all stations and generally indicated poor water quality. EPT taxa considered in this index are usually very sensitive to oxygen depletion. In naturally eutrophic systems such as the Great Cataraqui River, these families may be less abundant because high biological productivity is associated with excessive algal growth and can result in oxygen-poor conditions, which these taxa cannot tolerate. There were no significant differences in number of EPT taxa between test sites (BC1–BC7) and reference sites (BC 8 and BC9) (ANOVA, F=-0.18, P=0.67).

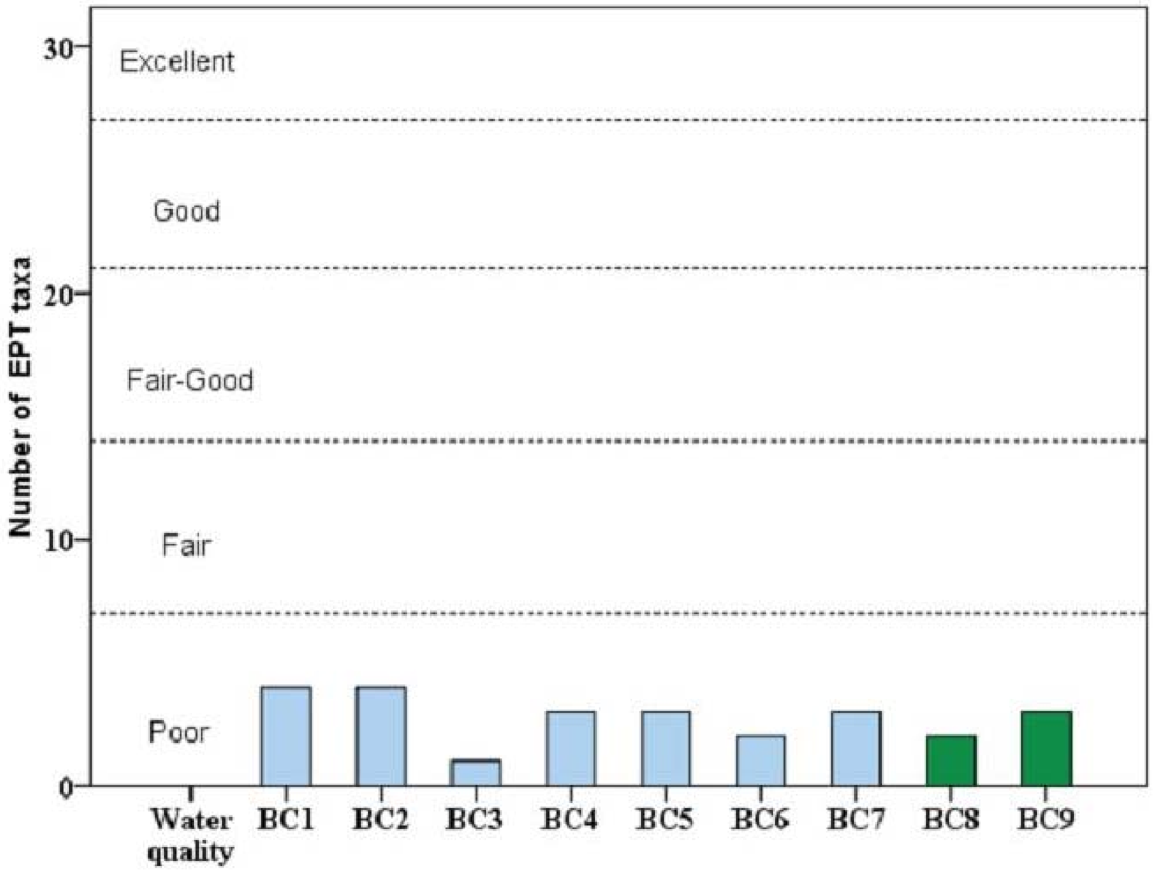


Figure III-16: Relative percentage of EPT taxa in the benthic communities of stations BC1 to BC9. Green bars represent reference sites.

6. Percentage Shredders

The percentage of shredders was highest at BC6 and BC7, the two locations closest to the south shore of the Belle Park Landfill, and at BC2 (Figure III-17). While BC2 shows a high percentage of shredding chironomid and gastropod species, the communities at BC6 and BC7 are dominated by *Leptocerus americanus*, an herbivore species that grazes on periphyton and shreds larger plants and detritus. *Leptocerus* make their case out of organic matter that is found in slow parts of flowing waters and shallow areas of lakes and ponds where debris can accumulate and where the case will not be swept away. Caddisflies have a large range of tolerance to organic nutrient pollution, and some species can actually thrive in conditions with elevated nutrients because they cause more periphyton, a favourite food, to grow. *Leptocerus* can tolerate some organic pollution (Bode et al. 1996). A high abundance of caddisflies from sampling stations south of Belle Park has also been reported by Tinney (2006), but he also points out that some caddisfly species shed their cases when they molt (Merrit and Cummins 1996), which may cause overrepresentation of cases in surface sediments. There were no significant differences in percentage of shredders between test sites (BC1–BC7) and reference sites (BC8 and BC9) (ANOVA, F=0.5, p=0.49).

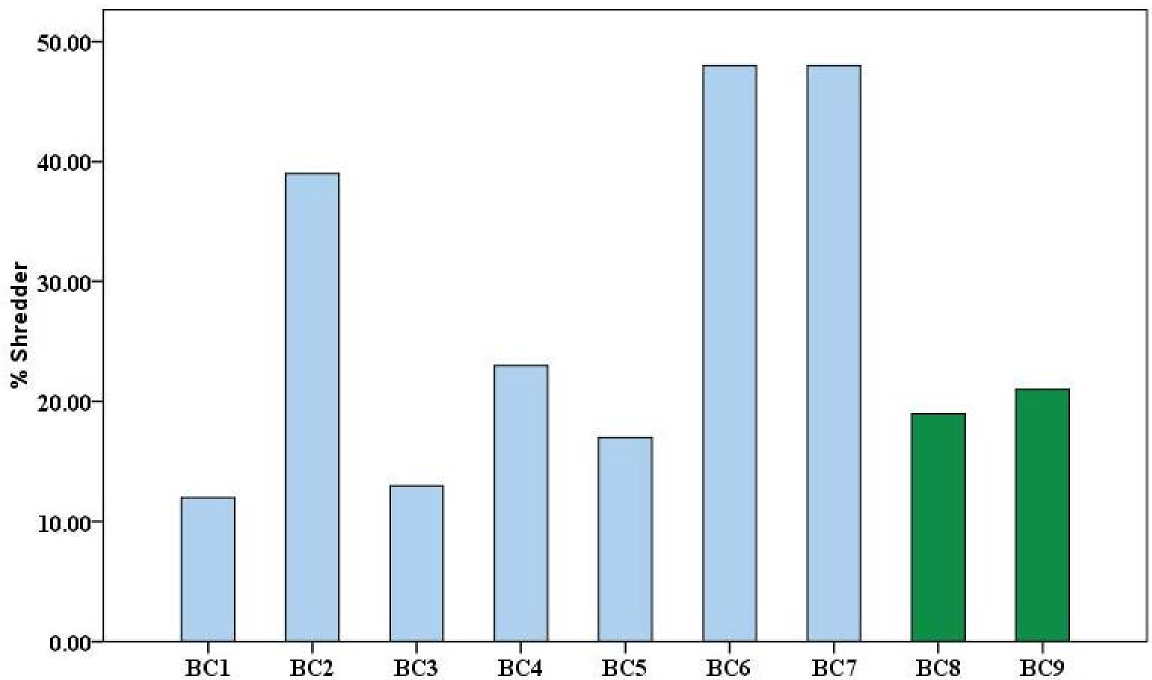


Figure III-17: Relative percentage of shredders in the benthic communities at stations BC1 to BC9. Test sites are represented by blue bars, while green bars represent potential reference sites.

7. *Multivariate Analyses of Macroinvertebrate Communities*

a. <u>BEAST</u>

Results from the BEAST community assessment, performed at the family level, are summarized in Table III-3. All seven test sites were maximally (100 percent) predicted to the Great Lakes Reference Groups based on the BEAST model and five habitat attributes (alkalinity, depth, total organic carbon, latitude and longitude). For each test site, the model assigned a probability of it belonging to each of five reference faunal groups.

Stations BC1, BC3, BC4, BC6 and BC7 were assigned to Reference Group 1 with a probability of at least 0.97. For stations BC2 and BC 5, the probability of belonging to Reference Group 3 was 1.

Table III-3: Results from BEAST analyses for the KIH stations

Station	Sampling date	Probability of group membership					BEAST Assessment
		Group 1	Group 2	Group 3	Group 4	Group 5	
BC1	Nov 4, 2008	***0.97***	0.01	0.01	0.00	0.01	***Severely stressed***
BC2	Nov 4, 2008	0.00	0.00	***1.00***	0.00	0.00	***Severely stressed***
BC3	Nov 9, 2007	***0.99***	0.00	0.00	0.00	0.00	Potentially stressed
BC4	Nov 9, 2007	***0.98***	0.01	0.01	0.00	0.01	***Severely stressed***
BC5	Nov 4, 2008	0.00	0.00	***1.00***	0.00	0.00	Unstressed
BC6	Nov 9, 2007	***0.97***	0.01	0.02	0.00	0.01	***Severely stressed***
BC7	Nov 9, 2007	***0.98***	0.01	0.01	0.00	0.01	***Severely stressed***
BC8*	Nov 9, 2007	***0.98***	0.01	0.01	0.00	0.01	***Stressed***
BC9*	Nov 9, 2007	***0.98***	0.01	0.01	0.00	0.01	***Stressed***

*Reference sites

Results of the BEAST community assessment indicate that five (BC1, BC2, BC4, BC6, BC7) of the seven test sites were evaluated as severely stressed, one was evaluated as potentially stressed (BC3) and one was evaluated as unstressed (BC5). A map showing the level of benthic community alteration by site is shown in Appendix B, Map B-III-11. The two stations that are less stressed according to BEAST are a station located south of Belle Park, close to the former Davis Tannery property shoreline (BC3), and the outermost station (BC5).

Comparing the KIH taxa abundances to the mean of the Great Lake Reference stations shows that the KIH sites are clearly dominated by nutrient-tolerant taxa. While chironomids of the Great Lakes sites have a mean abundance of 16 percent, abundances for the KIH sites range between 52 and 85 percent. The high percentage of organic enrichment-tolerant taxa at the reference sites is probably the reason why the reference stations are classified as stressed. However, it remains unclear why station BC5 is classified as unstressed despite the high percentages of chironomids and oligochaetes. The presence of amphipods may have an influence on this classification.

Although not a CABIN requirement, the benthic community composition of the two reference sites was evaluated using the BEAST method. BC8 and BC9 were assigned to Reference Group 1 with a probability of 0.98. The results of the BEAST community assessment suggest that both potential reference sites are stressed, indicating either that BC8 and BC9 may not be in reference condition or that the BEAST analysis is not appropriate. A PCA was performed to test whether the BEAST reference sites were suitable for comparison with the KIH sites. The ordination based on benthologically important environmental variables (grain size, sediment TOC, depth and alkalinity) for selected Lake Ontario BEAST sites showed that the nine KIH sites lie within the range of the Lake Ontario reference sites along the first PC axis, which was the only significant axis, indicating that the Lake Ontario reference sites are an appropriate comparison for the KIH sites (Grapentine unpublished data, 2010; see Appendix H, Figure H-III-1).

b. Benthic community and habitat structure

To evaluate benthos–habitat relationships, multivariate analyses were conducted on the benthic community structure and environmental variables of the KIH samples alone.

1) Similarity between station replicates

The first step in analyzing the benthic community structure was to explore similarities among replicates to confirm that replicate samples within sites were closer together than samples from different sites. ANOSIM permutation tests were performed to test whether there were any significant differences between replicates.

Figure III-18 displays the results of a cluster analysis on the family-level abundance data of the KIH replicate samples. The dendrogram indicates that for stations BC1, BC2, BC5, BC7 and BC9, the three replicates are very similar to each other. Two of the replicates for stations BC4, BC6 and BC8 appear closely related to each other, while replicates from station BC3 appear quite different from each other.

Figure III-19 shows the two-dimensional MDS plot of the same taxa similarities. The stress level of 0.18 indicates a fairly good two-dimensional picture and was crosschecked by the superimposition of groups from cluster analysis. At a 20 percent similarity, two groups were formed, and at 40 percent similarity level, seven groups were determined. Replicates within most stations are grouped in very close proximity, indicating good agreement in benthic community composition for the field replicates. An exception is the replicates of stations BC3, which seem to be quite distinct. ANOSIM indicates a significant separation among the nine stations ($p<0.004$, $R=0.61$).

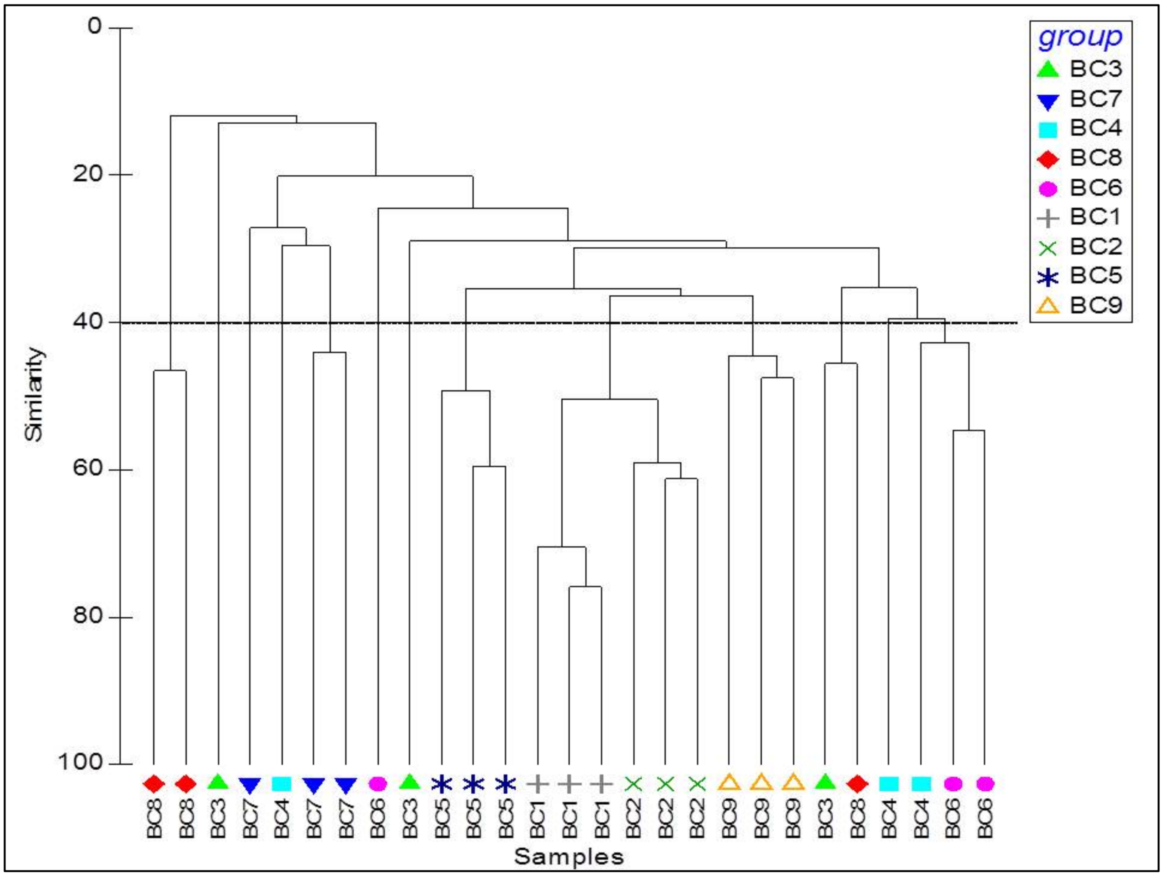


Figure III-18: Dendrogram of benthic invertebrate communities for three replicates from each of the nine KIH sampling stations. BC8 and BC9 represent upstream reference sites.

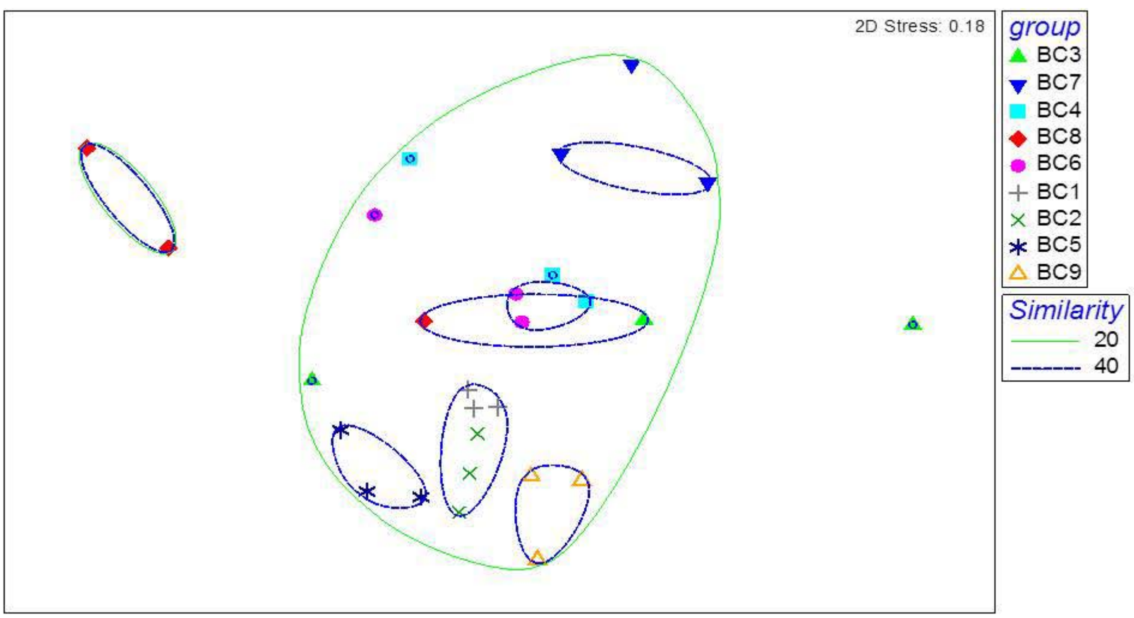


Figure III-19: NMDS of benthic invertebrate communities for the replicates from each of the nine KIH samples with superimposed clusters from Figure III-18 at similarity levels of 20 percent (continuous line) and 40 percent (dashed line).

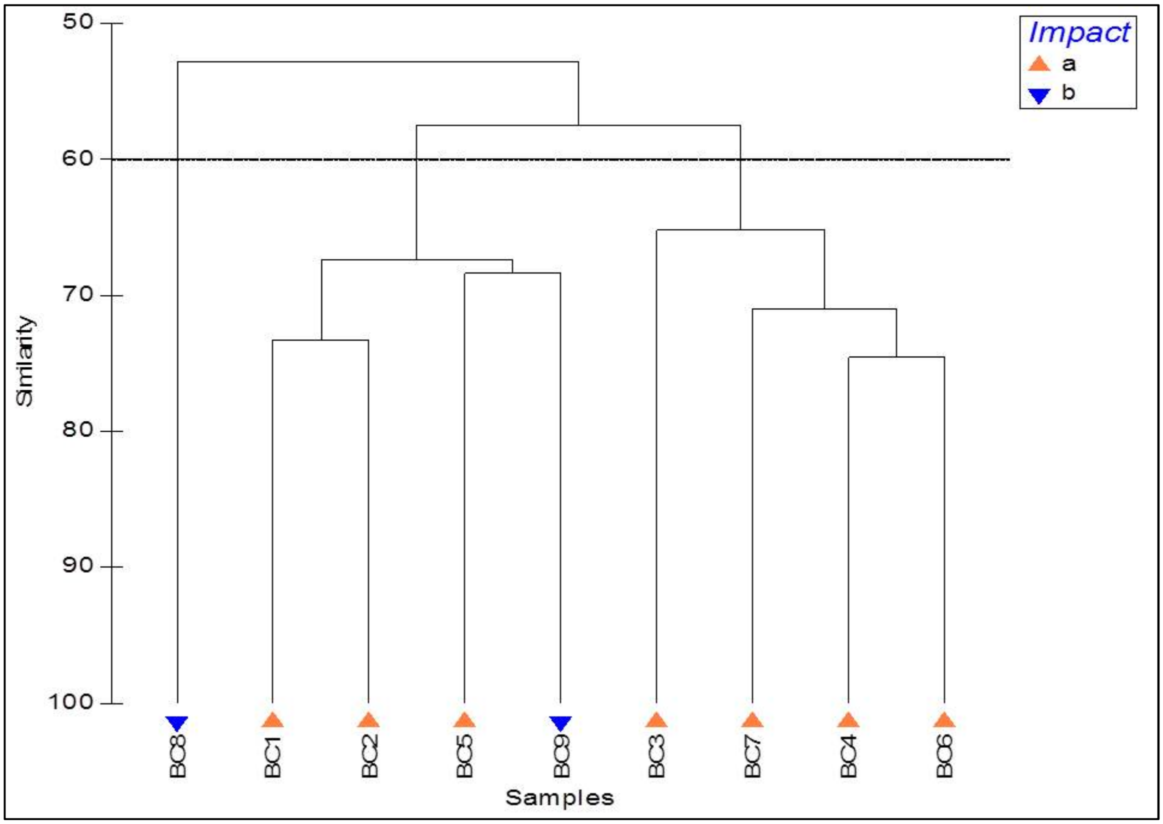


Figure III-20: Dendrogram of the benthic invertebrate community structure of the KIH sampling stations. Blue triangles indicate upstream reference sites.

2) Similarity between stations

As a next step, the benthic community abundance data of the field replicates were combined for each station and cluster analysis was performed to classify the sites based on their similarity to one another. The dendrogram (Figure III-20) shows that BC8 is clearly distinct from the remaining stations. The cluster analysis also suggests a division of sites into two main groups: group 1, consisting of stations BC1, BC2, BC5 and BC9, and group 2, consisting of stations BC3, BC7, BC4 and BC6. The reference station BC9 is grouped with the most southern stations and the ones closest to the Kingston Rowing Club.

MDS on the family-level abundance data of the stations (Figure III-21) also shows that the reference site BC8 can be distinguished from all other sites based on the second axis, with BC8 being clearly distinct in the upper right corner. It is challenging to describe the community composition at either axis extreme, because chironomids and oligochaetes are predominant at all sites. Nevertheless, the first axis seems to be correlated with increasing amphipod abundance and the second axis with decreasing abundances of Naididae (oligochaetes) and gastropods. At a similarity level of 60 percent, reference site BC8 is clearly separated from the two site groups consisting of BC3, BC4, BC6 and BC7 and BC1, BC2, BC5 and BC9. The stress level of 0.1 indicates that the benthic community structure is well presented in two dimensions. One-way ANOSIM test suggests that the benthic community structure is significantly different between test and reference sites ($R=0.468$, $p<0.02$).

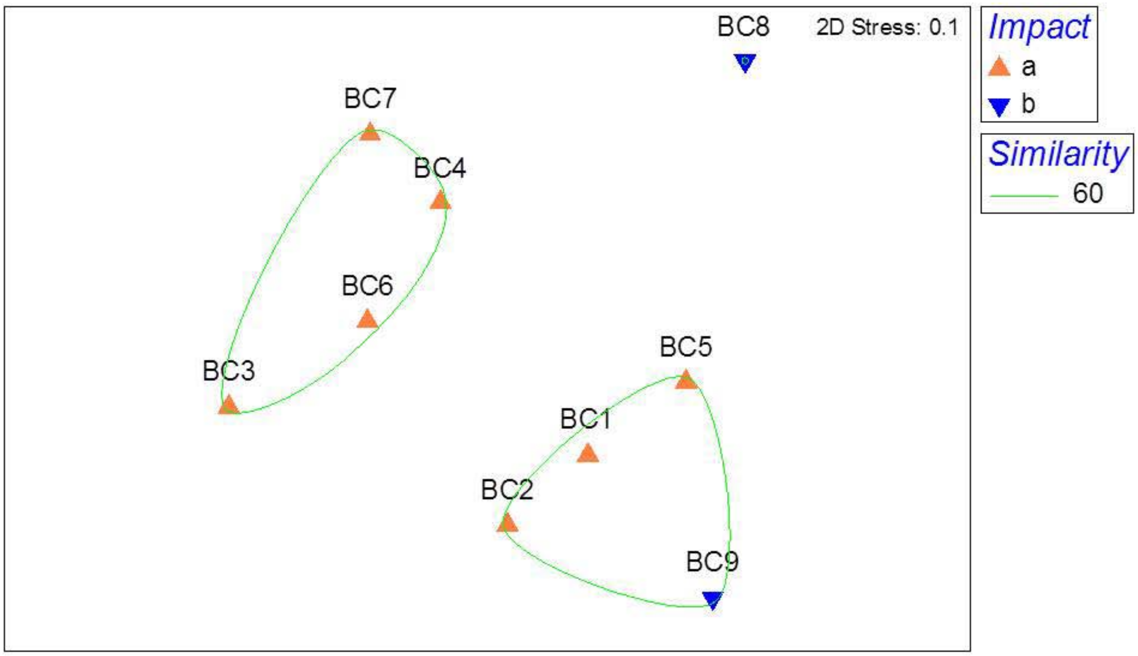


Figure III-21: Non-metric multidimensional scaling ordination for log(x+1)-transformed macroinvertebrate abundance data (stress=0.1) for each of the KIH sampling stations with superimposed clusters from Figure III-19 at a similarity level of 68 percent. Blue triangles indicate upstream reference sites.

3) Similarity between species and habitat variables

Multivariate analysis was also performed on the environmental data. MDS ordination of the normalized environmental variables (Appendix H, Figure H-III-2) shows that the reference sites are separated from test sites along the first axis, similar to the MDS performed on the biotic data. BC5, where the highest Cr concentration was determined, is clearly separated from the test and reference sites. The small stress value of less than 0.5 indicates an excellent representation of the samples in a two-dimensional plot.

In a next step, the benthic community structure was related to the multivariate descriptions of the environmental variables to find a subset of environmental variables that explain the observed biotic pattern. The BIOENV analysis was used to search for the explanatory environmental variables that best explain the species data.

The BIOENV results indicate that four environmental variables give the highest rank correlation ($\rho=0.64$, $p<0.03$) between biotic and abiotic similarity matrices. Listed in order of importance, the environmental variables that explain a significant portion of the benthic invertebrate structure in the KIH are related to grain size (% sands and % clays), sediment Cr concentrations and water alkalinity (Table III-4).

Table III-4: Summary of results from BIOENV giving the Spearman rank correlation for the environmental variables that best explain the biotic data

Spearman Rank Correlation	Environmental variable
0.51	% sand in grain size
0.48	% clay in grain size
0.36	Cr concentrations
0.27	Alkalinity

A PCA analysis was performed using the most important environmental variables Figure III-22). PCA axis 1 explains 61 percent of the variance and is correlated with the grain size variables (percent sand, percent clay, percent silt). The two reference stations BC8 and BC9 are separated along PCA axis 1, indicating that the grain sizes at the two reference sites are different, with BC8 having a higher percentage of sands than BC9. PCA axis 2 explains 25 percent of the variance and separates the test sites from the reference sites. PCA axis 2 is correlated with sediment Cr concentrations and alkalinity, suggesting that test sites have higher sediment Cr concentrations and higher alkalinity values. The highest Cr concentration was measured at BC5.

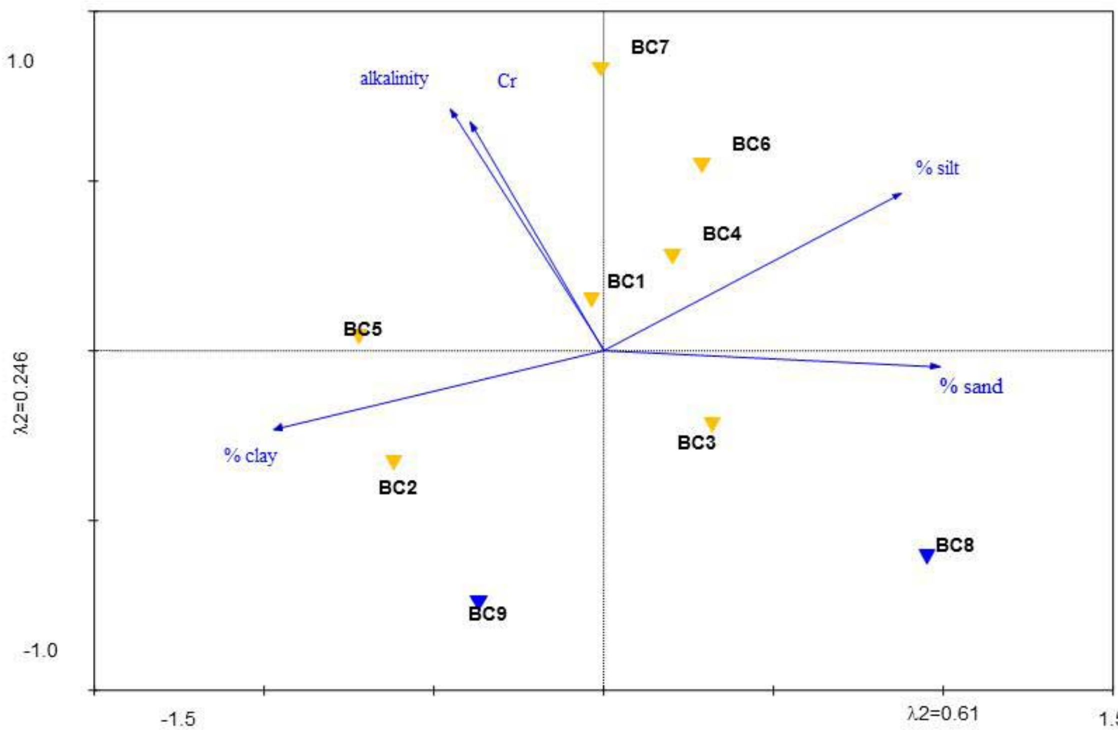


Figure III-22: PCA ordination of normalized environmental variables for the KIH. Only variables that best explain the biotic data are shown. Blue triangles indicate upstream reference sites.

C. Summary

The univariate metrics of the benthic community assessment for the nine KIH sites, such as taxa richness, diversity and evenness, did not show any differences between test and reference stations. Indices based on percentage EPT and feeding groups suggest that stations BC2, BC6 and BC7 have better water quality because of the abundance of herbivorous macroinvertebrates. Larval stages of many taxa considered in these indices often depend on the oxygen concentrated in the water, which declines with increasing organic nutrient pollution. Thus, it is possible that these indices are indicative of water quality rather than sediment conditions. The increase of caddisflies at these stations may also suggest the presence of a different habitat substrate that affects colonization by herbivorous invertebrates. Variation in substrate composition is a key determinant in macroinvertebrate communities. Biotic indices based on family tolerance levels indicate considerable organic nutrient pollution throughout the KIH and the indices reflect the dominance of a community tolerant to organic-rich sediments.

Multivariate methods based on MDS clearly separated test sites from reference sites. Within the test sites, two station groups can be distinguished: one consists of stations along the western shoreline (BC1, BC2 and BC5), and a second consists of stations south of Belle Park (BC6, BC7, BC4 and BC3) that show clear affinity. It is difficult to demonstrate which families differentiate between the sites because chironomids and oligochaetes are predominant at all sites, including the reference sites. Multivariate approaches such as BEAST suggest that the presence of amphipods and gastropods in higher abundances indicates a less disturbed community.

Challenges when assessing benthic invertebrate community structure have been reported in other studies from Great Lakes areas of concern. Environ (2009) studied the benthic community structure in the St. Clair River using the BEAST approach and found poor matching of test sites with the Great Lakes reference groups. A comparison of upstream sites with downstream sites did not show significant differences because of the dominance of pollution-tolerant taxa (i.e, Tubificidae and Chironomidae). In Jackfish Bay, Peninsula Harbour, invertebrate community composition was found to be different from that predicted based on data from reference sites (Environ 2007). The observed differences showed no relationship to Hg concentrations and were attributed to organic enrichment and water depth rather than chemical contamination.

While multivariate analysis showed that test sites were different from reference sites, they did not allow conclusions regarding the level of stress on the benthic community. Comparison to analogous reference sites in the Great Lakes through BEAST analysis indicates that most stations south of Belle Park are severely stressed, but suggests that the upstream reference sites are also in a stressed condition. This illustrates the importance of finding appropriate upstream reference sites. It is possible that station BC8, located in an area within the Rideau Canal with high boat traffic, is not a suitable reference site. It is also possible that the high organic content in the sediments throughout the KIH has an overriding influence on macroinvertebrate distribution patterns and makes it more difficult to reveal the contamination gradients.

In general, benthic communities in the KIH are dominated by organisms that are tolerant of organic (i.e., nutrient) pollution. The KIH is a complex system with extensive macrophyte beds, and the macroinvertebrate community in some areas may reflect sediment habitat and local conditions of contamination while at other stations it may reflect the vegetative habitat. For future assessments of benthic community structure, multiple upstream reference sites should be included to cover the full range of habitat variables.

Multivariate analyses showed that natural environmental gradients, such as substrate, organic content and alkalinity, as well as contamination gradients, such as Cr concentrations, explain the differences in the macroinvertebrate communities. A comparison of the KIH benthic community data with data from reference sites having similar environmental conditions, such as naturally eutrophic and shallow systems (St. Lawrence River system), may allow further determination of the level of stress on the benthic community.

D. Integration of Benthic Community Structure Results from all KIH Studies

Several previous studies have investigated benthic community structure at sites throughout the KIH (see summary in Chapter I). In 2010 and 2011, a total of 20 additional test stations in the southern KIH and three upstream reference stations were sampled for benthic invertebrates by Golder Associates (Golder 2011, 2012). Samples were processed using a 400 µm sieve and benthic invertebrates were identified to the lowest practical taxonomic level (species level where possible). The data were interpreted using both univariate metrics (total abundance, taxa richness, Simpson's Diversity and Shannon-Wiener Diversity) and multivariate statistical comparisons (NMDS ordinations). For the metrics, the station was ranked as being "significantly different" if the metric value was at least 50 percent less than for the mean reference sediments, "possibly different" if the metric was at least 20 percent less than for the mean reference sediments, and "equivalent" for differences of less than 20 percent from the mean reference sediments. A weight-of-evidence approach was used to define the overall ranking for the station based on the results of the metric and multivariate analyses. The results from the Golder (2011, 2012) benthic community studies indicated that 10 test sites were equivalent to reference condition, nine test sites were possibly different from reference condition and one test site was significantly different from reference condition (Appendix A, Golder Associates 2012, Figure B-8). Benthic communities at stations in the general vicinity of Anglin Bay and the north end of Douglas R. Fluhrer Park appeared to have the greatest evidence of impairment.

Differences in sample processing and taxonomic identification schemes make it challenging to compare the results of previous studies. For example, the studies summarized in Chapter I and the Golder studies used a larger sieve size for sample processing than was used in the ESG 2007 and 2008 studies, meaning that small-bodied organisms less than 400 μm in diameter were not included in the benthic community counts. However, since all of the studies sampled upstream reference sites as well as test sites, it is possible to use the ranking categories defined above (equivalent, possibly different and significantly different) to interpret results from each sampling station relative to study-specific reference condition. Using this approach, Golder identified that benthic communities at 20 test sites in the southern KIH were equivalent to reference condition, 15 test sites were possibly different from reference condition and benthic communities at one test site were significantly different from reference condition (Appendix A, Golder Associates 2012, Figure B-8). Although several sites showed possible benthic community effects on the Parks Canada water lot and the northern portion of the Transport Canada water lot, most of the stations exhibiting adverse effects were located in the vicinity of Anglin Bay and the northern part of Douglas R. Fluhrer Park. Two test sites in the southeastern portion of the KIH close to HMCS Cataraqui also showed potential benthic community effects.

V. INTEGRATION OF THE THREE LINES OF EVIDENCE (LOE)

The lateral and vertical extent of sediment contamination in the KIH was reviewed in Chapter II. The main conclusions were:

- **Sediment chemistry:** Concentrations of Cr, Pb, Zn, Cu, Hg, As, PCBs, PAHs and DDT exceed the PEL in the surficial sediments of the KIH south of Belle Island. Chromium is the most widespread contaminant in the KIH. Deeper sediments generally contain higher concentrations of Cr, Pb, Hg and PCBs from historical activities.
- **Sediment dynamics:** The relatively uniform contaminant concentrations in the top 20–30 cm of sediments and the shallow water depths throughout the KIH suggest that mixing and resuspension of contaminated sediments probably occurs continuously.

The key findings from the three lines of biological evidence presented in Chapter III are as follows:

- **Bioaccumulation of contaminants in KIH biota:** Aquatic macrophytes, cattails, benthic invertebrates and fish sampled from the KIH show consistent evidence for bioaccumulation of contaminants such as Cr, PCBs and Hg from the southwest portion of the KIH. Where tissue residue guidelines are available to assess biota contaminant concentrations, field invertebrate and fish biota from this area of the harbour generally exceed the relevant guidelines, indicating potential risk to wildlife consumers of aquatic biota. In contrast, aquatic biota from other areas of the KIH do not appear to have accumulated contaminants to the same degree. Following the COA framework under Step 4a, the data strongly indicate that there is potential for contaminant biomagnification from the sediments through aquatic food chains in the southwest portion of the KIH.
- **Sediment toxicity:** According to the criteria outlined in the COA framework, there is evidence for sediment toxicity effects to benthic invertebrates at several locations southwest of Belle Island Park (Appendix A, Golder Associates 2012, Figure B-3). However, most test locations do not show toxicity effects, with some co-located samples showing mixed results. There is no evidence of toxicity for samples collected from other areas of the KIH with lower concentrations of

sedimentary contaminants. The presence of multiple contaminants in the sediments complicates the definition of causal relationships.

- **Benthic community structure:** Benthic communities in the KIH are dominated by organisms that are tolerant of organic (i.e., nutrient) pollution. Univariate metrics such as taxa richness, diversity and evenness did not reveal any differences between test and reference stations. The BEAST analysis indicates that the benthic community at most stations south of Belle Park is severely stressed. Multivariate analyses suggest that test stations are significantly different from reference stations. Differences in the macroinvertebrate community structure can be explained by environmental variables related to habitat and to contamination variables such as sediment Cr concentrations.

The COA framework provides ranking criteria for weight-of-evidence characterization of sediment chemistry and biological effect data (Table III-5). Using the available data for the KIH and the supplementary results provided in the 2010 and 2011 studies, Golder (2012) provided an integrated assessment of the evidence for benthic community impacts in several sediment management zones, as follows:

- **Northern KIH (all sediment north of Belle Island):** Adverse effects unlikely. Sediment chemistry is relatively clean, with few guideline exceedances, and all stations showed negligible toxicity to benthic organisms.
- **Eastern KIH (FF-2, FF-3, FF-4, MF-4, MF-5, MF-6):** Adverse effects unlikely. Sediment chemistry is relatively clean, with few guideline exceedances. All test sites showed negligible toxicity and most test sites (five of seven) had benthic communities equivalent to reference condition.
- **Parks Canada water lot (IF):** Potential effects. There is elevated sediment contamination for inorganic elements (especially Cr and Pb), PCBs and PAHs. Although most sediment toxicity tests indicated negligible toxicity (10 of 13), three locations showed minor toxicity and one location exhibited major toxicity effects. There is some uncertainty in the benthic community analyses due to limited spatial coverage. However, two of three benthic community samples were equivalent to reference condition.

- **Northern Transport Canada water lot (NF-3):** Adverse effects unlikely. Most sediment toxicity tests (13 of 16) showed negligible toxicity and most benthic community samples (seven of eight) were equivalent to reference condition.
- **West Central KIH (NF-1, NF-2, MF-2, MF-3):** Adverse effects unlikely. Most test sites showed negligible toxicity and benthic communities were similar to reference condition. Two test sites had minor differences in benthic communities compared with reference areas, but this could be explained by differences in biological habitat (i.e., macrophyte abundance). Minor toxicity effects at these two stations in 2010 were not confirmed in 2011.
- **Southwestern KIH (MF-1, FF-0, FF-1):** Adverse effects likely. These areas are indicated in Appendix A, Golder Associates 2012, Figures B-3 and B-8, and include:
  - **Adjacent to Douglas R. Fluhrer Park at the south end:** Elevated sediment contamination for metals, PAHs and PCBs, as well as moderate toxicity responses and indications of benthic community alteration.
  - **Adjacent to Douglas Fluhrer Park at the northern end:** As above.
  - **Dry dock area within Anglin Bay:** Sediment chemistry with elevated concentrations of copper, lead, zinc, tributyltin and PAHs, as well as multiple instances of sediment toxicity and altered benthic community structure.

Table III- 5: Ordinal ranking for WOE categorization for chemistry, toxicity, benthos and biomagnification potential

	■	◘	□
Bulk Chemistry (compared to SQG)	**Adverse Effects Likely:** One or more exceedances of SQG-high	**Adverse Effects May or May not Occur:** One or more exceedances of SQG-low	**Adverse Effects Unlikely:** All contaminant concentrations below SQG-low
Toxicity Endpoints (relative to reference)	**Major:** Statistically significant reduction of more than 50% in one or more toxicological endpoints	**Minor:** Statistically significant reduction of more than 20% in one or more toxicological endpoints	**Negligible:** Reduction of 20% or less in all toxicological endpoints
Overall Toxicity	**Significant:** Multiple tests/endpoints exhibit major toxicological effects	**Potential:** Multiple tests/endpoints exhibit minor toxicological effects and/or one test/endpoint exhibits major effect	**Negligible:** Minor toxicological effects observed in no more than one endpoint
Benthos Alteration (multivariate assessment, e.g., ordination)	"different" or "very different" from reference stations	"possibly different" from reference stations	"equivalent" to reference stations
Biomagnification Potential (relative to reference)	**Significant:** Based on Step 6	**Possible:** Based on Step 4a	**Negligible:** Based on Steps 4a or 6
Overall WOE assessment	**Significant adverse effects:** elevated chemistry; greater than a 50% reduction in one or more toxicological endpoints; benthic community structure different (from reference) ; **and/or** significant potential for biomagnification	**Potential adverse effects:** elevated chemistry; greater than a 20% reduction in two or more toxicological endpoints; benthic community structure possibly different (from reference); **and/or** possible biomagnification potential	**No significant adverse effects:** minor reduction in no more than one toxicological endpoint; benthic community structure not different from reference; **and** negligible biomagnification potential

SQG = Sediment Quality Guideline; EC = Effective Concentration. Note That The Overall Definition Of "No Significant Adverse Effects" Is Independent Of Sediment Chemistry.

Source: Environment Canada and OMOE 2008.

VI. Conclusions

A review of the biota bioaccumulation, sediment toxicity and benthic community data available for the Kingston Inner Harbour identified that biological effects are occurring in the southwestern portion of the harbour. Using the COA framework to evaluate benthic community effects, it was determined that adverse effects are likely for areas in the vicinity of Douglas R. Fluhrer Park and Anglin Bay, while potential effects were identified for the Parks Canada water lot south of Belle Park (see Appendix A, Golder Associates 2012, Figures B-3 and B-8). The lack of evidence for adverse ecological effects north of Belle Island and in the central and eastern portion of the southern KIH indicates that no further action is necessary in these areas.

As a complementary approach for determining environmental risk from KIH contaminated sediments, an ecological and human health risk assessment is presented in Chapter IV. This determines the potential risk to upper-trophic-level consumers and humans using the area.

Given that a review of biological effects under the COA framework has indicated that management actions are needed to address the sediment contamination southwest of Belle Park, the next step is to define the extent of the area requiring management. Chapter V presents an integration of the evidence to date, as an options analysis, to identify potential management scenarios for the site.

VII. References

Ankley, G.T., D.A. Benoit, J.C. Balogh, T.B. Reynoldson, K.E. Day and R.A. Hoke. 1994. "Evaluation of potential confounding factors in sediment toxicity tests with three freshwater benthic invertebrates." *Environmental Toxicology and Chemistry* 13: 627–635.

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Becker, D.S., E.R. Long, D.M. Proctor and T.C. Ginn. 2006. "Evaluation of potential toxicity and bioavailability of chromium in sediments associated with chromite ore processing residue." *Environmental Toxicology and Chemistry* 25: 2576–2583.

Benoit, N. and A. Dove. 2006. Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 Monitoring Programs. Technical Report. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Berry, W.J., W.S. Boothman, J.R. Serbst and P.A. Edwards. 2004. "Predicting the toxicity of chromium in sediments." *Environmental Toxicology and Chemistry* 23 (12): 2981–2992.

Bode, R.W., Novak, M.A. and Abele, L.E. 1996. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. New York State Department of Environmental Conservation, Albany, NY. 89 pp.

Borgmann, U., W.P. Norwood, T.B. Reynoldson and F. Rosa. 2001. "Identifying cause in sediment assessments: Bioavailability and the Sediment Quality Triad." *Canadian Journal of Fisheries and Aquatic Sciences* 58: 950–960.

Bray, J.R. and J.T. Curtis. 1957. "An ordination of the upland forest communities of southern Wisconsin." *Ecological Monographs* 27 (October 1957): 325–349.

Chapman, P.M. 2000. "The Sediment Quality Triad: Then, now and tomorrow." *International Journal of Environment and Pollution* 13: 351–356.

Chapman, P.M. and E.R. Long, 1983. "The use of bioassays as part of a comprehensive approach to marine pollution assessment." *Marine Pollution Bulletin* 14: 81–84.

Clarke, K.R. and M. Ainsworth.1993. “A method of linking multivariate community structure to environmental variables.” *Marine Ecology Progress Series* 92: 205–219.

Clarke, K.R. and R.H. Green. 1988. “Statistical design and analysis for a “biological effects” study.” *Marine Ecology Progress Series* 46: 213–226.

Clarke, K.R., and R.M., Warwick, 2001. Changes in Marine Communities: An Approach to Statistical Analysis and Interpretation. Natural Environmental Research Council, Plymouth Marine Laboratory, Plymouth, UK.

Derry, A., A. Dove, R. Fletcher and N. Benoit. 2003. PCB Source Trackdown in the Cataraqui River: 2001 Findings. Technical Memorandum. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON

Environ International Corporation. 2007. Environmental Risk Assessment for Peninsula Harbour, Lake Superior — Final Report, Volume I. Prepared for Environment Canada. March 2007.

Environ International Corporation. 2009. Final Project Report for Applying the COA Framework to the St. Clair River Area of Concern. Prepared for St. Clair Region Conservation Authority. March 2009.

Environment Canada and Ontario Ministry of the Environment (OMOE). 2008. Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment. Prepared by Peter Chapman (Golder Associates Ltd.) with the COA Sediment Task Group on behalf of Environment Canada and the Ontario Ministry of the Environment under the Canada–Ontario Agreement (COA 2002), March 2008.

Environmental Sciences Group (ESG). 2003. Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour. Royal Military College of Canada, Kingston, ON. October 2003.

Golder Associates. 2011. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment: Kingston Inner Harbour — Framework Steps 4 and 5 (PQRA). Final report prepared for Public Works and Government Services Canada on behalf of Transport Canada. March 31 2011.

Golder Associates. 2012. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment: Kingston Inner

Harbour — Framework Step 6 (Detailed Quantitative Assessment). Final report prepared for Public Works and Government Services Canada on behalf of Transport Canada. March 30, 2012.

Hayton, A. 2000. Juvenile Fish Monitoring Study, Belle Island Landfill, Lower Cataraqui River. Prepared for Kingston District Office, Biomonitoring Section, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment.

Hilsenhoff, W.L. 1982. Using a Biotic Index to Evaluate Water Quality in Streams. Techical Bulletin. Wisconsin Department of Natural Resources. 132 pp.

Long, Edward R. and P.M. Chapman. 1985. "A Sediment Quality Triad: Measures of Sediment Contamination, Toxicity and Infaunal Community Composition in Puget Sound." *Marine Pollution Bulletin*,16, no. 10: 405–415.

Mandaville, S.M. 2002. Benthic Macroinvertebrates in Freshwaters: Taxa Tolerance Values, Metrics, and Protocols. Soil & Water Conservation Society of Metro Halifax. Available from http://lakes.chebucto.org/ZOOBENTH/BENTHOS/tolerance.html

Marchant, R. 1989. "A subsampler for samples of benthic invertebrates." *Bull. Aust. Soc. Limnol* 12: 49–52.

Merrit, R.W. and K.W. Cummins. 1996. *Introduction to the aquatic insects of North America.* 3rd edition. Dubuque, Iowa: Kendall/Hunt Publishing Company.

Norberg-King, T.J., P.K. Sibley, G.A. Burton, C.G. Ingersoll, N.E. Kemble, S. Ireland, D.R. Mount and C.D. Rowland. 2006. "Interlaboratory evaluation of *Hyalella azteca* and *Chironomus tentans* short-term and long-term sediment toxicity tests." *Environmental Toxicology and Chemistry* 25: 2662–2674.

Ontario Ministry of the Environment (OMOE). 2013. Guide to Eating Ontario Sport Fish, 2013–2014 — 27th Edition. Queen's Printer for Ontario.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross and R.M. Hughes. 1989. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish. EPA 440/4-89/001. U.S. Environmental Protection Agency.

Reynoldson, T.B., R.C. Bailey, K.E. Day and R.H. Norris. 1995. Biological guidelines for fresh-water sediment based on BEnthic Assessment of SedimenT (the BEAST) using a multivariate approach for predicting biological state." *Australian Journal of Ecology* 20: 198–219.

Reynoldson , T. B. and K.E. Day. 1998. Biological Guidelines for the Assessment of Sediment Quality in the Laurentian Great Lakes. NWRI-98-232. National Water Research Institute, Burlington, ON.

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: Wright, J.F., D.W. Sutcliffe and M.T. Furse (eds.), *Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques*, pp 165–80. Freshwater Biological Association.

Ristola, T., J. Pellinen, M. Roukolainen, A. Kostamo,and J.V.K. Kukkonen. 1999. "Effect of sediment type, feeding level, and larval density on growth and development of a midge (*Chironomus riparius*)." *Environmental Toxicology and Chemistry* 18: 756–764.

Rook, E.J.S. 2002. *Typha latifolia* (Common Catttail). Available from http://www.rook.org/earl/bwca/ nature/aquatics/typhalat.html. Accessed January 21, 2010.

Scheider, W. 2009. Methylmercury Study in the Kingston Inner Harbour. Technical Memorandum. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Scott, W.B. and E.J. Crossman. 1973. "Freshwater Fishes of Canada." Bulletin 184, *Bulletins of the Fisheries Research Board of Canada*. Ottawa, ON.

ter Braak, C.J.F. and Šmilauer, P. 2002. CANOCO Reference Manual and CanoDraw for Windows User's Guide: Software for Canonical Community Ordination (version 4.5). Microcomputer Power, Ithaca, NY, 500 pp.

Tinney, M.D. 2006. "Site Investigation and Ecological Risk Assessment of the Kingston Inner Harbour." Master of Applied Science (Environmental Engineering) thesis, Royal Military College of Canada.

United States Environmental Protection Agency (US EPA). 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. 2nd edition. EPA 600/R-99/064. March 2000.

Washington State Department of Ecology. Non-native Invasive Freshwater Plants: *Myriophyllum spicatum* (Eurasian Watermilfoil). Available from http://www.ecy.wa.gov/programs/wq/plants/weeds/aqua004.html. Accessed January 21, 2010.

Watershed Science Institute. 2008. Watershed Condition Series Technical Notes 3: The EPT Index. Natural Resources Conservation Service, United States Department of Agriculture. ftp://ftp.wcc.nrcs.usda.gov/wntsc/strmRest/wshedCondition/EPTIndex.pdf.

Watson-Leung, T. 2004. Laboratory Sediment Toxicity and Bioaccumulation Tests: Report on Cataraqui River Sediments 2002. Technical Memorandum. Appendix J to: Derry, A., A. Dove, R. Fletcher and N. Benoit (2003).

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Chapter IV: Human Health and Ecological Risk Assessment of the Kingston Inner Harbour

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT'D

TABLE OF CONTENTS, CONT'D

LIST OF FIGURES

LIST OF TABLES

List of Tables, cont'd

I. INTRODUCTION

The KIH is located at the mouth of the Great Cataraqui River, where the river discharges into Lake Ontario. Historically, the southwest portion of the KIH was heavily industrialized. Operations included a tannery, a lead smelter, a woolen mill, shipbuilding operations, railway yards, fuel depots and a number of small industrial and commercial enterprises. Three waste disposal areas were also located on the shores of the Inner Harbour: the Belle Park Landfill; a Federal Dredged Sediments Disposal Site on the north side of the landfill; and the Arcom Waste Disposal Facility located within the former Davis Tannery site. Sections of the Inner Harbour are under the jurisdiction of two federal agencies (Parks Canada and Transport Canada), while the adjacent lands are owned by the City of Kingston, Department of National Defence, and various private parties and corporations. A detailed Phase I historical review of the former industrial sources around the KIH, previous site investigations, and current land uses of the harbour is presented in Chapter I of this report.

Although water quality in the KIH is generally good, industrial operations and waste disposal practices have contaminated sediments in some portions of the river. Investigations of sediment quality have indicated that concentrations of As, Cr, Cu, Hg, Pb, Zn, Sb, PCBs, DDT, chlordane, and PAHs are the CoPC in the harbour, with Cr being the most abundant and widespread contaminant. As expected given the industrial history of the KIH, the highest contaminant concentrations are found in the southwest portion of the harbour. This area has been identified as an APEC. Sediments north of Belle Park generally have low levels of contamination, and this area is considered suitable as an upstream reference location. Chapter II of this report provides a detailed review of sediment contamination patterns at surface and depth within the KIH. Evidence for biological uptake of contaminants and a review of the ecological effects of the sediment contamination on benthic (i.e., sediment-dwelling) organisms is presented in Chapter III of this report.

This chapter presents the results of a HHERA for the portion of the KIH southwest of Belle Park. The objective was to assess the potential human health risks resulting from contamination in the KIH during recreational use of the harbour, and to evaluate the potential environmental risk to upper-trophic-level organisms. This approach complements the COA with some aspects of the FCSAP Ecological Risk Assessment Guidance (Azimuth 2012) included. The results from the HHERA will be integrated with those from Chapters II and III to evaluate potential management actions for the southwest portion of the KIH; this information is presented in Chapter V of this report.

II. HUMAN HEALTH RISK ASSESSMENT

A. Introduction

The main objectives of this study were to quantitatively evaluate the potential of chemical exposures and health risks associated with recreational activities taking place in the Kingston Inner Harbour (KIH), and to identify the need for further management actions. For risk management considerations and for establishing site-specific remediation objectives, the most critical pathways contributing to the risk were determined.

Risk assessment uses a tiered approach to estimate the risks posed to human and ecological receptors. In the first tier, the most conservative values of exposure (time exposed, maximum concentrations of contaminants, etc.) are used to develop a worst-case scenario. If, under the most conservative exposure scenario, the outcome implies an acceptable level of risk to the receptors, no further work is required. However, if the outcome implies that the risk level is above acceptable criteria, scenarios may be developed that use a combination of more site-specific information and different statistical analyses of the data.

This HHRA was conducted at the Detailed Quantitative Risk Assessment (DQRA) level according to Health Canada (2010c) to present a defensible and representative estimate of risk. Health Canada outlines the specific characteristics which are used to evaluate the level of risk assessment approach used, which can be found in Table IV-1 along with the rationale used to consider this risk assessment at the DQRA level. Several scenarios were included to examine a more accurate, realistic exposure to contaminants of potential concern (CoPC) identified in the hazard screening process. This human health risk assessment was conducted in accordance with Health Canada's widely accepted risk assessment framework (Health Canada 2010a, b; 2012b).

The KIH is defined as the 5 km river bounded by Highway 401 to the north and the LaSalle causeway to the south (Chapter I, Fig. I-2). Current activities in the KIH include pleasure-craft boating, with three marinas operating in the KIH (Kingston Marina, Music Marina and Rideau Marina), as well as commercial and sport fishing. Although commercial fishing is limited to north of Belle Island, recreational fishing occurs throughout the harbour. Canoeing and rowing are common activities in the sheltered inner harbour and this area also provides safe anchorage for larger boats. There are no organized bathing beaches within the KIH; however, the docks located near the

LaSalle Causeway and Anglin Bay are often used for swimming and other water-related recreational activities (Malroz 2003). Visitors currently walk through the former industrial land located on the western shore of KIH south of Belle Island, especially along the waterfront, and squatters are known to be living on the site.

A residential area is proposed for the western shore of the KIH south of Belle Island, and a Waterfront Pathway is also being considered. The proposed waterfront trail includes paths along most of the eastern shore north of Belle Island, as well as the southwest shore from Highway 2 to a point north of the Belle Park Landfill. This development could increase the number of potential visitors swimming and fishing within the KIH. The City of Kingston has identified the cleanup of the KIH as a key sustainability initiative. Future land use for the KIH is therefore expected to be recreational and the area is very unlikely to change to commercial or industrial land use. This section of the report presents an assessment of the potential human health risks associated with these recreational activities.

Table IV-1: Rationale for the detailed quantitative risk assessment approach used

Characteristic	**Rationale**
Environmental media	Sediment, surface water, pore water and fish sampled.
Quantity of data	Extensive information on each CoPC and media.
Statistic used to represent CoPC	>10 samples per CoPC and media allows use of 95UCL.
Use of modeling	No modeling required. Direct data input into risk calculations.
Site characterization	Extensive; chemical and physical characterization of sediment, contamination sources well characterized and understood, extensive mapping of chemical data with few data gaps.
Receptor characterization	Primarily generic receptor characterization with site specific exposure times included and refinement of fish consumption rates (OMOE sport fish data).
Risk characterization	Background exposure investigated for some CoPCs.

B. Risk Screening

1. Data Selection

Data were sourced from the most recent information available, specifically, from ESG site investigation activities, as well as from external sources such as the Ontario Ministry of the Environment (OMOE). A detailed review of past site investigation activities is provided in Chapter 1 of this report.

Water, sediment and fish tissue samples used for the HHRA were collected from the southern portion of the KIH located between Belle Island and the LaSalle Causeway.

Most of the sediment samples for which results were used in this HHRA were collected by ESG, OMOE, or Environment Canada from 2001 to 2011 following standard practices. Sediment results from Golder (2011, 2012) were also included. Sampling methodologies and a detailed discussion of the sediment contaminant patterns are presented in Chapter II of this report. Sampling locations are shown in Appendix B, Map B-II-2.

The water data were collected by ESG and OMOE between 2002 and 2009. Sampling locations are shown on Map B-9 in ESG (2003), in Figures 1-4 of Tinney (2006), and in Figure 1 and Table 1 in the OMOE report by Benoit and Berniston (2010). ESG water samples were collected from the water column 0.5 m above the river bed using a Van Dorn sampler. OMOE collected grab samples but did not provide details about depth or equipment used. All samples were kept cool at 4˚C until they were submitted for analysis. All samples were analysed for total contaminants (i.e., they were not filtered), except for eight samples (2009 samples) that were analysed for both total inorganic elements and dissolved inorganic elements (after filtering).

The sport fish data used for the HHRA were collected by the OMOE and reported in Scheider (2009). Fish data were also obtained from Golder (2011). The data are summarized in Chapter III of this report. The OMOE sport fish contaminant data were deemed appropriate for this HHRA because of the part of the fish analyzed (i.e., filets, a boneless and skinless portion of fish muscle) and the larger sample size. For a subset of this data, the fish part analyzed was not clear but since it was part of the sport fish program, and was included for human health fish advisories, it was included in the present data set. Since the OMOE program contained limited information on fish As concentrations and no information on fish Cr concentrations, ESG investigated bioaccumulation of inorganic elements and PCBs by fish from the KIH. Benthivorous fish (brown bullhead) and piscivorous fish (northern pike and yellow perch) were collected in the fall of 2009 using 1” and 2” gill nets (one-hour set) from a test site immediately south of Belle Park and an upstream reference location just south of Kingston Mills (Appendix B, Map B-III-7). For the OMOE data, sport fish tissue samples collected from Colonel By Lake in 1997 were used for the background or reference area, while samples collected in 1999 and 2002 from the bay south of Belle Island Park were used for the APEC. Sampling locations for the ESG fish data are shown in Appendix B, Map B-III-7. A detailed discussion of the fish data is presented in Chapter III of this report.

Samples collected by ESG were analyzed by the Analytical Services Unit (ASU) of Queen’s University and the Analytical Sciences Group (ASG) of RMC. Both of these laboratories are accredited by Canadian Association for Laboratory Accreditation Inc. (CALA, formerly Canadian Association for Environmental Analytical Laboratories or CAEAL), and the methods used to produce the results used in this risk assessment are within their scopes of accreditation (CALA 2013a, b). ESG performed a detailed quality assurance and quality control review of the data; this is presented in Appendix E of this report.

Potential CoPCs were screened in Chapter II, and carried forward for further evaluation in the present chapter. This evaluation was carried out by screening the CoPC data against environmental quality guidelines, if available, and the upstream reference site concentrations for the CoPC in all media. If the maximum value of the CoPC from the APEC exceeded both the maximum concentration from the reference site and guideline concentrations, that CoPC was carried forward in the risk assessment for further evaluation. The exception to this approach was for fish tissue concentrations, where the CoPC was only used in the risk assessment if the APEC values were statistically different from the reference values.

The 95-percent upper confidence limit (95UCL) was used as the exposure point concentration (EPC) in all risk calculations for each CoPC in sediment, water, and fish tissue. EPCs are used to estimate the chemical concentration found within a defined area of exposure, and provide a conservative estimate of what receptors will be exposed to during the timeframe of the risk assessment (US EPA 2002 1992). The 95UCL represents a value that meets or exceeds the true mean 95 percent of the time (US EPA 2002 1992). The program ProUCL 4.00.02, provided by the US EPA for the purpose of calculating 95UCLs, was used to calculate the 95UCL and mean using the appropriate statistical method. In all cases non-parametric statistics that included non-detects were used to produce the UCL recommended by the program (usually Kaplan-Meier Chebyshev). The recommended UCL was used in most cases, but where the recommended UCL was not a 95UCL (e.g., it was a 99 percent UCL), the Kaplan-Meier Chebyshev 95UCL was selected as the EPC. In cases where the CoPC was represented by a sum (i.e., DDT and PCBs), non-detects were replaced with half the detection limit to calculate the sum, since a comparison of DDT sums obtained by this method and by a statistically more robust method (KMStats worksheet available at Helsel 2013) gave similar values. If all values contributing to the sum were non-detects, the highest detection limit was used to represent the sum, as recommended in the Washington State Washington Administrative Code (WAC) (Washington State Legislature 2013).

a. Potential Hazards from Sediment

The following CoPCs were determined in Chapter II to be appropriate for human health risk assessment: Cu, Pb, Zn, Cr, As, Hg, Sb, DDT, chlordane, PCBs and PAHs. The PAHs include the carcinogenic compounds specified by Health Canada (2012b) for which results were available, as well as naphthalene and pyrene, which are considered by Health Canada to be threshold PAHs (non-carcinogenic) (Health Canada 2010a). A summary of the results for these CoPCs obtained for sediment samples from the APEC and reference site is provided in Tables IV-2, IV-3, IV-4, IV-5, IV-6 and IV-7, as well as in Appendix D. Sediment sample locations are shown in Appendix B, Map B-II-2.

There are no federal sediment quality guidelines for the protection of human health specifically; the existing CCME sediment quality guidelines are derived for the protection of aquatic biota (CCME 1999a). As a screening tool, the OMOE sediment quality guidelines (OMOE 2009) applicable to a residential/parkland setting, as well as the reference concentration of each CoPC, were used. The maximum concentration of each CoPC was compared with these values: if the maximum value exceeded both screening values the contaminant was carried forward in the risk assessment. The 95UCL was calculated for both the reference and APEC data where more than 10 results were available and the data set included depths down to 1 m because of the possibility of redistribution through human activities. The 95UCL of each contaminant from the APEC locations was used as the EPC in risk calculations.

PAH concentrations in sediment were available for a reasonable representation of the geographic area of the KIH. One set of data was available from a 1991 report (CH2M Hill Engineering Ltd. 1991) generated from samples collected from the Anglin Bay area, from 80–100 cm depths; the depths were estimated from a range of depths (31–123 cm). In these samples extremely high concentrations of PAHs occur: total PAHs 18–20,600 mg/kg dry weight, compared with a maximum of 175 mg/kg total PAH detected at other depths and elsewhere in KIH. Anglin Bay is an area not expected to encounter much use in terms of wading or even swimming and thus these depth samples are unlikely to be available to pose risk to humans. As a result, these samples were not included in the PAH data analysis.

Table IV-2: Sediment concentrations for inorganic element CoPCs in the reference locations

	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	As (mg/kg)	Sb (mg/kg)	Hg (mg/kg)
Maximum	58	290	2,200	240	16	<10	0.181
Minimum	17	13	53	<20	<1	0.2	0.04
Mean	30	53	160	63	2.6	0.3	0.099
# samples	45	44	46	38	35	16	12
95 UCL	35	83	361	94	2.9	0.48	0.12
# Non-detects	1	0	0	3	2	14	0
Ontario background concentrations[1]	25	23	65	31	4	0.35[2]	0.1

[1]From Table 3 and 4 in OMOE 2008;
[2]Background soil value in old urban parks, Table 8.2 in OMOE 2011.

Table IV-3: Sediment concentrations for inorganic element CoPCs in the APEC locations

	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	As (mg/kg)	Sb (mg/kg)	Hg (mg/kg)
Maximum	780	3246	2,460	42,737	742	894	11
Minimum	11	5.9	6.2	31	1.7	0.1	0.0035
Mean	49	176	190	1,564	26	14	1.1
# Samples	456	454	444	449	195	131	156
# Non-detects	21	1	5	58	4	55	5
% non-detects	4.6	0.2	1.1	13	2.1	42	3.2
95 UCL of reference samples	35	83	361	94	2.9	0.48	0.12
OMOE Sediment Quality Standards[1]	16	31	120	26	6	N/A	0.2
95UCL	53	196	205	2,457	49	45	1.7
Carried forward in risk assessment	Y	Y	Y	Y	Y	Y	Y

N/A = not available
[1]From Table 1 and 2 in OMOE 2008.

Table IV-4: Sediment concentrations for organic CoPCs in the reference locations

	DDT (mg/kg)	Chlordane (mg/kg)	PCBs (mg/kg)
Maximum	0.036	<0.004	0.58
Minimum	<0.002	<0.002	<0.003
Mean	0.016	NP	0.059
# samples	4	4	28
95 UCL	NP	NP	0.11
# Non-detects	1	4	9
Ontario background concentrations[1]	0.01	0.001	0.02

NP = could not be processed because data set too small or no detectable values.
[1]From Table 3 and 4 in OMOE 2008.
[2]Background soil value in old urban parks, Table 8.2 in OMOE 2011.

Table IV-5: Sediment concentrations for organic CoPCs in the APEC locations

	DDT (mg/kg)	Chlordane (mg/kg)	PCBs (mg/kg)
Maximum	0.15	0.041	12.0
Minimum	0.002	0.0005	<0.0001
Mean	0.015	0.004	0.63
# Samples	51	49	242
# non-detects	14	13	18
% non-detects	27	27	7.4
95 UCL of reference samples	0.036	<0.004*	0.11
OMOE Sediment Quality Standards[1]	0.007	0.007	0.070
95UCL	0.020	0.009	0.96
Carried forward in risk assessment	Y	Y	Y

[1]From Table 1 and 2 in OMOE 2008
*Maximum concentration of DDT and chlordane in reference samples because 95UCL could not be calculated.

Table IV-6: Sediment concentrations for PAH CoPCs (mg/kg dw) in the reference locations

	Benzo[a]-pyrene	Benzo[a]-anthracene	Benzo[b]-fluoranthene	Benzo[g,h,i]-perylene	Benzo[k]-fluoranthene	Chrysene	Dibenzo[a,h]-anthracene	Fluor-anthene	Indeno[1,2,3-cd]pyrene	Phen-anthrene	Naphth-alene	Pyrene	Total PAH
Maximum	0.57	0.48	0.35	0.27	0.24	0.46	0.22	1.3	0.38	0.50	0.25	1.00	5.9
Minimum	0.024	0.021	0.023	NDR	0.021	0.041	<0.005	0.08	NDR	<0.05	0.02	0.07	0.15
Mean	0.15	0.13	0.12	0.091	0.078	0.15	0.037	0.27	0.10	0.11	0.065	0.26	1.6
# samples	19	19	19	19	18	19	19	19	19	19	19	19	19
95 UCL	0.21	0.18	0.16	0.12	0.10	0.20	0.060	0.54	0.14	0.21	0.088	0.35	2.9
# non-detects	3	2	2	6	4	1	8	0	5	2	2	0	0
BG	0.37	0.32	0.040*	0.17	0.24	0.34	0.06	0.75	0.2	0.56	NR	0.49	NR

BG = Background concentrations from OMOE 2011; OMOE set them equivalent to lowest effect levels (LEL) since generally LELs were within an order of magnitude of the mean of measured background sediment, where data are available in OMOE 1993 and, as such, are reasonably representative of an upper level of background.
NDR = code given by OMOE laboratory indicating peak detected but did not meet quantification criteria.
NR = not reported.
*Background from Heit et al. (1981) because no value available from OMOE 2011.

Table IV-7: Sediment concentrations for PAH CoPCs (mg/kg dw) in the APEC locations

	Benzo[a]-pyrene	Benzo[a]-anthracene	Benzo[b]-fluoranthene	Benzo[g,h,i]-perylene	Benzo[k]-fluoranthene	Chrysene	Dibenzo[a,h]-anthracene	Fluor-anthene	Indeno-[1,2,3-cd] pyrene	Phen-anthrene	Naph-thalene	Pyrene	Total PAH
Maximum	22	9.4	29	14	5.1	18	2.2	20	21	8.6	2.2	34	175
Minimum	0.1	0.05	0.05	0.07	0.035	0.05	0.02	0.05	0.096	0.05	0.026	0.05	0.13
Mean	1.5	0.91	1.7	0.90	0.39	1.2	0.20	1.4	0.9	0.73	0.23	2.0	10
n	104	104	103	104	70	104	104	104	104	104	104	104	130
# non-detects	14	14	10	15	13	11	21	5	16	10	10	4	5
% non-detects	14	14	9.7	14.4	18.6	10.6	20.2	4.8	15.4	9.6	9.6	3.8	3.8
95 UCL of reference samples	0.21	0.18	0.16	0.12	0.10	0.20	0.060	0.54	0.14	0.21	0.088	0.35	2.9
OMOE Sediment Quality Standards[1]	0.37	0.32	NV	0.17	0.24	0.34	0.060	0.75	0.2	0.56	NV	0.49	4
95UCL	2.7	1.5	3.2	1.7	0.76	2.2	0.26	2.6	2.0	1.3	0.38	3.7	18
Carried forward in risk assessment	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

NV = no value derived.
[1]From Table 2b in OMOE 2008

1) Chromium Speciation in Sediment

Chromium is a naturally occurring inorganic element often found with oxygen, iron and lead. Chromium exists in several oxidation states, with the trivalent and hexavalent forms being the most common species in the environment. Cr(VI) is not considered thermodynamically stable and is rarely found in soils naturally. The presence of Cr(VI) is often due to anthropogenic inputs resulting from its use in metal finishing, pigments or wood treatments (CCME 1999b).

The toxicity of chromium depends heavily on its oxidation state, with Cr(VI) being more toxic than Cr(III) for both acute and chronic exposures. In fact, Cr(III) is considered by some to be a micronutrient (ATSDR 2008).

Cr(III) has been found to be the predominant species in tannery sludge (Chuan and Liu 1996) and in sludge suspected to have been contaminated with tannery operations (Martin et al. 2003). This implies that the input of chromium into the KIH was from a source suspected to be Cr(III); additionally, the redox conditions in the KIH favor the reduction of Cr(VI) to Cr(III). Studies of sediment Cr, sediment pore water, and soils from adjacent sites indicate that Cr in the KIH is present as the less toxic, trivalent form (Cr(III)) (See Chapter II of this report, Koch et al. 2012, and Burbridge et al. 2012). All reference to chromium throughout this risk assessment will be made under the assumption that all chromium within the KIH sediments is in the form of Cr(III).

b. Potential Hazards in Surface Water

A summary of the results for the CoPCs obtained for water samples from APEC and reference sites is provided in Table IV-8, as well as in Appendix D (Tables D-IV-3, D-IV-4 and D-IV-5). Hg, Sb, chlordane, and DDT are not included because Hg results in water were not available, and values for the other CoPCs in all samples analyzed were less than the detection limits: Sb < 0.01 mg/L; chlordane and DDT <5 ng/L = 5 x 10^{-6} mg/L.

Exposure to contaminants in KIH surface water may occur during recreational activities (incidental ingestion or dermal contact with contaminated water) such as swimming or boating. Neither OMOE nor the CCME provide recreational water quality guidelines for chemical concentrations in water because there are no data for this type of exposure. Therefore, the surface water samples were screened against the Health Canada’s drinking water guidelines (Health Canada 2012c) and the OMOE Drinking Water Standards (OMOE 2006b), even though it is not expected that any human receptors will be using the water from the KIH as drinking water. In the absence of alternative guidelines, the drinking water guidelines give an indication of the water quality with respect to human health in the KIH.

Most CoPCs in water were below Health Canada's or OMOE's drinking water criteria with some considerations. PAHs were difficult to assess since criteria exist only for benzo[a]pyrene, but all concentrations for this compound in all water samples (KIH or reference locations) were below detection limits. In 10 of 22 samples analyzed from the KIH, the detection limit (0.001 mg/L) was higher than the criterion value, but in the remainder of samples, the detection limit was 0.000001 mg/L, an order of magnitude lower than the criterion value of 0.00001 mg/L. This suggests that PAHs were not present in significant concentrations in the surface water and therefore were not carried forward in the risk assessment.

Table IV-8: Summary of detectable results from water samples from the reference location (Maximum Reference) and APEC locations. The < value refers to the analytical detection limit for that CoPC.

CoPC	Maximum total (mg/L)	Minimum total (mg/L)	Maximum dissolved (mg/L)[1]	Maximum reference (mg/L)	Ontario Drinking Water standard (mg/L)[2]	Health Canada criterion (mg/L)[2]	Carried forward
Cu	0.214	0.0006	0.0064	0.005	1 (AO)	1	No
Pb	1.1	0.00024	<0.01	<0.01	0.01 (MAC)	0.01	No
Zn	5.3	0.0011	1.9	0.02	0.035 (AO)	≤5.0	No
Cr	22	0.0009	<0.005	<0.005	0.05 (MAC)	0.05	No
PCBs	0.000094	0.00000067	N/A	<0.00002	0.003 (IMAC)	N/A	No
PAHs (total)	<0.01	0.00014	N/A	<0.01	0.00001[3]	0.00001[3]	No

N/A = not available.
[1]Number of samples = 8; only inorganic elements were analyzed.
[2]Criteria sourced from OMOE 2006b, and Health Canada 2012c. MAC = Maximum Acceptable Concentration; IMAC = Interim Maximum Acceptable Concentration; AO = Aesthetic Objective.
[3]Criteria are available only for benzo[a]pyrene; values in all KIH water samples for this compound were <0.001mg/L.

Inorganic contaminants were elevated in some samples. As mentioned previously, all samples were analyzed for "total" contaminant concentrations, and suspended particulate matter was suspected to be the source of contaminants in these cases. This is similar to Benoit and Berniston (2010) observation that PCB concentrations in water were correlated with suspended solids concentrations. Samples collected from 8 locations near the outlet from the Davis Tannery were analyzed both for "total" inorganic contaminants, and for "dissolved" inorganic contaminants (following a filtering step).

The results shown in Table IV-8 indicate that “dissolved” concentrations were not detectable, or they were much lower than “total” concentrations, and below the Health Canada drinking water standards, giving support for the indication that contamination in water samples is attributable to suspended solids. The significance of this affects the consideration of exposure pathways, as discussed in Section 3. Specifically, suspended solids are included in sediment exposure pathways, and ingestion of water is not considered as a pathway.

c. Potential Hazards in Harvested Foods

The KIH is fully accessible by boat and has waterfront access, making both recreational and sport fishing activities possible. Northern pike, yellow perch, brown bullhead, carp and largemouth bass are some fish species known to be living in the waters within the inner harbour. These species are reported in Scheider (2009) as a part of the OMOE’s sport fish monitoring program and have been assessed for a suite of inorganic and organic CoPCs. The majority of mercury in fish tissue is composed of MeHg (> 95 %) and therefore the CoPC listed for risk posed by fish consumption is MeHg rather than total Hg. OMOE collected sport fish tissue samples in 1997 from Colonel By Lake (located upstream on the Cataraqui River) as reference area samples, and they collected samples in 1999–2008 from the bay south of Belle Island Park to represent the APEC. These data were reported mostly from filet samples.

ESG also collected northern pike, yellow perch and brown bullhead in 2009 but contaminants were analyzed in homogenized whole fish samples where one filet had been removed (for archive) from each sample. For the initial data analysis all fish results were examined because data were, with the exception of Hg and PCBs, not numerous (n = 15-24; n = 0 for As in reference fish). For Hg and PCBs, only filet data were examined, to represent the fish part that humans are likely to eat. The results summarized in Table IV-9 therefore include all fish for Cu, Pb, Zn, Cr, As and pp-DDE, and filet data only for Hg and PCBs.

Analytical results for OMOE and Golder fish data are presented in Appendix D and a summary of the results is provided in Table IV-9. In the data analysis, the fish data were not separated by species because all of the fish species sampled are known to be consumed by humans.

PAH concentrations in fish were not available and bioaccumulation in fish is not thought to be significant (Van der Oost et al. 2003). Therefore PAHs in fish were not included in the HHRA. Sb concentrations in fish were also not available. Based on the findings of other inorganic contaminants (see below) and the low uptake of this element into biological tissues (Environment Canada and Health Canada 2010), the Sb concentrations in fish are assumed to not differ from background concentrations, and they are not included in the HHRA. The uncertainties associated with not including the ingestion pathway for these CoPCs are discussed in the uncertainties section of this HHRA.

Table IV-9: Contaminant concentrations (wet weight) for fish samples from the KIH reference and APEC locations and a comparison to guidelines and standards and between reference and APEC locations

	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cr (mg/kg)	As (mg/kg)	MeHg (filet) (mg/kg)	pp-DDE (mg/kg)	PCB (filet) (mg/kg)
APEC fish samples								
Maximum	1.3	1.3	39	1.21	0.2	0.5	0.004	2.7
Minimum	0.2	<0.1	3.8	<0.25	<0.05	<0.01	0.002	<0.03
# samples	38	38	38	14	38	104	15	104
% non-detects	0	71	0	29	82	2	7	6
95UCL	0.71	0.28	19.5	0.64	0.095	0.10	0.0033	0.34
Reference site fish samples								
Maximum	1.8	1.5	35	0.424	<0.30	0.2	0.002	0.12
Minimum	<0.02	<0.11	4.8	<0.23	<0.23	0.02	0.002	<0.01
# samples	24	24	24	7	7	59	5	25
% non-detects	4.2	29	0	29	100	0	0	60
95UCL	0.82	0.82	15.6	0.36	NP	0.076	NP	0.047
Comparison								
Max_{APEC} > Max_{ref}	N	N	Y	Y	n/a	Y	Y	Y
Statistical APEC > reference	n/a	n/a	N	N	n/a	N	N	Y
OMOE consumption guidelines						0.26–0.52[1]		0.105–0.211[1]
						0.61–1.84[2]		0.844[2]
FDR/HC guidelines[3,4]		0.5[3]			3.5[3]	0.5[4]		Under review[4]
Carried forward in risk assessment	N	N	N	N	N	N	N	Y

NP = could not be processed because data set too small; n/a = not applicable
[1]Consumption restrictions for women in child-bearing age and children under 15 years.
[2]Consumption restrictions for the general population.
[3]Tolerances published in Food and Drug Regulation (FDR) C.R.C., c. 870, B.15.003, Table 1, content in fish protein (Department of Justice 2013).
[4]Canadian standards (maximum levels) for various chemicals in specified retail foods, Table 1 (Health Canada 2012a). Hg standard applies to edible portion of all retail fish except escolar, orange roughy, marlin, fresh and frozen tuna, shark and swordfish.

To assess CoPCs by comparison to published standards, a search revealed that only MeHg and PCBs consumption guidelines were available for sport fish (OMOE 2013) and therefore only these contaminants (using the maximum concentration) could be assessed in this way. The OMOE consumption guidelines were developed for use by Ontario anglers and are based on tolerable daily intake guidelines provided by the Food Directorate of Health Canada. The fish consumption guidelines specify the contaminant levels at which consumption restrictions begin and levels at which total consumption restriction is advised for both the sensitive (women at child-bearing age and children under the age of 15 years) and the general population. The maximum value for Hg from the APEC was above the lowest guideline for women in child-bearing age and children under 15 years (i.e., where restrictions are advised to begin in this age group), but below the upper guideline. The maximum value for PCBs was well above all of the OMOE guidelines.

Tolerances and standards for fish and fish protein in retail foods are available for several contaminants (Department of Justice 2013; Health Canada 2012a) and the available values were also included for comparison. In this comparison only Pb and PCBs were substantially above the published values.

To help clarify the above assessments and to assess the CoPCs for which no guidelines or standards are available, maximum concentrations of all CoPCs were compared with the maximum concentrations in fish tissue from reference locations (Table IV-9). Pb was above the Food and Drug Regulation value, but this was true both at the APEC and reference sites. The APEC values for Pb were below those for the reference site, and therefore Pb was not carried forward in the risk assessment, since this comparison was considered more relevant. CoPCs for which the maximum APEC concentrations exceeded the maximum reference site values were further evaluated by statistical comparison using ProUCL hypothesis testing including non-detects. The results indicated that PCBs were the only CoPC statistically significantly elevated in KIH APEC fish compared with reference fish, and therefore this was the only CoPC included in the risk assessment for consumption of fish. The 95UCL of PCBs (filet) from the APEC locations was used as the EPC in risk calculations.

2. Identification of Receptors

The goal of the HHRA is to estimate the potential health risks for all human users of the KIH during recreational activities such as fishing, boating (canoeing and rowing), wading along the shoreline, swimming and consuming harvested fish from the KIH.

Receptors are not expected to be using the KIH as a source of drinking water, which is provided to all nearby residents through the Kingston drinking water supply.

Adult, teen, child and toddler recreational users of the KIH were assessed in this report. Adults and children (5–11 years) are the receptors most likely to be using the site with the highest frequency. The health risks associated with the KIH to toddlers who may be on site have been included because toddlers are considered the most sensitive receptors to CoPCs (Health Canada 2012b).

3. Identification of Exposure Pathways

Only operable exposure pathways were considered in the KIH HHRA, that is, those pathways available for the receptor to come into contact with the CoPCs on site. Inoperable pathways are either non-existent on site or represent situations in which all CoPC concentrations are below guidelines or reference values. The extent of exposure is determined by the mechanism through which a receptor may come into contact with a CoPC and the transport of the CoPC in the environment.

The following generic transport mechanisms that may cause a receptor to come in contact with CoPCs are considered when assessing exposure pathways for an HHRA:

1. Direct contact (with soil, sediment, dust, liquid product phase or dissolved in water);
2. Transport of liquid product phase contaminants;
3. Transport of contaminants dissolved in ground- or surface water;
4. Airborne transport (dust); and
5. Vapour transport.

The following generic exposure mechanisms through which a receptor may come in contact with CoPCs are also considered:

1. Inhalation (dust, soil particles, vapour);
2. Direct ingestion (soil, contaminants dissolved in water, sediment);
3. Indirect ingestion (contaminated foodstuffs, suspended sediments); and
4. Dermal contact (soil, water, sediment).

Exposure scenarios that may exist in the KIH were qualitatively assessed to determine the potential for human receptors to come into contact with CoPCs on site. The definitions of the terms used to make the qualitative assessment are given in Table IV-10. Potential exposure pathways in the KIH are outlined in Table IV-11, along with the assessment of the likelihood of contact associated with the exposure pathway and the rationale for inclusion or exclusion in the risk assessment.

Table IV-10: Definition of terms used to classify exposure scenarios

Likelihood of exposure	Definition
Very unlikely	Level of exposure that could result in adverse effects is not expected.
Unlikely	Level of exposure that could result in adverse effects would probably not occur.
Possible	Level of exposure that could result in adverse effects might occur.
Likely	Level of exposure that could result in adverse effects is expected.

Table IV-11: Potential exposure pathways considered in the assessment of human health in the KIH

Exposure pathway	Likelihood of exposure	Carried forward	Justification
Ingestion of soil	Unlikely	No	This HHRA estimates the health risks associated with the aquatic aspects of the KIH.
Dermal contact with soil	Unlikely	No	
Inhalation of soil particles	Unlikely	No	
Inhalation of soil vapours	Unlikely	No	
Direct and indirect ingestion of sediment	Likely	Yes	Direct ingestion of bulk sediment is a possible pathway and can be considered significant especially for toddlers and children who play in shallow water. Sediments on their hands would contribute to some incidental ingestion. Indirect ingestion of sediments generated from re-suspension of contaminated bottom sediments during activities such as swimming in turbid or recently disturbed water is also considered a possible pathway. Exposure to suspended sediments via ingestion and dermal contact would be significantly less than exposure via direct ingestion due to several factors including the low amount of suspended sediments in water.

Table IV-11: Potential exposure pathways considered in the assessment of human health in the KIH, cont'd.

Exposure pathway	**Likelihood of exposure**	**Carried forward**	**Justification**
Direct and indirect dermal contact with sediment	Likely	Yes	Direct dermal contact with sediment is likely during wading, walking, boating and playing activities. The depth of the KIH allows for standing on top of the sediment across most of the area. Indirect dermal contact with suspended sediments via swimming has also been considered in this HHRA. Indirect dermal contact would be significantly less than exposure via direct dermal contact with bottom sediments due to several factors including the low amount of suspended sediments in water (presence of water prevents significant adherence of suspended particles to skin). The extent to which the contact or ingestion occurs may differ between exposure scenarios (e.g., the dermal contact associated with boating vs. swimming).
Inhalation of sediment particles/vapour	Very Unlikely	No	It is very unlikely that CoPCs contained in the sediment will volatilize allowing for inhalation to be considered an operable exposure pathway, because sediments are not exposed to air for a sufficient time to dry up and generate dust particles.
Ingestion of surface water	Possible	No	All recreational activities assessed in this risk assessment may involve direct contact with the surface water and the inadvertent ingestion of surface water. However, suspended solids are the source of CoPCs in the surface water, and these are included in the sediment pathways above. The CoPCs analyzed in the surface water samples (dissolved) were below Health Canada or OMOE drinking water criteria.
Dermal contact with surface water	Possible	No	
Inhalation of surface water vapours	Unlikely	No	The CoPCs analyzed in this study are not expected to volatilize from surface water.
Ingestion of groundwater	Very unlikely	No	Groundwater is not used as a source for consumption or other uses and therefore is considered an inoperable pathway.
Dermal contact with groundwater	Very unlikely	No	
Inhalation of groundwater vapours	Very unlikely	No	
Ingestion of wild game/ foodstuffs	Likely	Yes	Consumption of fish caught within the KIH is considered likely.

4. Conceptual Site Model for HHRA

Based on the qualitative screening presented above, the conceptual site model (CSM) that forms the basis of the HHRA is as follows:

1. An adult (>20 years of age) who visits the KIH may be exposed to the CoPCs by the following routes:
    a. inadvertent ingestion of and dermal contact with sediment during wading, walking, and playing activities;
    b. ingestion and dermal contact with suspended sediments during swimming and rowing; and
    c. ingestion of contaminated food stuffs (fish caught in the KIH).
2. A teen who visits the KIH may be exposed to the CoPCs by the following routes:
    a. inadvertent ingestion of and dermal contact with sediment during wading, walking, and playing activities;
    b. ingestion and dermal contact with suspended sediments during swimming and rowing; and
    c. ingestion of contaminated food stuffs (fish caught in the KIH).
3. A toddler who visits the KIH may be exposed to the CoPCs by the following routes:
    a. inadvertent ingestion of and dermal contact with sediment during wading, walking, and playing activities;
    b. ingestion and dermal contact with suspended sediments during swimming and rowing; and
    c. ingestion of contaminated food stuffs (fish caught in the KIH).
4. A child who visits the KIH may be exposed to the CoPCs by the following routes:
    a. inadvertent ingestion of and dermal contact with sediment during wading, walking, and playing activities;
    b. ingestion and dermal contact with suspended sediments during swimming and rowing; and
    c. ingestion of contaminated food stuffs (fish caught in the KIH).

A CSM illustrating all of the processes mentioned above is shown in Figure IV-1.

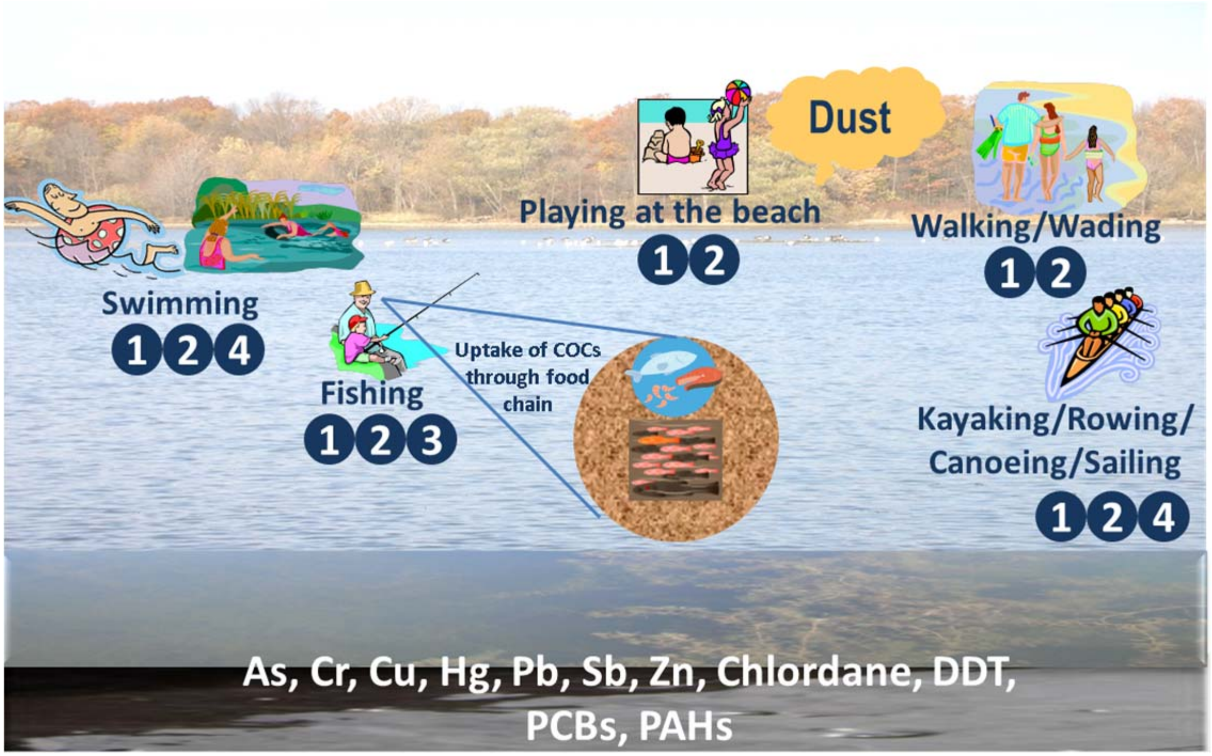


Figure IV-1: Human health risk conceptual site model (CSM) for the KIH. Major exposure pathways are (1) incidental ingestion of sediments, (2) dermal contact with bulk sediments, (3) ingestion of fish (who have taken up CoPCs from sediments), and (4) dermal contact and ingestion of suspended bottom sediments.

C. Exposure Scenarios

All exposure scenarios in this HHRA assessed recreational activities such as swimming, playing and wading along the shoreline, picnicking, water sports such as canoeing, rowing or sailing during the months in which weather permits. The estimated time of exposure associated with each of these activities is provided in Table IV-12.

Swimming exposure time reflects the average time per day spent in outdoor activities for adult, toddler and child receptors based on Richardson (1997). Children would be expected to spend the greatest amount of time in the water compared with other groups. The number of days per year associated with recreational activities was chosen based on climate records provided by Environment Canada for days in Kingston with average daily temperatures above 20°C (EC 2009).

Exposure to contaminants through fish consumption has been estimated based on the 2003 Guide to Eating Ontario Sport Fish Questionnaire (OMOE 2006a) which provides information on fishing frequency and fish consumption patterns in the Great

Lakes. The average meal size calculated based on 251 responses was 236 g in 2003 and the mean annual consumption was 39 meals per year. OMOE estimated the average daily consumption of sport fish to be 24.9 g. OMOE (2006a) provides an ingestion rate only for the adult receptor; therefore ingestion rates normalized to body weight were calculated for the teen, child and toddler receptors. The OMOE ingestion rate has been deemed appropriate to assess risk from fish consumption for the receptors of the KIH, because it is based only on sport fishing. Health Canada no longer recommends fish ingestion rates in their risk assessment guidance and instead refers the reader to the Food Directorate. Fish consumption rates were located in Health Canada (2007), but sport fish amounts that were recommended were based on all seafood, apply to heavy consumers, and include subsistence fishing; thus they were not considered to be locally representative of the conditions in KIH.

Table IV-12: Exposure times associated with recreational activities in the KIH

Activity	Exposure	d/y	Source
Recreational activities such as wading, boating, fishing	2–4 h/d	61 (July and August)	Shoaf 2005a/ site-specific timing
Swimming: Adult Teen Child Toddler	 72.8 min/d 72.8 min/d 79.5 min/d 72.8 min/d	61 (July and August)	Richardson 1997/ site-specific timing
Fish ingestion: Adult Teen Child Toddler	 24.9 g/d 21.0 g/d 11.6 g/d 5.8 g/d	365	OMOE 2006a

1. Calculation of Estimated Daily Intake (EDI)

A summary of the receptor characteristics and exposure scenarios for toddler, child, teen and adult receptors is presented in Table IV-13. These characteristics were used to calculate the EDI of CoPCs for each receptor for the three main exposure pathways (incidental sediment ingestion, dermal contact with sediments and fish consumption). The EDI for each pathway was then summed to achieve a total EDI used to assess risk. Sample calculations for EDI are presented in Appendix I (HHRA Calculations).

Table IV-13: Receptor characteristics for possible human exposure at the KIH

Characteristics		Values				Source
		Toddler	Child	Teen	Adult	
		7 mo.–4 y	5–11 y	11–19 y	≥20 y	
ED	Exposure duration (yrs) (carcinogens only)	4.5	7	8	60	HC 2010a
F	Fraction of lifetime represented (carcinogens only); life expectancy = 80 yrs	0.056	0.088	0.1	0.75	HC 2010c
EF	Exposure frequency (d/365d) swimming/recreation	61	61	61	61	Exposure scenarios present on site
EF	Exposure frequency (d/365 d) fish consumption	365	365	365	365	Exposure scenarios present on site
MS_{Fish}	Average meal size (fish) (g)	NA	NA	NA	236	OMOE 2006a
ET	Exposure time (d/7 d)	7	7	7	7	Exposure scenarios present on site
BW	Body weight (kg)	16.5	32.9	59.7	70.7	HC 2010a
Ingestion rate						
$IR_{sediment}$[1]	Ingestion rate — sediment (mg/d)	200	200	100	100	Health Canada personal commun. Jones-Otazo
$IR_{suspended\ sediment}$[1]	Ingestion rate — suspended sediment (mg/d)	1.5	1.5	1.5	1.5	Health Canada personal commun. Jones-Otazo
IR_{water}	Ingestion rate — water (L/d)	0.6	0.8	1.0	1.5	HC 2010a
IR_{fish}	Ingestion rate — tissue (g/d)	5.8[2]	11.6[2]	21.0[2]	24.9	OMOE 2006a
Dermal contact						
SA_{body}	Total body surface area (cm^2)	6130	10,140	15,470	17640	HC 2010a
SA_{hand}	Exposed surface area — hand (cm^2)	430	590	800	890	HC 2010a
SA_{feet}	Exposed surface area — feet (cm^2)	430	780	1,250	1370	US EPA 2009

Table IV-13: Receptor characteristics for possible human exposure at the KIH, cont'd.

Characteristics		Values				Source
		Toddler	**Child**	**Teen**	**Adult**	
		7 mo.–4 y	**5–11 y**	**11–19 y**	**≥20 y**	
$SA_{arms+legs}$	Exposed surface area — other (cm^2)	2580	4550	7200	8220	HC 2010a
$SA_{body-hands}$	Exposed surface area body — hands	5,700	8,660	14,670	16,750	HC 2010a
$SAF_{arms+legs}$	Soil adherence factor — body (kg/cm^2-d)[3]	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}	HC 2010a
SAF_{hand}	Soil adherence factor — hand (kg/cm^2-d)[3]	1×10^{-7}	1×10^{-7}	1×10^{-7}	1×10^{-7}	HC 2010a
SL_{hand}	Sediment loading factor — hand (kg/cm^2-d)[3]	4.9×10^{-7}	4.9×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	Shoaf 2005a, b
SL_{feet}	Sediment loading factor — feet (kg/cm^2-d)[3]	2.1×10^{-5}	2.1×10^{-5}	5.8×10^{-7}	5.8×10^{-7}	Shoaf 2005a, b

N/A = not available
HC = Health Canada
[1]Health Canada does not provide ingestion rates for incidental sediment ingestion; therefore, the soil ingestion rate was used as the incidental sediment ingestion rate.
[2]Calculated by normalizing the daily rate estimated by OMOE (2006a) to body weight.
[3]Health Canada (2012b) and Shoaf (2005a, b) values per event; one event per day assumed.

a. Exposure Factors for Dermal Contact

For dermal contact, exposure factors were selected from four sources: Health Canada (2012b), Shoaf (2005a, b) and US EPA (2011). To model the scenario of wading, which represents the likeliest and most conservative scenario of *direct* contact between skin and sediment, Shoaf (2005a, b) values were used for the sediment loading (i.e., adherence) that takes place from hand and foot contact, as the Shoaf values are more specific to wading scenarios. In the same scenario, Health Canada (2012b) values were used for sediment loading through arm + leg contact (Shoaf values were not available for both parts combined). Soil and sediment loading values from Health Canada (2012b) and Shoaf (2005a, b) are reported in units per event (kg/cm^2) and the event was assumed in the present HHRA to take place once per day, allowing the values to be expressed in kg/cm^2-d. Health Canada (2012b) values were used for the surface areas of hands, arms and legs, but values were not available for the surface area of feet; the surface area was obtained from US EPA 2011 instead.

To model the scenario of *indirect* contact between skin and sediment, specifically through swimming and contacting suspended sediments, Health Canada (2012b) values were used for hands and for the rest of the body, for both surface area and sediment loading.

b. Lifetime Average Daily Dose (LADD) for Dermal Exposure to PAHs

For the calculation of risk from dermal exposure to PAHs, a different approach was taken from the above calculations of EDI. Since this is a new approach with technical guidance from Health Canada still pending, it is described in detail here.

For the calculation of cancer risk, which applies for most PAHs, the EDI is calculated as a LADD, which is usually the same calculation as the EDI but includes any amortization of the exposure time to the CoPC over a lifetime. For example, in a worker scenario, where workers are exposed for 30 years but live for 80 years, the exposure would be amortized over the lifetime by multiplying the EDI by 30/80. For the present HHRA, the most conservative assumption applies, specifically that a person may be exposed to the KIH for their entire life. Therefore this amortization does not apply, although a weighting for each stage of a lifetime was used (for all carcinogens; details are shown in Appendix I).

A specific feature of PAH risk assessment is that the dermal exposure route is targeted, since skin cancers from PAHs have been observed, in animal studies, to occur at the site of dermal contact. Therefore, a LADD for this route is calculated separately. The equation below shows the approach taken by Knafla et al. 2011, modified for the calculation of the LADD (in Knafla et al. 2011, the risk is calculated) and recently adopted by Health Canada (personal communication, Lindsay Smith-Munoz).

$$LADD = \frac{C_s \times SM \times SA_{SL\ EXP} \times RAF_{AS} \times ETF \times D_1 \times D_2 \times D_3}{SA_{ST\ EXP} \times LE \times 1000}$$

Equation 1

The terms are explained with comments in Table IV-14.

Table IV-14: Definition of terms in LADD equation for PAH dermal risk calculations

Term	Definition	Comments
LADD	Lifetime average daily dose in µg/cm^2-d	Note the difference in units compared with other LADD (mg/kg of body weight-d)
C_S	Soil concentration in µg/g	Sediment concentration used in present HHRA, µg/g = mg/kg
SM	Soil monolayer loading rate, 5 mg/cm^2	This term is cancelled when multiplied by the next term
$SA_{SL\ EXP}$	Surface area of skin loaded with a monolayer of soil (cm^2)	$SA_{SL\ EXP} = \frac{SL}{SM} \times SA_{EXP}$, Where *SL* = soil loading factor in mg/cm^2-event *SM* = as defined above SA_{EXP} = surface area of exposed body parts e.g., hands, in cm^2
RAF_{AS}	Relative retention factor for benzo[a]pyrene (B[a]P) in a soil monolayer compared to acetone	Health Canada recommends this value as RAF_{derm}, equal to 0.148, see Table IV-17 and Section D.2
ETF	Viable cellular epidermal thickness factor	Value recommended is 0.2 as follows: $ETF = \frac{0.0104\ mm\ (skin\ from\ back\ of\ mice)}{0.052\ mm\ (average\ of\ human\ hands\ and\ arms)} = 0.2$
D_1, D_2, D_3, *LE*	Exposure time factors	In present HHRA, 61 d/365 d per year; other factors are 1.
$SA_{SL\ EXP}$	Surface area of mouse skin dosed with B[a]P in acetone, 6 cm^2	
1000	Conversion factor (mg to µg)	

Simplification of the LADD equation (Equation 1) and consideration of the terms and comments in Table IV-14 gives the following equation:

$$LADD = \frac{C_s \times SL \times SA_{EXP} \times RAF_{derm} \times 1\frac{event}{d} \times ETF \times D_1}{SA_{ST\ EXP}}$$

Equation 2

Where:

Cs = concentration of PAH equivalent to B[a]P in sediment (mg/kg x 1000 = μg/kg)

SL = sediment loading factors (Table IV-13) (kg/cm^2*event)

SA_{EXP} = surface area of exposed skin (Table IV-13) (cm^2)

RAF_{derm} = skin absorption of B[a]P from soil relative to acetone (0.148)

ETF = adjustment for different in mouse and human epidermal thickness (0.2)

D_1 = exposure time for swimming/wading (61 d/365d), other factors are 1

$SA_{ST\,EXP}$ = Surface area of mouse skin dosed with B[a]P in acetone (6 cm^2)

An example of the calculation for adults exposed dermally and indirectly (to suspended particles during swimming; hands with higher loading factor than the rest of the body) to 2.9 mg/kg (2900 μg/kg) of B[a]P is shown:

$$LADD\ (\mu g/cm^2 \cdot d) = \frac{2900\ \mu g/kg \times (1\times\ 10^{-7}\ kg/cm^2 \cdot d\ \times 890\ cm^2 + 1\times\ 10^{-8}\ kg/cm^2 \cdot d\ \times 16750\ cm^2) \times 0.148 \times 0.2\ \times \frac{61d}{365d}}{6\ cm^2}$$

$$LADD = 6.1\ \times 10^{-4}\ \mu g/cm^2 \cdot d$$

The simplified Equation 2 reveals three unique features of this approach compared with the usual calculation of EDI or LADD. (1) A value to adjust for the difference between mouse skin and human skin is included, the ETF, equivalent to 0.2. This reduces the LADD, taking into account that mouse skin is thinner than human skin, and assumes that human response to cancer is reduced as a result of thicker skin. (2) The surface area of mouse skin dosed with B[a]P in acetone is included (6 cm^2). This spreads the amount of B[a]P to which a human is exposed (in μg, calculated in the numerator) over the surface area of mouse skin used in the carcinogenicity assay used to develop the carcinogenic slope factor, expressing the LADD in $\mu g/cm^2$. (3) No adjustment for body weight of humans is included.

The latter two features are based on the argument in Knafla et al. (2011) and accepted by Health Canada, that a body weight scaling factor for humans compared with mice is not appropriate for dermally derived cancer. (The only adjustment to accommodate interspecies differences is the ETF). The use of the $SA_{ST\ EXP}$ term in the calculation essentially scales the larger surface area of human skin that can be exposed (e.g., 430 cm^2 for a toddler's hands) relative to that of the mouse exposed surface area (6 cm^2).

D. Toxicity Assessment

CoPCs considered to have an exposure threshold below which adverse health effects are not expected are classified as threshold or non-carcinogenic contaminants. CoPCs that are expected to cause an adverse health effect at any level of exposure are referred to as non-threshold contaminants and are assumed to have the potential to cause cancer. Some contaminants may be carcinogenic but also exhibit non-carcinogenic effects for other toxicological endpoints.

Both carcinogenic and non-carcinogenic endpoints were considered for the applicable CoPCs. The classification of the CoPC, based on the endpoint from exposure and the exposure scenario used to assess risk for each CoPC, can be seen in Table IV-15.

Table IV-15: Applicable endpoints and the receptor exposure scenario for CoPCs considered in the KIH HHRA

Endpoint from exposure	Receptor exposure scenario
Carcinogenic CoPCs: As and several PAHs	Receptor model assumes visits to the KIH throughout a lifetime, starting in childhood and lasting for 80 years.
Non-carcinogenic CoPCs: As, Cr, Hg, Pb, Sb, Zn, DDT, chlordane, PCBs, naphthalene and pyrene	Most sensitive receptor modeled (toddler). Accurate receptor of on-site uses modeled (adult, teen and child visitor).

1. Selection of Toxicological Reference Values (TRVs)

TRVs are used to define the dose of a substance to which an individual may be exposed without causing adverse health effects. TRVs have been established by several agencies, including Health Canada, the US EPA, and the World Health Organization. Values published by Health Canada are accepted for use at federal contaminated sites; however, in the absence of a Health Canada value, values reported by the US EPA have been cited. The TRVs used in the HHRA of the KIH are presented in Table IV-16. The source of the TRVs should be assumed to be Health Canada (2010a) unless otherwise noted. TRVs for inhalation exposure have not been included because the pathway was not considered in this risk assessment.

TRVs specific to the dermal route are not available for most contaminants and according to standard risk assessment practices, dermal exposures are assessed by comparison to oral TRVs. The exception is a group of carcinogenic PAHs (in the present HHRA, anthracene, benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, and phenanthrene). Health Canada has derived a dermal carcinogenic TRV for benzo[a]pyrene, and exposures for the previously listed compounds are adjusted through the use of potency equivalence factors (PEFs) (Health Canada 2010a, 2012b) and the TRV is then used for the sum of all these PAHs. The adjustment was carried out as follows for each PAH (Equation 3):

$$TRV_{PAH} = slope\ factor\ [2.3(mg/kg \cdot d)^{-1}] \times PEF_{PAH}$$

Equation 3

Table IV-16: TRVs used in the KIH HHRA. PAH TRVs have been adjusted for PEF (see text for details).

CoPC	PEF/ TEF	Non-carcinogenic TRV	Carcinogenic TRV	
		TDI (oral) (mg/kg-d)	CSF (oral) $(mg/kg\text{-}d)^{-1}$	CSF (dermal) $(\mu g/cm^2\text{-}d)^{-1}$
As		3.0×10^{-4}*	1.8	
Cr(III)		1.5*		
Hg		3.0×10^{-4}		
Pb		1.85×10^{-3}†		
Sb		4.0×10^{-4}*		
Cu		0.091 (toddler) 0.11 (child) 0.126 (teen) 0.141 (adult)		
Zn		0.48 (toddler and child) 0.54 (teen) 0.57 (adult)		
DDT		1.0×10^{-2}		
Chlordane		3.3×10^{-5}		
PCBs (total)		1.3×10^{-4}		
Benzo[a]pyrene	1		2.3	3.5
Benzo[a]anthracene	0.1		0.23	0.35
Benzo[b]fluoranthene	0.1		0.23	0.35
Benzo[g,h,i]perylene	0.01		0.023	0.035
Benzo[k]fluoranthene	0.1		0.23	0.35
Chrysene	0.01		0.023	0.035
Dibenzo[a,h]anthracene	1		2.3	3.5
Fluoranthene	0.001		0.0023	0.0035
Indeno[1,2,3-cd]pyrene	0.1		0.23	0.35
Phenanthrene	0.001		0.0023	0.0035
Naphthalene		0.02		
Pyrene		0.03		

TDI = tolerable daily intake; CSF = cancer slope factor.
* Source: US EPA (1998a, 1997, 1996, 1993a)
†OMOE and Health Canada personal communication; currently under review by Health Canada

For chromium, only the less toxic chemical species, Cr(III), is considered in this HHRA, since this is the form found the sediment of the KIH (see Chapter 2 for more details). Health Canada considers Cr(III) to be an essential nutrient, and recommends that for these types of chemicals, a tolerable upper intake level (UL), based on those published by the Institute of Medicine of the National Academies (IOM), be used as the TRV in risk assessment (Health Canada 2010a). However, a UL for Cr(III) has not been provided by Health Canada, nor published by IOM (Otten et al. 2006). IOM recommends that in the absence of the UL, adequate intake (AI) values should not be exceeded. AIs expressed as µg/d have been published for human receptors (infants, children, and adults, for males and females, in pregnancy and lactation) ranging from 0.2–45 µg/d (Otten et al. 2006; Cr information found on pages 296-303). TRVs obtained in this way range from 0.00033-0.0005 mg/kg-d, which is less than the TRV recommended by Health Canada for total Cr (and based on Cr(VI) toxicity) of 0.001 mg/kg-d (Health Canada 2010a). Since Cr(VI) is not considered in this risk assessment, the more conservative AI-based TRVs are also not applicable. US-EPA has derived an oral reference dose (RfD) specific for Cr(III) and its insoluble salts (US-EPA 1998a, b) that has also been used as a TRV by OMOE to derive human health soil and groundwater standards for total Cr (OMOE 2011). This RfD is used commonly in many risk assessments of chromium-contaminated soil since primarily Cr(III) is found in soils at contaminated sites. Based on the knowledge of the chromium speciation at the site, the US EPA-based TRV was used in the present risk assessment.

A summary of the toxicological data relevant to this HHRA has been included in Appendix J.

2. Bioavailability

Bioavailability refers to the proportion of the exposure dose of a contaminant that reaches systemic circulation (bloodstream) (Oomen et al. 2002). This is the amount that causes the toxic response in the toxicological studies used to derive TRVs. In most of these toxicological studies a soluble form of a contaminant is used, and thus if contaminants are not as soluble in the exposure matrix, such as soil, the risk can be overestimated. To adjust for this, the relative absorption factor (RAF) is used in risk assessment calculations. The bioavailability of all CoPCs for the ingestion exposure pathway is assumed to be 100 percent in the present risk assessment (a factor of 1.0 is applied).

Absorption through skin is known to be low and therefore dermal relative absorption factors are typically used. In the present risk assessment they were sourced from Health Canada (2010a) and OMOE (2011), and are summarized in Table IV-17. For all of these CoPCs, except several PAHs, this factor adjusts for the difference in absorption from soil through skin, compared with the absorption through the gastrointestinal tract of a soluble form of the CoPC. This adjustment is necessary since the dermal absorption risk is evaluated by comparison to an oral TRV for all the CoPCs, except several PAHs.

Table IV-17: Dermal relative absorption factors (RAF_{derm})

	Cu	**Pb**	**Zn**	**Cr**	**As**	**Hg**	**Sb**	**DDT**	**Chlor**	**PCBs**	**PAHs**
RAF_{derm}	0.06	0.006	0.1	0.1	0.03	1	0.1	0.03	0.04	0.14	0.148
Source	HC 2010a	OMOE 2011	HC 2010a	HC 2010a	HC 2010a	HC 2010a	OMOE 2011	OMOE 2011	OMOE 2011	HC 2010a	HC 2010a

Chlor = chlordane
HC = Health Canada

Health Canada has derived a dermal TRV for benzo[a]pyrene, and states that the dermal relative absorption factor for this compound adjusts for the difference between dermal absorption of benzo[a]pyrene from soil compared with dermal absorption in the toxicological study (from acetone), in both cases into the epidermis (not the bloodstream) (Health Canada 2010a, Knafla et al. 2011). Additionally Health Canada recommends that the dermal relative absorption factors for all PAHs are the same as the one listed for benzo[a]pyrene.

E. Risk Characterization

A detailed explanation of the calculations used to assess risk posed by the CoPCs found on site is attached in Appendix I.

1. Non-carcinogenic Risk

Risks posed by non-carcinogenic CoPCs are calculated by comparing the estimated daily exposure on site with the identified toxicological reference value (TRV) for each chemical. Since this study evaluated only the potential risk posed by CoPCs found in the KIH, a target hazard quotient (HQ) of 0.2 (20 percent of the TRV) was used. Using an HQ of 0.2 allows for 80 percent of the exposure from CoPCs found in the KIH to come from background or non-site-related incidences.

The HQ was calculated using Equation 4:

$$HQ = \frac{EDI}{TDI}$$

Equation 4

where: EDI = estimated daily intake (mg/kg-d) from on-site CoPCs

TDI = tolerable daily intake (mg/kg-d) of CoPC

If the HQ ≤ 0.2, the intake of CoPCs from site exposure does not exceed 20% of the tolerable level of intake and no adverse health effects are expected. The EDIs from the oral and dermal routes were summed before being compared with the oral TDI value.

A detailed summary of the calculated HQs for the exposure pathways is presented in Table IV-18 for each threshold contaminant. Individual EDIs are provided for the oral ingestion, dermal contact and fish consumption pathways in Appendix I.

Table IV-18: Hazard quotients for each receptor by exposure pathway (fish = fish consumption; sediment = sediment contact, both ingestion and dermal). Shaded values represent HQs equal to or above the acceptable health criterion of 0.2.

CoPC	Adult HQ			Teen HQ			Child HQ			Toddler HQ		
	Total	Fish	Sediment	Total	Fish	Sediment	Total	Fish	Sediment	Total	Fish	Sediment
As	0.061	0	0.061	0.070	0	0.070	0.59	0	0.59	0.80	0	0.80
Cr(III)	0.001	0	0.001	0.001	0	0.001	0.016	0	0.016	0.019	0	0.019
Hg	0.028	0	0.028	0.030	0	0.030	0.50	0	0.50	0.56	0	0.56
Pb	0.028	0	0.028	0.033	0	0.033	0.16	0	0.16	0.28	0	0.28
Sb	0.077	0	0.077	0.086	0	0.086	1.1	0	1.1	1.3	0	1.3
Cu	1.9×10^{-4}	0	1.9×10^{-4}	2.4×10^{-4}	0	2.4×10^{-4}	3.0×10^{-3}	0	3.0×10^{-3}	4.5×10^{-3}	0	4.5×10^{-3}
Zn	2.5×10^{-4}	0	2.5×10^{-4}	2.9×10^{-4}	0	2.9×10^{-4}	4.1×10^{-3}	0	4.1×10^{-3}	4.9×10^{-3}	0	4.9×10^{-3}
DDT	7.5×10^{-7}	0	7.5×10^{-7}	8.6×10^{-7}	0	8.6×10^{-7}	7.2×10^{-6}	0	7.2×10^{-6}	9.8×10^{-6}	0	9.8×10^{-6}
Chlordane	1.2×10^{-4}	0	1.2×10^{-4}	1.3×10^{-4}	0	1.3×10^{-4}	1.3×10^{-3}	0	1.3×10^{-3}	1.6×10^{-3}	0	1.6×10^{-3}
PCBs	0.92	0.916	0.006	0.92	0.91	0.007	1.01	0.92	0.097	1.03	0.91	0.11
Naphthalene	1.7×10^{-5}	0	1.7×10^{-5}	2.0×10^{-5}	0	2.0×10^{-5}	2.6×10^{-3}	0	2.6×10^{-4}	3.0×10^{-3}	0	3.0×10^{-3}
Pyrene	1.1×10^{-4}	0	1.1 x 10-4	1.3×10^{-4}	0	1.3×10^{-4}	1.7×10^{-3}	0	1.7×10^{-3}	2.0×10^{-3}	0	2.0×10^{-3}

2. Carcinogenic Risk

The incremental lifetime cancer risk (ILCR) associated with exposure to carcinogenic CoPCs is calculated by multiplying the daily dose of the on-site contaminant by the cancer slope factor specific to each CoPC. A benchmark of 1 in 100,000 was used to screen contaminants that had the potential of causing cancer through exposure to the CoPCs present. That is, if the ILCR is $<10^{-5}$, the potential of developing cancer from exposure to carcinogenic CoPCs at the KIH is negligible.

The ILCR is calculated using Equation 5:

$$ILCR = LADD\ x\ CSF$$

Equation 5

where: LADD = lifetime average daily dose in mg/kg-d or μg/cm^2-d

CSF = cancer slope factor in (mg/kg-d)$^{-1}$ or (μg/cm^2-d)$^{-1}$

ILCRs were amortized throughout all age groups over a lifetime, for all carcinogenic CoPCs. The calculated ILCRs are presented in Table IV-19.

A feature that is specific to the dermal ILCR for PAHs is related to the slope factor calculation, which was carried out by Knafla et al. (2011) from a slope factor of 0.58 (μg/animal)$^{-1}$ derived by Knafla et al. in 2006. This was done by multiplying the per animal slope factor by the surface area of mouse skin dosed with B[a]P in acetone, of 6 cm^2, to give a value of 0.58 (μg/animal)$^{-1}$ × 6 cm^2 = 3.5 (μg/cm^2)$^{-1}$. Multiplying the LADD for dermal PAH exposure by the slope factor to obtain the ILCR (Equation 2 × Equation 5), and simplifying gives:

$$ILCR = \frac{C_s \times SL \times SA_{EXP} \times RAF_{derm} \times ETF \times D_1}{SA_{ST\ EXP}\ (6\ cm^2)} \times CSF\ (0.58\ (\mu g/animal)^{-1} \times 6\ cm^2)$$

$$ILCR = (C_s \times SL \times SA_{EXP} \times RAF_{derm} \times ETF \times D_1)(\mu g/human) \times CSF\ (0.58\ (\mu g/animal)^{-1})$$

Equation 6

Examination of Equation 6 reveals that the human cancer risk is almost exactly comparable (with an adjustment for differences in skin thickness in the ETF) to the mouse cancer risk on a per entire-body basis. This is consistent with the previously mentioned assumption that a human to mouse carcinogenicity adjustment is not appropriate.

Table IV-19: ILCRs for carcinogenic (non-threshold) CoPCs. Shaded values represent ILCRs above the acceptable health criterion of 1 in 100,000 or 1 x 10^{-5}.

CoPC	Oral ingestion of sediment	Dermal contact with sediment	Total
As	3.6 x 10^{-5}	4.4 x 10^{-5}	8.0 x 10^{-5}
Benzo[a]pyrene	2.6 x 10^{-6}	2.9 x 10^{-2}	2.9 x 10^{-2}
Benzo[a]anthracene	1.5 x 10^{-7}	1.6 x 10^{-3}	1.6 x 10^{-3}
Benzo[b]fluoranthene	3.0 x 10^{-7}	3.4 x 10^{-3}	3.4 x 10^{-3}
Benzo[g,h,i]perylene	1.6 x 10^{-8}	1.8 x 10^{-4}	1.8 x 10^{-4}
Benzo[k]fluoranthene	7.2 x 10^{-8}	8.0 x 10^{-4}	8.0 x 10^{-4}
Chrysene	2.1 x 10^{-7}	2.3 x 10^{-4}	2.3 x 10^{-4}
Dibenzo[a,h]anthracene	2.5 x 10^{-7}	2.7 x 10^{-3}	2.7 x 10^{-3}
Fluoranthene	2.4 x 10^{-9}	2.7 x 10^{-5}	2.7 x 10^{-5}
Indeno[1,2,3-cd]pyrene	1.9 x 10^{-7}	2.0 x 10^{-3}	2.0 x 10^{-3}
Phenanthrene	1.2 x 10^{-9}	1.3 x 10^{-5}	1.3 x 10^{-5}
PAH sum	3.6 x 10^{-6}	4.0 x 10^{-2}	4.0 x 10^{-2}

3. Summary of Site Risk

Potential health risks from recreational activities in the KIH were assessed for adult, teen, child and toddler receptors. All receptors face potential non-cancer risks from the concentrations of PCBs. Toddler and child receptors also face potential non-cancer risk from As, Hg, Pb, and Sb. Risk calculations indicate that Cr(III), Cu, Zn, DDT, chlordane, naphthalene and pyrene do not pose a health risk to any of the modeled receptors.

KIH fish consumption was adapted from OMOE’s (2006a) sport fish consumption estimate for over 365 days a year. Using this rate contributed 89 to 99.5% of the health risk that was evident for PCBs.

For carcinogens in the KIH, namely As and PAHs, the main contributor to cancer risk was dermal contact with sediment, with the direct dermal contact (wading in sediments) contribution usually at least an order of magnitude higher than that from indirect dermal contact (via suspended sediments in water, through activities like swimming).

A visual example of the relative contribution of each exposure pathway to the overall hazard quotient is presented in Figure IV-2 to Figure IV-6 for As, Pb, Hg, Sb, and total PCBs using the most sensitive receptor (toddlers). The primary driver of overall risk posed by As, Pb, Hg and Sb is exposure to sediments during recreational activities, such as wading, for the child and toddler receptor. As previously mentioned, fish consumption is the primary contributing exposure pathway to overall risk from PCBs (Figure IV-2 to Figure IV-6).

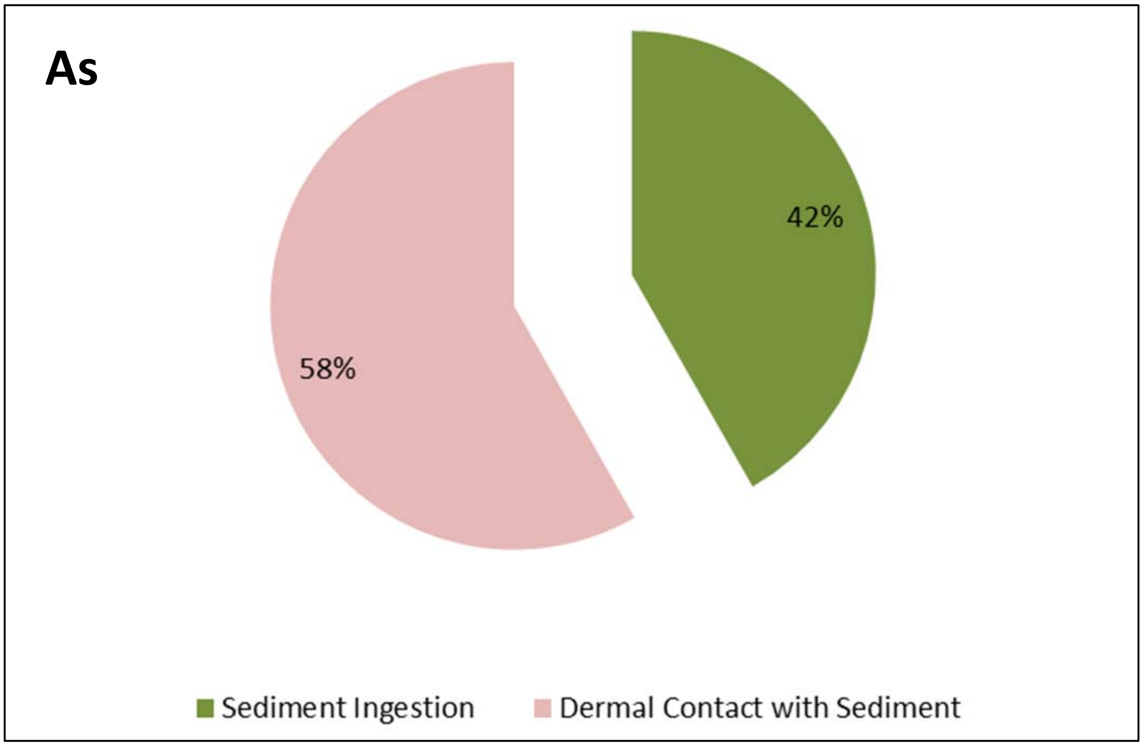


Figure IV-2: Relative contribution of the major exposure pathways to the As HQ for the toddler receptor.

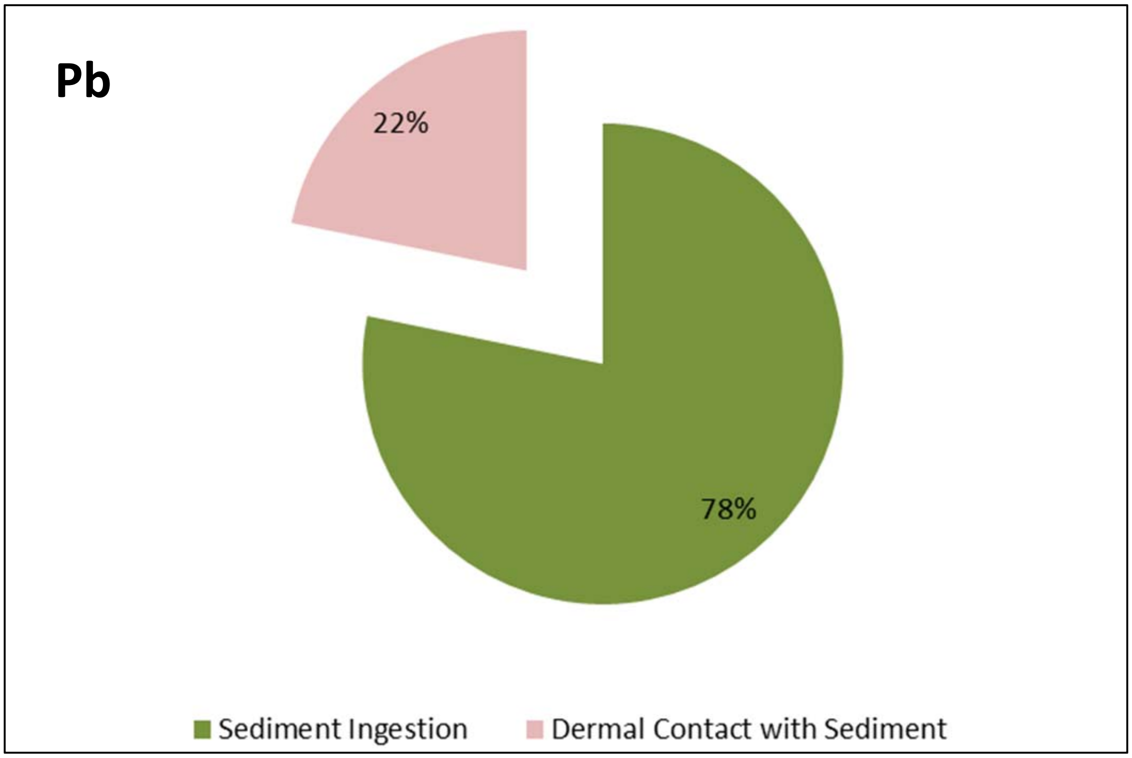


Figure IV-3: Relative contribution of the major exposure pathways to the Pb HQ for the toddler receptor.

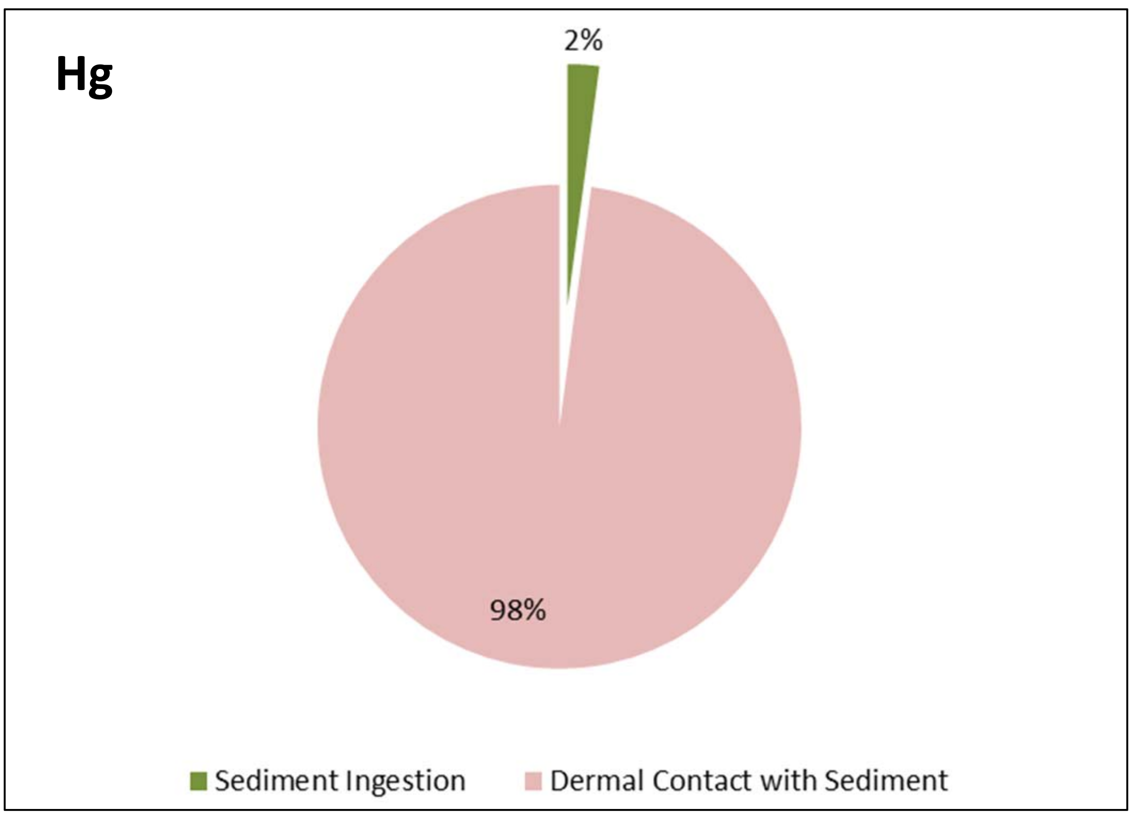


Figure IV-4: Relative contribution of the major exposure pathways to the Hg HQ for the toddler receptor.

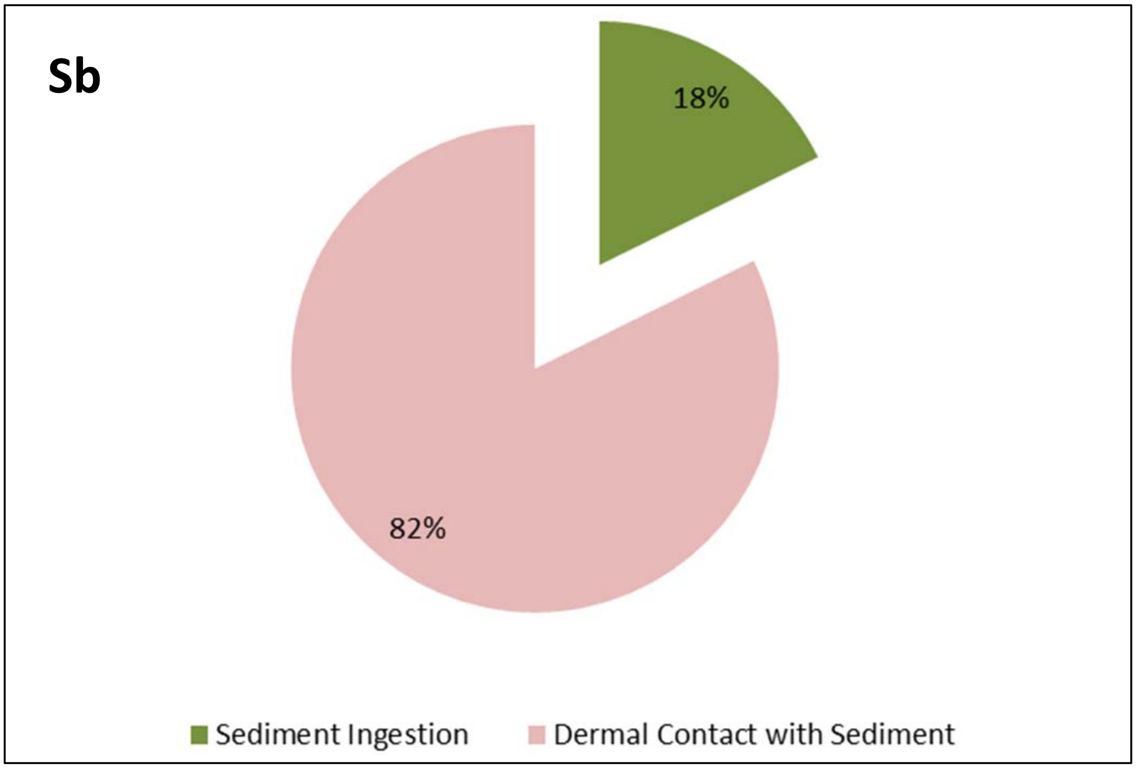


Figure IV-5: Relative contribution of the major exposure pathways to the Sb HQ for the toddler receptor.

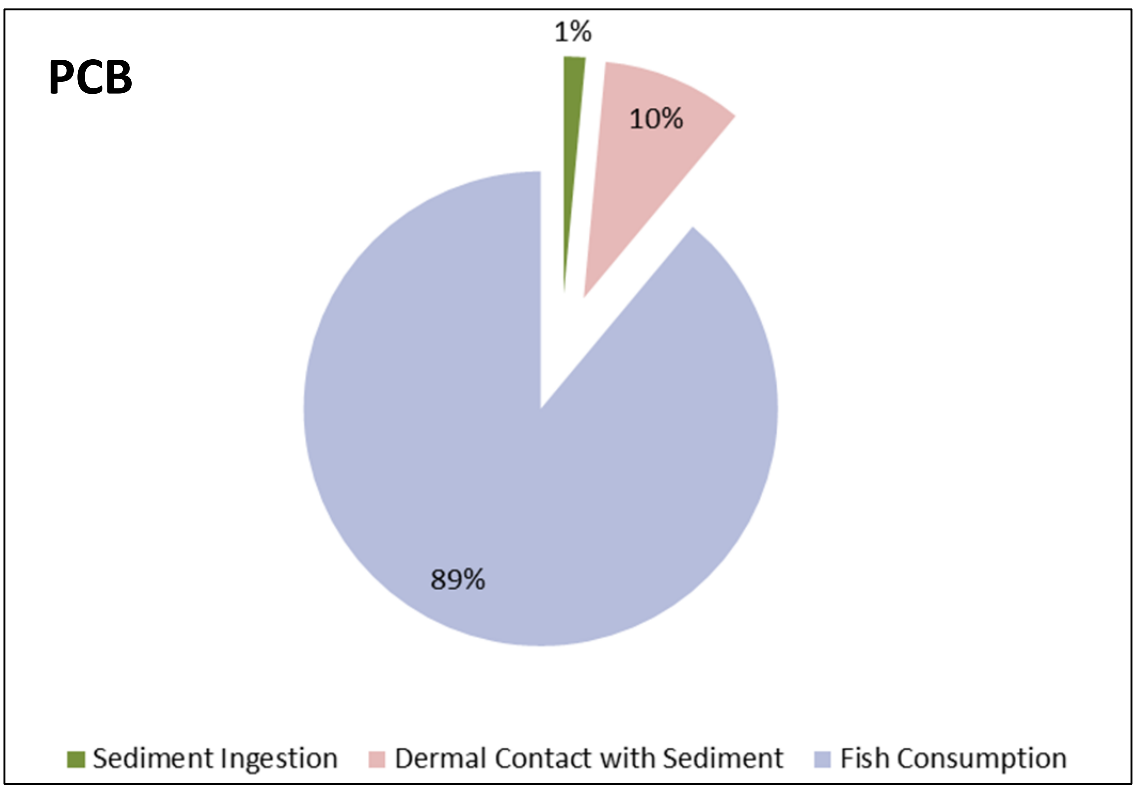


Figure IV-6: Relative contribution of the major exposure pathways to the total PCB HQ for the toddler receptor.

The risk calculations for fish consumption support current fish consumption advisories. The OMOE Guide to Eating Ontario Sport Fish (OMOE 2013) has recommended that certain populations (women of child-bearing age and children under 15 because of their higher sensitivity to contaminants) should not consume brown bullhead greater than 30 cm length, or carp greater than 55 cm caught within the KIH (the KIH-specific information for the Belle Island area is accessible at http://www.ene.gov.on.ca/environment/en/mapping/sportfish/index.htm).

F. Modification of Risk Based on Special Management Area (SMA) and Inclusion of Background Exposures

The risk that was calculated in the previous sections was estimated from point concentrations represented by 95UCLs of the entire KIH area. However, the concentration plume maps found in Chapter 2 indicate that some of the contamination is localized to smaller areas (i.e., there are "hotspots"). These areas can be designated "special management areas" (SMA). SMAs are discussed in more detail in Chapter V, but one such area that is of interest is based on high As and Hg concentrations and receptor use of the KIH shoreline at Emma Martin Park (the brown-hatched area designated Area of Special Consideration (Rowing Club) in Map B-V-1). Stakeholder input will be sought for finalized boundaries of this SMA and any other SMAs, as discussed further in Chapter V. To determine the effect on the risk when such areas are designated, risk calculations for the Emma Martin Park/Rowing Club SMA were carried out.

The contaminants for which risk was determined, because they show localized higher concentrations in the SMA, are Hg and As. The resulting values for the contaminants and risk are summarized in Table IV-20. The results indicate that outside of the SMA the As mean (6.6 mg/kg) and 95UCL (7.4 mg/kg) values fall below the CCME soil quality guideline of 12 mg/kg (CCME 2007), and approach the OMOE sediment quality standard of 6 mg/kg (OMOE 2009). Carcinogenic risk is still apparent at the concentrations outside of the SMA but approaches the Health Canada recommended safe risk level of 1 in 100,000. For Hg, risk is apparent both within and outside of the SMA for children and toddlers, but HQs are much lower when the SMA is not included.

Sb risk was noted in Table IV-18, based on a 95 UCL of 48 mg/kg. This 95 UCL was obtained from a data set that is summarized in Chapter II, as having a large number of non-detects (42%), and not being statistically different from the reference area data set.

The high 95UCL was influenced by the inclusion of two samples with 249 and 894 mg/kg Sb in them; these samples were both located at the outlet of the Orchard Marsh, south of Belle Island, and were collected from 17.5 and 52.5 cm depths. If these two outliers are removed from the data set, the maximum value becomes 81 mg/kg, and the 95 UCL is 10 mg/kg. With these values, children and toddlers have an HQ just greater than 0.2, at 0.24 and 0.29, respectively.

Table IV-20: Concentrations of As and Hg in the SMA and in the APEC outside the SMA, and concentrations of Sb minus two outlier samples, as well as risks to humans for these areas. Shaded values represent HQs equal to or above the acceptable health criterion of 0.2, or ILCRs above the acceptable health criterion of 1 in 100,000 or 1 x 10^{-5}.

Parameter	As		Hg		Sb (minus outliers)
	SMA	Outside SMA	SMA	Outside SMA	
Maximum (mg/kg)	742	38	10.7	4.9	81
Minimum (mg/kg)	6	1.7	0.0035	0.01	0.4
Mean (mg/kg)	80	6.6	1.9	0.56	5.3
# Samples	51	136	68	80	91
# Non-detects	0	4	1	4	54
% non-detects	0	2.9	1.5	5	59
95 UCL (mg/kg)	160	7.4	3.1	0.91	10
Adult HQ	0.20	0.009	0.049	0.014	0.017
Teen HQ	0.23	0.011	0.052	0.015	0.019
Child HQ	1.9	0.088	0.89	0.26	0.24
Toddler HQ	2.6	0.12	0.99	0.29	0.29
ILCR	2.6 x 10^{-4}	1.2 x 10^{-5}	NC	NC	NC

NC = not a carcinogen

Health Canada states that for a DQRA, risk characterization for non-carcinogens (i.e., hazard quotients) “can be based on 100% of the TDI because exposure from other media and background sources is quantified” (Health Canada 2010b). Therefore, the results in Table IV-20 and those for Pb (Table IV-18) should be taken in context with the background risk for these elements. The literature was reviewed for background exposures, and they are estimated in Table IV-21.

Table IV-21: Background intakes (EDI, means) and risk of inorganic As and Hg, and Pb and Sb for the human receptors at risk in the KIH HHRA. ILCR was amortized over all age groups.

Parameter	Inorganic As		Inorganic Hg		Pb	Sb	
	Child	Toddler	Child	Toddler	Toddler	Child	Toddler
EDI (mg/kg-d)	7.0×10^{-5}	1.2×10^{-4}	3.9×10^{-5}	4.5×10^{-5}	1.0×10^{-3}	0.002	0.0032
HQ	0.23	0.41	0.13	0.15	0.55	5	8
ILCR	1.1×10^{-4}		NC	NC	NC	NC	NC
Source	Xue et al. 2010[a]		Dabeka et al. 2003[b]		SENES 2010[c]	Environment Canada/ Health Canada 2010, Appendix 3	

NC = not a carcinogen
[a]95 UCL, inorganic arsenic from diet and water only. Meacher et al. 2002 shows that other media contribute small to negligible amounts of arsenic to total background intake.
[b]Mean value for Ottawa, dietary intake only (not adjusted for fish, which contributes approximately 40% Hg as MeHg); dental amalgams not included.
[c]Mean EDI; dermal contribution adjusted for RAF of 0.006.

For inorganic As, as well as for Hg and Sb, dietary input is assumed to contribute most of the human exposure (SCHER 2007, Meacher et al. 2002, ATSDR 1999, ATSDR 2007a, Environment Canada and Health Canada 2010). The As background daily intake values presented in Table IV-21 were selected for use in the present study because they summarize the intake of inorganic As specifically (only inorganic As is found in sediments), and they are based on a recent study for the U.S. population (Xue et al. 2010), which is assumed to be similar to the Canadian population in terms of exposures. More local (i.e., Canadian) estimates would have been preferable, and Health Canada provides dietary intakes for arsenic from their Total Diet Study in Winnipeg in 2004, in Toronto in 2005, in Halifax in 2006, and in Vancouver in 2007 (Health Canada 2011). However, the Health Canada values include both inorganic and organic forms of As, and the information given in the Total Diet Study results is not sufficiently detailed to estimate the amount of arsenic in the daily intakes that would be from inorganic arsenic only.

Background HQs for arsenic are 0.23 for children and 0.41 for toddlers. When the ILCR is calculated for background dietary intakes for all age groups, and with the exposures at different ages weighted over a lifetime, the result is 1.1×10^{-4}. This indicates that North Americans are at an unacceptable risk from developing cancer from As through a normal diet alone. The ILCR of 1.2×10^{-5} that resulted from a 95 UCL value of 7.4 ppm in the KIH, outside the SMA, in Table IV-20 should be considered in the context of background risk in this case (11% higher than the background risk), although Health Canada does not recommend making any adjustments to the assessment of such results.

The background exposure estimate for total Sb was obtained from a screening assessment for antimony trioxide (Environment Canada and Health Canada 2010). It includes food and beverages as the major contributor to Sb exposure (81%), but also exposures through drinking water and soil. The HQs calculated for children and toddlers from this exposure are well above 1, using the TRV applied in the present HHRA, specifically the US EPA oral reference dose value of 0.0004 mg/kg-d[1]. Therefore an adjustment using the background Sb HQs was not possible. The additional risk of exposure to KIH sediments (HQ = 1.1 for a child and 1.3 for a toddler) would constitute risk that is 16–22% higher than background risk.

The background estimates for Hg were obtained from a study conducted in Ottawa and Whitehorse in 1998–2000 (Dabeka et al. 2003), since no Hg values are provided by Health Canada. The values selected (Table IV-21) are the mean values for Ottawa, based on dietary intake only. They were not adjusted for MeHg in fish, which contributes approximately 40% Hg to the daily intake values (i.e., the value for only inorganic Hg would be approximately 60% of that shown). The Ottawa results for toddlers were approximately half of those estimated in an earlier (1982–1984) US Food and Drug Administration (FDA) dietary study (ATSDR 1999) that found that 2 year olds were exposed to 10×10^{-5} mg/kg-d (compared with 4.5×10^{-5} mg/kg-d in Table IV-21), but comparable for children (all other age groups in the FDA study had daily intakes of 5×10^{-5} mg/kg-d). A recent California study (Vogt et al. 2012) presented similar values (expressed as MeHg, since they found the major exposures to Hg were through fish) for toddlers (2–4-year-olds, mean of 3.2×10^{-5} mg/kg-d) and children (5–7-year-olds, 3.0×10^{-5} mg/kg-d). Clearly it is difficult to compare the inorganic Hg intakes between these studies since different ratios of MeHg are assumed to apply, but these values are generally consistent for total Hg, and inorganic Hg values would be lower in all cases. That is, assuming total Hg is equal to inorganic Hg in estimates of background exposure is protective.

No contributions from Hg-based dental amalgams are included in the background exposures. A TRV is not available for elemental Hg vapour (Health Canada 2010a) but

[1] Environment Canada/Health Canada (2010), however, concluded that the exposures to Sb were not excessive, since they used a LOEL of 500 mg/kg-d (not adjusted for inter-species variability or other uncertainty factors).

the Hg^0 (elemental) form can be oxidized to inorganic Hg in humans and it is therefore not unreasonable that exposures might add to those for inorganic Hg. However, no information about the frequency of dental amalgams for children and toddlers was available, nor was guidance about how to include exposures through dental amalgams. For adults, a range of exposures to elemental mercury vapour from dental amalgams was reported, and there was considerable variability (3.8–21 µg/d) (SCHER 2007). This indicates that such estimates for children and toddlers would be highly variable, as well as uncertain, and of limited value.

Children and toddlers are exposed to Pb not only through diet but through other media as well (ATSDR 2007b, SENES 2010). Health Canada contracted calculation of Pb EDIs for the Canadian population and provided ESG with the report by SENES (2010). The Pb daily intake was obtained from this report, in which the EDIs had been calculated for exposures to food (ingestion), drinking water or breast milk (ingestion), soil (ingestion and dermal), settled indoor dust (ingestion and dermal), ambient air (inhalation) and indoor air (inhalation) using probabilistic methods. The probabilistic methods resulted in EDIs expressed as distributions and the mean EDI for toddlers was selected for comparison in the present HHRA. In the SENES (2010) report, a large proportion (52%) of the exposure for toddlers was through the dermal pathway but this was because the dermal exposures had not been corrected for the Health Canada recommended RAF of 0.006 for Pb (SENES 2010). Therefore this adjustment was made to allow for comparison with the KIH EDIs in the present HHRA, and the dermal exposure was then less than 1% of the total EDI, with ingestion of soil (71%) and food/water (28%) making up the rest.

Adjustments could be made for HQ values for As, Hg and Pb, where the maximum allowable HQ can be 1 if background exposures are included. This calculation is summarized in Table IV-22.

Table IV-22: Adjustments to HQ values when background exposures are included for Hg and Pb in children and toddlers

Parameter	As		Inorganic Hg		Pb
	Child	Toddler	Child	Toddler	Toddler
Background HQ	0.23	0.41	0.13	0.15	0.55
HQ outside SMA	0.088	0.12	0.26	0.29	Not calculated
HQ all KIH	0.59	0.80	0.52	0.58	0.28
Sum HQ outside SMA	0.32	0.54	0.39	0.44	Not calculated
Sum HQ all KIH	0.82	1.21	0.65	0.73	0.83

The results indicate that all HQs are less than 1 for inorganic Hg and Pb, which suggests that the risk to children and toddlers from exposure to these two CoPCs is negligible, even when the entire KIH is considered (including the SMA). For As, HQs are less than 1 for children in both scenarios (outside the SMA, and for the entire KIH). Toddler risk is negligible outside the SMA but not when the entire KIH is considered.

G. Uncertainty Analysis

In every HHRA there are varying levels of uncertainty related to the data and assumptions made for all calculations. The purpose of performing an uncertainty analysis is to inform the reader of the possibility of over- or underestimations of the hazards presented, as well as to identify specific uncertainties.

CCME does not provide recreational water quality guidelines for chemical concentrations in water because there are few data associated with this type of exposure. Therefore, the surface water samples were screened against Health Canada's drinking water guidelines, which likely provide conservative criteria for exposure through dermal contact.

Dermal contact with sediments can be a significant exposure route, especially for toddlers and children. However, no sediment loading factors have been published for swimming and wading (where contact with water is constantly occurring) activities. Schoaf et al. (2005a and b) published bulk sediment dermal adherence factors from studies in which activities were carried out with exposed sediments (tidal flats), and where swimming or rinsing activities were not. US EPA has recently adopted these sediment dermal adherence factors for their "playing in sediment" for children, and “clamming” activity for adults (see Table 7-4 in US EPA 2011). The US EPA values for sediment adherence to hands and feet, judged to be applicable to the wading scenario examined here, were used in the present risk assessment. The Health Canada soil adherence factors (specified for general areas other than hand) were used for arms and legs in the same wading scenario (Health Canada 2012b). While the Shoaf et al. (2005b) adherence factors are more representative of the scenario than the Health Canada soil adherence, the data are based on relatively small sample sizes (nine children in Shoaf et al. 2005b, and 18 adults in Shoaf et al. 2005a), limited days (one day in Shoaf et al. 2005b, and 3 days in Shoaf et al. 2005a), and at one location. Additionally, all sediment in the KIH area being considered is covered by water; that is, no beach area with exposed sediment currently exists. Therefore, the degree to which the sediment can be washed off, and the consequent reduction in the sediment loading factor for wading activities, are not known. No data were available on the frequency of receptors spending time at the KIH for recreational activities and therefore, a conservative exposure time of 61 days per year has been used. Generally, the dermal contact exposure pathway overestimates the actual risk.

Another area of uncertainty is the sport fish consumption rate for recreational users of the KIH. In the absence of any site-specific data for the KIH, the OMOE ingestion rate (which is based on the average fish consumption habits of recreational fishermen in the Great Lakes) is a representative estimate for fish ingestion and reflects visual observations made by people frequently fishing in the area. The values used are similar to the range suggested by Health Canada for general fish consumption (10-22 g/d) but lower than their recommended values for heavy consumers that are part of a subsistence or recreational fishing culture (40 g/d for adults; 33 g/d for children, and 20 g/d for toddlers) (Health Canada 2007). The latter values were considered to be overly conservative in the present case.

Additionally a group of fish data from Scheider (2009) was not detailed with respect to the part of the fish (filet or whole body). As they were juvenile perch, it is possible that these were analyzed whole, and if this was the case the exposure to PCBs through fish consumption might be overestimated. A 95UCL for PCBs in filets was computed without this data set and the maximum HQ obtained was 0.91 for toddlers. This is above the acceptable HQ of 0.2, but when background exposure to PCBs is included (HQ = 0.05; see Appendix I), the value is just under 1, at 0.96. This HQ value is still close enough to 1 to merit concern. Calculations with fish filets larger than 25 cm (all fish species), similar to the fish advisory limits (OMOE Guide to Eating Ontario Sport

Fish, OMOE 2013) (greater than 25 cm in length for northern pike and brown bullhead, and greater than 55 cm in length for carp), indicate that the risk from fish consumption could be substantial (HQ>1.5 for all receptors).

The Cr(III) TRV value was selected from US EPA (used as the TRV for total Cr by OMOE), since a TRV for this chromium form is not specified by Health Canada, nor has a tolerable upper intake level (UL) (which can be used for essential nutrients, such as Cr(III)) been established. Dietary daily amounts have been established for Cr(III). Health Canada suggests adequate intakes (AI), which are 0.2–45 μg/d (Health Canada 2005), corresponding to approximately 0.3–0.5 μg/kg-d (Otten et al. 2006). FDA gives a reference daily intake of 120 μg/d, corresponding to 1.7–7.3 μg/kg-d (FDA 2011). The older Recommended Daily Allowances (RDAs) by the Food and Nutrition Board of the National Research Council (US) were published with guidance that stated: "Since the toxic levels for many trace elements may be only several times usual intakes, the upper levels for the trace elements given in this table should not be habitually exceeded" (NRC 1989). The upper levels are 20–200 μg/d, corresponding to 2.8 to 3.6 μg/kg-d. Taking all these values together gives a range of 0.3 to 7.3 μg/kg-d as values that are considered safe for ingestion. These values straddle the TRV for total Cr suggested by Health Canada of 1 μg/kg-d, which is based on adverse effects from exposure to Cr(VI) in drinking water. Therefore the use of these recommended dietary guidelines as TRVs for Cr(III) in KIH would likely introduce overestimates of risk that would not be appropriate.

At the same time, there is uncertainty associated with the use of the US EPA RfD/OMOE TRV for Cr(III)/total Cr, since it is based on a dose-response study using an insoluble compound, Cr_2O_3 (Ivankovic and Preussman 1975, US EPA 1998b). This was probably based on US EPA's assumption that chromium exists as $Cr_2O_3 \cdot xH_2O$ in the environment (US EPA 1998b). We have observed in other samples from the Davis Tannery that Cr(III) in soils is not completely insoluble and is in fact more soluble than Cr_2O_3 (Koch et al. 2012). The use of an insoluble compound to establish a TRV introduces uncertainty about a dose that may in fact cause adverse effects (it may be lower than the developed TRV), and therefore the risk to Cr(III) may be underestimated.

The Sb data set was largely undetectable (42%) and thus highly uncertain. Two samples collected at approximately 20 and 50 cm depths close to Belle Island had very high Sb concentrations, causing great variability in the data set. Consequently no statistically significant differences could be ascertained between the KIH and reference data (see Chapter II). The inclusion of these samples also led to a relatively high EPC in the risk assessment. The removal of these samples from the overall data set removed the risk to adults and teens. However the significance of these points is unknown at the present time. Sb concentrations in fish were not available and this introduces uncertainty regarding the relevance of this exposure pathway. Generally Sb uptake into biota is not high and a recent review (Environment Canada and Health Canada 2010) did not find any estimates of biota-sediment bioaccumulation factors (BSAFs) for fish from sediment; only a bioaccumulation factor <1 from water was reported. The samples with the highest Sb values are generally co-located with Cr (11,700 and 34,000 mg/kg) and Pb (800 and 2900 mg/kg), and they are located generally in the vicinity of the highest PCB and PAH concentrations. This suggests that the Sb contamination, and uncertainties associated with it, can be addressed with the consideration of other contaminants, and does not warrant further assessment.

The cancer risk for PAHs is solely attributable to the dermal exposure pathway. PAHs are the only class of chemicals for which Health Canada has established this approach; US EPA is considering it in their revised version (currently in draft form for public review) of their Integrated Risk Information System (IRIS) toxicological assessment of B[a]P (US EPA 2013). The calculations via the dermal pathway have several sources of uncertainties. The first is the aforementioned sediment loading rates for the wading scenario. Removal of the wading scenario would reduce the risk to 6.5% of that obtained when the wading scenario is included. Although this is a substantial reduction, dermal cancer risk would still remain significant (2.7 in 1000).

The second source of uncertainty is the skin thickness adjustment (accounting for differences in human and mouse skin thickness), specifically that the assumed human skin thickness used in the HHRA may be thinner than the actual values for the body parts considered. A range of thicknesses for various body parts from 0.047 to 0.082 mm was described in Knafla et al. (2011), suggesting that adjustments for larger values for humans might decrease the LADD estimates to approximately 65% of the values currently estimated. This is not considered to be a large source of uncertainty.

Another source of uncertainty that may apply to the dermal risk estimate for PAHs is the assumption that the RAF_{derm} for PAHs in the KIH sediments is as high as 14.8%. Knafla et al. (2011) report that for weathered PAHs in both sandy and clay soils, the RAF is no higher than 4.4%. A lack of data for the RAF_{derm} for any PAHs in sediments makes it difficult to make adjustments in the current HHRA, but the likelihood that PAHs in KIH are weathered suggests that risks could be lowered to values approximately 30% of their current values. This is also not considered a large source of uncertainty.

Probably the largest source of uncertainty for dermal risk of PAHs is the assumption that the per-animal slope factor (for mice) is directly applicable to humans on a per-body basis (see Equation 6). This is based on the assumption that interspecies variability (between mice and humans) does not apply because of the mode of cancer risk. This approach may be overly conservative.

PAH concentrations in fish were not available for the present HHRA. PAHs tend not to bioaccumulate in fish as they are easily metabolized and excreted and for this reason they are not commonly used as evidence for bioaccumulation of contaminants (Van der Oost et al. 2003). However, it is possible to model fish PAH concentrations from sediment concentrations using BSAFs (see Section III.C.1.e in ERA), and US EPA provides a database from contaminants reported at US Superfund sites in sediments and various biota, including fish (US EPA 2009). This method of estimating fish concentrations was considered to introduce too much uncertainty into the HHRA and therefore was not carried out. Should fish consumption continue in the KIH, however, especially after any remedial actions, PAH concentrations may need to be considered in the risk assessment. Not only parent PAHs may be of concern but possibly also PAH metabolites, warranting consideration for future studies.

H. Summary of Human Health Risk Assessment

This risk assessment calculated the potential health risks for human receptors using the KIH. The exposures modeled were based on recreational use of the site for activities, such as swimming, and consumption of fish caught from the KIH. Exposure scenarios assumed that adult, teen, child and toddler receptors would be swimming in the KIH 61 days per year and consuming 39 fish meals of an average size of 236 g (for adults, and scaled according to body weight for other receptors) from the KIH throughout the year.

Surface water samples were analyzed for 30 inorganic contaminants as well as PCBs. Guidelines applicable to the recreational use of surface water are not available to evaluate chemical concentrations. As a consequence, the Canadian drinking water guidelines were used to screen the CoPC concentrations. None of the surface water samples analyzed contained dissolved concentrations of CoPCs above Health Canada drinking water guidelines; therefore, the risks posed by ingestion of or dermal contact with surface water from swimming activities were deemed negligible.

In sediment, seven inorganic contaminants (As, Cr, Hg, Cu, Pb, Zn and Sb), as well as four groups of organic contaminants (DDT, chlordane, PCBs, and PAHs), exceeded the applicable screening criteria. Sport fish tissue concentrations of PCBs exceeded levels found in upstream reference fish and the OMOE fish consumption guidelines. These CoPCs for sediment and sport fish were carried forward into the risk assessment to assess potential human health risks.

The risk calculations for the KIH showed that adult, teen, child and toddler receptors incur potential non-cancer risks from the concentrations of PCBs. PCBs pose potential risk to all receptors through the consumption of fish.

As, Pb, Hg and Sb pose a potential health threat for non-cancer effects to child and toddler receptors, but when background exposures are included, no risk is apparent for Hg or Pb for any receptor, or for As in children. Potential carcinogenic health risks were evident for As and PAHs.

The primary driver of risk for toddlers and children from As and Sb is from dermal exposure to bulk sediments while playing in the sediments (i.e., wading), but a substantial proportion of risk for As is also attributable to sediment ingestion. Dermal exposure to sediments is the route leading to cancer risk for PAHs.

When the risk is recalculated excluding a SMA adjacent to Emma Martin Park, As risks decrease substantially but still pose cancer risk. This must be considered in the context of the risk from background exposures to As, which is also unacceptable with respect to cancer risk; exposures in KIH increase the cancer risk by 11%. Risks from background exposures to Sb are also unacceptable and KIH use increases the risk by approximately 20%. The Sb data set is highly variable and the highest concentrations appear to be co-located with PCBs.

Consumption advisories already exist for several species of sport fish in the KIH. The OMOE Guide to Eating Ontario Sport Fish (OMOE 2013) has recommended that certain populations (women of child-bearing age and children under 15 because of their higher sensitivity to contaminants) should not consume northern pike, brown bullhead greater than 25 cm length or carp greater than 55 cm in length caught within the KIH. This guide should be consulted for further information on the advisory.

III. Ecological Risk Assessment

A. Introduction

Biological organisms (receptors) other than humans are also exposed to contaminants in air, water, soil and food, and this exposure can result in acute and chronic health effects (NRC 1991). An ecological risk assessment (ERA) is the process of estimating the probability that adverse ecological effects to receptors may occur, or are occurring, from exposure to contaminants or other stressors (US EPA 1992a). Evidence of ecological effects can come from a variety of sources, including field observations, field tests and laboratory tests (US EPA 1992a). While ERAs are clearly relevant to environmental decision-making, other types of assessments and decision tools (*e.g.* human health risk assessments and life-cycle assessments) can be complementary and therefore collectively aid decision-makers (Suter 2006).

The methodology used is according to the guidance recently provided by Environment Canada, entitled FCSAP Ecological Risk Assessment Guidance (Azimuth 2012), which includes aspects of older guidance provided by CCME (CCME 1996). Included in the guidance is a weight-of-evidence (WOE) and lines-of-evidence (LOE) approach. Since this approach is incorporated into the COA framework overall, and in a strength of evidence analysis (Chapter V), it will not be included in the present section.

The aspects of ERA listed in the FCSAP guidance that will be addressed are risk to higher trophic organisms (birds and mammals) through a food chain model LOE and risk to fish through a tissue residue LOE.

B. Problem Formulation

1. Site Management Goals, Regulatory Context and Existing Site Information

Existing site information, including regulatory aspects and site management goals, have been reviewed in detail in other chapters of this report (Chapters I and II), and some background information is provided in the introduction to this chapter.

2. Contaminants of Potential Concern (CoPCs) and their Characteristics

In the present ERA, we will maintain the common practice of considering contaminants to be of "potential concern" when selecting them for assessment, rather than the usage of the term "contaminants of concern" at this stage, as found in the FCSAP guidance (Azimuth 2012).

In sediment samples taken from within the APEC, several contaminants were found to exceed the ISQGs for the Protection of Aquatic Life, or were higher than background sediment concentrations (see justifications in Chapter II). The following CoPCs will be evaluated for their risk to receptors in this ERA: As, Cr, Cu, Hg, Pb, Zn, Sb, PCBs, DDT, chlordane, and PAHs.

As recommended in the FCSAP guidance (Azimuth 2012), sediment concentrations to a depth of 1 m were included in the data set. The spatial coverage for the KIH ecological risk assessment is larger than the area used for the human health risk assessment, since the aquatic ecosystem, especially higher receptors, access two distinct but inextricably connected areas: the portion of the KIH south of Belle Park and east of the former Davis Tannery property (the area used by humans, and assessed for human health risk); and the Orchard Street Marsh. For the purposes of the ERA, these two geographical areas will be included in the APEC. The Orchard Street Marsh has been included as part of the APEC because most of the CoPCs present in the other portion of the KIH are also present in the Orchard Street Marsh, and as mentioned previously all the receptors upon which this ERA is based use both areas as habitat. It is not advisable to consider the contaminated portion of the KIH in isolation from the Orchard Street Marsh, as this could result in an underestimation of ecological risk. Receptors that use only the marsh habitat will not be included, since assessing the effects of the Orchard Street Marsh alone is outside the scope of the present ERA.

Cr is assumed to be entirely in the Cr(III) oxidation state since analysis of soils from the former Davis Tannery property (Gibson 2010 and Koch et al. 2012), as well as sediments and pore water from within the APEC (see Chapter II; Burbridge 2010 and Burbridge et al. 2012), has determined that negligible concentrations of Cr(VI) are present.

Characteristics of CoPCs, both chemical and toxicological, are presented in CCME (1999) and/or are summarized in Chapters I and II of this report.

3. Methodology

This ERA has been performed in accordance with FCSAP guidance (Azimuth 2012). Sediment, plant and fish samples were collected and analyzed to determine the concentration of CoPCs within these environmental media, as well as to model the effect of ingestion to these contaminated media would have on higher-trophic-level receptors. The CoPCs to be evaluated for their risk to receptors in this ERA were those that were selected for further study as detailed in Chapter II: As, Cr, Cu, Pb, Hg, Zn, PCBs, DDT, chlordane, and PAHs (see Chapter II of this report). Measured fish tissue concentrations were used in this ERA, instead of concentrations modeled from site-specific sediment concentrations, in order to provide the most accurate estimate of risk to piscivorous wildlife. The exception to this was the use of modeled PAH and chlordane concentrations in fish using BSAF values obtained from the US EPA database (US EPA 2009), developed from contaminants reported at US Superfund sites in sediments and various biota, including fish. As previously stated, PAH bioaccumulation in fish is not thought to be significant (Van der Oost et al. 2003), and in the absence of measured data, modeled PAH (and chlordane) fish concentrations are considered to be highly uncertain; this was the main reason that they were not included in the HHRA. Additionally, in the HHRA, a major exposure pathway was through sediment contact; that is, fish are not the only exposure pathway. In the present ERA, for some receptors, fish ingestion is the only exposure pathway, and therefore the uncertainty in using modeled PAH and chlordane values was accepted, in order to allow for risk estimation for piscivorous receptors.

Sediment, plant and fish samples were collected from upstream reference sites in the KIH that have not been impacted by contamination to establish local baseline concentrations of these sample types. A detailed discussion of the selection of reference sites is found in Chapter II of this report.

Table IV-6 summarizes sediment contaminant concentrations for upstream reference sites in the KIH. All data used in this ERA are contained within Appendix D.

4. Receptors of Concern

Receptors of concern (ROCs) are non-human aspects of an ecosystem, including species, populations, communities or habitats, which have the potential to be exposed to CoPCs (Azimuth 2012); the term valued ecosystem components (VECs) is similar, encompassing environmental elements, such as resources or features, which have ecological significance, are important to human populations, and can act as a basis for assessing the impact of contamination (CCME 1996). ROCs/VECs tend to be represented by communities at lower trophic levels, whereas at higher trophic levels species may be identified (e.g., mink, mallard) (Azimuth 2012). At higher trophic levels, species may be selected to represent groups of similar organisms, in particular, those at similar feeding levels. Consideration is given to “sentinel species”, which are those species that “can be used to identify potential health hazards to other animals or humans” (NRC 1991). Among other characteristics, sentinel species have high trophic status, a restricted home range, well-known biology, and are sensitive to pollutants (Basu et al. 2007). Clearly, selection of appropriate receptors is a crucial aspect of conducting an effective ERA, since the ERA should ideally provide insight into the health of the entire ecosystem being studied (Seston et al. 2009).

a. Information Compilation, Receptor Characteristics and Receptor Selection

A summary of site conditions pertaining to ecological habitats is given in Chapter I, along with the results of a survey of species identified in the Orchard Street Marsh. According to FCSAP guidance (Aizmuth 2012), OMOE (2011) was consulted for recommended ROCs, but guidance on VECs for aquatic sites is not provided.

ROCs considered in the present ERA encompass the following receptor types: fish; herbivorous and piscivorous mammals; non-piscivorous, piscivorous and omnivorous birds; and reptiles and amphibians. Selection of surrogate ROCs is summarized in Table IV-23, with further explanations and characteristics given in the sections that follow.

Table IV-23: Selection of receptors of concern and rationale

Receptor group	Receptor type	Included (Y/N)	Rationale	Surrogate ROC*
Primary producer	Phytoplankton, periphyton and macrophytes	N	Discussed in Chapter III, in CSM.	N/A
Pelagic invertebrate	Zooplankton and others	N	Discussed in Chapter III.	N/A
Benthic invertebrate	Epifauna and infauna	N	Discussed in Chapter III, in CSM.	N/A
Fish	Benthivorous	Y	High population in KIH, close contact with sediments.	Brown bullhead
	Planktivorous	N	Fish data available did not include this receptor type.	None selected
	Piscivorous	Y	High populations in KIH, benthic feeding habits, economic and recreational relevance.	Yellow perch and northern pike
Mammal	Herbivorous	N	In CSM only; habitat limited to Orchard Street Marsh (outside scope).	Muskrat
	Piscivorous	Y	Present in KIH, exposure to PCBs via fish.	Mink
	Omnivorous	N	Not observed in KIH.	None selected
Bird	Herbivorous	N	In CSM only; habitat limited to Orchard Street Marsh (outside scope) and diet is partially insectivorous (no data).	Red-winged blackbird
	Insectivorous	N	In CSM only; habitat limited to Orchard Street Marsh (outside scope); insectivorous diet not possible to assess because no data.	Red-winged blackbird
	Piscivorous	Y	Present in KIH, important and highly visible to public.	Great blue heron and osprey
	Omnivorous	Y	High populations in KIH.	Mallard duck
Amphibian	Carnivorous	N	Present in KIH but limited toxicological information.	Bullfrog, green frog and leopard frog
Reptile	Omnivorous	N	Present in KIH but limited toxicological information.	Snakes and turtles

CSM = conceptual site model; N/A = not available.
*Described in sections that follow.

1) Brown Bullhead

The brown bullhead (*Ameiurus nebulosus*) is a nocturnal feeder known to inhabit warmer temperature waters that are slow moving, have abundant aquatic vegetation, and have sediments composed of mud or sand (Scott and Crossman 1973; Sinnot and Ringler 1987). The brown bullhead is currently not listed under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Aside from its high population in the KIH, the brown bullhead is an ideal VEC for many reasons. First, its home range is very small. In habitats that are conducive to spawning, which include shallow water, low flow, and natural shelter such as logs and vegetation (all of which are characteristic of the APEC), the average annual linear home range is less than 1 km (Sakaris and Jesian 2005). Second, brown bullheads are bottom-dwelling fish that feed on benthic invertebrates throughout their life. As such, they are a crucial link between the benthic community and piscivorous wildlife. Third, brown bullhead bury themselves in sediment, with this behaviour occurring more frequently and for longer periods as water temperature drops (Loeb 1964; cited in Cranshaw et al. 1982). Loeb (1964; cited in Cranshaw et al. 1982) found that when the temperature dropped below 8^{o}C, fish would often remain buried for periods exceeding 24 hours. Based on the climate of southeastern Ontario, the brown bullhead will therefore spend a large portion of the year buried in sediment; thus its health could potentially be greatly impacted by the sediment quality within its habitat. The limited home range of the brown bullhead, along with its intimate relationship with the sediment through diet and cold weather dormancy, makes it a good indicator of biological effects of local contamination (Rafferty et al. 2009; Logan 2007). For the past quarter-century, the brown bullhead has often been used as an indicator of environmental contamination, and it has regularly been referred to as a sentinel species (Iwanowicz et al. 2009).

2) Yellow Perch

Yellow perch (*Perca flavescens*) are known to inhabit small to medium sized rivers as well as lakes and ponds (Page and Burr 1991). The yellow perch is currently not listed under COSEWIC. These fish have long had importance to both commercial and recreational fishing, especially in the Great Lakes region (Scott and Crossman 1973), and are found in abundance in the KIH. They have a preference for clear water near vegetation (Page and Burr 1991; Fish and Savitz 1983), a quality characteristic of the APEC, and are seldom found in open water (Fish and Savitz 1983). Yellow perch are highly adaptable, can use a variety of habitats from warm to cooler temperatures, and are inactive at night and rest on the bottom (Scott and Crossman 1973). Yellow perch remain active during the winter months and can be found under the ice in both shallow and deeper water (Scott and Crossman 1973). The home range of yellow perch has been reported to be 0.54 to 2.20 ha (Fish and Savitz 1983). The yellow perch has a high appetite, and although its foraging habits vary depending on its size and the season, its diet consists mostly of immature insects, larger invertebrates and other fish (Scott and Crossman 1973). The yellow perch was chosen as a suitable VEC for this ERA because of its limited home range and benthic feeding habits, as well as its economic and recreational relevance.

3) Northern Pike

The top predator with large populations in the KIH (Malroz 2003), the northern pike (*Esox lucius*) lives in habitats characterized by clear, vegetated lakes and small to medium rivers (Page and Burr 1991). The northern pike is currently not listed under COSEWIC. The northern pike is a carnivore that feeds predominantly on vertebrates, and generally behaves as an opportunist with no particular species primarily selected as prey (Scott and Crossman 1973). Prey is approximately 90 percent fish, but will also include frogs, crayfish and even mice or ducklings (Scott and Crossman 1973). Northern pike have been noted to lack a well-defined home range (Cook and Bergensen 1988). Diana et al. (1977) noted that while linear movements varied from zero to 4,000 m/d, fish would sometimes move within confined areas as small as 0.5 km, and other times travel to distant locations. The northern pike was selected as a VEC because of its position as top predator in the aquatic food chain, as well as its relative importance as a sport fish.

4) Muskrat

Only two herbivorous mammals were identified at the APEC: muskrat (*Ondatra zibethica*) and beaver (*Castor canadensis*) (Ecological Services 2008). Between these two species, the muskrat would have a greater suitability as a VEC for the following reasons. Its home range is much smaller, making it more vulnerable to local conditions. It is the most aquatic of the two mammals (US EPA 1993b). Data regarding its feeding and living habits was more readily available than for the beaver (Azimuth 2012); receptor characteristics for beaver have not been reported either in the FCSAP guidance (Azimuth 2012), or by US EPA (1993, 1993b).

Muskrats inhabit marshes, lakes and streams and feed principally on aquatic plants (US EPA 1993b). In many aquatic ecosystems, muskrats are the dominant herbivore (Erb and Perry 2003). Primarily foraging at night, muskrats show a preference for cattails and usually feed on the roots and basal portions, although they are also known to consume other parts of the plant (US EPA 1993b). In a study of an Ontario marsh, Proulx and Gilbert (1983) found that muskrats spent most of their time within 17 to 33 m of their den. They extended their home range as marsh water levels declined, and cattails were the most important food item. The muskrat is currently not listed under COSEWIC.

In the present risk assessment, the muskrat, although an ideal VEC, was not carried forward for the KIH, since it was assumed to inhabit only the Orchard Street Marsh; risk assessment of this area alone is outside the scope of the present study.

5) Mink

The mink (*Mustela vison*) is a member of the weasel family and is found throughout North American forested regions, especially those that contain wetlands (Basu et al. 2007). It is currently not listed under COSEWIC. These mammals are active, solitary, opportunistic predators (Basu et al. 2007). Primarily nocturnal hunters, mink are the most numerous and widespread carnivorous mammal in North America (US EPA 1993b). Fish often comprise a considerable fraction of the mink's diet (Hinck et al. 2009), but they are also known to prey on aquatic invertebrates, as well as birds and mammals (US EPA 1993b). In a study of mink inhabiting a Michigan river, 85 percent of their year-round diet was found to be fish, while the remainder was composed mainly of crustaceans, amphibians, birds and mammals (US EPA, 1993b).

Many organizations, including Environment Canada and the US EPA, consider mink a sentinel species because of its high susceptibility to many pollutants (Basu et al. 2007). Research has shown that MeHg and PCBs are especially toxic to mink, and that these contaminants act synergistically in this receptor (Wren et al. 1987a, b). Mink are regarded to be among the most sensitive mammals to PCBs (Bleavins et al. 1981).

Visual observations have confirmed the presence of mink in the APEC, as well as other areas of the KIH. A roadkill study on Highway 401 north of the KIH found that mink were the most common roadkill species (H. Knack personal communication, Sept. 24, 2010). For these reasons, mink are included as a VEC in this ERA.

6) Red-winged Blackbird

The red-winged blackbird (*Agelaius phoeniceus*) is one of the most numerous and ubiquitous avian species in North America (Mosimann and James 1979), and it is the most abundant species in the Orchard Street Marsh (Ecological Services 2008). It is currently not listed under COSEWIC. Red-winged blackbirds have frequently been studied by ornithologists not only because of their large populations, but because of their strongly expressed polygyny. Contrary to the behaviour of most birds, which breed monogamously, male red-winged blackbirds can attract 15 or more mates per year to their exclusive territories (Beletsky 1996). Roosts of red-winged blackbirds are usually found in wetland habitats, especially cattail marshes, as the combination of water and dense vegetation provides safety from predators (Beletsky 1996). The main diet of these non-piscivorous birds, when in a non-agricultural area, is seeds and insects (McNicol et al. 1982), both of which are found in the APEC. Red-winged blackbirds would be a suitable VEC because of their close association with the aquatic marsh environment, their representation of non-piscivorous birds, and their high recognisability and scientific importance. However, red-winged blackbirds spend most of the breeding season within their nesting territories, to defend breeding space (Orians 1985), leading to the assumption that 100 percent of their feeding takes place within the vegetated part of the APEC, which is the Orchard Street Marsh.

Since assessing only the Orchard Street Marsh is outside the scope of the present study, the red-winged blackbird was not carried forward for the ERA.

Other bird species that are non-piscivorous in KIH are either rare and receptor characteristics were not available, or in the case of the marsh wren, for which receptor characteristics are available (US EPA 1993a, 1993b), no data are available to assess their insectivore diet.

7) Mallard Duck

The mallard (*Anas platyrhynchos)* has been included as a VEC in this ERA to represent migrant waterfowl in the KIH. The mallard duck is the second most common breeding duck in the Kingston region (Weir 2008). Mallard ducks feed on a variety of food items such as aquatic plants, seeds and aquatic insects. They are “dabbling” ducks, which means they do not dive for their food, but rather “tip up” to obtain food from below the surface of the water, or dip their bills into the surface of the water. In winter they feed on seeds, and on invertebrates associated with leaf decomposition. In spring, female mallard ducks shift from a largely herbivorous diet to a diet of mainly invertebrates to obtain protein for their moult and then for egg production (US EPA 1993b). Mallards are migrating waterfowl and are assumed to be on site during the months of April to October. For the Kingston region it is also known that mallard ducks sometimes overwinter annually and in mild winters their numbers are in the hundreds (Weir 2008).

8) Great Blue Heron

Great blue herons are colonial nesters currently not listed under COSEWIC. They can be considered a sentinel species because of their predominantly piscivorous feeding habits and their placement at the top of the aquatic food chain (Baker and Sepúlveda 2009). They are commonly found in wetland areas and have a preference for eating fish, although they will also consume other prey such as amphibians, reptiles and insects (US EPA 1993b). When great blue herons are looking for fish they generally seek shallow areas where smaller fish are numerous (US EPA 1993b). Two studies on the composition of the diet of great blue herons in Michigan reported 98 percent and 94 percent of the diet, respectively, being fish (US EPA 1993b). Great blue herons have been found to be poor predators of healthy fish yet good predators of unhealthy fish (Kushlan and Hancock 2005). Great blue herons have many characteristics that make them an ideal VEC in this ERA: their high consumption of aquatic prey yields a high potential for exposure to contaminants, particularly for bioaccumulative contaminants (Seston et al. 2009); data concerning their eating and behaviour are readily available (US EPA, 1993b); and they are widely recognized and appreciated by the public, who would have an interest in ensuring their preservation (Seston et al. 2009; Kushlan and Hancock 2005).

9) Osprey

A once-endangered species, the osprey (*Pandion haliaetus*) is highly recognized by the general public and has been the recipient of efforts to provide suitable nesting locations with anti-raccoon guards to boost its populations (EC 2005). The osprey is not currently listed under COSEWIC. One nesting pair of osprey is known to inhabit the APEC, and lives on an artificial nesting platform located on the south side of Belle Park, adjacent to the APEC (D. Kristensen, personal communication 2010). Ospreys are large birds of prey and are found close to water bodies. These birds feed almost exclusively on fish (more than 99 percent of their diet) and are adapted to hovering over water bodies before capturing fish with their talons (US EPA 1993b). In particular, ospreys have a preference for hunting fish that inhabit shallow waters, are slow-moving, and eat benthic organisms (US EPA 1993b), such as the brown bullhead. In the Great Lakes basin ecosystem, ospreys have been observed to consume a variety of fish, with an average of almost 35 percent brown bullhead, approximately 12 percent yellow perch, and approximately 5 percent northern pike (Environment Canada 2005). Local availability will affect the actual proportions in an osprey's diet (Environment Canada 2005). After catching a fish, the osprey will consume the entire fish except for the large bones.

Because of their high fish consumption, osprey can be exposed to especially high levels of bioaccumulative contaminants (Linkov et al. 2001). Of all toxins, the organochlorine compounds have had the most harmful effect on osprey populations (Poole 1989). The osprey is a sentinel species and has been included as a VEC because of the need to help populations recover, their prominence and vulnerability at the top of the aquatic food chain, and their wide recognition by the public, who have an interest in seeing this species preserved. Although piscivorous birds are represented by both the osprey and great blue heron, redundancy at the highest trophic level is favourable because of these species' vulnerability to aquatic contamination, particularly bioaccumulative contamination.

10) Reptiles

Numerous reptiles have been documented to inhabit the APEC, including the northern water snake (*Nerodia sipedon*), garter snake (*Thamnophis sirtalis*), painted turtle (*Chrysemys picta marginalis*), and snapping turtle (*Chelydra serpentine*), which is listed as a species of special concern (Ecological Services 2008). Also known to inhabit the APEC is the map turtle (*Graptemys geographica*), a provincial species of concern, as well as the stinkpot turtle (*Sternotherus odoratus*), which is listed as a threatened species under SARA as well as provincially. These reptiles are all recognized as very important constituents of the APEC ecosystem. The high level of contact that these reptiles have with the sediment, by burrowing in the summer and hibernating in the winter, may make these species susceptible to the adverse biological impacts that are attributable to sediment toxicity.

Although reptile species are generally widespread in wildlife habitats, relatively few toxicological studies have been conducted on them (Salice et al. 2009). The limited toxicological data (upon which TRVs are based) for the APEC CoPCs and for this animal class makes it impossible to quantitatively include them in this ERA through the use of dose-based risk assessment models.

11) Amphibians

Three species of amphibians are known to inhabit the APEC: the bullfrog (*Rana catesbeiana*), the green frog (*Rana clamitans*), and the leopard frog (*Rana pipiens*) (Ecological Services 2008). None of these species are listed by the Ontario Ministry of Natural Resources or Environment Canada as a provincial species of concern or as an endangered species. Because of the extensive contact these species have with the sediments, they may have a predisposition to adverse biological impacts related to sediment toxicity.

Similar to the reptiles, there is a lack of toxicological information that would allow these species to be considered quantitatively in the present ERA.

5. Exposure Pathways

Exposure pathways link CoPCs to ROCs. These were selected for the food chain model approach for risk to the higher trophic level ROCs listed above. According to the FCSAP guidance (Azimuth 2012), the following pathways were considered.

- Direct contact with CoPCs in sediment, sediment pore water, and water (aquatic species including fish)
- Ingestion of CoPCs in sediment (higher trophic level organisms);
- Ingestion of CoPCs in water (higher trophic level organisms); and
- Ingestion of CoPCs in food (higher trophic level organisms and fish).

Dermal exposure to CoPCs in sediment and water for higher trophic level organisms was considered to be an inoperative pathway. Inhalation exposure to CoPCs was not considered, since wind-blown dust is not a consideration in an aquatic ecosystem, and vapours are also not a concern. Indirect pathways such as food source depletion attributable to CoPCs were also not considered.

The operative pathways are summarized in Table IV-24 and more details are given in Section III.C.2

Table IV-24: Selection of exposure pathways for ROCs used in KIH ERA

Receptor group	ROC	Exposure pathway	Included (Y/N)	Rationale
Primary producer, invertebrates	n/a	All	N	Discussed in Chapter III, in CSM
Fish	Brown bullhead	All	N	Tissue residue approach; not needed.
	Yellow perch	All	N	Tissue residue approach; not needed.
	Northern pike	All	N	Tissue residue approach; not needed.
Mammal	Mink	Water ingestion	Y	Suspended sediments in water a possible pathway
		Food (fish) ingestion	Y	Major dietary component
		Incidental sediment ingestion	N	Not known to ingest sediment
Bird	Great blue heron	Water ingestion	N	Suspended sediments in water accounted for in incidental sediment ingestion pathway
		Food (fish) ingestion	Y	Major dietary component
		Incidental sediment ingestion	Y	Ingests sediment
	Osprey	Water ingestion	Y	Suspended sediments in water a possible pathway
		Food (fish) ingestion		Major dietary component
		Incidental sediment ingestion	N	Not known to ingest sediment
	Mallard	Water ingestion	N	Suspended sediments in water accounted for in incidental sediment ingestion pathway
		Food ingestion	Y	Macrophytes and invertebrates main diet
		Incidental sediment ingestion	Y	Ingests sediment

n/a = not applicable
CSM = conceptual site model

6. Conceptual Site Model

Subsequent to identifying VECs, it is necessary to develop a conceptual site model (CSM) to represent the ecosystem. CSMs can include such details as contaminated media, receptors, and pathways of exposure (CCME 1996). The complexity of a CSM is influenced by the inherent complexity of the ecosystem being studied, as well as the availability of data to support the risk assessment. The CSM for this ERA, based on the receptors identified above, is found in Figure IV-7. The exposure pathways identified in the CSM for each of these receptors are not exhaustive, but reflect those that are dominant and are thus considered in this ERA. Numerous trophic levels are represented in the CSM, with sediment ingestion and food consumption being the main exposure pathways considered. Benthic invertebrates and aquatic plant life are considered the foundation of the aquatic food chain. Benthic invertebrates are consumed by bottom-feeding fish, which in turn are consumed by piscivorous predators. These piscivorous predators can be subdivided into three main groups: piscivorous fish, represented by the northern pike and larger yellow perch; piscivorous mammals, represented by the mink; and piscivorous birds, represented by the great blue heron and osprey. Both the muskrat and red-winged blackbird are modeled as being herbivorous; with the omnivorous amphibians and reptiles represented by the bullfrog and painted turtle.

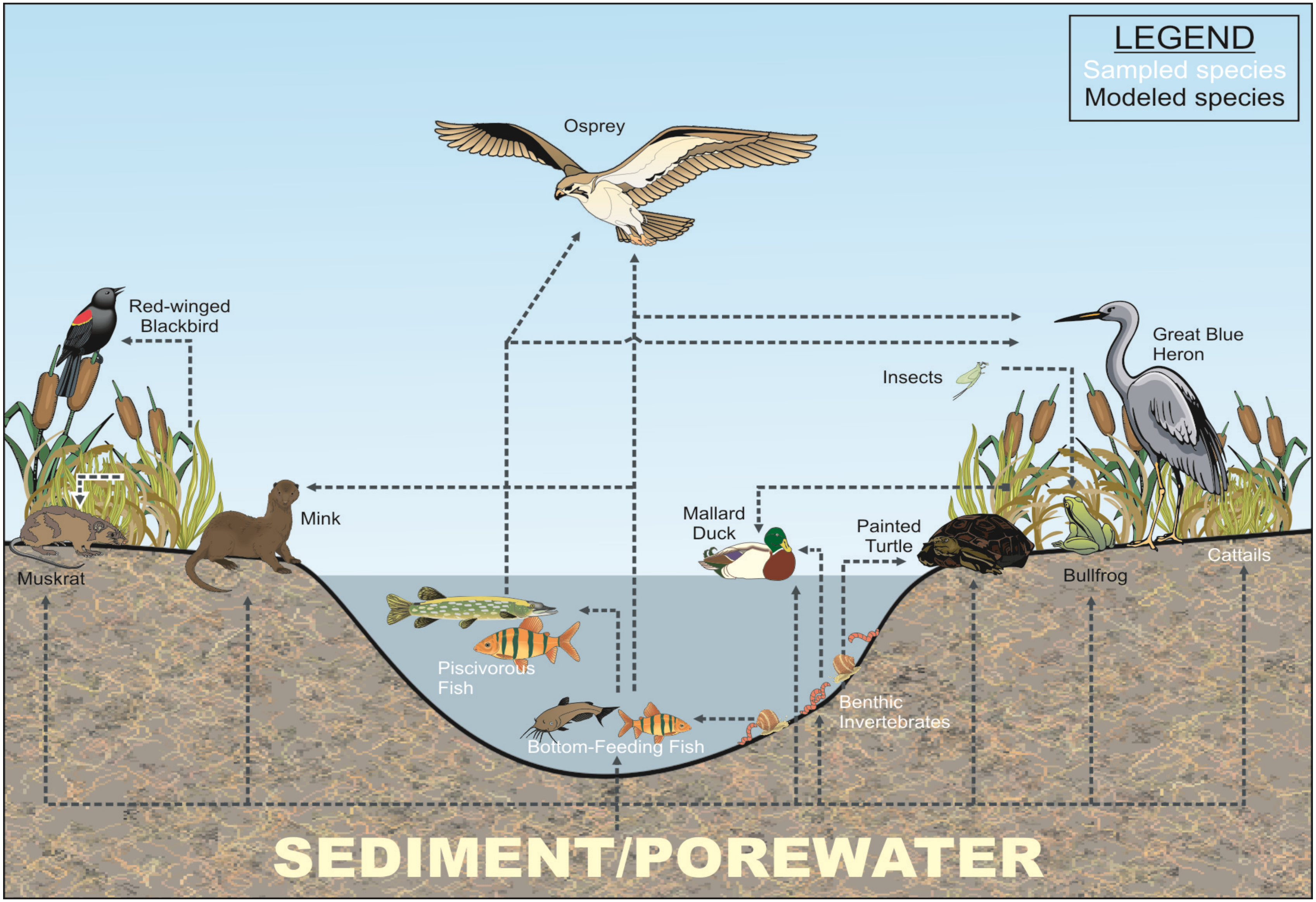


Figure IV-7: Conceptual site model (CSM) of the APEC.

7. Assessment and Measurement Endpoints

Assessment endpoints state the environmental objectives to be achieved and must be ecologically relevant, explicitly defined, and capable of being assessed (CCME 1996). Assessment endpoints are seldom based on ecosystem-level endpoints as they are difficult to predict or define; instead, they are usually defined at the population level and sometimes at the community level (CCME 1996).

Based on the ROC/VECs and CSM that have been adopted in this ERA, the following assessment endpoints have been selected for assessment: the survival, fecundity (reproduction), and growth of (1) fish, (2) piscivorous mammals (represented by mink), (3) piscivorous birds (represented by great blue heron and osprey), and (4) omnivorous birds (represented by mallard duck). In addition, supplementary information on fish health was used as supporting evidence in the risk characterization for fish. Note that herbivorous mammals and birds were not assessed since they were assumed to inhabit the vegetated area only, namely, the Orchard Street Marsh, which was a location outside the scope of the present ERA.

Assessment endpoints must be expressed in terms of measurement endpoints because they are generally not measureable in a practical or numerical sense. Measurement endpoints are quantifiable ecological characteristics associated with the assessment endpoint, and are usually expressed at the individual or population level (CCME 1996). More than one measurement endpoint may be expressed for a single assessment endpoint (CCME 1996).

Two measurement endpoints were used for fish. First, whole-body CoPC concentrations were compared with fish tissue toxicity thresholds (Hinck et al. 2009; Environ 2007; Hansen 1974) to assure protection of the most sensitive of the attributes of survival, fecundity and growth. Secondly, the prevalence of deformities, erosions, lesions and tumours (DELTs) for brown bullhead were assessed as a measure of fish health.

The measurement endpoint for all other receptors was to compare the estimated dietary intake of CoPCs of representative species with professionally recognized, conservative toxicological reference values (through the calculation of HQs) to assure protection of the most sensitive of the attributes of survival, fecundity, and growth.

C. Exposure Assessment

An exposure assessment must identify contaminants, exposure media and exposure pathways, as well as major data gaps or uncertainties (CCME 1996). CoPC concentrations that were obtained through direct measurement were available for most media. The exceptions are listed in the following sections.

1. *Exposure Point Concentrations in Media from KIH*

Exposure point concentrations (EPCs) are summarized in Table IV-25 for all media to which ecological receptors might be exposed in the present ecological risk assessment.

Table IV-25: EPC values (mg/kg) of sediment, fish, water, macrophytes and invertebrates from the APEC (includes Orchard Street Marsh). All EPCs are 95 UCLs unless otherwise noted. Cells are blank when value is not used in the risk assessment because it was non-detect (water) or not available (biota).

CoPC	Sediment		Fish	Water	Macrophytes	Invertebrates	
	dw	ww	ww	mg/L	dw	dw	ww[c]
As	43	8.6	0.095		1.7		
Cr	3893	780	0.64	3.1	25	260[a]	47[b]
Cu	53	10.6	0.71	0.040	7.8		
Hg	1.7	0.34	0.069				
Pb	215	43	0.28	0.17	7.4		
Zn	207	41	20	0.76	33		
Sb	42	8.4	0.08[g]		0.43[a]		
PCBs	0.98	0.20	0.62	0.019		1.4[b]	0.26[c]
DDT	0.056	0.011	0.0033			0.55[b]	0.099[c]
Chlordane	0.031	0.0062	0.053[c]			0.14[b]	0.024[c]
BaP equiv[e]	239	48	0.0032[c]	0.0023	0.018[d]	0.0055[b]	0.0010[c]
LMW PAH[e]	416	83	0.0058[c]	0.0031	0.25[d]	0.0086[b]	0.0015[c]
HMW PAH[e]	639	128	0.040[c]	0.0032	0.44[d]	0.084[b]	0.015[c]
Total PAH[f]	835	167	0.065[c]	0.00030	0.68[d]	0.12[b]	0.021[c]

dw = dry weight
ww = wet weight
[a]Maximum value (n<10)
[b]Converted by using 82% moisture (wet mass:dry mass = 5.56:1)
[c]Modeled value
[d]Includes three samples collected from Kingston outer harbour; maximum value (n<10).
[e]B[a]P equiv = sum of benzo[a]pyrene equivalent PAHs; LMW PAH = sum of low molecular weight PAHs (naphthalene, acenaphthylene, acenaphthene, anthracene, phenanthrene, and fluorene); HMW PAH = sum of high molecular weight PAHs (fluoranthene, pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, dibenzo[ah]anthracene, and indeno[1,2,3-cd]pyrene).
[f]Total PAH values are not the sum of LMW and HMW PAHs because they were calculated from a larger data set, for which some samples only provided total PAH concentrations (not individual PAHs). Additionally for water concentrations, LMW and HMW sums were approximated by including ½ detection limit for non-detects, which inflated the results.
[g]Values representing background exposures, obtained from Environment Canada and Health Canada 2010.

a. Exposure Point Concentrations for Sediment

Sediments from the KIH and Orchard Street Marsh were included together in the data set since the entire KIH is seen as prime habitat for wildlife, which is also likely to forage in the Orchard Street Marsh. The 95UCL value was used in all calculations. The EPCs used for the Orchard Street Marsh and KIH sediments can be found in Table IV-25.

Tinney (2006) and Asquini et al. (2007) found that sediments within the KIH were generally about 80–90 percent water. To convert the sediment dry-weight laboratory concentrations to a wet-weight concentration, an assumption of 80 percent moisture was assumed.

PAH concentrations were obtained according to the TRVs available: B[a]P equiv = sum of benzo[a]pyrene equivalent PAHs; LMW PAH = sum of low molecular weight PAHs (naphthalene, acenaphthylene, acenaphthene, anthracene, phenanthrene, and fluorene); HMW PAH = sum of high molecular weight PAHs (fluoranthene, pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]-pyrene, benzo[ghi]perylene, dibenzo[ah]anthracene, and indeno[1,2,3-cd]pyrene; and total PAH.

b. Exposure Point Concentrations for Water

Water ingestion (with suspended solids) was considered as an exposure pathway for only the receptors for which sediment ingestion was not otherwise considered in their risk assessments (mink and osprey). These receptors were assumed to obtain their food and water from the entire Orchard Street Marsh and KIH area and therefore water concentrations were estimated from the KIH data set as well as surface waters obtained from the Orchard Street Marsh. The 95 UCL was used. Where all results were non-detects, water was not included in the calculation (for As, Sb, DDT and chlordane). Hg water results were not available and not included in the calculation.

For PAHs, total PAH values are not the sum of LMW and HMW PAHs because LMW and HMW sums were approximated by substituting ½ detection limit for non-detects, which inflated the results. Non-parametric methods were attempted for these estimates (KMStats worksheet available at Helsel 2013), giving similar values, and therefore a simpler method, substituting half the detection limit, was used. Total PAH values were estimated with ProUCL including non-detects.

c. Exposure Point Concentrations for Macrophytes

Inorganic CoPC concentrations were available for sixteen macrophyte samples from across the APEC south of Belle Island and data are available for As, Cu, Pb, Zn and Cr; only seven samples were analyzed for Sb. PAH concentrations were available for three macrophyte samples that had been collected from the outer Kingston Harbour in addition to six others from KIH. Although the outer harbour macrophytes were not in the area of interest, they were used because they were considered to be the best conservative estimate of PAH concentrations in this type of sample; the maximum value (one the values from the outer harbour macrophytes) was used because the total number of measurements was less than 10. The 95 UCL was used for As, Cu, Pb, Zn and Cr, and maximum concentrations were used for Sb and PAHs.

Data were not available for PCBs, DDT, chlordane, or Hg. Concentrations of these contaminants were not modeled because reliable models were not available, and because modeling of organic contaminants into invertebrates (a mallard duck dietary component that can be used in place of macrophytes) can be carried out more easily and reliably, as discussed in the next section.

d. Exposure Point Concentrations for Invertebrates

The invertebrate concentration for Cr was the maximum reported value from six invertebrate samples collected from the APEC. Data were not available for As, Cu, Hg, Pb, Zn and Sb; macrophyte data were available instead for all of these CoPCs except Hg. Hg concentrations were not modeled because a reliable model was not available.

Modeling was carried out to obtain concentrations of PCBs, DDT, chlordane and PAHs. This is not an ideal method of obtaining biota concentrations (Azimuth 2012), but was judged to be acceptable in the present ERA to allow inclusion of the food exposure pathway to these CoPCs for mallard ducks. This was rationalized by the lack of available measured data for PCBs, DDT, and chlordane for macrophytes (another mallard duck dietary component), but the relative ease with which invertebrate concentrations can be modeled for these CoPCs from sediment values. The invertebrate concentration for PCBs was calculated using a regression equation between sediment and invertebrate uptake based on Labencki (2008). PAHs, DDT and chlordane invertebrate concentrations were calculated from sediment values using BSAFs provided by US EPA (US EPA 2009). The calculations can be found in Appendix I and the values used are reported in wet weight in Table IV-25.

e. Exposure Point Concentrations for Fish Consumption

In the autumn of 2009, brown bullhead, yellow perch and northern pike were collected from the APEC and a reference site located approximately 2 km upriver, adjacent to the Great Cataraqui Marsh. These were subsequently analyzed for CoPC concentrations (not including Hg and PCBs). The results are included in Appendix D.

Historical data for the APEC and a reference site (located above Kingston Mills, in Colonel By Lake) were obtained from Scheider (2009) for total mercury (total Hg) and PCB concentrations, and are found in Appendix D: all data can be found in Tables D-III-5 and D-III-6, and the data selected for the present ERA are presented in Tables D-IV-9 and D-IV-10; the data selection process is described in the following paragraphs. Because almost all of the mercury in fish (95 to 100 percent) is present as MeHg (Grieb et al. 1990; Bloom 1992), standard practice for risk assessment is to measure total Hg in fish and assume that it is 100 percent MeHg. APEC data for brown bullhead, yellow perch, and northern pike were available from this data set. However, from the reference site, only yellow perch samples were in sufficient number for comparison, with only two brown bullheads and no northern pike reported for this location.

Receptors such as mink, heron and osprey have species- and size-specific foraging preferences, and therefore these were considered when calculating exposure point concentrations from the available fish data.

Northern pike is rarely consumed by either great blue herons (US EPA 1993b) or ospreys (US EPA 1993b; Environment Canada 2005) but are consumed by mink (US EPA 1993b); additionally most of the northern pike data were for fish that were larger than 35 cm. This has been reported to be the maximum size that is typically consumed by osprey (Environ 2007; US EPA 1993b). Mink have been reported to eat fish of a maximum size of 25 cm (Environ 2007) and great blue herons eat fish that are predominantly less than 25 cm (US EPA 1993b). As a result, fish greater than 35 cm in length and pike larger than 25 cm were excluded from the calculations. (Consequently, the data set used did not include any pike data).

Ecological receptors are assumed to consume whole-body fish. For brown bullhead whole-fish samples were analyzed, while whole-body-minus-one-filet samples were analyzed for ESG-collected yellow perch and northern pike. Although these whole-body samples were incomplete, the concentrations are not likely to be underestimated (but rather, overestimated) because the CoPCs (As, Cr, Cu, Pb, and Zn) affected by this uncertainty generally do not accumulate in the muscle tissue of the missing filet.

All data from Scheider (2009) represented filet samples. To convert this data to whole-body concentrations, relations were obtained from the literature, and information was found only for PCBs and Hg.

The method used for converting filet concentrations to whole-body concentrations for Hg for all fish was performed according to the formula determined by Peterson et al. (2005); a sample calculation is provided in Appendix I. To generate the whole-body concentrations for PCBs, US EPA (2006) data analysis for Lake Michigan samples suggests that yellow perch filet concentrations should be multiplied by 5.5 and carp concentrations by 1.61, to convert to whole-body PCB concentrations. A conversion factor was not available for brown bullhead and therefore filet concentrations were converted to whole body concentrations using a calculated ratio (average of 2.2 of whole body/filet) for the present data set. This method has uncertainty associated with it since the whole body and filet concentrations used to compute the ratio were not paired (i.e., from the same fish), but the length was not statistically different for the filet and whole body fish used in the calculation. PCB conversions were not carried out for bluegill, largemouth bass, and bass since no conversion factor was available in US EPA (2006) for these species. Additionally no conversion was carried out for the perch samples where the body part was not specified.

Since the sample sizes for the individual data sets were large enough, the 95UCL of the mean was calculated for whole body Hg and PCB concentrations using ProUCL 4.00.02, and the results are included in Table IV-25.

As mentioned previously, only PCB concentrations are elevated in the APEC with respect to the reference location. Similar to the finding for filets and all data together, Hg values for whole body fish were not significantly different between the reference site and the APEC. Therefore all CoPCs in fish other than PCBs were used in the present risk assessment to represent approximate background exposures for ecological receptors. Values for As, Cr, Cu, Pb, Zn and DDT in Table IV-25 are 95 UCL values of all data, repeated from those reported in Table IV-9 (data and literature information were insufficient to estimate whole body fish concentrations). The 95UCL for Hg in whole body fish was used to estimate the normal exposure that receptors would experience in the KIH area.

Concentrations in fish were modeled using US EPA BSAF values for chlordane and PAHs. This was done in the absence of measured data to obtain an approximate estimate of risk from these chemicals for receptors who were assumed to ingest only fish (mink and osprey).The modeled chlordane value (0.053 mg/kg wet weight) is close to the upper geometric mean (0.039 mg/kg wet weight) for freshwater fish (pg 422) in WHO-IARC (2001), which agrees with the assumption that chlordane values are likely equivalent to background concentrations in freshwater fish.

The Sb concentration was the background concentration reported for fish (not specific to freshwater varieties), which Environment Canada/Health Canada (2010) used to obtain background Sb exposures (for humans).

2. Estimation of Total Dose

The estimation of total dose was carried out by calculating an estimated daily intake (EDI), which is the amount of a given chemical to which a receptor is exposed, expressed as mg per kg of body mass per day (mg/kg-d). The EDI is then compared with a TRV of identical units to assess risk.

As described in the exposure pathways section (Section B.5), oral exposure to a contaminant in an aquatic ecosystem can occur through consumption of contaminated food, water and/or sediment. For this ERA, the environmental media that will be considered as potentially orally consumable are contaminated food and sediment, and water for receptors with no sediment intake.

To determine the EDI of a specific contaminant for a particular receptor, the exposure assessment requires consideration of a number of exposure factors. Equation 7 is the formula typically used in ecological risk assessments to determine a receptor's EDI:

$$EDI = \left[\left\{\left\{\left(\sum_{i=1}^{n} EPC_{fi} \times F_i\right) + (EPC_{sed} \times F_{sed})\right\} \times FIR\right\} + (EPC_w \times WIR)\right] \times \frac{F_{site} \times ED}{BW}$$

Equation 7

where:

EPC_{fi} = the exposure point concentration of the receptor's *i*th dietary food item, and having units of mg/kg

F_i = the fraction of the receptor's diet that the *i*th food item comprises; this is a dimensionless quantity.

EPC_{sed} = the exposure point concentration of sediment within the APEC, and having units of mg/kg.

F_{sed} = the fraction of the receptor's diet that sediment comprises; this is a dimensionless quantity.

FIR = the food ingestion rate, defined as the total mass of dietary intake the receptor consumes on a daily basis and having units of kg/d. In this aquatic ERA, the dietary intake of a receptor can be comprised of both food and incidental sediment intake.

EPC_w = the exposure point concentration of water (unfiltered, which includes suspended sediments), and having units of mg/L. Used only for receptors that have no sediment intake.

WIR = the water ingestion rate, defined as the total mass of water the receptor consumes on a daily basis and having units of kg or L/d. Used only for receptors that have no sediment intake.

F_{site} = the fraction of the receptor's diet that is harvested from the APEC; this is a dimensionless quantity.

ED = the exposure duration, defined as the fraction of the year that the receptor feeds at that site. This quantity is important for migratory animals and is dimensionless.

BW = the body weight of the receptor, and is expressed in kg.

The FIR and the EPC of sediment and food must be calculated using the same moisture weight basis (i.e., wet or dry weights for both the FIR and EPC). Consequently, interconversions between dry weight to wet weight FIRs and EPCs may be necessary since FIRs are often given in wet weight, sediment (soil) fractions of diet are usually measured and reported with respect to dry weight, and EPCs are often reported in dry weight. Where sediments were included in dietary intake, calculations were based on dry weight masses and concentrations, except where the food source and the sediment had similar moisture content: specifically, fish and invertebrates with a moisture content of approximately 80%, similar to the sediment moisture content of 80%. When this was the case, or when sediment was not part of the dietary estimate, wet weight FIRs were calculated using either the default values provided in the FCSAP guidance, or where none were available, allometric equations as recommended in the FCSAP guidance (Azimuth 2012).

Ecological receptors drink water as it is available to them (i.e., unfiltered), and therefore suspended solids might introduce contaminants in this way. However, incorporating water ingestion for receptors where sediments are already included as an exposure source would include suspended solids twice. This is because sediment/soil ingestion rates are based on measurements of the solids remaining after stomach content analysis, and would include any source of sediments or soils, whether they are from water or food. Therefore water ingestion, using total CoPC concentrations in water, was not considered as a pathway for receptors that have an estimated sediment ingestion rate.

Water ingestion using dissolved CoPC concentrations was not included because these data were scant, and because all CoPCs were non-detect in these circumstances. Water ingestion (total CoPC concentrations) was included for the other receptors, namely mink and osprey.

The variables listed in Equation 7 must be determined to calculate the EDI of each receptor in the CSM. These variables are discussed below for each individual receptor, and the data are summarized in Table IV-26.

1) Mink

Default values have been provided in the FCSAP guidance for mink (Azimuth 2012). The body weight suggested is 0.82 kg (average of male and female).

The mink's diet is suggested as 30% fish but 100% is used in the present ERA, since no data were available for the other dietary components (crustaceans, small mammals and birds, amphibians, and insects). The FIR is given as 0.14 kg food/kg body weight/d (equivalent to 0.1148 kg/d) and no sediment ingestion was identified, which is consistent with the sediment ingestion of the mink being considered negligible by others (Sample and Suter 1999). Therefore water ingestion, at a rate of 0.03 L/kg body weight/d (equivalent to 0.0246 L/d) was included as an exposure pathway because inorganic contaminants in the form of suspended solids in the water might be introduced.

The home ranges of mink are highly variable, with riverine home ranges being linear and those in marsh habitats having a circular home range (US EPA 1993b). The extent of a mink's home range is primarily based on availability of food, but additionally on the age and sex of the mink, as well as the season (US EPA 1993b). FCSAP guidance recommends default home range values of 0.06 km^2, and 0.4 km in length (Azimuth 2012). As the length of shoreline within the APEC is a minimum of 2.0 km, and the recommended home range with well within the KIH, it is conservatively estimated that mink inhabiting this area will harvest 100 percent of their diet from the APEC.

Mink do not hibernate in the winter and are therefore assumed to inhabit and forage the APEC year-round.

2) Great Blue Heron

Default values have been provided in the FCSAP guidance for great blue heron (Azimuth 2012). The body weight suggested is 2.3 kg (average of male and female).

The great blue heron's diet is suggested as 65% fish but 90% is used in the present ERA, which includes one of the other dietary components for which no data are available (small mammals) and allows 10% to be attributed to the other dietary component, aquatic invertebrates (the default proportion in Azimuth 2012). The FIR is given as 0.18 kg food/kg body weight/d (equivalent to 0.414 kg/d) and no sediment ingestion was identified. However, sediment ingestion was included in the heron's diet because of their behaviour while foraging for food. In the absence of any published sediment ingestion rates, the fraction of sediment in the great blue heron's diet was assumed to be 2 percent, which is the smallest percentage of soil/sediment in the diet of birds listed in Beyer et al. (1994).

The home range of the great blue heron is variable, and is greatly influenced by the local availability of food (US EPA 1993b). A default value of 16.6 km^2 is given with linear foraging distances ranging from 2.3 km to 30 km (Azimuth 2012). A study of great blue herons in Minnesota found that they travel smaller distances, 0 to 4.2 km, and average 1.8 km, between heronries and foraging areas (US EPA 1993b). The linear distance of the APEC, from the marsh to the middle of the Great Cataraqui River, is a minimum of 0.8 km. Based on a minimum foraging radius of 2.3 km, as well as the abundance of small fish within the APEC, it is assumed that approximately 50 percent of the great blue heron's prey is captured inside the APEC.

Great blue herons are migratory birds, and based on figures in US EPA (1993b) and Weir (2008), it is assumed that they inhabit the KIH from mid-March to mid-November (245 d).

3) Osprey

No default values for osprey characteristics are given in the FCSAP guidance (Azimuth 2012). Sample et al. (1996) lists the average body weight of the osprey as 1.5 kg, which was the value adopted in this ERA.

The FIR was calculated to be 0.385 kg/d (ww) using values from Nagy et al. (1999) with the calculation shown in Appendix I. Sample and Suter (1999) consider the sediment ingestion of osprey to be negligible. Water ingestion was included as an exposure pathway to incorporate introduction to inorganic contaminants in the form of suspended solids in the water. A value of 0.0795 L/d was used, equivalent to 0.053 g/g body weight/d given as the maximum in US EPA (1993a).

The home range of osprey is highly variable, and is primarily dependent on the abundance of local fish (US EPA 1993b). The foraging radius of osprey on a Minnesota lake was only 1.7 km, whereas a study in coastal Nova Scotia found the foraging radius to be 10 km (US EPA 1993b). However, because of the relatively shallow conditions in the APEC which favours the capture of fish, as well as the high population of fish in the APEC, a foraging radius of 1.7 km will be assumed. Again, as the minimum linear distance across the APEC is approximately 0.8 km, it is assumed that the osprey obtains approximately 50 percent of its prey in the APEC. Ospreys are migratory, and based on figures in US EPA (1993b) and Weir (2008), it is assumed that they inhabit the KIH from the beginning of April to the end of October (214 d). As ospreys are known to have very high nest site fidelity, it is expected that the same nesting ospreys return to the nest each year (US EPA 1993b), and perhaps even successive generations (Kristensen, personal communication 2010).

4) Mallard Duck

Default characteristics for the mallard duck are provided in the FCSAP guidance (Azimuth 2012). The body weight is 1.2 kg.

The mallard is a dabbling duck that feeds on aquatic plants (50%), aquatic invertebrates (40%), and other minor components (berries, seeds, insects and fish). To obtain the aquatic invertebrates, the duck scoops sediment into its mouth and filters through it to find food. The FCSAP guidance followed Beyer et al. (1994), recommending a maximum incidental sediment ingestion rate of mallard duck to 3.3 percent of the total (dry weight) diet, which was used in the present ERA. The dry weight dietary ingestion rate was given as 0.05 g/kg body weight/d (Azimuth 2012), equivalent to 0.06 kg/d.

Although mallard ducks are known to ingest different food items and more than one type of aquatic invertebrate, for the purposes of this ERA, different proportions of the dietary items listed above were used, based on the data availability of contaminant concentrations in food items. For Cr, only invertebrate data were used to obtain the most conservative estimate of dose and for As, Cu, Pb and Zn, only macrophyte data were used because no invertebrate data were available. Macrophyte data was chosen instead of cattail shoot data because of the availability of macrophytes throughout the KIH whereas cattails grow mainly within the Orchard Street Marsh area. Because there were data limitations for invertebrate and macrophyte data ($n<10$), the maximum value of each was used in the risk calculations.

For PCBs, DDT and chlordane, no macrophyte data were available, and in the absence of this data, risks were estimated assuming that the dietary component was entirely invertebrates with modeled values. The PCB invertebrate data were estimated using a regression model for sediment to invertebrate uptake (Labencki 2008), and DDT and chlordane concentrations were estimated from BSAF values (US EPA 2009). The resulting concentrations were on a wet weight basis; therefore the invertebrate water content (82%, Table 4-1 in US EPA 1993b) was used to convert the values to dry weight concentrations.

For PAHs, macrophyte data (n = 9) were available from both the inner and outer Kingston Harbour; the maximum concentration (a value from the outer harbour) was selected as the EPC. Invertebrate data were not available and were thus modeled from sediment values using BSAF values (US EPA). Sources of data for both macrophytes and invertebrates are high in uncertainty, with respect the representativeness of the KIH (i.e., one is not necessarily preferable over another), so both food types (50% of each) were included in the mallard diet for this CoPC.

The home range of mallard ducks is variable and depends on the distribution of the water habitats and population density. The default value is given as 9.2 ha, although Dwyer et al. (1979) report home ranges varying from 111 to 468 ha. Based on these values it has been conservatively assumed that mallard ducks forage 100 percent from the area south of Belle Park and that they inhabit the area from April 1 to October 31 (214 d).

Table IV-26: Receptor characteristics and exposure factors used in the KIH ERA for KIH + Orchard Street Marsh. F_i = food fraction of FIR (food ingestion rate); F_{sed} = sediment fraction of FIR; F_{site} = fraction of food caught from site.

Receptor	Food item	F_i	F_{sed}[a]	FIR (kg/d ww)	FIR (kg/d dw)	WIR (L/d)[b]	F_{site}	ED	BW (kg)
Mink	Fish	1.0	0	0.115	n/a	0.025	1.0	1.0	0.82
Great blue heron	Fish (As, Cu, Hg, Pb, Zn)	0.98	0.02	0.414	n/a	0	0.5	0.67	2.3
Great blue heron	Fish (90%) + invertebrates (10%) (PCBs, DDT, chlordane, PAHs, Cr)	0.98	0.02	0.414	n/a	0	0.5	0.67	2.3
Osprey	Fish	1.0	0	0.39	n/a	0.08	0.5	0.59	1.5
Mallard duck	Invertebrates (PCBs, DDT, chlordane, PAHs, Cr)	0.97	0.03	n/a	0.06	0	1	0.59	1.1
Mallard duck	Macrophytes (As, Cu, Hg, Pb, Zn, PAHs)	0.97	0.03	n/a	0.06	0	1	0.59	1.1

ww = wet weight
dw = dry weight
ED = exposure duration on site
n/a = not applicable
[a]Based on dry weight diet but no conversions necessary for heron wet diet because % moisture similar in food and sediments; therefore $F_{sed(dw)} = F_{sed(ww)}$.
[b]Water included only for receptors with no sediment ingestion, since "total" contaminant concentrations used.

3. Calculation of Receptor EDIs

Using Equation 7, the data presented in Table IV-25 and Table IV-26 were used to calculate the receptor EDI for each CoPC. These EDIs are presented in Table IV-27.

Table IV-27: Calculated estimated daily intake (EDI) for KIH receptors, in mg/kg body weight-d. No sed = no sediment ingestion, applicable to Hg for mink and osprey, who obtain Hg as MeHg, in fish. No fish pertains to no MeHg exposure, because of non-piscivorous diet (mallard duck).

CoPC	Mink	Great blue heron	Osprey	Mallard duck
As	0.013	0.0161	0.0072	0.081
Cr	0.18	0.97	0.097	9.9
Cu	0.10	0.055	0.054	0.24
Hg	No sed	4.1×10^{-4}	No sed	0.0016
MeHg	0.010	0.0041	0.0053	No fish
Pb	0.045	0.068	0.024	0.38
Zn	2.8	1.2	1.5	0.97
Sb	0.011	0.015	0.0061	0.051
PCBs	0.087	0.033	0.047	0.035
DDT	4.6×10^{-5}	1.9×10^{-4}	2.5×10^{-4}	0.013
Chlordane	0.0075	0.0029	0.0041	0.0032
BaP equiv	5.1×10^{-4}	0.0011	2.8×10^{-4}	0.0039
LMW PAH	9.1×10^{-4}	0.0012	4.9×10^{-4}	0.0072
HMW PAH	0.0057	0.0071	0.0031	0.027
Total PAH	0.0091	0.0080	0.0049	0.029

D. Effects Assessment

1. Identification of Receptor Toxicological Reference Values

To determine whether a receptor's EDI for a particular CoPC might result in risk, it is compared with a toxicological reference value (TRV). The TRVs used in the present ERA are found in Table IV-28.

The TRVs used for As, Cr(III), Cu, Pb, Zn, Sb, and DDT have been taken from those derived in the US EPA's Eco-SSL program. In producing these TRVs, the US EPA performed the following general four-step process: (1) conducted an extensive literature search of all available toxicological data on that CoPC, (2) completed a review of the literature and extracted applicable data, (3) evaluated and scored data, and (4) derived the TRV (US EPA 2003). For all Eco-SSLs, values were only used in which growth, reproduction and/or survival were measured. For Sb, no avian TRV was available. Eco-SSLs are considered to be appropriate for screening-level ERAs.

The US EPA's Eco-SSL document for PAHs was also used to obtain TRVs for this class of compounds, which were grouped into low molecular weight PAHs (LMW-PAHs) and high molecular weight PAHs (HMW-PAHs). LMW-PAHs have fewer than four rings, and HMW-PAHs have four or more rings. Specifically, LMW-PAHs include naphthalene, acenaphthylene, acenaphthene, anthracene, phenanthrene, and fluorene. HMW-PAH include fluoranthene, pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[ghi]perylene, dibenzo[ah]anthracene, and indeno[1,2,3-cd]pyrene.

For CoPCs for which there was no derived Eco-SSL TRV *(*i.e., Hg, MeHg, chlordane and PCBs), TRVs were derived from the literature. For MeHg the TRVs were obtained from Environ (2007). TRVs for MeHg were selected for use in the risk assessment for piscivorous species since MeHg is assumed to make up all of the Hg in fish. Reproductive success in loons were used to derive the avian (applicable to osprey in Environ 2007) TRV value, and behavioral effects and histopathological abnormalities in mink were the endpoints used to obtain the mammalian TRV value (Environ 2007). TRVs for inorganic Hg in sediments (for receptors exposed to sediment) were obtained from Nichols et al. (1999) and are more conservative than those in Sample 1996.

For PCBs, the ecologically relevant response for mink was chosen to be reproductive toxicity because this endpoint is known to be one of the most sensitive ones for PCB toxicity in mammals. Fuschman et al. (2008) compiled published results of 17 studies of reproductive effects in mink from exposure to PCBs in the form of technical mixtures or as accumulated in prey. The value chosen for use as the toxicological reference value (0.053 mg/kg-d; Brunström et al. 2001 in Fuschman et al. 2008) was based on a no effects level (i.e., no effect on the survival rate of mink kits, on mated female minks or on individual mink kit weights, a less sensitive endpoint, in comparison to a control set referenced in Fuschman et al. (2008)). The PCB mixture used was Chlophen A50 (Bayer trade name) equivalent to Aroclor 1254 (Monsanto trade name), the more toxic of the two PCB mixtures (also Aroclor 1260) that dominate the KIH, and will therefore add conservatism to the associated HQ. Aroclor 1254 was also used as the PCB mixture for the PCB TRV for osprey and heron, based on Sample's (1996) no observed adverse effect level, NOAEL, based on reproductive effects in ring-necked pheasants, developed for avian receptors.

For comparison to PAH Eco-SSL TRV values, Sample's values (1996) for benzo[a]pyrene were included, calculating B[a]P equivalency for the other PAH compounds, using toxic equivalency factors and methods found in Sun et al. 2012. Harwell et al. (2010) derived a TRV for total PAHs for sea otters and this was included as another mammalian TRV for comparison. No avian TRVs were available for PAHs either in the Eco-SSL document or in Sample (1996), but Harwell et al. (2012) used studies of mallard ducks dosed with weathered crude oil, containing PAHs (Stubblefield et al. 1995a, b), to obtain an estimated "total PAHs" TRV, and this was used in the present study.

Toxicological research is usually conducted on very few species, such as mice, rats, chickens and quail (Knopper et al. 2009). Allometric scaling is utilized when applying toxicological data from one species to another, as it has been observed that, between species, a relationship exists between metabolic rate (reflected in the TRV) and body mass (Knopper et al. 2009). Applicable to both mammalian and avian species, this relationship (Equation 8) can be used to estimate a receptor's TRV for a given chemical based on a test species' TRV (NOAEL) which has been determined in toxicological research (Sample et al. 1996; Knopper et al. 2009):

$$TRV_{receptor\ species} = TRV_{test\ species}\left(\frac{BW_{test\ species}}{BW_{receptor\ species}}\right)^{\frac{1}{4}}$$

Equation 8

The form of Equation 8 suggests that larger animals have smaller TRVs than smaller animals. As an amalgamation of many different studies on many different types of receptors, the Eco-SSL TRVs (i.e., used for As, Cr(III), Cu, Pb, Zn, Sb, DDT, and LMW and HMW PAHs) are inappropriate for body mass scaling. However, the individual species toxicological data upon which the TRVs for benzo[a]pyrene (for mink), chlordane (for mink) and total PAH (for avian receptors) are based make these values appropriate for body mass scaling. Recently, the use of allometric scaling for wildlife TRVs has come under review and this will be discussed in the sources of uncertainty section.

The use of NOAEL values to derive TRVs has also come under review, with FCSAP guidance (Azimuth 2012) suggesting that a preferred approach is to develop

TRVs that are site specific and related to a defined level of effect (e.g., inhibitory dose values, such as ID_{10}) (Azimuth 2012; Golder 2012). Golder (2012) recently derived KIH-specific TRVs for PCBs and Cr(III) and these are included in the TRVs for comparison. The endpoints used by Golder (2012) were reproduction, growth and survival.

Table IV-28: TRVs for receptors modeled in ERA. TRVs are from Eco-SSL documents (US EPA 2005a, b, c, d, e, f, and US EPA 2007a, b), unless otherwise noted. Golder values are from Golder 2012. All units in mg/kg-d.

CoPC	Mink	Great blue heron	Osprey	Mallard duck
As	1.04	2.24	2.24	2.24
Cr	2.40	2.66	2.66	2.66
Cu	5.60	4.05	4.05	4.05
Hg[a]	0.016	0.013	0.013	0.013
MeHg[b]	0.081	0.029	0.029	n/a
Pb	4.70	1.63	1.63	1.63
Zn	75.4	66.1	66.1	66.1
Sb	0.059	n/a	n/a	n/a
PCBs	0.053[b]	0.18[c]	0.18[c]	0.18[c]
DDT	0.147	0.227	0.227	0.227
Chlordane	1.87[d]	2.1[c]	2.1[c]	2.1[c]
BaP equiv	0.42[d,e]	n/a	n/a	n/a
LMW PAH	65.6	n/a	n/a	n/a
HMW PAH	0.615	n/a	n/a	n/a
Total PAH	51.8[f]	1.7[g]	1.85[g]	2[g]
Golder low Cr	46	5	5	5
Golder high Cr	280	100	100	100
Golder low PCB	0.082	0.26	0.26	0.26
Golder high PCB	0.105	1.8	1.8	1.8

n/a = not applicable since MeHg risk assessment only applies to piscivorous species.
[a]Nichols et al. 1999.
[b]Environ 2007; PCB value based on Brunström et al. 2001.
[c]Values from Sample et al. 1996; only one TRV given for all avian receptors.
[d]Value was derived in Sample et al. 1996 using Equation 8 and NOAEL for mouse.
[e]Using toxic equivalence factors and methods described in Sun et al. 2012.
[f]Harwell et al. 2010.
[g]Harwell et al. 2012, with avian values estimated from Stubblefield et al. 1995a,b, and Equation 8.

2. Tissue Residue Approach (TRA) for Whole-body Fish Tissue

The tissue residue approach is a comparison of tissue concentrations of CoPCs in a receptor to toxicity thresholds, represent tissue concentrations at which CoPCs are likely to become hazardous the receptor. The TRA was carried out for fish using fish toxicity thresholds obtained from a review of the relevant scientific literature. Table IV-29 contains fish toxicity thresholds for those non-bioaccumulative CoPCs for which values could be obtained. Table IV-30 contains toxicity thresholds for bioaccumulative CoPCs. A detailed overview of the scientific studies reviewed and the rationale for the derivation of toxicity thresholds for PCBs and Hg is presented in Environ (2007).

Table IV-29: Toxicity thresholds for whole-body fish tissue for inorganic elements, cited in Hinck et al. (2009)

CoPC	Toxicity threshold (mg·kg-1 ww)	Reference
As	2.0	McGeachy and Dixon (1992)
Cu	11.1 – 42.0	Stouthart et al. (1996)
Pb	0.4 – 8.8	Holcombe et al. (1976)
Zn	40 – 60	Spehar (1976)

Table IV-30: Toxicity thresholds for whole-body fish tissue for Hg and PCBs, cited in Environ (2007)

CoPC	Toxicity threshold (mg·kg^{-1} ww)	Reference
Hg	0.21	Beckvar et al. (2005)
Total PCBs	4.2	Hansen (1974)

E. Ecological Risk Characterization

1. Calculation of Hazard Quotients for Risk Characterization

HQs were calculated based on the exposure scenarios generated for this ERA, and Table IV-31 contains the calculated HQs of each CoPC and receptor. There is negligible risk to all receptors from all CoPCs except PCBs and Cr.

Mink are potentially at risk from PCBs (HQ = 1.6), and remain at risk using the lower Golder TRV developed for KIH specifically. This TRV represents the ID_{20} (inhibitory dose resulting in 20% reduction of an endpoint relative to a control) estimated from a meta-analysis of mink toxicity studies, that were well matched to the KIH scenario for Aroclor pattern (Golder 2012). The most sensitive endpoint (reproduction) was used to derive the ID_{20}.

Cr(III) poses a potential risk to mallard ducks, attributable mainly to a very high estimation of Cr concentrations in invertebrates, which was conservatively assumed to make up most of the diet of mallard ducks. The invertebrates were not depurated and therefore sediment was not included in the calculation, since it is likely that most of the sediment that a mallard duck would be exposed to would be present in a mallard duck's diet as a result of undepurated sediment remaining in invertebrates, or sediment adhered to macrophytes. (Mallard ducks are dabbling ducks, which means they do not dive into the sediment to obtain food, but rather, forage just below the water-air interface.) The HQ remains above 1 for the mallard duck using the lowest TRV presented by Golder (2012), but it is substantially less than 1 using the highest value.

Table IV-31: Calculated HQs for receptors. All values are dimensionless. Shaded cells indicate HQs that exceed the risk threshold of 1.0.

CoPC	Mink	Great blue heron	Osprey	Mallard duck
As	0.013	0.007	0.003	0.036
Cr(III)	0.076	0.47	0.036	2.3[a]
Cu	0.018	0.013	0.013	0.058
Hg	No sed	0.041	No sed	0.13
MeHg	0.12	0.14	0.18	N/A
Pb	0.01	0.042	0.015	0.23
Zn	0.036	0.018	0.023	0.015
Sb	0.19	No TRV	No TRV	No TRV
PCBs	1.6	0.19	0.26	0.19
DDT	0.003	0.003	0.001	0.15
Chlordane	0.004	0.001	0.002	0.017
BaP equiv	0.001	No TRV	No TRV	No TRV
LMW PAH	1.4×10^{-5}	No TRV	No TRV	No TRV
HMW PAH	0.0092	No TRV	No TRV	No TRV
Total PAH	1.8×10^{-4}	0.005	0.003	0.014
Golder low Cr	0.004	0.25	0.019	1.2[a]
Golder high Cr	0.001	0.013	0.001	0.061[a]
Golder low PCB	1.1	0.13	0.18	0.12
Golder high PCB	0.83	0.02	0.026	0.02

N/A: data not available for calculations.
No sed = no sediment ingestion (fish only), so no sources of inorganic Hg.
No TRV = no TRV available and assessment not possible.
[a]Sediment not included because diet modeled with 100% invertebrates, and invertebrates were not depurated.

2. Assessment of KIH Fish Health

a. Calculation of Hazard Indices to Assess Fish Tissue Concentrations

To compare fish tissue residue concentrations with the fish toxicity thresholds presented in Table IV-29 and Table IV-30, hazard indices (HI's) were calculated: HI = (fish tissue residue concentration)/fish toxicity threshold. The calculation was carried out for all fish species (including northern pike) and all locations for which data were available (including reference areas), and conversions were made to whole body concentrations for Hg and PCBs (information about converting to whole body concentrations was not available in the literature for other CoPCs). When a value range for fish toxicity thresholds was present for the CoPCs in Table IV-29 (i.e., Cu and Pb), the minimum value was assumed. As displayed in Table IV-29, no comparison for Cr could be made as no fish toxicity threshold could be found in the literature.

Table IV-32: 95 UCL and maximum values (mg/kg ww (wet weight)) and hazard indices (HIs) for fish in the KIH and the reference location. Hazard index = 95UCL OR maximum/fish toxicity threshold.

CoPC	KIH		Reference	
	95UCL	Maximum	95UCL	Maximum
	Concentration (mg/kg ww)			
As	0.10	0.2	n/a	<0.30
Cu	0.71	1.3	0.82	1.8
Pb	0.28	1.3	0.82	1.5
Zn	19	39	16	35
Hg	0.080	0.29	0.052	0.13
PCBs	0.62	5.7	0.17	0.62
	Hazard index			
As	0.048	0.10	n/a	<0.15
Cu	0.064	0.12	0.074	0.16
Pb	0.71	3.3	2.1	3.8
Zn	0.49	0.98	0.39	0.88
Hg	0.38	1.4	0.25	0.60
PCBs	0.15	1.4	0.041	0.15

n/a = not applicable

A summary of HI's, using 95 UCL values and maximum concentrations of CoPCs in fish tissues is given in Table IV-32. Similar to hazard quotients, values greater than one suggest that risk is possible. Values for Pb were above 1 in both the KIH and reference locations, but Pb concentrations were much less than the upper range of fish toxicity concentrations given in Table IV-29. HI's for As, Cu and Zn are less than 1. Maximum fish Hg and PCB concentrations are above threshold concentrations, but the 95

UCLs are not. The maximum values represent concentrations in large northern pike (n = 2 for Hg, n = 1 for PCB; length > 0.5 m). As discussed previously, the KIH Hg concentrations in fish are not significantly elevated over the reference fish concentrations.

b. Field Observations of Fish Morphological Abnormalities

As previously stated, the brown bullhead is highly regarded as a sentinel species because of its very limited home range, along with its intimate relationship to the sediment through diet and cold weather dormancy. During the fall 2009 fish sampling program conducted in the KIH 14 brown bullhead were caught in the APEC, and 19 at the reference site. Using Rafferty and Grazio (2006) as a guide, all fish were visually inspected for skin discoloration or black pigmentation, lesions and ulcers of the lip or body, fin and tail erosion, and missing, deformed or shortened barbels. These anomalies may be attributed to a variety of causes, from chemical exposure to infectious disease. No internal organ inspection was made, although obvious signs of physical abnormalities were noted. Of the 14 brown bullhead caught in the APEC, 11 (79 percent) suffered from one or more of the above anomalies. However, of the 19 fish obtained from the reference site, only 2 (11 percent) exhibited any type of anomaly. Furthermore, the reference-site brown bullhead anomalies were much less severe than those at the APEC.

As the populations of brown bullhead from the APEC and the reference site are from the same river system and separated by less than 2 km, the elevated concentrations of CoPCs at the APEC are the only discernable difference between the two sites. The contaminated sediments at the APEC may therefore be the cause of the observed anomalies in brown bullhead from that location. Figure IV-8 displays a typical epidermal ulcer found on brown bullhead from the APEC.

Tumours in freshwater fish may be caused by various factors such viruses, parasites, and exposure to chemical carcinogens. The causes of orocutaneous (skin) deformities for brown bullhead are not well established in the scientific literature. However, higher rates are generally found in contaminated areas and a viral etiology for these tumours has not been found for brown bullhead (Rafferty et al. 2009). There is strong evidence that exposure to PAHs is linked with elevated levels of orocutaneous and liver tumours for brown bullhead (Rafferty et al. 2009; Blazer et al. 2009), and this is a possible cause of the tumours in the KIH fish. Fish exposure to PCBs has also been associated with histopathological lesions, as well as changes in immunomodulation, depressed disease resistance, endocrine disruption, and reproductive and developmental effects (Niimi 1996; Iwanowicz et al. 2009). A study of fish tumours in goldfish (a bottom-feeding fish) sampled from the Housatonic River (Massachusetts, USA), which contains elevated PCB concentrations in the sediments, found multiple abnormalities such as skin lesions that were not related to viral infection (Appendix G; Weston Solutions 2004). It is possible that elevated concentrations of PAHs, PCBs and other contaminants in the KIH sediments may be responsible for the observed brown bullhead anomalies, although the causes of the tumours cannot be conclusively determined.

Under the Great Lakes Water Quality Agreement (GLWQA) (1994), the presence of fish tumours and other deformities in the southwestern portion of the KIH is considered a beneficial use impairment and has been identified in 14 of 31 AOCs located within or partially within the United States (Rafferty and Grazio 2006). Within these 14 AOCs, fish tumours and other deformities are most often found on the brown bullhead, leading Rafferty and Grazio (2006) to state that “the ability to accurately and consistently identify tumours or other deformities in brown bullhead is critical for proper assessment and monitoring of the status of this [impairment of beneficial use].” Data on orocutaneous (skin) tumours in brown bullhead from other Great Lakes AOCs is reviewed in Blazer et al. (2009). The prevalence of skin tumours and other deformities in brown bullhead from the KIH reference site is similar to that of other Great Lake reference sites, while brown bullhead sampled from the APEC exhibited a higher prevalence of skin tumours compared with other Great Lakes AOCs (Blazer et al. 2009). Information on the prevalence of this same beneficial use impairment at Canadian AOCs was not available.

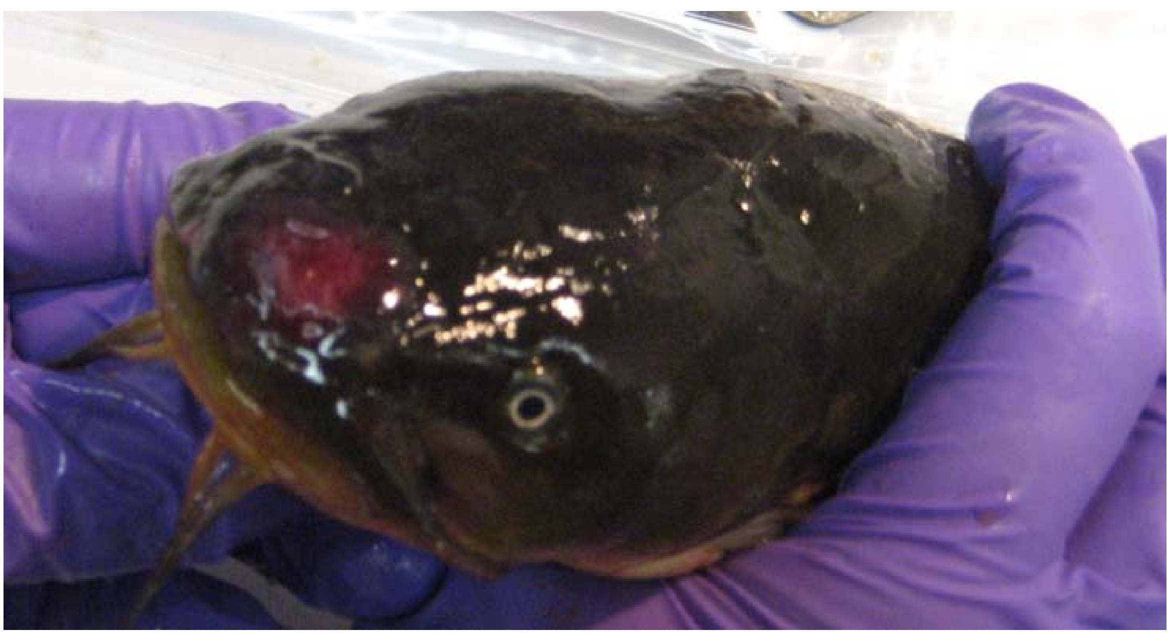


Figure IV-8: Brown bullhead from the APEC with an epidermal ulcer.

c. Comparison of Field Observations with Risk Assessment for Fish

The widespread evidence for physical abnormalities of the brown bullhead in the APEC is contradictory to risk assessment outcomes, indicating that most CoPC tissue residue concentrations are below the published toxicity thresholds for fish. There may be several reasons for this. First, the generalized toxicity thresholds used for assessing risk do not appear to be applicable to brown bullheads. All toxicity thresholds in both Table IV-29 and Table IV-30 are based on toxicological data for species other than brown bullheads; there are currently no toxicity thresholds that are specific to brown bullheads. Furthermore, the published toxicity thresholds are for fish species with different habitats from the brown bullhead, and they do not share the same degree of exposure to sediments. Toxicity thresholds may need to be uniquely determined for this species and particularly for PCBs.

Second, sediments in the KIH contain a mixture of contaminants, while toxicity thresholds are derived from studies assessing exposure to a single contaminant. It is known that in the presence of another chemical, the toxicokinetics and toxicodynamics of a chemical can be significantly altered (Bhat and Ahangar 2007). The interaction of chemical mixtures can result in three general outcomes: the toxic effect resulting from the simultaneous presence of two or more chemicals can be equal (addition), less than (antagonism), or greater than (synergism) the sum of the toxic effects produced when each chemical is only individually present (Beck et al. 2008). The complex mixture of chemicals present within the APEC may be producing additive or synergistic effects in fish, which may explain the frequency and magnitude of the observed morphological anomalies for the brown bullhead. Toxicity thresholds do not take into account these possible additive or synergistic effects and therefore may underestimate risk in areas where mixtures of contaminants are present. Additionally, PAHs have not been evaluated and may contribute to the overall toxicity. PAHs could not be assessed with respect to fish tissue concentrations because values were not available.

F. Sources of Uncertainty

Sources of uncertainty that have been identified for this ERA are summarized below.

1. Receptor Characteristics

The receptor characteristics used in the calculation of ADDs in this ERA were obtained from a variety of sources, although default values from FCSAP (Azimuth 2012) were used when they were available. To obtain protective scenarios, sediment ingestion was included where appropriate, even if none was mentioned in the FCSAP guidance. Although many of the receptor characteristics are considered benchmarks for these data, reported values may not reflect the characteristics that receptors actually exhibit in the KIH. Accordingly, conservative values for these characteristics (e.g., home range) were used in this ERA to provide a worst-case scenario.

a. <u>Mallard Duck Diet Scenarios and Sediment Bioaccessibility</u>

The mallard duck was estimated to be potentially at risk from Cr(III) exposure and this was attributed to high concentrations of Cr in invertebrates from KIH. The invertebrate Cr concentration was the highest value from a small data set of six samples (range: 1.7 to 260 mg/kg dry weight; mean of 130 mg/kg). The invertebrate samples had been analyzed without depuration of the samples, and therefore sediment was not included in the risk estimate.

FCSAP default receptor characteristic information indicates that the mallard duck feeds on aquatic plants (50%), aquatic invertebrates (40%), and other minor components (berries, seeds, insects and fish) (Azimuth 2012). This suggests that the modeled scenario may be overly conservative, and that plant concentrations should be considered in the dose calculations. This calculation included sediment, since with the addition of plants (which were analyzed after washing), the sediment ingestion might be underestimated if it is assumed that all sediment exposure is via invertebrate ingestion. Estimates using 50% plants in the diet and 50% invertebrates indicated that risk was still possible, similar to the findings in Table IV-31 (new HQ = 2.9 for EcoSSL TRV; HQ = 1.6 for low Golder TRV). Without inclusion of the sediment, the potential for risk is still apparent (HQ = 1.5 for EcoSSL TRV; HQ = 0.8 for low Golder TRV).

It is known that Cr is not soluble in sediments, and bioaccessibility measurements were carried out to obtain an ecologically relevant estimate of the amount of Cr that might be available for uptake into avian receptors (Appendix K). The 95UCL bioaccessibility was 3.4 % and when this was applied to the 50% invertebrate/50% plant scenario (including sediments), the HQ was still above one (1.6) using the EcoSSL TRV, but was less than one using the low Golder TRV (0.8). Clearly the risk may be slightly overestimated for mallard duck, but given the uncertainty in the Golder TRVs (see Section III.F.7), and the uncertainty overall, we may assume that there is still possible risk to the mallard duck from Cr(III) in the APEC, even when plants and bioaccessibility consideration are incorporated.

2. Filet to Whole-body Conversions for MeHg and PCBs

The equation for converting filet Hg concentrations to whole-body Hg concentrations taken from Peterson et al. (2005), as well as the conversion factors taken from US EPA (2006) for PCBs, may not be predictive of whole-body concentrations in the KIH. As the two studies on which these conversions were based were conducted in water bodies other than the Great Cataraqui River, differences in the qualities of the water bodies may create asymmetries in the proportions in which these chemicals partition between the filet and the remainder of the body. The data of Peterson et al. (2005), however, are based on a large amount of data from 12 of the western United States; therefore their Hg equation is more likely to be generally applicable to other sites.

Conversely, the US EPA (2006) data on which the conversion factors for PCBs are based were solely taken from Lake Michigan. Depending on the degree of difference between Lake Michigan and the Great Cataraqui River (e.g., pH), there may be greater variance between the theoretical and actual values calculated in the conversions used for this ERA. The optimal way to eliminate the uncertainty regarding true whole-body fish concentrations for Hg and PCBs is to analyze homogenized whole-body fish samples.

To assess the uncertainty with using published conversion factors compared with site-specific data, whole body/filet PCB ratios were calculated using the data in Tables D-III-5 and D-III-6 for yellow perch (the fish data for which body part was not specified were not used), and northern pike. As mentioned previously for brown bullhead, this method is also uncertain since the fish were not paired (except for the fish from Golder 2011). The original report used a conversion factor of 5.5, while site-specific conversion factors for KIH fish were 2.1 for yellow perch and 1.0 for pike. Only perch was used in the HQ calculations, and the outcomes, specifically the risk to mink, do not change significantly when the site-specific conversion factor of 2.1 is used. For the assessment of risk to fish based on fish tissue residue toxicity thresholds, the risk may change, since all values fall below the threshold (4.2 mg/kg wet weight) when the lower conversion factors are used for perch and pike (maximum of 2.7 mg/kg in a perch sample).

3. Fish Tissue Residue Toxicity Thresholds

The fish tissue residue toxicity thresholds presented in Table IV-29 and Table IV-30 serve as a useful guideline against which to compare fish tissue residue concentrations from the APEC as well as the reference site. However, as these values were not developed in the same species as have been sampled for this ERA, nor were they necessarily developed in water bodies with similar chemical characteristics (i.e., pH, alkalinity, etc.), it is unlikely that these toxicity thresholds exactly reflect those that would be expected for the species in this ERA which have been extracted from the Great Cataraqui River. Nevertheless, in the absence of more accurate data and consistent with common ERA practice, it was deemed to be acceptable to apply these toxicity thresholds as a benchmark for assessing fish tissue concentrations.

4. Toxicological Information for Reptiles and Amphibians

A recent review of the literature and ecotoxicological databases has confirmed that no suitable dose-based TRVs are currently available for amphibians or reptiles. Consequently, risk calculations cannot be completed for these species. An alternative approach would be to identify sediment and tissue-based toxicity thresholds for herptiles through literature review. However, there are generally greater uncertainties in the assessment of ecological risk using this approach, especially given the lack of measured tissue contaminant concentrations for amphibian and reptile species in the KIH. Furthermore, inclusion of this information would not alter the classification of the site as a Class I (action required) site because of potential risks to humans and other higher trophic level receptors.

5. Use of Allometric Scaling for TRVs

The use of allometric scaling for wildlife TRVs has been considered acceptable practice in risk assessment. However, this practice has recently come under review and the scientific basis for allometric scaling of TRVs has been called into question.

Allometric scaling was used in Sample et al. (1996) to obtain TRVs for chlordane and benzo[a]pyrene and mink, based on mouse toxicity studies. For both these CoPCs, negligible risk was estimated for mink in the present ERA. If allometric scaling had not been carried out, the TRV would have been larger, resulting in even less risk.

Allometric scaling was also applied in the present ERA to obtain "Total PAH" TRVs for avian receptors, based on a mallard duck toxicity study (Harwell et al. 2012, with values estimated from Stubblefield et al. 1995a, b). The scaling resulted in slightly smaller TRVs than the one estimated in Harwell et al. (2012) for mallard duck; therefore the allometric scaling introduced a slight amount of conservatism into the estimation. For all avian receptors negligible risk was estimated.

Since risk outcomes did not change for any of the receptors for which allometric scaling was carried out, allometric conversion did not have any significant impact on the risk estimates in the present ERA and is not a significant source of uncertainty.

6. Causes and Ecological Significance of Brown Bullhead Tumours and Deformities

The scientific knowledge for definitively determining the causes of the observed brown bullhead orocutaneous tumours and deformities is not currently available. Although the evidence suggests that elevated chemical concentrations in the sediments are related to the prevalence of fish tumours, it is possible that other factors (viruses, pathogens) could explain the results. The ecological significance of these tumours in terms of fish survival, reproduction, or growth is unknown.

7. Toxicological Reference Values

A large amount of uncertainty is inherent in the derivation and use of toxicological reference values. US EPA has published Eco-SSL documents for a number of contaminants. In these documents the stringent review process ensures that a comprehensive, critical, and conservative approach has been taken. However, the derivation of TRVs is based on statistical examination of all the published data that passed the screening requirements, specifically expressed as NOAEL values. This approach has been criticized recently (Allard et al. 2009) and an alternative approach has been proposed involving derivation of exposure doses or inhibitory doses resulting in measured effects (i.e., ED_x or ID_x); this has been promulgated by FCSAP (Azimuth 2012).

Together with Azimuth, Golder drafted the FCSAP guidance and also recently derived KIH-specific TRVs for PCBs and Cr(III) (Golder 2012). An examination of their data analysis figures reveals that a great deal of uncertainty exists in the derived TRVs when attempting to derive numerical response values from the data published in the literature. For Cr, no avian TRV could be derived using this approach because a dose-response relationship was not apparent. The reports states (pages 10–11, Appendix J, Golder 2012): “The chromium dose-response plot for all bird species and endpoints combined shows that few effects estimates greater than 10% were observed. The distribution of data did not allow for fitting of a reliable statistical model.” Additionally, in the footnote d to Table 2 it is stated: “ID_x values were not calculable (NC) based on the lack of clear dose-response. With the exception of a single unpublished study by Haseltine et al. (1985), effect sizes are below 20% for all exposures below 100 mg/kg-d trivalent chromium.” Instead, a TRV range of 5–100 mg/kg-d, based on professional judgement was reported (in Table 3 it is stated: “Range based on professional judgement considering weight of evidence from data shown in Figure 8 and discussed in Section

4.2.2”). Although the authors did not explicitly describe how they arrived at the TRV range, it is possible the low value is the LOAEL derived in Sample et al. (1996) from the Haseltine et al. (1985) study, and the high value is obtained from the concentration below which effect sizes are below 20%. (Note that US EPA in their EcoSSL document derived a LOAEL of 2.78 mg/kg-d from the Haseltine et al. (1985) study, which is lower than the Sample derived value of 5 mg/kg-d). Thus substantial uncertainty is inherent with these values.

For the Cr TRV in mammals, the problematic Ivankovic and Preussman (1975) study (see Section II.G, HHRA uncertainty) was included, with Golder justifying the inclusion of this study based on their interpretation that the study reported measured effects (Golder 2012), even though the study conclusions clearly state that no effects were observed (Ivankovic and Preussman 1975). The inclusion of this study in the TRV derivation, both because of its lack of effects and the use of an insoluble compound (as discussed in Section II.G), makes the Cr mammalian TRV also highly uncertain. However, negligible risk was apparent using all TRVs for mink, the only mammalian receptor considered, and therefore the impact of this uncertainty does not affect the outcome of the ERA.

For MeHg, values derived in Environ (2007) were adopted. These were, as stated earlier, based on reproductive success in loons for the avian TRV, which Environ (2007) considered applicable to loons and osprey, and based on behavioral effects and histopathological abnormalities in mink for the mammalian TRV value (Environ 2007). In both cases, the TRV was computed as the geometric mean of the lowest observed adverse effect level (LOAEL) and the NOAEL; in the case of the mink TRV a NOAEL was not measured and was estimated by Environ (2007) as one-tenth of the measured LOEAL. Both values are substantially less conservative than the NOAEL or LOAEL for mink, or the avian NOAEL reported in Sample et al. (1996). However, if the Sample et al. (1996) values are used, the risk outcomes are the same: the risk is negligible to all receptors. Therefore the uncertainty in the MeHg TRVs does not affect the present ERA.

For PAH TRVs, only values for LMW and HMW PAHs were available from US EPA for mammalian receptors. Several other PAH TRVs were obtained from the literature but only as indicative points for comparison, since a comprehensive literature review and screening was not undertaken. We did not choose to carry out this review, since the HQs were all substantially less than one for all receptors, using the identified TRVs. The TRV reported for total PAHs by Harwell et al. (2010) for sea otters was used without any adjustments for body weight, since the value appeared to have been derived in the same manner as the other TRVS in the Eco-SSL report, precluding adjustments for animal body weights.

G. Summary of Ecological Risk Assessment

Based on the exposure scenarios developed in this semi-quantitative screening level ERA for the Orchard Street Marsh and southwest portion of the KIH, Cr(III) appears to pose a potential risk to mallard ducks. In addition, mink are at potential risk from exposure to PCBs.

Comparisons of fish-tissue CoPC concentrations with published fish toxicity thresholds suggest that the fish community in the APEC is not at risk. However, field observations of the brown bullhead indicate a substantial frequency of morphological abnormalities for fish in the APEC which appear rare at the reference site. In contrast to those obtained at the reference site, and with the only difference between the two sites being the elevated concentrations of CoPCs in the sediments of the APEC, most brown bullhead caught within the APEC suffer from the GLWQA-defined beneficial use impairment of fish tumours and other deformities. The causes for these tumours and other deformities could not be determined. Although the whole-body tissue residue concentrations of CoPCs do not indicate a high likelihood of risk, the available fish toxicity thresholds are not specific to brown bullheads, which may be particularly sensitive to sediment contamination. In addition, toxicity thresholds do not account for possible additive or synergistic effects from the complex mixture of contaminants in the APEC, and therefore the assessed risk may be underestimated. The frequency of observed morphological abnormalities for brown bullhead within the APEC suggests that contaminated sediments may pose an ecological risk for this species.

IV. SUMMARY

A human health and ecological risk assessment for the southwest portion of the KIH has indicated that there are both potential human health and ecological risks from sediment and biological contamination. The human health risk assessment indicated that adults, teens, children and toddlers face potential risks from the concentrations of PCBs, mostly through consumption of fish. Although Pb and Hg exposures are more than one-fifth of non-cancer safe doses for children and toddlers, these contaminants do not pose risk when they are added to background exposures. As and Sb pose a potential health threat for non-cancer effects to child and toddler receptors, and potential carcinogenic health risks were evident for As; however, exposure to even background concentrations of these contaminants poses risk. PAHs in sediment pose a potential carcinogenic health risk, attributable solely to exposures through skin.

Risk calculations for the ERA indicated that mallard ducks are potentially at risk from Cr(III) ingestion. Mink are potentially at risk because of PCBs. Risk calculations comparing fish tissue CoPC concentrations with published fish toxicity thresholds suggest that the fish community in the APEC is not at risk. However, field observations of the brown bullhead noted a high frequency of morphological abnormalities (i.e., tumours and other deformities) in the APEC which appeared rare at the reference site. The only apparent difference between the two sites is the presence of elevated concentrations of CoPCs in the sediments of the APEC, suggesting that the contaminated sediments pose an ecological risk for this species. Furthermore, the published toxicity thresholds are not specific to brown bullhead and do not take into account possible synergistic or additive toxic effects of the contaminant mixture in the sediment, suggesting that the calculated risks for fish may be greatly underestimated.

Overall, the identification of both potential human health and ecological risks for the southwest portion of the KIH indicates that management is needed to address risks posed by contaminated media in this area. Chapter V of this report integrates information from the first four chapters into an options analysis for management of the APEC.

V. References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Mercury. U.S. Department of Health and Human Services, Public Health Service. Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007a. Toxicological Profile for Arsenic. Updated 2007. U.S. Department of Health and Human Services, Public Health Service. Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2007b. Toxicological Profile for Lead. U.S. Department of Health and Human Services, Public Health Service. Atlanta, GA.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological Profile for Chromium (Draft). U.S. Department of Health and Human Services, Public Health Service. Atlanta, GA.

Allard, P.. A. Fairbrother, B.K. Hope, R.N. Hull, M.S. Johnson, L. Kapustka, G. Mann, B. McDonald and B.E. Sample (Allard et al.). 2009. "Recommendations for the development and application of wildlife toxicity reference values." *Integrated Environmental Assessment and Management* 6, no. 1: 28–37.

Asquini, A., M. McLeod and C. Sollows (Asquini et al.). 2007. "Remediation of sediment contamination in the Cataraqui River, Kingston Inner Harbour." Unpublished undergraduate thesis, Royal Military College of Canada, Kingston, ON.

Azimuth Consulting Group. 2012. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Prepared for Environment Canada.

Baker, S.D. and M.S. Sepúlveda. 2009. "An evaluation of the effects of persistent environmental contaminants on the reproductive success of Great Blue Herons (*Ardea herodias*) in Indiana." *Ecotoxicology* 18: 271–280.

Basu, N., A.M. Scheuhammer, S.J. Bursian, J. Elliot, K. Rouvinen-Watt and H.M. Chan (Basu et al.). 2007. "Mink as a sentinel species." *Environ. Res.* 103: 130–144.

Beck, B.D., E.J. Calabrese, T.M. Slayton and R. Rudel (Beck et al.). 2008. "The use of toxicology in the regulatory process." In *Principals and Methods of Toxicology*, Fifth Edition (ed. A.W. Hayes), Informa Healthcare, New York, NY.

Beckvar, N., T.M. Dillon and L.B. Read (Read et al.). 2005. "Approaches for linking whole-body fish tissue residues of mercury or DDT to biological effects thresholds." *Environ. Toxicol. Chem.* 24(8): 2094–2105.

Beletsky. L. 1996. *The Red-winged Blackbird: The Biology of a Strongly Polygynous Songbird*. Academic Press, San Diego, CA.

Benoit, N. and D. Berniston. 2010. Cataraqui River Project Trackdown: Follow-up Study on Success of Remediation Efforts in the Cataraqui River 2006. Prepared for Ontario Ministry of the Environment, Eastern Region.

Beyer, W.N., E.E. Connor and S. Gerould (Beyer et al). 1994. “Estimates of soil ingestion by wildlife.” *J. Wildl. Manage.* 58, no. 2: 375–382.

Bhat, A.S. and A.A. Ahangar. 2007. “Methods for detecting chemical-chemical interaction in toxicology.” *Toxicol. Mech. Method* 17: 441–450.

Blazer, V.S., S.D. Rafferty, P.C. Baumann, S.B. Smith and E.C. Obert (Blazer et al.). 2009. “Assessment of the “fish tumors or other deformities” beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): II. Liver neoplasia.” *Journal of Great Lakes Research* 35: 527–537.

Bleavins, M.R., R.J. Aulerich and R.K. Ringer (Bleavins et al.). 1981. “Placental and mammary transfer of polychlorinated and polybrominated biphenyls in the mink and ferret.” In: *Avian and Mammalian Wildlife Toxicology: Second Conference* (eds. E.E. Kenaga and D.W. Lamb), pp 121–131. American Society for Testing and Materials, Baltimore, MD.

Bloom, N.S. 1992. “On the chemical form of mercury in edible fish and marine invertebrate tissue.” *Canadian Journal of Fisheries and Aquatic Sciences* 49, no. 5: 1010–1017.

Brunström, B., B.-O. Lund, A. Bergman, L. Asplund, I. Athanassiadis, A. Athanasiadou, S. Jensen and J. Örberg (Brunström et al.). 2001. “Reproductive toxicity in mink (*Mustella vision*) chronically exposed to environmentally relevant polychlorinated biphenyl concentrations.” *Environ. Toxicol. Chem.* 20, no. 10: 2318–2327.

Burbridge, D.J. 2010. “Contaminated sediments in the Kingston inner Harbour: Assessing ecological effects, evaluating and minimizing remediation impacts.” MSc thesis, Royal Military College of Canada, Kingston.

Burbridge, D.J., I. Koch, J. Zhang and K.J. Reimer (Burbridge et al.). 2012. “Chromium speciation in river sediment pore water contaminated by tannery effluent.” *Chemosphere* 89: 838–843.

Canadian Association for Laboratory Accreditation (CALA). 2013a. Scope of Accreditation, Analytical Sciences Group and Slowpoke-2 Facility at RMC (2965). Canadian Association for Laboratory Accreditation Inc. Available at http://www.cala.ca/scopes/2965.pdf

Canadian Association for Laboratory Accreditation (CALA). 2013b. Scope of Accreditation, Queen’s Analytical Services Unit (2709). Canadian Association for Laboratory Accreditation Inc. Available at http://www.cala.ca/scopes/2709.pdf

Canadian Council of Ministers of the Environment (CCME). 1996. A Framework for Ecological Risk Assessment: General Guidance. PN 1195. The Contaminated Sites Remediation Program, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 1999a. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Retrieved from www.ccme.ca on February 9, 2010.

Canadian Council of Ministers of the Environment (CCME). 1999b. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Chromium (total 1997) (VI 1999). In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME). 2007. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health.

CH2M Hill Engineering Ltd. 1991. Final Report for Phase I of the Investigation to Determine Presence/Absence of Coal Tar Contamination in Anglin Bay and Lake Ontario in the City of Kingston. Report submitted to the Kingston Public Utilities Commission.

Chapman, P.M. and F. Wang. 2000. "Issues in ecological risk assessment of inorganic metals and metalloids." *Hum. Ecol. Risk Assess.* 6, no. 6: 965–988.

Chuan, M.C. and J.C. Liu. 1996. "Release behavior of chromium from tannery sludge." *Wat. Res.* 30, no. 4: 932–938.

Cook, M.F. and E.P. Bergensen. 1988. "Movements, habitat selection, and activity periods of northern pike in Eleven Mile Reservoir, Colorado." *T. Am. Fish. Soc.* 117: 495–502.

Cranshaw, L.I., D.E. Lemons, M. Parmer and J.M. Messing (Cranshaw et al.). 1982. "Behavioral and metabolic aspects of low temperature dormancy in the brown bullhead, *Ictalurus nebulosis*." *J. Comp. Physiol.* 148: 41–47.

Dabeka, R.W., A.D. McKenzie and P. Bradley (Dabeka et al.). 2003. "Survey of total mercury in total diet food composites and an estimation of the dietary intake of mercury by adults and children from two Canadian cities, 1998–2000." *Food Additives and Contaminants* 20: 629–638.

Department of Justice Canada. 2013. Food and Drug Regulations C.R.C., c. 870, B.15.003. Available at http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.,_c._870/page-158.html

Diana, J.S., W.C. Mackay and M. Ehrman (Diana et al.). 1977. "Movements and habitat preference of northern pike (*Esox lucius*) in Lac St. Anne, Alberta." *Trans. Am. Fish. Soc.* 106: 560–565.

Dwyer, T.J., G.L. Krapu and G.M. Janke (Dwyer et al.). 1979. "Use of prairie pothole habitat by breeding mallards." *J. Wildl. Manag.* 43: 526–531.

Ecological Services. 2008. Species Inventory and Ecological Evaluation, Orchard St. Marsh, Kingston Ontario. Prepared for Environmental Sciences Group, Royal Military College of Canada, Kingston, ON.

ENVIRON International Corporation. 2007. Environmental Risk Assessment for Peninsula Harbour, Lake Superior. Final Report: Volume 1. Project No. 21-16548A. Prepared for Environment Canada. Portland, ME.

Environment Canada. 2005. Great Lakes Factsheet: The Rise and Fall of Osprey Populations in the Great Lakes Basin. Retrieved online on February 15, 2010 at http://www.on.ec.gc.ca/wildlife/factsheets/fs_osprey-e.html.

Environment Canada. 2009. Canadian Climate Normals (1971–2000): Kingston, Ontario Pumping Station. Retrieved online at http://climate.weatheroffice.gc.ca/ climate_normals/results_e.html?stnID=4300&lang=e&dCode=0&StationName=KINGSTON&SearchType=Contains&province=ALL&provBut=&month1=0&month2=12.

Environment Canada and Health Canada. 2010. Screening Assessment for the Challenge: Antimony trioxide (Antimony oxide). Accessed from http://www.ec.gc.ca/ese-ees/ 9889ABB5-3396-435B-8428-F270074EA2A7/batch9_1309-64-4_en.pdf. 86 pages.

Environmental Sciences Group. 2003. Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour. Royal Military College of Canada, Kingston, ON. October 2003.

Erb, J. and H.R. Perry. 2003. "Muskrats." In: *Wild Mammals of North America: Biology, Management, and Conservation*, Second Edition (eds. G.A. Feldhammer, B.C. Thompson and J.A. Chapman). Johns Hopkins University Press, Baltimore, MD.

Fish, P.A. and J. Savitz. 1983. "Variations in home ranges of largemouth bass, yellow perch, bluegills, and pumpkinseeds in an Illinois Lake." *T. Am. Fish. Soc.* 112: 147–153.

Food and Drug Administration (FDA) 2011. Code of Federal Regulations Title 21, Volume 2, April 1, 2011, 21 CRF 101.9(c)(8)(iv). Available at http://www.accessdata.fda.gov/cripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?FR=101.9

Fuchsman, P.C., T.R. Barber and M.J. Bock (Fuchsman et al.). 2008. "Effectiveness of various exposure metrics in defining dose-response relationships for mink (*Mustela vison*) exposed to polychlorinated biphenyls." *Arch Environ Contam Toxicol* 54: 130–144.

Gibson, B.C.T. 2010. "A study of chromium and lead in the environment and the effect of bioaccessibility on human health and ecological risk assessments: The Davis Tannery site." Unpublished MSc thesis, Royal Military College of Canada, Kingston, ON.

Golder Associates. 2011. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment — Kingston Inner Harbour: Framework Steps 4 and 5 (PQRA). Submitted to Public Works and Government Services Canada. Report number 10-1421-0039. 469 pp.

Golder Associates. 2012. Implementation of the Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment — Kingston Inner Harbour: Framework Step 6 (detailed quantitative assessment). Submitted to Public Works and Government Services Canada. Report number 11-1122-0154. 497 pp.

Great Lakes Water Quality Agreement of 1978 (GLWQA). 1994. International Joint Commission, United States and Canada. Reprinted February 1994.

Grieb T.M., C.T. Driscoll and S.P. Gloss (Grieb et al.). 1990. "Factors affecting mercury accumulation in fish in the upper Michigan peninsula." *Environ. Toxicol. Chem.* 9: 919–930.

Hansen, D,J. 1974. "Aroclor® 1254 in eggs of sheepshead minnows: Effect on fertilization success and survival of embryos and fry." *Proceedings of the Southeastern Association of Fish and Wildlife Agencies*. pp. 420–426.

Harwell, M.A., J.A. Gentile, C.B. Johnson, D.L. Garshelis and K.R. Parker (Harwell et al.). 2010. "A quantitative ecological risk assessment of the toxicological risks from Exxon Valdez subsurface oil residues to sea otters at Northern Knight Island, Prince William Sound, Alaska." *Human and Ecological Risk Assessment* 16: 727–761.

Harwell, M.A., J.A. Gentile, K.R. Parker, S.M. Murphy, R.H. Day, A.E. Bence, J.M. Neff and J.A. Wiens (Harwell et al.). 2012. "Quantitative assessment of current risks to harlequin ducks in Prince William Sound, Alaska, from the Exxon Valdez oil spill." *Human and Ecological Risk Assessment* 18: 261–328.

Haseltine, S.D., L. Sileo, D.J. Hoffman and B.D. Mulhern (Haseltine et al.). 1985. "Effects of chromium on reproduction and growth in black ducks." Unpublished (cited in US EPA 2005c).

Health Canada. 2005. Dietary Reference Intakes. Available at http://www.hc-sc.gc.ca/fn-an/nutrition/reference/table/ref_elements_tbl-eng.php

Health Canada. 2007. Bureau of Chemical Safety Food Directorate, Health Products and Food Branch, Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. H164-54/2007E-PDF. 76 pages. Available at http://www.hc-sc.gc.ca/fn-an/pubs/mercur/merc_fish_poisson-eng.php#appd

Health Canada. 2010a. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-specific Factors, Version 2.0. September 2010. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals ($DQRA_{chem}$). September 2010. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Health Canada. 2011. Dietary Intakes of Contaminants & Other Chemicals for Different Age-Sex Groups of Canadians. Available at http://www.hc-sc.gc.ca/fn-an/surveill/total-diet/intake-apport/index-eng.php

Health Canada. 2012a. Canadian Standards (Maximum Levels) for Various Chemical Contaminants in Foods. Available at http://www.hc-sc.gc.ca/fn-an/securit/chem-chim/contaminants-guidelines-directives-eng.php#guidelines

Health Canada. 2012b. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. September 2010; revised 2012. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Health Canada. 2012c. Guidelines for Canadian Drinking Water Quality—Summary Table. Water, Air and Climate Change Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/water-eau/2012-sum_guide-res_recom/2012-sum_guide-res_recom-eng.pdf. Accessed June 25, 2013.

Heit, M., Y. Tan, C. Klusek and J.C. Burke (Heit et al.). 1981. "Anthropogenic trace elements and polycyclic aromatic hydrocarbon levels in sediment cores from two lakes in the Adirondack acid lake region." *Water, Air, and Soil Pollution* 15: 441–464.

Helsel, D.R. 2013. Practical Stats. http://www.practicalstats.com/

Hinck, J.E., C.J. Schmitt, K.A. Chojnacki and D.E. Tillitt (Hinck et al.). 2009. "Environmental contaminants in freshwater fish and their risk to piscivorous wildlife based on a national monitoring program." *Environ. Monit. Assess.* 152: 469–494.

Holcombe, G.W., D.A. Benoit, E.N. Leonard and J.M. McKim (Holcombe et al.). 1976. "Long-term effects of lead exposure on three generations of brook trout (*Salvelinus fontinalis*)." *J. Fish Res. Board Can.* 33: 1731–1741.

Ivankovic, S. and R. Preussman. 1975. "Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats." *Food Cosmet. Toxicol.* 13, no. 3: 347–351.

Iwanowicz, L.R., V.S. Blazer, S.D. McCormick, P.A. VanVeld and C.A. Ottinger (Iwanowicz et al.). 2009. "Aroclor 1248 exposure leads to immunomodulation, decreased disease resistance and endocrine disruption in the brown bullhead, *Ameiurus nebulosis*." *Aquat. Toxicol.* 93: 70–82.

Knafla, A., S. Petrovic, M. Richardson, J. Campbell and C. Rowat (Knafla et al.). 2011. "Development and application of a skin cancer slope factor for exposures to benzo[a]pyrene in soil." *Regulatory Toxicology and Pharmacology* 59: 101–110.

Knafla, A., K.A. Phillipps, R.W. Brecher, S. Petrovic and M. Richardson (Knafla et al.). 2006. “Development of a dermal cancer slope factor for benzo[a]pyrene.” *Regulatory Toxicology and Pharmacology* 45: 159–168.

Knopper, L.D., G.K. Smith, C.A. Ollsen and M. Stephenson (Knopper et al.). 2009. “Use of body mass scaling of dose in ecological risk assessments.” In: *Ecotoxicology Research Developments* (ed. E.B. Santos). Nova Science Publishers Inc., Hauppauge, NY.

Koch, I., M. Moriarty, J. Sui, B. Gibson and K.J. Reimer (Koch et al.). 2012. “Insolubility of Cr_2O_3 in bioaccessibility tests points to requirement for a new human oral reference dose for trivalent chromium.” *Human and Ecological Risk Assessment* 18: 1292–1306.

Kushlan, J.A. and J.A. Hancock. 2005. *The Herons*. Oxford University Press Inc., New York, NY.

Labencki, T. 2008. An Assessment of Polychlorinated Biphenyls (PCBs) in the Hamilton Harbour Area of Concern (AOC) in Support of the Beneficial Use Impairment (BUI): Restrictions on Fish and Wildlife Consumption. Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment. On behalf of: Toxic Substances and Sediment Technical Team, Hamilton Harbour Remedial Action Plan. Available at http://www.hamiltonharbour.ca/documents/2008_Labencki_-_Hamilton_Harbour_PCB_Study.pdf

Linkov, I., K.E. von Stackelburg, D. Burmistrov and T.S. Bridges (Linkov et al.). 2001. “Uncertainty and variability in risk from trophic transfer on contaminants in dredged sediments.” *Sci. Total Environ.* 274: 255–269.

Logan, D.T. 2007. “Perspective on ecotoxicology of PAHs to fish.” *Hum. Ecol. Risk Assess.* 13, no. 2: 302–316.

Malroz Engineering Inc. 2003. Kingston Inner Harbour: Data Compilation and Gap Analysis. Prepared for Kingston Environmental Advisory Forum — Inner Harbour Group, February 21, 2003.

Martin, R.R., S.J. Naftel, T.K. Sham, B. Hart and M.A. Powell (Martin et al.). 2003. “XANES of chromium in sludges used as soil ameliorants.” *Can. J. Chem.* 81: 193–196.

McGeachy, S.M. and D.G. Dixon. 1992. “Whole-body arsenic concentrations in rainbow trout during acute exposure to arsenate.” *Ecotox. Environ. Safe.* 24: 301–308.

McNicol, D.K., R.J. Robertson and P.J. Weatherhead (McNicol et al.). 1982. “Seasonal, habitat, and sex-specific food habits of red-winged blackbirds: Implications for agriculture.” *Can. J. Zool.* 60: 3282–3289.

Meacher, D.M., D.B. Menzel, M.D. Dillencourt, L.F. Bic, R.A. Schoof, L.J. Yost, J.C. Eickhoff and C.H. Farr (Meacher et al.). 2002. “Estimation of Multimedia Inorganic Arsenic Intake in the U.S. Population.” *Human and Ecological Risk Assessment* 8, no. 7: 1697–1721.

Ontario Ministry of the Environment (OMOE). 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.

Ontario Ministry of the Environment (OMOE). 2006a. Results of the 2003 Guide to Eating Ontario Sport Fish Questionnaire.

Ontario Ministry of the Environment (OMOE). 2006b. Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines. 40 pp.

Ontario Ministry of the Environment (OMOE). 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An integrated approach.

Ontario Ministry of the Environment (OMOE). 2009. OMOE Soil, Ground Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act.

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario. Prepared by Standards Development Branch. PIBS 7386e01. 571 pp. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_086518.pdf. April 15, 2011.

Ontario Ministry of the Environment (OMOE). 2013. Guide to Eating Ontario Sport Fish 2013–2014 — 27th Edition, revised. Queen’s Printer for Ontario.

Mosimann, J.E. and F.C. James. 1979. « New statistical methods for allometry with application to Florida red-winged blackbirds.” *Evolution* 33, no. 1: 444–459.

Nagy, K.A., I.A. Girard and T.K. Brown (Nagy et al.). 1999. “Energetics of free-ranging mammals, reptiles, and birds.” *Annu. Rev. Nutr.* 19: 247–77.

National Research Council (NRC). 1989. Recommended Dietary Allowances, 10th Edition. Subcommittee on the Tenth Edition of the RDAs, Food and Nutrition Board, Commission on Life Sciences, National Research Council. National Academies Press, Washington, D.C. Available at http://www.nap.edu/openbook.php?isbn=0309046335.

National Research Council (NRC). 1991. Animals as Sentinels of Environmental Health Hazards. Committee on Animals as Monitors of Environmental Hazards. National Academies Press, Washington, D.C.

Nichols, J., S. Bradbury and J. Swartout (Nichols et al.). 1999. “Derivation of wildlife values for mercury.” *Journal of Toxicology and Environmental Health Part B: Critical Reviews* 2, no. 4: 325–355.

Niimi, A.J. 1996. "Evaluation of PCBs and PCDD/Fs retention by aquatic organisms." *Sci. Tot. Environ.* 192: 123–150.

Oomen, A.G., A. Hack, M. Minekus, E. Zeijdner, C. Cornelis, G. Schoeters, W. Verstrate, T. Van de Wiele, J. Wragg, C. Rompelberg, A. Sips and J. Van Wijen (Oomen et al.). 2002. "Comparison of five *in vitro* digestion models to study the bioaccessibility of soil contaminants." *Environ. Sci. Technol.* 36: 3326–334.

Orians, G.H. 1985. *Blackbirds of the Americas*. University of Washington Press, Seattle, WA.

Otten, J.J., J. Pitzi Hellwig and L.D. Meyers (Otten et al.), eds. 2006. *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements.* National Academy of Sciences, National Academies Press.

Page, L.M. and B.M. Burr. 1991. *A Field Guide to Freshwater Fishes: North America North of Mexico*. Houghton Mifflin Company, Boston, Mass.

Peterson, S.A., J. Van Sickle, R.M. Hughes, J.A. Schacher and S.F. Echols (Peterson et al.). 2005. "A biopsy procedure for determining filet and predicting whole-fish mercury concentration." *Arch. Environ. Contam. Toxicol.* 48: 99–107.

Poole, A.F. 1989. *Ospreys: A Natural and Unnatural History.* Cambridge University Press, Cambridge, UK.

Proulx, G. and F.F. Gilbert. 1983. "The ecology of the muskrat, *Ondatra zibethicus*, at Luther Marsh, Ontario." *Can. Field Nat.* 97, no. 4: 377–390.

Rafferty, S.D., V.S. Blazer, A.E. Pinkney, J.L. Grazio, E.C. Obert and L. Boughton (Rafferty et al.). 2009. "A historical perspective on the "fish tumors and other deficiencies" beneficial use impairment at Great Lakes Areas of Concern." *J. Great Lakes Res.* 35: 496–506.

Rafferty, S.D. and J.L. Grazio. 2006. Field Manual for Assessing Internal and External Anomalies in Brown Bullhead (*Ameiurus nebulosus*). http://seagrant.psu.edu/publications/technicaldocs/BullheadFieldManual.pdf. Accessed October 2009.

Richardson, M. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc., Ottawa, ON.

Sakaris, P.C. and R.V. Jesian. 2005. "Brown bullhead as an indicator species: Seasonal movement patterns and home ranges within the Anacostia River, Washington, D.C." *T. Am. Fish. Soc.* 134: 1262–1270.

Salice, C.J., J.G. Suski, M.A. Bazar and L.G. Talent (Salice et al.). 2009. "Effects of inorganic lead on Western fence lizards (*Sceloporus occidentalis*)." *Environ. Pollut.* 157: 3457–3464.

Sample, B.E., D.M. Ospreko and G.W. Suter (Sample et al.). 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. Risk Assessment Program, Health Sciences Research Division, Oak Ridge, Tennessee. ES/ER/TM-86/R3.

Sample, B.E. and G.W. Suter. 1999. “Ecological risk assessment in a large river-reservoir: 4. Piscivorous wildlife.” *Environ. Toxicol. Chem.* 18, no. 4: 610–620.

Scheider, W. 2009. Methylmercury Study in the Kingston Inner Harbour — Technical Memorandum. Prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Scientific Committee on Health and Environmental Risks (SCHER). 2007. Preliminary report on the environmental risks and indirect health effects of mercury in dental amalgam. Health and Consumer Protection Directorate General, European Commission, Brussels. 16 pp. Available at http://ec.europa.eu/health/ph_risk/ committees/04_scher/docs/ scher_o_089.pdf. Accessed August 28, 2013.

Scott, W.B. and E.J. Crossman. 1973. “Freshwater Fishes of Canada.” *Bulletin 184, Bulletins of the Fisheries Research Board of Canada*. Ottawa, ON.

SENES Consultants Limited. 2010. Collection of data to develop Canadian estimated daily intake rates of lead in pertinent media of exposure. Prepared for Health Canada Quebec Region, Safe Environments Programme, Healthy Environments and Consumer Safety Branch. Quebec, PQ. 96 pp.

Seston, R.M., M.J. Zwiernik, T.B. Fredricks, S.J. Coefield, D.L. Tazelaar, D.W. Hamman, J.D. Paulson and J.P. Giesy (Seston et al.). 2009. “Utilizing the great blue heron (*Ardea herodias*) in ecological risk assessments of bioaccumulative contaminants.” *Environ. Monit. Assess.* 157: 199–210.

Shoaf, M.B., J.H. Shirai, G. Kedan, J. Schaum and J.C. Kissel (Shoaf et al.). 2005a. “Adult Dermal Sediment Loads Following Clam Digging in Tide Flats.” *Soil and Sediment Contamination* 14, no. 5: 463–470.

Shoaf, M., J.H. Shirai, G. Kedan, J. Schaum and J.C. Kissel (Shoaf et al.). 2005b. “Child dermal sediment loads following play in a tide flat.” *J. of Exposure Analysis and Environmental Epidemiology* 15: 407–412.

Sinnot, T.J. and N.H. Ringler. 1987. “Population biology of the brown bullhead (*Ictalurus nebulosus).” J. Freshwater Ecol.* 4: 225–234.

Spehar, R.L. 1976. “Cadmium and zinc toxicity to flagfish, *Jordanella floridae*.” *J. Fish. Res. Board Can.* 33: 1939–1945.

Stouthart, X.J.H.X., J.L.M. Haans, A.C. Lock and S.E. Wendelaar Bonga (Stouthart et al.). 1996. “Effects of water pH on copper toxicity to early life stages of the common carp (*Cyprinus carpio*).” *Environ. Toxicol. Chem.* 15, no. 3: 376–383.

Stubblefield, W.A., G.A. Hancock, W.H. Ford and R.K. Ringer (Stubblefield et al.). 1995a. “Acute and subchronic toxicity of naturally weathered Exxon Valdez crude oil in mallards and ferrets.” *Environ. Toxicol. Chem.* 14: 1941–1950.

Stubblefield, W.A., G.A. Hancock, H.H. Prince and R.K. Ringer (Stubblefield et al.). 1995b. “Effects of naturally weathered Exxon Valdez crude oil on mallard reproduction.” *Environ. Toxicol. Chem.* 14: 1951–1960.

Sun, J.L., H.G. Ni and H. Zeng (Sun et al.). 2012. “Ecological risk assessment of parent and halogenated polycyclic aromatic hydrocarbons in surface sediments from an urban river in south China.” *Environ. Toxicol. Chem.* 31 (8): 1867–1873.

Suter, G.W. 2006. *Ecological Risk Assessment, Second Edition*. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Tinney, M.D. 2006. Site Investigation and Ecological Risk Assessment of Kingston Inner Harbour. MSc thesis, Royal Military College of Canada, Kingston, ON.

United States Environmental Protection Agency (US EPA). 1992a. Framework for Ecological Risk Assessment. Risk Assessment Forum, Washington, DC. EPA/630/R-92/001.

United States Environmental Protection Agency (US EPA). 1992b. Supplemental Guidance to RAGS: Calculating the Concentration Term. Office of Solid Waste and Emergency Response, Washington, DC. PB92-963373.

United States Environmental Protection Agency (US EPA). 1993a. Integrated Risk Information System (IRIS) Summary for As. Available at http://www.epa.gov/NCEA/ iris/subst/0278.htm. Accessed March 16, 2010.

United States Environmental Protection Agency (US EPA). 1993b. Wildlife Exposures Handbook: Volume I of II. Office of Research and Development, Washington, DC. EPA/600/R-93/187.

United States Environmental Protection Agency (US EPA). 1996. Integrated Risk Information System (IRIS) Summary for DDT. Available at http://www.epa.gov/iris/ subst/0147.htm. Accessed March 16, 2010.

United States Environmental Protection Agency (US EPA). 1997. Integrated Risk Information System (IRIS) Summary for PCBs. Available at http://www.epa.gov/NCEA/iris/subst/0294.htm. Accessed March 16, 2010.

United States Environmental Protection Agency (US EPA). 1998a. Integrated Risk Information System (IRIS) Summary for Trivalent Chromium. Available at http://www.epa.gov/ NCEA/iris/subst/0028.htm. Accessed March 16, 2010.

United States Environmental Protection Agency (US EPA). 1998b. Toxicological Review of Trivalent Chromium (CAS No. 16065-83-1) in Support of Summary Information on the Integrated Risk Information System (IRIS). Washington, DC.

United States Environmental Protection Agency (US EPA). 2002. Calculating upper confidence limits for exposure point concentrations at hazardous waste sites. OSWER 9285.6-10. United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. http://www.epa.gov/oswer/ riskassessment/pdf/ucl.pdf

United States Environmental Protection Agency (US EPA). 2003. Guidance for Developing Ecological Soil Screening Levels. OSWER Directive 9285.7-55. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005a. Ecological Soil Screening Levels for Antimony. Interim Final, OSWER Directive 9285.7-761. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005b. Ecological Soil Screening Levels for Arsenic. Interim Final, OSWER Directive 9285.7-62. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005c. Ecological Soil Screening Levels for Chromium. Interim Final, OSWER Directive 9285.7-66. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005d. Ecological Soil Screening Levels for Copper. Interim Final, OSWER Directive 9285.7-68. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005e. Ecological Soil Screening Levels for Lead. Interim Final, OSWER Directive 9285.7-70. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2005f. Ecological Soil Screening Levels for Zinc. Interim Final, OSWER Directive 9285.7-73. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2006. Results of the Lake Michigan Mass Balance Project: Polychlorinated Biphenyls Modeling Report. Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division, Grosse Ile, Michigan. EPA-600/R-04/167. http://catalogue.nla.gov.au/Record/4185997. Retrieved on February 10, 2010.

United States Environmental Protection Agency (US EPA). 2007a. Ecological Soil Screening Levels for DDT and Metabolites. OSWER Directive 9285.7-57. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2007b. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs). Interim Final, OSWER Directive 9285.7-78. Office of Solid Waste and Emergency Response, Washington, DC.

United States Environmental Protection Agency (US EPA). 2009. BSAF (Biota-Sediment Accumulation Factor) database. Available at http://www.epa.gov/med/Prods_Pubs/bsaf.htm

United States Environmental Protection Agency (US EPA). 2011. Exposure Factors Handbook: 2011 Edition. Office of Research and Development, National Center for Environmental Assessment, Washington, DC. 20460, EPA/600/R-090/052F. 1436 pages.

United States Environmental Protection Agency (US EPA). 2013. DRAFT Toxicological (CASRN 50-32-8) Review of Benzo[a]pyrene in Support of Summary Information on the Integrated Risk Information System (IRIS). EPA/635/R13/138a Public Comment Draft. Available at http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=66193. Accessed December 2013.

Van de Oost, R, J. Beyer and N.P.E. Vermeulen (Van de Oost et al.). "Fish bioaccumulation and biomarkers in environmental risk assessment: A review." *Environmental Toxicology and Pharmacology* 13 (2003) 57–149.

Vogt, R., D. Bennett, D. Cassady, J. Frost, B. Ritz and I. Hertz-Picciotto (Vogt et al.). 2012. "Cancer and non-cancer health effects from food contaminant exposures for children and adults in California: A risk assessment." *Environmental Health* 11: 83–97.

Washington State Legislature, 2013. WAC 173-204-320, Marine Sediment Quality Standards. http://apps.leg.wa.gov/wac/default.aspx?cite=173-204-320

Weir, R.D. 2008. *Birds of the Kingston Region.* Second Edition. Kingston Field Naturalists, Kingston, ON.

Weston Solutions, Inc. 2004. Ecological risk assessment for General Electric (GE)/Housatonic River site, rest of river. Volumes 1 and 2, Sections 1–12. Prepared for the US Army Corps of Engineers and the United States Environmental Protection Agency.

World Health Organization-International Agency for Research on Cancer (WHO-IARC). 2001. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 79, Some Thyrotropic Agents, Chlordane and Heptachlor. Pp 411–492. IARC, Lyon, France. Available at http://monographs.iarc.fr/ENG/Monographs/vol79/mono79-17.pdf. Accessed August 24, 2013.

Wren, C.D., D.B. Hunter, J.F. Leatherland and P.M. Stokes (Wren et al.). 1987a. "The effects of polychlorinated biphenyls and methylmercury, singly and in combination on mink. I: Uptake and toxic responses." *Arch. Environ. Contam. Toxicol*. 16: 441–447.

Wren, C.D., D.B. Hunter, J.F. Leatherland and P.M. Stokes (Wren et al.). 1987b. "The effects of polychlorinated biphenyls and methylmercury, singly and in combination on mink. II: Reproduction and kit development." *Arch. Environ. Contam. Toxicol.* 16: 449–454.

Xue, J., V. Zartarian, S.-W. Wang, L.V. Liu and P. Georgopoulos (Xue et al.). 2010. "Probabilistic Modeling of Dietary Arsenic Exposure and Dose and Evaluation with 2003–2004 NHANES Data." *Environ. Health Perspect.* 118: 345–350.

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Chapter V: An Options Analysis of Management Scenarios for the Kingston Inner Harbour

Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

Table of Contents

TABLE OF CONTENTS, CONT`D

LIST OF FIGURES

LIST OF TABLES

I. NEED FOR MANAGEMENT ACTIONS: SUMMARY OF MAIN OUTCOMES FROM CHAPTERS II, III AND IV

The KIH is located at the mouth of the Great Cataraqui River, where the river discharges into Lake Ontario. The KIH is defined as the stretch of water between Highway 401 to the north and the LaSalle Causeway to the south. Historically, the lands along the western shoreline south of Belle Park were heavily industrialized and former industries included a woolen mill, a lead smelter, a leather tannery, a coal gasification plant and a landfill. These past industrial activities and waste disposal practices have led to elevated levels of several inorganic and organic chemicals in the sediments of the KIH in the area south of Belle Park to Anglin Bay, particularly along the western shoreline (see Chapter I for a discussion of the history of potentially contaminating activities). The sediments north of Belle Park are relatively clean compared to sediments in the area of potential environmental concern (APEC) south of Belle Park. Studies have confirmed that the KIH north of Belle Park is a suitable reference site for assessing the extent of the contamination and the potential for sediments in the APEC to cause adverse effects to ecological and human receptors.

Chapter II of this report summarizes the spatial extent of contaminants of potential concern (CoPCs) in the KIH. Investigations of sediment quality have indicated that concentrations of arsenic (As), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), zinc (Zn), antimony (Sb), polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethane (DDT), chlordane and PAHs are the main CoPCs in the harbour, with Cr and PAHs being the most abundant and widespread contaminant. Some of these contaminants (i.e., PCBs, DDT, chlordane and organic mercury) may biomagnify.

Chapter III integrates existing data on biological effects in the KIH using the three lines of evidence (LOEs) examined under the Canada–Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment (COA framework): (i) modelling or measurement of contaminant concentrations in the aquatic food web to assess whether biomagnification is a potential concern; (ii) laboratory bioassays using several sediment-associated species to assess sediment toxicity; and (iii) assessment of benthic (i.e., sediment-dwelling) invertebrate community structure. The studies have indicated that biota from the southwestern KIH are accumulating more contaminants than are those found in areas north of Belle Park and that sediments in the vicinity of Anglin Bay and Douglas R. Fluhrer Park appear to have the greatest potential for adverse effects on benthic communities, with eight of 14 stations in this area showing evidence of minor or major toxicity effects.

In Chapter IV, potential risks to human and ecological health are explored. The KIH HHERA has identified that there are both potential human health risks and potential ecological risks from sediment and biological contamination in the southwestern portion of the KIH. The human health risk assessment outcomes indicated that all receptors face potential risks for non-cancer effects from the concentrations of PCBs, while the child and toddler receptors are also at potential risk from As, Pb, inorganic Hg and Sb. The main driver for risk to PCBs is consumption of fish and for risk to inorganic CoPCs is ingested plus dermal sediment exposure. When background exposures to inorganic CoPCs were included, risk for non-cancer effects was negligible for As, Pb and Hg, but background exposures alone contributed to unacceptable risk for Sb. Potential carcinogenic health risks were evident for As and PAHs. For PAHs, the carcinogenic risk is through dermal exposure.

The ecological risk assessment outcomes indicated that, for mammal and bird receptors, mallard ducks are potentially at risk because of dietary (invertebrate) Cr(III) ingestion. Mink are potentially at risk because of exposure to PCBs in fish tissue. For fish, field observations of the brown bullhead noted in the APEC a high frequency of morphological abnormalities (i.e., tumours and other deformities), which appeared rare at the reference site. The only apparent difference between the two sites is the presence of elevated concentrations of CoPCs in the sediments of the APEC, suggesting that the contaminated sediments pose an ecological risk for this species. Risk calculations comparing fish tissue CoPC concentrations with published fish toxicity thresholds suggest that the fish community in the APEC is not at risk; however, the available fish toxicity thresholds are not specific to brown bullheads. In addition, toxicity thresholds do not account for possible additive or synergistic effects resulting from the complex mixture of contaminants in the APEC; therefore, the assessed risk may be greatly underestimated.

Step 6 in the FCSAP aquatic ten-step assessment and remediation process is reclassification of the site based on the outcomes of the evaluation of effects to benthic and higher-trophic-level organisms. The reclassification of the KIH, incorporating the three LOEs and the results of the HHERA, has confirmed that the KIH is a Class 1 (High Priority for Action) site.

Based on the findings presented in Chapters I–IV of this report and additional sediment characterization and other investigation activities carried out in the KIH, Chapter V examines remediation strategies and proposes sediment management goals. The chapter includes discussions of the guiding principles for remediation, management objectives for the KIH, a remediation options analysis, the development of site-specific remediation criteria, and the examination of residual risk.

II. The Framework for Addressing and Managing Contaminated Sites Under the Federal Contaminated Sites Action Plan

The Framework for Addressing and Managing Aquatic Contaminated Sites under the Federal Contaminated Sites Action Plan (FCSAP) (Chapman 2010), a risk-based approach for assessing and managing aquatic contaminated sites under federal custody1, has been used to assess the contaminated sediments of the KIH. This is a 10-step process based on the terrestrial framework developed by the Contaminated Sites Management Working Group (CSMWG) (1999) that combines aspects of human health risk assessment (HHRA) with ecological risk assessment (ERA) approaches. Steps 1–3 and Step 5 correspond to the weight-of-evidence (WOE) approach used in the Canada–Ontario Decision-making Framework (EC and OMOE 2008) and include guidance regarding data quality objectives (US EPA 2000, 2006) and contaminated sediment management options. Risk management strategies are developed and implemented for prioritized contaminated aquatic sites in Steps 7 and 8. Risk management monitoring (confirmatory sampling and long-term monitoring) is conducted in Steps 9 and 10.

A. Aquatic Site Classification for the KIH

In the FCSAP 10-step framework to address and manage aquatic contaminated sites (Chapman 2010), initial classification of a site according to the FCSAP Aquatic Sites Classification System (ASCS) is required at Step 4. The ASCS is a unified approach used to classify a site as either requiring risk management, requiring further assessment or eliminated from further consideration. Sites classified for further assessment are re-classified at Step 6 to update the ranking after obtaining results from detailed investigations.

The ASCS is used to inform the prioritization and establish site eligibility for FCSAP remediation and/or risk management funding. The classification approach consists of a pre-screening checklist, a site description, a summary score sheet and three

1 Section 6.1.1.2 of Treasury Board Guidelines (in effect since November 2006) states that custodial departments are responsible for ensuring that known and suspected contaminated sites are assessed and classified and risk management principles are applied to determine the most appropriate and cost-effective course of action for each site. Priority must be given to sites posing the highest human health and ecological risks. Management activities (including remediation) must be undertaken to the extent required for current or intended use. These activities must be guided by standards endorsed by the CCME or similar standards. The cost of managing contamination caused by others must be recovered when this is economically feasible.

worksheets: Contaminant Characteristics, Receptors and Exposure, and Physical and Other Disturbances. The spreadsheets completed for the KIH classification are attached in Appendix L. A detailed user guidance manual for the FCSAP ASCS may be found in Franz Environmental Inc. (2009).

In the Pre-screening Checklist of the ASCS worksheets (Table 4 in Appendix L), the presence of direct and significant evidence of impacts to ecological receptors in the KIH (Question 3) was confirmed. Fish sampled from the impacted site showed occurrences of orocutaneous DELTs (deformities, erosions, lesions, tumours) that significantly exceeded DELT occurrences at unimpacted control sites. The DELTS observed for the impacted site fish were more severe than those for the upstream reference site. Based on the above evidence, the KIH site was automatically given a Class 1 designation. For comparative purposes, scoring was also completed for the other worksheets to identify an overall site score based on other information available for the KIH.

Table 5 (Appendix L), the "Contaminant Characteristics" worksheet of the ASCS, evaluates the degree and scale of chemical contamination on the site. Known concentrations in surface water, surficial sediment, deep sediment, groundwater and biological tissue were used to evaluate the degree and scale of contamination. Chemical classes measured included PCBs and PCDD/Fs, PAHs, metals/inorganics and pesticides. Option "D" was chosen to describe the spatial extent of the contaminated area as it has a radius greater than 50 m. The total raw score for the Contaminant Characteristics worksheet (Table 5, Appendix L) was 230/230 and the adjusted score was 30/30.

Table 6 (Appendix L), the "Receptors and Exposure" worksheet of the ASCS, identifies human and ecological receptors using the site and evaluates potential exposure pathways by which receptors could come into contact with identified contaminants. For characterization of human receptors and potential for human exposure, the KIH is evaluated as a recreational property, as residents frequently use the site for activities such as swimming, boating and fishing. It is strongly suspected that human receptors have had current/past exposure. The HHRA indicates that the greatest potential risk to humans is posed by PCBs through fish consumption and by PAHs through dermal exposure. A sport fish consumption advisory for the area is currently in effect for PCBs. The OMOE Guide to Eating Ontario Sport Fish (OMOE 2013) has recommended that certain populations (both women of child-bearing age and children under 15, who have a higher sensitivity to contaminants) should not consume brown bullhead greater than 30 cm length or carp greater than 55 cm in length caught within the KIH.

For characterization of ecological receptors and the potential for ecological exposure, the KIH has been evaluated in terms of the sensitivity of species that spend all or part of their life cycle at the site. The southwest portion of the KIH includes the home range of piscivorous wildlife that are classed as species of special concern (Table V-3). The site is also known to be frequented by wildlife that use the southwest portion of the KIH as a source of food, drinking water, bathing water etc. and that are classified as endangered or threatened (Table V-3). Exposure to aquatic and terrestrial organisms quantified and determined to be high has been confirmed and adverse effects, including the following, have been documented:

- sediment toxicity to benthic invertebrates
- benthic community impairment
- morphological deformities in brown bullhead fish
- ecological risk to muskrats, minks, red-winged blackbirds, great blue herons and mallard ducks

Table 6 also evaluates the potential for continued or new exposure in the future. For the southwest portion of the KIH, there have been probable upstream/upgradient contamination events of soil, surface water and/or groundwater, mostly through historical activities. The KIH is shallow and sediments are resuspended by wind and wave action; it is therefore probable that contaminated sediments have migrated and are not effectively isolated through physical burial with cleaner material. The total raw score for the "Receptors and Exposure" worksheet (Table 6, Appendix L) was 55.5/80 and the adjusted score was 27.8/40.

Table 7 (Appendix L) of the ASCS, the "Physical Impacts and Other Disturbances" worksheet, identifies non-chemical environmental impacts at the aquatic site and assesses the scale of their impact. There has been evidence that fish habitat was impacted by the creation of the Belle Park Landfill. As well, previous reports mention that total suspended solids (TSS) can exceed CCME guidelines, especially during times of high precipitation. The total raw score for this worksheet (Table 7, Appendix L) was 6/30 and the adjusted score was 2/10.

In Table 8 (Appendix L) of the ASCS, the "Summary Score Sheet", the final score for the site based on the pre-screening checklist (Table 4) and the Contaminant Characteristics (Table 5), Receptors and Exposure (Table 6) and Physical Impacts and Other Disturbances (Table 7) worksheets is calculated. Only 4 percent of responses were

"Do Not Know." The overall total ASCS score for the KIH site is 79.8/100. The site is designated as Class 1, High Priority for Action.

The ASCS worksheets for the KIH were reviewed by HC, EC and Fisheries and Oceans Canada (DFO) expert support personnel, and peer review comments were incorporated and are reflected in the current classification score for the site.

B. Guiding Principles for Remediation from FCSAP

The primary objective for the management of the KIH sediments is to reduce the risk posed by contaminated sediments to human and ecological receptors to acceptable levels based on current and future use of the site.

Step 7 within the FCSAP framework involves developing a risk management strategy that follows 11 risk management principles as outlined in the US EPA contaminated site remediation guidance (2005). These principles are listed in Table V-1 below; details on how they are or will be addressed as part of the KIH sediment assessment and management decision-making process are provided in the table.

Table V-1: Eleven risk management principles and their application to the KIH sediment assessment and management decision-making process

Risk management principle	Application to the KIH
1. Control sources early.	Much work has been completed to date to identify and control sources of historical contamination to the KIH. A summary is presented in Section II.B.2 of this chapter.
2. Involve the community early and often.	Public consultation regarding the KIH was initiated in 2002 by the City of Kingston under the guidance of the Kingston Environmental Advisory Forum (KEAF), which is a committee providing advice to the City of Kingston on environmental issues. Public consultation was carried out through two public workshops as well as a public consultation document published in a local newspaper with a request for public input. The first public workshop was held on April 27, 2002, and communicated the main findings of a scientific review and gap analysis that summarized the available scientific knowledge for the KIH at that time. The second public workshop was a waterfront visioning exercise held on May 23, 2002, to receive input from the public regarding future uses of the KIH. Several briefing documents on the status of the KIH have been prepared and will be posted electronically. A community consultation strategy will be developed, and community meetings are planned for 2014 in conjunction with the release of this report.
3. Coordinate with provinces, territories, local governments and Aboriginal peoples.	The Cataraqui River Stakeholder Group (CRSG) was established in 2006 with its primary task to develop an environmental management strategy for KIH sediments. The stakeholder group consists of representatives of municipal, provincial and federal government as well as sediment contamination and remediation experts. Representatives of Transport Canada and Parks Canada, which own the contaminated portion of the KIH, are also members of the group. The group is facilitating a collaborative approach to the assessment process and is working to achieve consensus on plans for remediation of the river sediments. All parties have shared information regarding the KIH that is incorporated into this report. Since 2006, research conducted by ESG with guidance from the CRSG has improved understanding of the nature and extent of sediment contamination. Regular communication ensures that the most relevant information is considered in designing the studies and stakeholder viewpoints are considered in the remedy selection process. All chapters in this report have been peer-reviewed extensively by FCSAP and expert third-party expert support.

Table V-1: Eleven risk management principles and their application to the KIH sediment assessment and management decision-making process, cont'd.

Risk management principle	**Application to the KIH**
4. Develop and refine a conceptual site model that considers sediment stability.	Sediment transport and deposition patterns within the KIH suggest that sediment resuspension from wind and wave action, boating activities and flow patterns appears to be important in redistributing sediments within the harbour. A conceptual site model identifying all known and suspected sources of contamination, the types of contaminants and affected media, existing and potential exposure pathways and the known or potential human and ecological receptors that may be threatened has been developed and is included in Chapter IV.
5. Use an iterative approach in a risk-based framework.	Chapter IV characterizes the ecological and human health risks for the KIH. The risk assessment follows a detailed quantitative risk assessment (DQRA) and is based on an iterative approach, which provides additional certainty to support risk management decisions.
6. Carefully evaluate the assumptions and uncertainties associated with the site characterization data and site models.	Uncertainties related to the assumptions used in the HHERA are discussed in Chapter IV. The uncertainty associated with the risk-based SeQOs is discussed in Section V.B of this chapter.
7. Select site-specific, project-specific and sediment-specific risk management approaches that will achieve risk-based goals.	Risk management and remediation options presented in this chapter have been developed and evaluated using information specific to the site and project. Project SeQOs were developed based on a site-specific risk assessment and are discussed in Section IV.B of this chapter.
8. Use sediment cleanup levels that are clearly tied to risk management goals.	Sediment cleanup levels for the KIH have been developed using a risk-based approach and are discussed in Section IV of this chapter.
9. Maximize the effectiveness of institutional controls and recognize their limitations.	The potential implementation and effectiveness of institutional controls to manage sediment contamination in the KIH is discussed in Section III.B of this chapter.

Table V-1: Eleven risk management principles and their application to the KIH sediment assessment and management decision-making process, cont'd.

Risk management principle	**Application to the KIH**
10. Design remedies to minimize risks and achieve long-term protection.	A risk management and remediation options analysis has been carried out for the KIH and is summarized in Section III of this chapter.
11. Monitor appropriate media (water, sediment, tissue) during and after source control and/or sediment remediation to assess and document remedy effectiveness.	Performance monitoring to assess remedy effectiveness and a long-term monitoring plan will be addressed in the remedial action plan.

The three prerequisites to remedial planning are to (1) determine causation for biological effects, (2) control ongoing sources, and (3) ensure that remedial actions do not cause more environmental damage than they remedy. The following section discusses these prerequisites in more detail.

1. Determine Causation before Taking Remedial Actions Involving Physical Work

Before any remedial actions are performed, the cause of impacts must be determined; otherwise, remedial actions will not be efficient. The objective of determining the causes is to identify the factors that can be regulated or remediated to improve the ecological condition. Suter et al. (2002) have developed a methodology for causal evaluation of observed impairments in aquatic ecosystems by showing the evidence and logic that formed the basis of their conclusion about the cause. The evaluation includes (i) the definition of the impairments, (ii) the identification of possible causes and (iii) an analysis of evidence and a characterization of the cause.

The potential human health risks and ecological impairments identified for the KIH are discussed in more detail, along with potential causes, in the next section.

a. Survival of benthic organisms in toxicity tests

According to the criteria outlined in the COA framework, there is mixed evidence for benthic invertebrate toxicity in the southwestern portion of the KIH (Golder 2012, Appendix A, Figure B-3). Sediments in the vicinity of Anglin Bay and Douglas R. Fluhrer Park appear to have the greatest potential for adverse effects on benthic communities, with eight of 14 stations in this area showing evidence of minor or major toxicity effects. Although most samples showed negligible toxicity to benthic organisms, approximately one quarter of the stations sampled in the remaining southwestern KIH (Parks Canada water lot, northern Transport Canada water lot and the west-central KIH) had minor toxicity effects. In contrast, there is no evidence of toxicity for samples collected from other areas of the KIH with lower concentrations of sedimentary contaminants, such as the area north of Belle Park or the southeastern portion of the KIH. Determining causality for the observed toxicity effects is challenging when there are multiple contaminants present, as for the KIH. Toxicity identification evaluation (TIE) tests were carried out for two samples collected in the KIH in the vicinity of Anglin Bay and showing major toxic effects for at least one endpoint (Golder 2012). The tests were inconclusive for one sample but suggested that toxicity in the other sample could be due to photoreactive PAH compounds as well as the combined effects of multiple toxicants.

b. Benthic community impairment

Benthic communities in the KIH are dominated by organisms that are tolerant of organic (i.e., nutrient) pollution. For the studies done to date, benthic communities at 20 stations in the southern KIH were equivalent to reference condition, benthic communities at 15 stations were possibly different from reference condition, and benthic communities at one station were significantly different from reference condition (Golder 2012, Figure B-8, Appendix A). Although several stations showed possible benthic community effects on the Parks Canada water lot and the northern portion of the Transport Canada water lot, most of the stations exhibiting adverse effects were located in the vicinity of Anglin Bay and the northern part of Douglas R. Fluhrer Park. Two stations in the southeastern portion of the KIH close to HMCS Cataraqui also showed potential benthic community effects. Statistical analyses suggested that differences in the invertebrate community structure can be explained by environmental variables related to habitat characteristics (e.g., grain size, macrophyte abundance) and to contamination variables such as sediment PAH and Cr concentrations.

c. Bioaccumulation

Aquatic macrophytes, cattails, benthic invertebrates and fish sampled from the KIH show consistent evidence for bioaccumulation of contaminants such as Cr and especially PCBs in the southwest portion of the KIH. In contrast, aquatic organisms from upstream reference locations north of Belle Park do not appear to have accumulated contaminants to the same degree. Biomagnification of PCBs is also the cause for current fish advisories for the KIH, which recommend that brown bullhead greater than 25 cm length and carp greater than 55 cm caught within the KIH not be consumed by sensitive populations (*i.e.*, women of childbearing age and children under the age of 15; OMOE 2013). Observed elevated PCB concentrations in fish from the KIH compared with those from other areas in the Great Lakes prompted Environment Canada and the Ontario Ministry of the Environment to complete "PCB trackdown studies" (Derry et al. 2003, Benoit and Dove 2006) to evaluate the source of the contamination. The consistent evidence for elevated PCB concentrations in fish collected south of Belle Park provided by 30 years of monitoring data from the OMOE shows that the tissue bioaccumulation patterns can be reproduced over time and space (Derry et al. 2003).

Several lines of evidence indicate that the main source of bioavailable contaminants to KIH biota is from sediments that were contaminated through historical activities. The evidence includes:

- A number of scientific studies investigating fish collected in the southwestern KIH have noted that these organisms are accumulating higher levels of PCBs compared with upstream references sites. The most likely explanation is that contaminants in the sediments are bioavailable and are accumulating in the food chain through ingestion of incidental sediment and aquatic prey items. Studies assessing the possibility of existing terrestrial or groundwater sources of PCB contamination to the impacted area of the KIH have not located a present source to date (City of Kingston and OMOE 2005).
- Fathead minnow sediment uptake laboratory bioassays with KIH sediments support this conclusion: minnows exposed to contaminated sediments from the southwestern KIH accumulated Pb and PCBs in their tissue to a much greater extent than did minnows exposed to upstream reference sediments (Watson-Leung 2004).
- The OMOE has over 30 years of fish monitoring data from the KIH on PCB concentrations in young-of-the-year fish (Derry et al. 2003). Young-of-the-year fish have small home ranges and therefore are thought to be good indicators of

exposure to local contamination. These data show consistent evidence for elevated PCB concentrations in fish collected south of Belle Park compared with those in fish collected from reference sites in the northern KIH.

d. Fish health

The percentage of fish having external deformities in the KIH has also been evaluated as a measure of ecological health in the KIH. Fish tumours and deformities are widely used as an indicator of detrimental ecological effects and are designated as a beneficial use impairment for the Great Lakes Areas of Concern. Brown bullheads are a commonly used indicator species for fish health studies in the southern Great Lakes because they have a close association with sediments and have small home ranges. The prevalence of brown bullhead orocutaneous (skin) deformities, erosion, lesions, and tumours (DELTs) was significantly higher for fish collected in the southwestern KIH compared with the prevalence in fish collected from the upstream reference site, where there are trace levels of contaminants (see Chapter IV). The causes of orocutaneous fish tumours are not well established in the scientific literature, but higher rates are usually found in contaminated areas and a viral etiology for these tumours has not been found for brown bullhead (Rafferty et al. 2009).

ESG and Golder Associates have both carried out literature reviews to assess potential causes for the higher rates of brown bullhead DELTs observed in the southwestern KIH. The link between PAH exposure and fish tumours has been well established in the scientific literature and is a potential cause for the observed fish abnormalities in the KIH, given elevated PAH concentrations in some areas of the southern KIH (Golder 2012). However, the relationship between other contaminants and fish tumours has not been studied to the same degree and so the influence of other sedimentary contaminants in the KIH cannot be assessed. Tumours and deformities in some fish species may also be caused by viruses. Virology studies could be carried out to assess whether the observed deformities in the KIH brown bullhead are caused by pathogens. However, exposure to contaminant stressors may also result in increased fish susceptibility to hormonal imbalances and viral disease. If this were the case, sediment contaminant concentrations could not be ruled out as a stressor even if virology analyses indicated the presence of pathogens.

Lab toxicology tests have been carried out to evaluate whether fish show adverse effects related to PAH exposure. These studies measured the extent of ethoxyresorufin-O-deethylase (EROD – CYP1A) enzyme activity as a biomarker of previous PAH exposure.

Hamilton (2002) assessed EROD activity of juvenile trout and chronic toxicity to larval trout after exposure to KIH sediments collected from the following locations: Anglin Bay; adjacent to the old Woolen Mill; adjacent to the former Davis Tannery site; along the south shore of Belle Island; in the channel to the east of Belle Island; and just west of the channel to the north of Belle Island. This study found significantly elevated EROD activity for fish exposed to sediments from Anglin Bay and two Outer harbour sites, suggesting exposure to PAHs. EROD activity for fish exposed to sediments from all the other KIH sites was lower and not significantly different from control sites, indicating little exposure or few effects due to PAHs.

Overall, it is likely that elevated contaminant concentrations in KIH sediments are responsible for the observed brown bullhead abnormalities, although the cause of the DELTs cannot be determined conclusively. SeQOs for the KIH were not based on DELTs for the brown bullhead and therefore the definitive cause for observed deformities does not need to be known.

e. Adverse health effects to human and upper trophic level ecological receptors

Risk characterization was conducted for the KIH because it provides information that is important to any management decision. As Chapman and Holler (2006) suggest, relationships between morphological changes and ecological functions are often weak, and therefore the tools for evaluating risk are critical to assessing the health of aquatic environments. To present a defensible and representative estimate of risk, a detailed DQRA has been carried out for the KIH to increase certainty by making the best possible use of available information and to establish the appropriate level of protection. Risk assessment results are presented in Chapter IV of this report and a brief summary is provided below.

The HHRA focused on recreational uses of the KIH and considered sediment ingestion, dermal contact and contaminated food item pathways. The HHRA evaluated potential risks and health hazards in the absence of any remedial action or institutional controls, such as fish advisories, that might alter the behaviour of the community and sport fishers. There are currently fish advisories in place but recreational fishing by local residents is frequently observed. The risk assessment outcomes indicated that all receptors face potential risks for non-cancer effects from the concentrations of PCBs, while the child and toddler receptors are also at potential risk from As, Pb, inorganic Hg and Sb. The main driver for risk from PCBs is through consumption of fish and the main driver for risk from the inorganic CoPCs is a combination of ingested and dermal sediment exposure. When background exposures to inorganic CoPCs were included, risk for non-cancer effects was negligible for As, Pb and Hg, but background exposures alone contributed to unacceptable risk for Sb. Potential carcinogenic health risks were evident for As and PAHs, and the As cancer risk remained unacceptably high even when it was calculated without sediment concentrations from an SMA near the former Woolen Mill. For PAHs, the carcinogenic risk is through dermal exposure.

The ERA focused on potential exposure and adverse effects to benthic invertebrates, fish and piscivorous birds associated with chemicals in the biologically active zone of sediment in the KIH. Exposure pathways for ecological receptors included ingestion of contaminated sediments and biomagnification from prey (fish and benthic invertebrates) in piscivorous birds and mammals. For mammal and bird receptors, risk calculations indicated that mallard ducks are potentially at risk from Cr(III) ingestion. Mink are potentially at risk because of exposure to PCBs.

Causal inferences from risk assessment are fundamentally empirical and based on exposure- or dose-response models. Risk calculations predict whether exposure to inorganic and organic contaminants will increase the risk of developing an adverse health effect. Risk means that all such exposed individuals are more likely to develop an adverse effect, but it does not mean that most individuals will or even that any particular individual will. Risk assessment models concentrations from measured matrices. It requires integration of diverse information from various sources and disciplines, including epidemiology, toxicology and cell and molecular biology. The evaluation of risks to human and wildlife receptors in the KIH and the associated hazard quotients indicates that exposure to As, Cr, Sb, PAHs and PCBs in the southwest portion of the KIH has the potential to cause adverse effects.

f. Summary: Strength-of-evidence analysis for causation

A strength-of-evidence analysis for the causes of ecological impairments (inorganic and organic contamination) for the KIH is summarized in Table V-2.

The analysis shows that there is strong evidence to support that PCB and PAH concentrations in harbour sediments are linked with biological effects. There is moderate evidence to support that inorganic element (e.g., Cr) concentrations are linked with biological effects. Definitive conclusions on causation cannot be determined for all impairments without further study because of the combined effects of multiple stressors at the ecosystem level. The COA weight-of-evidence approach shows sufficient evidence that management actions are required in some areas of the harbour. Furthermore, risk assessment results clearly demonstrate the need for sediment management and identify the contaminants that are the major drivers for remediation. Inclusion of additional information would not alter the classification of the site as Class I (action required) because of potential risks to humans and other higher-trophic-level receptors.

Table V- 2. Strength-of evidence analysis for causes of impairment for the KIH

	Inorganic elements	PCBs	PAHs
1. Case-specific considerations			
a) Co-occurrence			
spatial co-location of the cause and the effect; effects occur downstream and not upstream of an identified source	Sediment metal concentrations exceed the relevant guidelines and were significantly higher in the southwestern KIH compared to upstream locations. Cr concentrations were significantly higher ($p<0.05$) for benthic invertebrates and brown bullhead collected from the test area compared to upstream reference locations. Toxicity effects to benthic organisms were not related to Cr concentrations in the sediments. However, the following lines of evidence indicate that inorganic contamination is likely causing biological effects: (1) detailed quantitative risk assessment indicated that there are potential risks to mallard ducks due to Cr concentrations in the southwestern KIH; (2) Multivariate analyses suggested that differences in benthic community structure between sites in the southern KIH and reference sites could be partially explained by Cr concentrations.	Sediment PCB concentrations exceeded the relevant guidelines in many areas of the southwestern KIH and were significantly higher at the impacted area compared to upstream locations. Total PCB concentrations (mg/g ww) in invertebrates, brown bullhead, perch, and northern pike collected from the test area were significantly higher than those collected from the reference area. Fish consumption advisories for some species and sizes of sport fish are in place for the southern KIH due to elevated levels of PCBs. In contrast, upstream reference areas do not currently have fish consumption advisories.	Sediment PAH concentrations exceed the relevant guidelines in many areas of the southwestern KIH and were significantly higher at the impacted area compared to upstream locations. Effects on benthic communities (toxicity, community composition) largely co-occur with areas that have elevated PAH concentrations. Hamilton (2002) assessed ethoxyresorufin-O-deethylase (EROD – CYP1A) enzyme activity of juvenile trout and chronic toxicity to larval trout as a biomarker of PAH exposure in lab toxicity experiments with sediments collected from six locations in the KIH. Her study found significantly elevated EROD activity for fish exposed to sediments from Anglin Bay, but EROD activity for fish exposed to sediments from all the other KIH sites was lower and not significantly different from control sites, indicating little exposure or effects due to PAHs.
b) Temporality			
Causes must precede effects. Baseline data required	Sediment core analysis indicates that inorganic contaminant concentrations in sediments deposited prior to the onset of industrial activities are comparable to surface sediment concentrations in upstream reference sites. However, no biological data are available from the time before the area was impacted by industrial activities.	No biological data is available from the time before the area was impacted by industrial activities.	No biological data is available from the time before the area was impacted by industrial activities.
c) Consistency of association			
repeated observation over time and in different places	Increased concentrations of inorganic elements (*i.e.* Cr) have been measured in subsequent years at several locations. Plants, invertebrates and fish collected from the impacted area have higher inorganic concentrations compared to the reference area.	The OMOE has over 30 years of fish monitoring data from the KIH on PCB concentrations in young-of-the-year fish (Derry et al., 2003). Young-of-the-year fish have small home ranges and therefore are thought to be good indicators of exposure to local contamination. These data show consistent evidence for elevated PCB concentrations in young-of-the-year fish at sites in the southwestern portion of the KIH compared with reference sites in the northern KIH. Similarly, sport fish monitoring carried out every 2 years south of Belle Park has consistently resulted in some fish consumption advisories due to elevated PCB concentrations in fish tissue (OMOE 2013).	There is some evidence for consistent effects on benthic communities due to PAHs for samples taken in different years (Golder 2011; Golder 2012). However, an earlier study concluded that observed effects on benthic community composition in the Anglin Bay area did not show any relationship with sediment PAH concentrations (Jaagumagi 1991).
d) Biological gradient			
increasing effect with increasing concentrations	Laboratory and field studies indicate that invertebrate and macrophyte tissue Cr concentrations show a significant postive correlation with Cr concentrations in sediments. Toxicity effects to benthic organisms do not appear to be related to Cr concentrations in the sediments but the relationship with other inorganic elements is unknown.	PCB body burdens in invertebrate tissue (resident), caged mussels, and fish demonstrate a positive correlation with concentrations in sediments.	Toxicity and benthic community effects showed significant correlations with increasing PAH concentrations in sediments (Golder 2012).
e) Complete exposure pathway			
physical course that a stressor takes from the source to the receptor organisms	Body burdens in plants, invertebrates, and fish indicate that Cr is bioaccumulating in the aquatic food chain. Sediments contaminated by historical activities appear to be the main source of contamination. Studies on porewater and groundwater did not find significantly elevated dissolved concentrations of inorganic elements.	Several lines of evidence indicate that currently the main source of PCB contamination to the KIH food chain is sediments contaminated by historical activities. These include: (1) invertebrates and fish in areas of the KIH with elevated PCB concentrations in the sediment show consistent evidence of increased PCB body burdens; (2) source investigations by OMOE and the City of Kingston have not located any present sources of PCBs to the KIH. PCBs biomagnify in the food chain and are stored in the lipids of organisms such as fish. Humans and ecological receptors are exposed to PCB contamination largely through fish consumption.	Several lines of evidence indicate that the main source of PAH exposure appears to be through contact with contaminated sediments: (1) toxicity and benthic community effects are correlated with sediment PAH concentrations; (2) risk assessment identified dermal contact with sediments as the main exposure pathway posing potential risks to humans; (3) lab toxicity experiments using KIH sediments identified fish biomarkers of PAH exposure (Hamilton 2002. It is possible that there is a storm sewer source given the proximity of elevated sediment PAH concentrations to areas where storm sewers discharge (Golder 2012).
f) Experiment			
manipulation of a source by eliminating a source or by altering exposure, evidence from experiments from similar situations	Lab tests investigated Cr uptake for *Hyalella azteca* during 28-day toxicity tests using sediment from the KIH with elevated Cr concentrations. A strong correlation was noted between sediment Cr concentrations and *Hyalella* body burdens.	Lab bioassays with juvenile fathead minnows using KIH sediments provide clear evidence for biomagnification of PCBs, as levels in biota are typically higher than those found in associated sediments. Fish exposed to contaminated sediments had greater body burdens than fish exposed to sediments from reference areas.	Toxicity identification evaluation (TIE) tests were carried out for two samples in the KIH collected in the vicinity of Anglin Bay showing major toxic effects for at least one endpoint (Golder 2012). The tests were inconclusive for one sample, but suggested that toxicity in the other sample could be due to photo-reactive PAH compounds as well as the combined effects of multiple toxicants.
2. Considerations based on other situations of biological knowledge			
a) Plausibility: Mechanism			
Given what is known about the biology, physics and chemistry of the causes, the environment and the affected organisms, is it plausible that the effect resulted from the cause?	Chromium has been shown to have genotoxic and cytotoxic (renal and respiratory enzymes) effects in estuarine fish species such as mummichogs (*Fundulus heteroclitus*). Several studies document the potential of chromium to bioaccumulate, with the kidney being the target organ for toxic symptoms.	Many studies indicate that PCB concentrations are elevated in fish frequenting areas with PCB-contaminated sediments, and that PCBs biomagnify in aquatic food webs. ATSDR (2000) reports that women who were exposed to PCBs while pregnant gave birth to babies of lower weight than average. Children of women who were exposed to high doses of PCBs while nursing showed poor motor skills as well as short-term memory complications. There is some evidence to suggest that PCBs are a carcinogen based on animal studies, but current data for humans is inconclusive.	There is a strong body of scientific literature linking chemical exposure to PAHs with liver and skin cancers in fish. Based on a literature review, Golder (2012) identified that 10 ppm of total PAHs can be considered to be a no-effect level for adverse responses in bullhead. PAH concentrations exceed 10 ppm in many locations throughout the southern KIH and could explain the higher levels of fish skin deformities in this area compared with upstream reference sites.
b) Plausibility: Stressor-receptor response			
Given a known relationship between the cause and the effect would it be expected at the level of the stressor seen in the environment?	Risk assessment are based on exposure- or dose-response models. The evaluation of risks to human and wildlife receptors of the KIH clearly indicate that contaminants such as Cr, As and Pb are associated with potential adverse health effects.	A detailed quantitative risk assessment for the KIH indicated that PCBs pose a potential adverse health effect to humans and mink through fish consumption.	A detailed quantitative risk assessment for the KIH indicated that PAHs pose a potential adverse health effect to humans through dermal exposure. See also 2a) above.
c) Consistency of association			
Specifity of cause			
Has the cause been consistently associated with effects at other sites?	See 2a) and 2d)	See 2a)	See 2a)
d) Analogy			
Is the hypothesized relationship between cause and effect similar to any well-established cases?	A number of studies indicate that benthic invertebrates are sensitive to inorganic contamination which can result in toxicity effects and alterations of community structure. The observed effects are mediated by factors that influence the bioavailability of the contaminants, such as oxygen-poor (reducing) conditions.	Fish consumption advisories due to PCB contamination have been the driver for a number of sediment remediation projects (e.g., Fox River, Wisconsin; Grasse River, NY; Saglek Bay, Labrador). In general, post-remediation monitoring indicates that fish PCB concentrations decline following remedial/risk management actions to address contaminated sediments.	Several sites have been targeted for remediation due to the biological effects of PAH-contaminated sediments, including Hamilton Harbour and Thunder Bay Harbour. The sediment quality objectives for both of these projects were developed based on effects to the benthic community and range from 30 ppm to 100 ppm of total PAHs in the sediment. These SeQOs are higher than PAH concentrations for most of the KIH.
e) Experiment			
(refers to manipuation of a cause by eliminating a source of altering exposure)	Not applicable.	Not applicable.	See 1f) above.
f) Predictive performance			
Does the cause have any initially unobserved properties that were predicted to occur?	No evidence.	No evidence.	No evidence.
3. Considerations based on multiple lines of evidence			
a) Consistency of evidence			
Is the hypothesized relationship between cause and effects consistent?	Several lines of evidence (e.g., assessment of risks to human and ecological receptors, benthic community structure) indicate consistent effects due to inorganic element concentrations in the southwest portion of the KIH.	There is consistent evidence to indicate that sediments contaminated with PCBs are the main source of PCBs to aquatic receptors of the KIH (see 1a to 1f above). Risk assessment indicates that there is potential risk to both human and ecological receptors for the southwest portion of the KIH.	Several lines of evidence suggest that sediments contaminated with PAHs are the main source of exposure for KIH aquatic receptors (see 1f). Ecological effects potentially linked to PAH exposure include benthic community effects (toxicity and structure), risks to human receptors through dermal contact, and biomarkers of fish exposure such as altered enzyme activity and skin lesions.
b) Coherence of evidence			
Does a mechanistic conceptual or mathematical model explain any apparent inconsistencies among the lines of evidence?	Although Cr concentrations in the sediment are high, they do not appear to be related to benthic toxicity effects. The main form of sedimentary Cr for KIH is the less-toxic Cr (III) form and pore-water studies did not find detectable Cr (VI), suggesting limited Cr mobility and bioavailability to benthic organisms.	Not applicable.	Not applicable.

2. Control Ongoing Sources of Contamination before Taking Remedial Action Involving Physical Work

Remedial actions are typically costly and ecologically invasive. Therefore, for any sediment cleanup to be successful, it is critical to determine whether there are any continuing contaminant input points or diffuse sources. Source removal or control is a requirement for remediation of the contaminated sediments to proceed to ensure that the disturbance associated with remedial action will not need to be repeated.

For the KIH, potential terrestrial sources of contaminants are shown in Chapter I (Figure I-4) and include (i) Emma Martin Park/Rowing Club, (ii) the former Davis Tannery site and Orchard Marsh, (iii) Belle Park Landfill, (iv) storm sewers, and (v) combined sewer overflows. Several investigations have been carried out to identify potential continuing contaminant sources to the KIH and are summarized in the following sections. Evidence to date indicates that the legacy contamination in Cataraqui River sediments is the main source of bioavailable contaminants to the river ecosystem. However, it is recommended that the remediation of the river sediments occur in conjunction with the cleanup of the Orchard Street Marsh and with plans for improving stormwater management.

a. <u>Emma Martin Park/Rowing Club</u>

Manion (2007) examined Hg concentrations in sediments of the KIH and found that the highest concentrations were identified adjacent to Emma Martin Park and the Rowing Club. A subsequent source trackdown completed as part of his research identified that Hg concentrations on particulate contained in surface runoff from the Rowing Club were elevated, suggesting a terrestrial source. The City of Kingston, in collaboration with the Ministry of the Environment, installed interim sediment control measures and commissioned a follow-up study in 2008, which, while not able to confirm all the findings from the Manion (2007) study, did identify elevated Hg within the surface soil materials surrounding the Kingston Rowing Club (Paul MacLatchy, City of Kingston, personal communication). The City subsequently implemented improvements to the Kingston Rowing Club building and grounds and modifications to the operating practices of the club to prevent the potential for stormwater runoff that could cause erosion and transportation of Hg-contaminated soils. Subsequent monitoring of the facility by the City of Kingston during high precipitation events has not identified any erosion of surface soils from the site.

The OMOE requested a hydrogeological assessment of Emma Martin Park/Rowing Club in July 2011. The purpose of the assessment was to determine whether the area is a continuing source of contaminants to the KIH. The specific contaminants of concern in the vicinity of Emma Martin Park/Rowing Club that were investigated are As, Hg, Cr and Pb. The study concluded that Emma Martin Park/Rowing Club is a continuing source of As to the KIH. The source is from historical activities at the site, and the primary pathway is the discharge of As-contaminated groundwater to the KIH. The study also concluded that Emma Martin Park/Rowing Club is a potential continuing source of Hg via overland transport. However, Emma Martin Park/Rowing Club is not currently a continuing source of Cr or Pb to the KIH (OMOE 2011b).

Since this study, the discharge of As-contaminated water from Emma Martin Park and the Rowing Club to the KIH has been addressed by the City of Kingston through the installation of an innovative permeable reactive barrier. As noted above, the City of Kingston has made improvements to the property to control the off-site transportation of the Hg-contaminated soils.

b. Former Davis Tannery site and Orchard Street Marsh

The Davis Tannery operated on the western shore of the KIH from the late 1800s to 1973. Liquid waste containing Cr was discharged directly into a wetland to the north of the tannery (currently designated as the Orchard Street Marsh). Milley (2010) investigated the extent of contamination in surface soils and groundwater at the former Davis Tannery site and the adjacent Orchard Street Marsh and assessed whether the site represents a continuing source of contamination to the KIH. This was done through analysis of groundwater and a surface water runoff program. Groundwater movement and leaching of CoCs from the former Davis Tannery property into the Cataraqui River are prevented by a clay berm that was constructed in the 1980s along the western shore of the KIH (Milley 2010); however, groundwater could be discharged from the Orchard Street Marsh into the KIH. The results of the investigation carried out by Milley (2010) show that inorganic metals were detected only in the suspended solid portion of the groundwater, and no contaminants were detected in the dissolved phase for the same samples. These results, combined with the results of leachate tests, indicate that contamination is confined to the soil particles and is not being dissolved in the aqueous phase.

The assessment of surface runoff involved collecting samples from streams, ponds and pools on the former Davis Tannery property after high precipitation events. Results of the surface runoff samples suggested that contaminants are bound to the particulate matter and are not contained in the dissolved phase. At high precipitation events, the potential exists for surface water runoff and suspended particulate matter with elevated CoCs to be transported into the KIH. However, surface water runoff is not a significant source of contaminants to the KIH and can be considered negligible compared to historical contaminant inputs. Because the Orchard Street Marsh and the Cataraqui River are hydrologically connected with the KIH, it is recommended that the river sediment cleanup be completed in tandem with the remediation of the Orchard Street Marsh.

c. Storm sewers

Storm sewers represent another potential source of contaminants to the KIH. The Kingscourt storm sewer, located between the former Davis Tannery property and Belle Park Landfill, is one of the biggest storm sewer outlets in Kingston and drains a large catchment area on the western shore. Urban contaminants such as inorganic elements and PAHs can enter the KIH through regular stormwater flow. During high rain events or periods of elevated snowmelt, high levels of sediments and urban runoff can be discharged into the KIH through the Kingscourt storm sewer. Another potential impact of the Kingscourt sewer is to flush contaminated sediments from the Orchard Street Marsh into the river through physical scouring during high flow events. Any remedial actions for the KIH must be considered in conjunction with a plan for stormwater management. At the workshop on remedial actions for the KIH in June 2010, as part of the plan for the ecological re-engineering/restoration of the marsh, a stormwater retention pond was discussed as a way to control the potential impacts from the Kingscourt storm sewer.

d. Combined sewer overflows (CSOs)

Combined sewer overflows into the KIH occur a number of times a year and consist of large pulses of nutrients and coliform bacteria associated with untreated sanitary sewage combined with runoff. The significance of CSOs as a source of contamination to the KIH is not known, given the lack of information on contaminant concentrations in CSO effluents. However, it is unlikely that the CSO effluent contains high levels of contaminants such as Cr and PCBs, which were identified as key contaminants of concern for the KIH in the risk assessment.

The City of Kingston has completed a number of recent upgrades to the sewer system that will aid in addressing potential impacts from CSOs (CH2MHill and XCG 2010). These include construction of a number of CSO holding tanks, including one located beneath Emma Martin Park in the southwest portion of the KIH. The capacity of the River Street Pump Station was also increased, and the sanitary sewer line that crosses underneath the KIH from the River St. pumping Station to the Ravensview Water Pollution Control Plant was twinned. All of these improvements increase capacity within the sewer system and should aid in reducing the frequency and volume of CSO effluent to the KIH. Furthermore, the City of Kingston has a goal to achieve "virtual elimination" of CSOs. Sewer separation is currently underway in the downtown core and in the catchment area for the Kingscourt storm sewer.

e. Belle Park Landfill

Leachate from the Belle Park Landfill has probably acted as a point source of PCBs in the past. A number of measures have since been implemented to contain and treat the leachate; these include installation of steel sheet pile barriers and extraction wells to intercept groundwater for pumping and off-site treatment, as well as the use of trees to intercept groundwater flow and sequester metals. Groundwater, surface water and wastewater are sampled semi-annually to assess contaminant concentrations for compliance with municipal and provincial environmental quality standards. Several investigations have been performed to investigate whether the Belle Park Landfill is still acting as a potential source of CoCs (Derry et al. 2003; City of Kingston and OMOE 2005; Benoit and Dove 2006; Benoit and Burniston 2010). No recent or ongoing studies investigating groundwater, surface water runoff and sediment pore water along the southwestern shore and Belle Park have found evidence of current significant inputs from terrestrial-based sources.

In 2010, OMOE performed a follow-up study to assess the success of the Cataraqui River Project Trackdown and to locate potential areas of ongoing PCB contamination. The study recommended that further assessment of potential groundwater sources from Belle Park be conducted and that PCB analysis be performed on flushed and unfiltered groundwater sample (Benoit and Burniston 2010). The City of Kingston followed this recommendation and conducted groundwater sampling at six monitoring wells along the south shore of Belle Park that were installed in 2003 as part of the Cataraqui River Project Trackdown. The samples were analyzed for total PCBs and PCB congeners as well as for other contaminants, including Pb, Hg, As and Cr. The study confirmed that groundwater discharging from the southern shore of Belle Park is not a significant ongoing source of PCBs, Pb, Hg, As or Cr to the Cataraqui River (City of Kingston 2011). The OMOE has reviewed the 2010 data as well as historical data provided by the City of Kingston and has concluded that the Belle Park Landfill is not a significant ongoing source of PCBs to the KIH (Castro 2011).

3. Remedial Actions Should Not Cause More Environmental Damage than They Remedy

Management options must be assessed for potential long-term (i.e., post-dredging) and short-term (i.e., during dredging) benefits and negative impacts. All federal projects have to comply with the *Canadian Environmental Assessment Act* (CEAA). CEAA ensures that the environmental effects of projects are reviewed carefully before federal authorities take action in connection with them so that projects do not cause significant adverse environmental effects. Under CEAA, an archaeological assessment is also required to assess potential effects on underwater cultural resources, such as shipwrecks. The environmental and archaeological assessments identify potential restrictions on remedial activities or mitigation measures that are required to limit potential adverse effects to valued environmental or cultural resources.

Remedial actions must comply with federal legislation, regulations and policies such as the *Species At Risk Act* (SARA), the no net loss of wetland functions goal as per the federal government wetland policy, and relevant sections of the *Fisheries Act*. (http://www.ramsar.org/cda/en/ramsar-documents-wurl-policies-national-wetland-21188/main/ramsar/1-31-116-162%5E21188_4000_0__)SARA requires that when an environmental assessment (EA) is being carried out on a project that may affect a listed wildlife species or any part of its critical habitat or the residences of its individuals, several preconditions must be met. The conditions are that (1) all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted; (2) all feasible measures will be taken to avoid or minimize the impact of the activity on the species and its critical habitat; and (3) the activity will not jeopardize the survival or recovery of the species (section 73.1 of SARA). For example, the KIH provides habitat for four SARA species of turtles that have special concern or endangered status. Measures for protecting turtles and their habitat could include scheduling the work to avoid sensitive periods such as breeding or nesting, relocating turtles from the work area to suitable habitat nearby, and establishing a turtle exclusion zone in the work area. Associated monitoring could involve radio-transmitter studies to track turtle location, monitoring reproductive success in zones adjacent to the work area, and including an environmental monitor in the work team who can observe remediation activities and relocate any individual turtles if needed. Table V-3 lists the SARA species identified for the KIH.

Remedial strategies under FCSAP also have to comply with the DFO long-term policy objective of achieving an overall net gain to the productive capacity of fish habitats (DFO 1986). Progress towards this objective can be achieved through the restoration of damaged fish habitats and the creation and enhancement of fish habitat.

Table V-3: List of SARA species identified for the KIH

Species	**SARA listing**
Lanius ludovicianus (loggerhead shrike)	Endangered
Rallus elegans (king rail)	Endangered
Chelydra serpentina (snapping turtle)	Special Concern
Graptemys geographica (northern map turtle)	Special Concern
Emydoidea blandingii (Blanding's turtle)	Threatened
Sternotherus odoratus (stinkpot turtle)	Threatened
Lampropeltis triangulum triangulum (eastern milk snake)	Special concern
Ixobrychus exilis (least bittern)	Threatened
Chordeiles minor (common nighthawk)	Threatened
Chaetura pelagica (chimney swift)	Threatened
Melanerpes erythrocephalus (red-headed woodpecker)	Threatened
Asio flammeus (short-eared owl)	Special concern
Chlidonias niger (black tern)	Special concern

III. Analysis of Management Options

This section discusses the different options available for management of the contaminated sediments in the Kingston Inner Harbour, which include taking no action, implementing administrative controls, pursuing monitored natural recovery or remediating portions of the site using capping or dredging. The available options were assessed using two main criteria: (1) the effectiveness of the strategy for managing risk due to sediment contamination in the KIH southwest of Belle Park; and (2) the feasibility of implementing the strategy given site-specific conditions in the KIH. A detailed review and ranking of potential management strategies is anticipated to be completed as part of a remedial/risk management action plan (RAP) for the site.

A. No Action

A no-action remedial alternative may be appropriate if the investigated site does not pose unacceptable risks to human health or the environment. This alternative cannot be selected for the KIH because a detailed quantitative human health and ecological risk assessment has indicated both potential human health risk and potential ecological risks from sediment and biological contamination (Chapter IV).

B. Institutional Controls

Institutional controls as part of a long-term solution may be appropriate in cases where access to a contaminated site and use of that site is limited, but that is not the case with the KIH, for the following reasons:

- People currently fish in the impacted area, including along the shoreline of the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE.
- There is a walking trail along the shoreline of the former Davis Tannery property that provides access to the shoreline and is popular with Kingston residents.
- The area of KIH that requires sediment management includes the Kingston Rowing Club, an area that is frequented by canoeists, kayakers and other recreational boaters.
- Proposed residential and trail development along the southwestern shoreline is anticipated to increase public access to this area.

- The revitalization of the KIH is strongly supported by a dynamic community organization called the Friends of Kingston Inner Harbour, whose initiatives include creating an inner harbour heritage trail and educating the community about KIH environmental issues (http://www.friendsofinnerharbour.com/).

Given the current public access to the waterfront at the southwest corner of the KIH, the proposed waterfront trail and plans for residential development in this area, institutional controls would be very difficult to implement as a long-term solution. Furthermore, they are not in accord with the outcomes of public consultation regarding the KIH, which indicated that the public wished to see access to the area encouraged. The public consultation was completed in 2002 by the City of Kingston under the guidance of the Kingston Environmental Advisory Forum (KEAF), which is a committee made up of technical members from academic institutions and the Cataraqui Region Conservation Authority, members from the public and several City councillors. The role of KEAF is to provide advice to the City of Kingston on environmental issues. Public consultation was carried out through two public workshops as well as a public consultation document published in a local newspaper with a request for public input.

The first public workshop was held on April 27, 2002, and communicated the main findings of a scientific review and gap analysis that summarized the available scientific knowledge for the KIH at that time. The second public workshop was a waterfront visioning exercise held on May 23, 2002. The goal of the latter workshop and the consulting document was to receive input from the public regarding future uses of the KIH, which could then be incorporated by the City of Kingston into a strategic plan for the KIH. Both workshops attracted approximately 65 participants.

As an interim, solution, institutional controls such as warning signs could be posted to minimize unacceptable exposure to potential waders/swimmers through use of the KIH. However, while institutional controls can help reduce risks associated with human health exposure by limiting the amount of direct contact with sediments or fish in the KIH, these controls would not be protective of ecological receptors.

C. Monitored Natural Recovery

MNR is an *in situ* remedial method that involves leaving the contaminated sediment in place and allowing natural aquatic processes to contain, destroy or reduce the bioavailability of the contaminants to an acceptable level in which there is no longer unacceptable risk to receptors (Magar et al. 2008). There are a number of chemical, physical and biological processes on which MNR relies, such as physical isolation of sedimentary contaminants through burial with clean material, chemical transformation of contaminants to less toxic forms, or biodegradation. Progress of this remedial technique is observed through monitoring indicators representative of the processes expected to be occurring on the site. Sites are usually given a timeline in which recovery should be completed, and a contingency plan is required in the event that expected recovery does not occur by the targeted time (ENVIRON 2006).

MNR was considered as a remedial option for the KIH because of its simplicity and relative low cost. However, because of the contaminants' persistence in the environment and a high sediment resuspension rate in the KIH, this remedial method is not suitable for this site. Contaminants in the KIH do not undergo significant chemical or biological transformation. Metals and PCBs will not degrade to non-toxic forms quickly or at all, and they will persist in their form indefinitely (Burbridge 2010). Thus, natural recovery would take longer than would be acceptable, and organisms would be exposed to the contaminants for an indefinite period of time.

Given this persistence and the hydrology of the KIH, the most important process for natural recovery would be physical isolation of the contaminants through burial with clean material. The burial of the contaminated sediment would have to be such that resuspension of contaminated sediment would not occur, and the new layer would have to remain in place permanently (ENVIRON 2006). In KIH, core samples indicate that similar concentrations of Cr are seen in the top 15 cm of sediment, and that these concentrations are generally much higher than the CCME probably effect level (PEL). Furthermore, radioisotope dating analyses indicate that the top layers of sediment are mixed (Tinney 2006). These findings suggest little dilution with clean sediments is occurring because of continual mixing and resuspension of contaminated sediment. As a result, physical isolation of the contaminants through natural burial with clean sediments is not occurring at rates high enough to permit natural recovery. This may be due in part to shallow depths of the KIH, which facilitate resuspension of sediments through wind action and boat activity, as well as the influence of the Kingscourt storm sewer discharge adjacent to Belle Park and the former Davis Tannery property. During high precipitation events, resuspension and mixing of contaminated sediments is probably occurring.

Although MNR is not appropriate as the primary management strategy for the KIH due to high sediment resuspension, there is value in using MNR as a supplementary approach for areas where net environmental risks are sufficiently low. For example, if hot spot areas of sediment contamination posing potential human health and ecological risks are addressed through other management strategies, MNR may be appropriate for the outlying areas where contaminant concentrations are low. The RAP should consider the use of MNR for areas where contaminant concentrations are below risk-based SeQOs for the KIH as a supplementary strategy for site management.

D. Capping

Capping is an *in situ* remedial technology that involves the controlled placement of clean material over contaminated sediments without disturbing the original bed (Palermo et al. 1998). By isolating contaminants through physical and chemical means and stabilizing the sediment to prevent resuspension, the risks posed by the contaminated sediments to human health and the environment are reduced (Palermo et al. 1998; SSC Pacific and ENVIRON 2010). Cap design varies to meet the needs of different site conditions, such as water depth and hydrodynamic flow. Single or multiple layers of materials may be used to cover the sediment and may include fine-grained material, sandy material to aid with sediment stability and/or geotextile membranes or armour stone to prevent erosion (SSC Pacific and ENVIRON 2010). Experience with capping remedies has been gained over the past decade; cap performance can now be better predicted and quantified, and this has led to greater acceptance among agencies (NRC 2007).

There are a number of technical limitations that must be addressed when considering this remedial method. One of the main restrictions for using this method in the KIH is the very shallow water depth (average = 1.2 m). This area is also used for recreational boating purposes, so navigational requirements should be considered. With such a shallow depth, the depth of the water after cap construction must be taken into consideration (ENVIRON 2006).

Furthermore, the KIH has very soft sediment; the upper layers are composed of organic gyttja. This may compromise geotechnical aspects of the cap which may be affected by the bearing capacity of the sediments and possibility of settlement due to consolidation (ENVIRON 2006). It also raises concerns of sediment resuspension during the capping process.

Caps are generally 60 cm to 160 cm thick, with the thinnest caps in the 50–60 cm range (Palermo et al. 1998). Water depths of less than 1 m above the cap are problematic, as the cap can be damaged easily by erosive processes such as wave action, ice scour or propeller wash from boat traffic and events such as floods and lake storms. The potential for these erosive processes in shallow water is considered a major limitation on the feasibility of capping, and, as such conditions are present in the KIH, this must also be considered when determining the feasibility of capping for the KIH (ENVIRON 2006). The following erosive processes are likely to occur in the KIH:

- Potential sediment resuspension and mixing caused by high discharge from the Kingscourt storm sewer during precipitation events
- Spring ice scouring
- Wave-induced currents from wind exposure
- Frequent boat traffic and propeller wash
- Lake storms through close proximity to Lake Ontario

All of these processes may jeopardize the long-term effectiveness of a cap for the KIH. After a cap is installed, it requires monitoring and regular maintenance to ensure the integrity of the cap. ENVIRON (2006) suggests budgeting for a few small repairs every five years. Both monitoring and maintenance activities would add additional cost to the project. As well, institutional controls are usually integrated into the remediation plan for capping (ENVIRON 2006). Such controls may include restriction to waterfront activities, including shoreline development (ENVIRON 2006).

Overall, capping is not considered a suitable remedial method for the KIH because of the shallow water depths, prevalence of erosive processes, soft sediments, potential for long-term maintenance issues, and unsuitability for the desired future use of the KIH.

E. Dredging

Dredging is an *ex situ* remediation method that involves the removal of sediment from a lake or river bottom. The environmental dredging process involves equipment mobilization and setup, site preparation and sediment removal and rehandling (Palermo et al. 1998). Removed sediment can then be treated or destroyed, although it is often disposed of in landfills, nearshore confinement facilities or confined aquatic disposal facilities (US EPA 2005; SPAWAR 2003). There are various types of dredging technologies, the suitability of which depends on the site characteristics and remedial goals.

One potential concern with dredging is the release of contaminants that may be contained in sediment pore water. It is particularly important to address this in areas such as the KIH, where sediments contain elevated concentrations of Cr. Cr may be found in two chemical forms: Cr(III), which is a relatively non-toxic and insoluble form of chromium, and Cr(VI), which is a more toxic and soluble form. Chromium speciation and concentrations in the pore water of the KIH were investigated through collection of pore water samples at sampling locations along the shoreline of the former Davis Tannery property, where sediment Cr concentrations are most elevated (Burbridge 2010). The results showed that Cr(VI) was below the analytical detection limit in pore water collected at all locations and all sediment depths. Cr(III) is present at concentrations below Health Canada's drinking water guidelines (HC 2008); however, the likelihood of Cr(III) oxidizing to Cr(VI) during dredging practices is negligible. A study of Hg concentrations in pore water from sediments located adjacent to the Woolen Mill and Rowing Club also found that concentrations were well below the applicable water quality guidelines (Manion 2007). These studies indicate that pore water chemical concentrations are not a limitation on dredging for the KIH.

A recent review investigating the effectiveness of dredging has identified a number of favourable site conditions that promote dredging effectiveness (NRC 2007). These include the following:

- Little or no debris
- A visual or physical texture difference or other rapid mechanism for differentiating clean and contaminated sediments
- Potential for overdredging into clean material
- Low-gradient bottom and side slopes
- Lack of piers and other obstacles
- Site conditions that promote rapid natural attenuation after dredging (e.g., through natural deposition)
- Absence of non-aqueous phase liquid or readily desorbable contaminants

Although the extent of underwater debris is unknown, site conditions in the KIH meet all of the other favourable criteria listed here. This suggests that dredging would be an effective remediation technology for the KIH. Overall, dredging has been selected as the preferred remedial strategy to treat contaminated sediments in the KIH, given its feasibility and likely effectiveness, lack of long-term maintenance issues and general acceptance by the public. The selection of dredging as a remedial strategy was supported by sediment remediation experts at a workshop on remedial options for the KIH held in June 2010.

Dredging does not require long-term maintenance or post-remediation performance monitoring. However, it is likely that there would be residual contaminated sediment after dredging due to incomplete dredging or losses during the remedial process (ENVIRON 2006). The loss of sediment to the water column can be minimized by choosing a higher-efficiency dredging method (ENVIRON 2006) and by employing mitigation measures during dredging operations such as double silt curtains to contain suspended sediments within the dredged areas and limit redistribution. The potential for recontamination of dredged areas by resuspension of adjacent contaminated sediment can be limited by completing remedial activities for both water lots at the same time. Follow-up treatments such as MNR or backfilling with clean sediment may also be considered to address residual contamination.

The environmental assessment process would address concerns related to dredging activities and suggest potential restrictions or mitigation measures to prevent adverse effects (see Section II-3B). For protection of reptiles, mitigation measures could include scheduling the work to avoid sensitive periods such as breeding or nesting season, relocating turtles from the work area to suitable habitat nearby and establishing a turtle exclusion zone in the work area. Associated monitoring could involve radio-transmitter studies to track turtle locations, monitoring reproductive success in zones adjacent to the work area and including in the work team an environmental monitor to observe dredging activities and relocate any individual turtles if needed.

F. Sediment Investigation Summary

1. Vertical Extent of Sediment Removal

Knowledge of sediment stratigraphy and the vertical extent of contaminants is important for making management decisions. If overlying sediments are disturbed, buried sediment that contains high levels of contaminants could be exposed and pose a potential risk to human and ecological receptors.

The sediment stratigraphy in cores collected from the southwest portion of the KIH is described in Chapter II. Generally, up to three types of sediments can be distinguished: a top layer of gyttja (a fine- to medium-grained silt), followed by a layer of clay and/or peat. A peat layer was present below the clay layer in some cores. The gyttja layer generally extends to a depth of 25–40 cm. In the western part of the harbour, close to the shoreline, only a peat layer is present under the gyttja. The fibrous peat usually consists of 70–75 percent organic detritus. Toward the central and eastern part of the KIH, a clay layer is predominant under the gyttja.

A map showing core locations for the KIH is shown in Appendix B (Map II-3). The sediment stratigraphy of selected cores collected in the KIH is shown in Figure V-2.

Figure V-1: Stratigraphic profiles of sediment cores collected from the KIH (Asquini et al. 2007).

Contaminant depth profiles have been discussed in detail in Chapter II. Except for the southwest corner of the KIH, elevated metal and PCB concentrations extend to a depth of approximately 35 cm throughout the western KIH.

A practical limit for vertical removal of sediment may be defined based on the sediment stratigraphy. For most of the harbour, the vertical depth of contamination corresponds closely with the depth of the organic gyttja. Dredging specifications may therefore specify removal of the sediments to the underlying clay or peat layer. In the southwest corner of the harbour at the mouth of the Kingscourt storm sewer discharge (core location C8), dredging into the peat layer is required as the most elevated contaminant concentrations occur at greater depths (55 to 60 cm).

2. Horizontal Extent of Sediment Removal

The results of the HHERA (Chapter IV) concluded that, under present conditions, concentrations of As, Sb, PAHs and PCBs in sediment and biota of the KIH have the potential to cause adverse health effects to human receptors. Results from the ERA indicated that PCBs posed potential risk to mink and Cr posed potential risk to mallard ducks.

The sediment management goals for the KIH were developed using risk-based calculations. This approach was endorsed by stakeholders at a workshop on remedial option for the KIH held in June 2010. The ecological and human receptors and scenarios that were found to drive risk were used to estimate sediment concentrations that would not be expected to cause adverse effects in key receptors. The following section outlines the process used to define sediment management goals for the KIH. These were used to delineate the horizontal extent of sediment management needed to decrease human health and ecological risks to acceptable levels.

IV. SEDIMENT MANAGEMENT GOALS FOR THE KIH

The management objectives for the KIH are to permanently reduce CoCs in sediments to concentrations below those that have the potential to affect human health and upper-trophic-level ecological receptors adversely.

Generic sediment quality guidelines provide a useful benchmark when examining sediment chemistry, but they are based solely on the protection of benthic invertebrates, and little is known about the effects of contaminated sediments on human receptors. They are also not considered practical for defining remediation goals, and a risk-based approach is recommended under the FCSAP aquatic contaminated sites framework (Chapman 2010). Therefore, the next step is to derive SeQOs for the southwest portion of the KIH at which risks to human and ecological receptors would be acceptable. In this section, the area and volume of sediment exceeding the SeQOs are calculated and mapped. The degree of risk reduction and residual risk remaining for each remediation scenario are also discussed, as is a sensitivity analysis.

The exposure scenarios developed for the HHERA (Chapter IV of this report) were used to determine site-specific remedial/risk management goals for the KIH. SeQOs were developed to determine the maximum concentration of CoCs in sediments that would result in reduction of risks to acceptable levels for humans and ecological upper-trophic-level receptors through dermal exposure, incidental sediment ingestion and fish consumption.

A. Risk Scenarios and Receptors Chosen for Criteria Development

1. Human Health Risk Assessment

Human health exposure scenarios used for the KIH followed the guidance of a detailed-level quantitative risk assessment (HC 2009) and assumed that an adult, a teen, a child and a toddler would use the KIH for recreational activities. These activities included swimming, walking, wading, boating, playing and fishing in the KIH, with an exposure frequency of 61 days per year. In addition, it was assumed that the adult recreational user would consume 39 meals of fish (236 g each) collected in the KIH over a year. The HHRA assumed a scenario under which fish advisories were not followed to ensure the health protectiveness of this HHRA. The exposure scenarios selected for the KIH are supported by anecdotal and observational evidence of people taking part in all of the recreational activities described above, including in areas along the southwestern shoreline where the greatest amounts of sediment contamination are found (see Chapter IV).

The major exposure pathways contributing to potential human health risk are

- direct dermal exposure,
- incidental sediment ingestion, and
- fish consumption.

The risk assessment outcomes indicated that all receptors face potential risks for non-cancer effects from the concentrations of PCBs, while the child and toddler receptors are also at potential risk from As, Pb, inorganic Hg and Sb. The main driver for risk from exposure to PCBs is through consumption of fish, and the main driver for risk from exposure to inorganic CoPCs is a combination of ingested and dermal sediment exposure. When background exposures to inorganic CoPCs were included, risk for non-cancer effects was negligible for As, Pb and Hg, but background exposures alone contributed to unacceptable risk for Sb. Potential carcinogenic health risks were evident for As and PAHs, and the As cancer risk remained unacceptably high even when it was calculated without sediment concentrations from an SMA near the former Woolen Mill. For PAHs, the carcinogenic risk is through dermal exposure. Details on the risk assessment and the outcomes are discussed in Chapter IV of this report.

2. *Ecological Risk Assessment*

Ecological risk scenarios evaluated the potential risk to ecological receptors found in the KIH selected to be representative of different feeding guilds — mink, great blue heron and mallard duck. The exposure pathways evaluated were incidental sediment ingestion and consumption of food. Detailed information on the ecological risk assessment is presented in Chapter IV of this report.

The outcomes of the ecological risk assessment showed that mallard ducks are at potential risk through exposure to Cr(III) through consumption of invertebrates, while PCBs pose a potential risk to mink through consumption of fish.

B. Approach for Developing Sediment Quality Objectives

The FCSAP framework for addressing and managing aquatic contaminated sites recommends that site-specific SeQOs should, ideally, be based on the HHERA outcomes (Chapman 2010). This risk-based approach was used for the KIH to develop site-specific

SeQOs for those exposure scenarios and pathways posing unacceptable risk to ecological and human receptors, as described in Chapter IV. According to Golder (2010), "the advantage of using a risk-based approach is transparency, availability of exposure equations and parameters in the risk assessment literature and the flexibility to adapt the exposure equations to obtain a representative scenario for guideline derivation."

The site protection goals for the KIH were discussed during a workshop on remedial options for the KIH held in June 2010, which involved members of the CRSG, site custodians and sediment remediation experts. It was agreed that a risk-based approach to address potential risks to humans and upper-trophic-level ecological receptors would be adopted. In accordance with the revised risk assessment, the protection goals and associated contaminants of concern included the following:

- Reduction of human health risks to acceptable levels for recreational fishers consuming sportfish from the KIH (PCBs)
- Reduction of human health risks through incidental sediment ingestion and dermal exposure to acceptable levels (As, Sb, PAHs)
- Reduction of ecological risks to mallard ducks through food ingestion to acceptable levels (Cr)
- Reduction of ecological risks to mink through prey ingestion to acceptable levels (PCBs)

Following federal risk assessment guidance (HC 2009), "acceptable levels" refers to a hazard quotient of less than 0.2 for human health risks (or less than 1.0 when background exposure is included) and a hazard quotient of less than 1.0 for risks to ecological receptors. Where SeQOs were developed for more than one receptor (e.g., humans and mink for PCBs), the more conservative value was adopted to ensure protection of the more sensitive receptor.

The site-specific SeQOs are designed to be protective of humans and upper-trophic-level receptors but not necessarily of benthic invertebrate communities. This approach was selected for the following reasons. First, developing site-specific sediment quality objectives based on benthic invertebrate effects is not protective of upper-trophic-level receptors (humans and aquatic wildlife consumers) where risks are due to substances that biomagnify, such as PCBs. This is an important consideration for the KIH. Secondly, stakeholder consultation affirmed protection goals based on risk to humans and upper-trophic-level receptors. Thirdly, the evidence for benthic community impacts is mixed for the KIH and the causality for the effects is somewhat uncertain, making it difficult to assess whether site management actions are necessary or would be effective in protecting benthic communities. A literature review also indicated that the drivers for most aquatic contaminated site remediation projects are risks to upper-trophic-level receptors (i.e., humans and aquatic wildlife consumers) rather than risks to benthic organisms (ESG and Franz 2013).

An overview of the assumptions and methodology used to derive the SeQOs is provided in the following sections. Details on the equations used to calculate SeQOs for each contaminant of concern and worked examples are presented in Appendix I.

1. *Derivation of SeQOs for Direct Contact (Dermal Exposure and Sediment Ingestion Pathway)*

The KIH HHRA indicated that direct contact with contaminated sediments through dermal exposure and incidental sediment ingestion poses unacceptable human health risks for As, Hg, Pb, Sb and PAHs using a hazard quotient (HQ) of 0.2 (see Chapter IV). Following Health Canada guidance, when background exposure from all other sources is factored into the equations and an HQ of 1.0 is used, Hg and Pb concentrations in the KIH no longer pose unacceptable risk (see Chapter IV, Section II.F). Consequently, SeQOs were developed for As, Sb and PAHs.

Derivation of SeQOs for direct contact with sediments was completed using the same exposure scenarios and receptor characteristics outlined in Chapter IV. SeQOs were developed using the most sensitive receptor (i.e., the toddler), as the resulting SeQOs would be protective of all other human receptors. The risk calculations for the dermal exposure and sediment ingestion pathways for As and PAHs were back-calculated to obtain SeQOs that would result in acceptable cancer risk of 1 in 100,000; the Sb SeQO was back-calculated using an acceptable non-cancer risk represented by an HQ of 0.2. For PAHs, two exposure scenarios were used: one that assumed indirect dermal exposure (i.e., no wading) and another that assumed direct exposure to sediments through wading. The equations and worked examples are presented in detail in Appendix I.

2. *Derivation of SeQOs for Cr to Address Ecological Risks to Mallard Ducks through Food Ingestion*

The KIH ERA indicated that Cr(III) concentrations in food items (macrophytes, benthic invertebrates) pose potential risk for the mallard duck receptor (see Chapter IV). SeQOs for Cr(III) in sediments were developed using the exposure scenarios outlined in detail in Section III of Chapter IV. For the development of the SeQO for Cr, the Eco-SSL TRV (toxicological reference value) developed by US EPA was judged to be the most supportable value for use. A stringent review process used to develop the Eco-SSL TRVs ensures that a comprehensive, critical, and conservative approach has been taken. The avian TRVs developed by Golder (2012) according to FCSAP guidance (Azimuth 2012) were not considered sufficiently robust for the calculation of SeQOs, being based on "professional judgement," with no rationale explicitly described or obvious. A large range (5–100 mg/kg-day) was published (Golder 2012), making the use of such values difficult and impractical.

Since the risk to mallard ducks is due to contaminant concentrations in food items, uptake models must be developed to define the relationship between sediment Cr(III) concentrations and corresponding Cr(III) concentrations in dietary items in order to calculate SeQOs. Available paired sediment and biota Cr concentrations from the KIH were used to develop uptake models for macrophytes and indigenous benthic invertebrates, which are assumed to make up the mallard duck diet in equal proportions (i.e., 50% each). These models are shown in Figures V-2 and V-3. SeQOs for Cr(III) in sediment were calculated iteratively from these uptake models using the equations and procedure outlined in Appendix I.

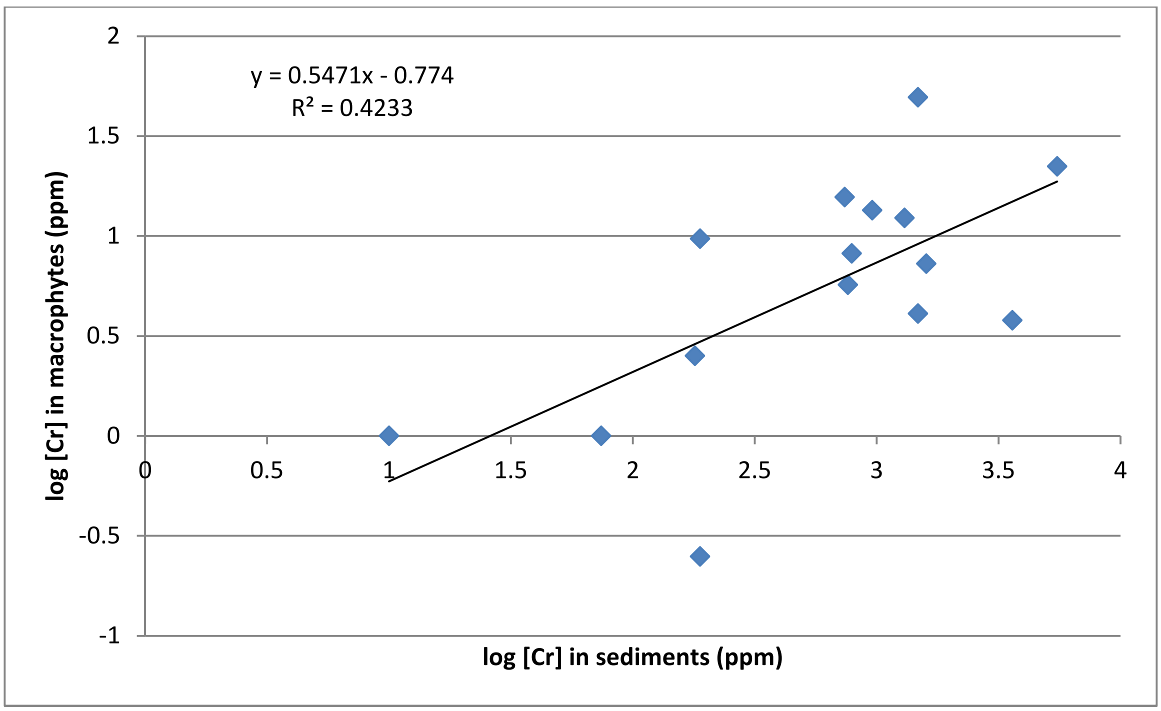


Figure V-2: Log-normalized relationship between [Cr] in sediments and [Cr] in macrophytes for test locations in the KIH.

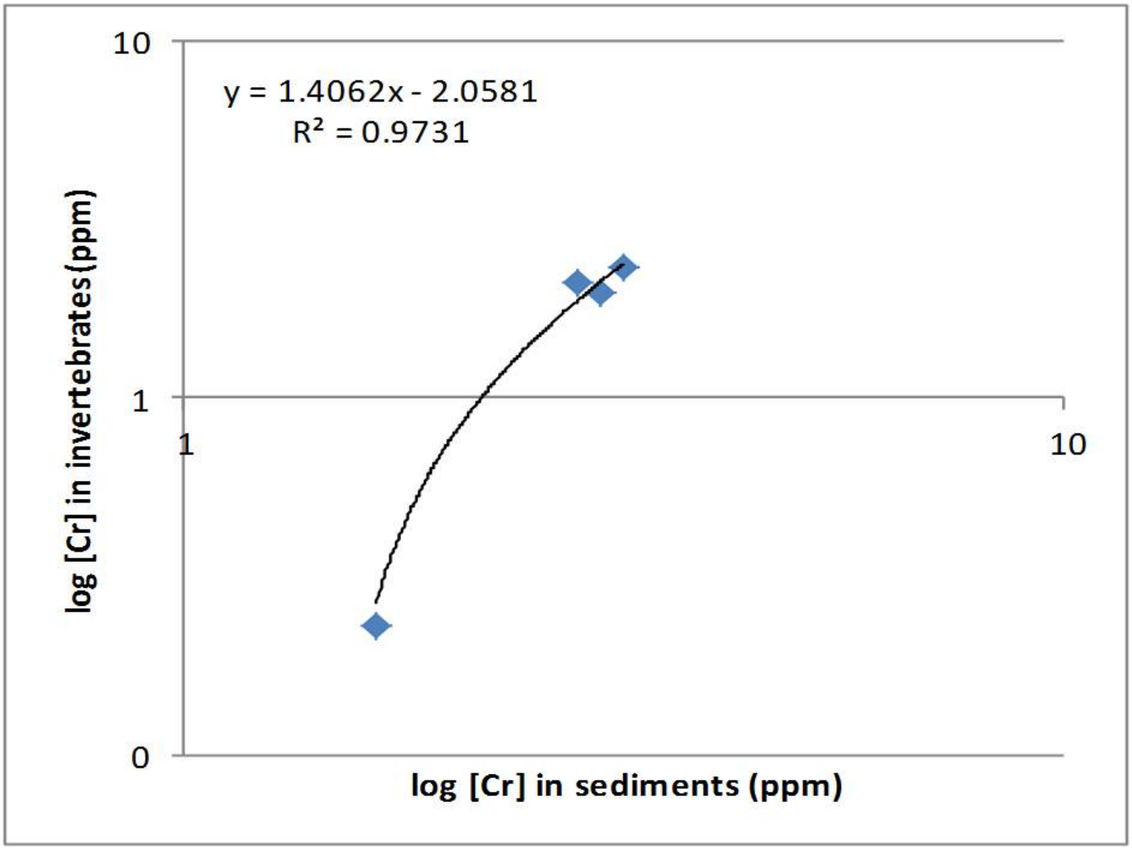


Figure V-3: Log-normalized relationship between [Cr] in sediments and [Cr] in indigenous benthic invertebrates for test locations in the KIH.

3. Derivation of SeQOs for PCBs to Address Risks to Human and Ecological Receptors through Fish Consumption

The KIH HHERA indicated that PCB concentrations in fish posed a potential risk to all human receptors and mink through the fish consumption pathway (Chapter IV). Since PCBs biomagnify throughout the aquatic food web and fish are mobile throughout the KIH, models must be developed to estimate the maximum PCB concentration in sediments such that the corresponding PCB concentrations in biota would be safe for consumption by humans or ecological receptors. Target tissue concentrations in the fish were estimated by back-calculating the risk calculations for the fish consumption pathway for humans and mink using the same receptor characteristics and exposure scenarios presented in Chapter IV. The risk calculations for humans incorporated background exposure to PCBs through food and other exposure pathways (see Section F in Chapter IV), and therefore an HQ of 1.0 was used. Details on the equations used to calculate target tissue concentrations and worked examples are presented in Appendix I.

The approach used to derive SeQOs for PCBs for the KIH was similar to that used by Labencki (2008) for Hamilton Harbour. A food web model was developed for the KIH and used to estimate sediment concentrations that would be required to attain the risk-based PCB target tissue concentrations in fish. The first step in model development was to identify relevant fish species for each trophic level. Generally, the ideal receptor eats and lives locally and has a high degree of exposure to the contaminated site. Based on generic food webs for the Great Lakes (e.g., Diamond et al. 1994; Milani and Grapentine 2006) and site-specific KIH information (i.e., fish consumption advisories, availability of data), a simplified food web model including three trophic levels was developed for the KIH (Figure V-4). Trophic Level 2 was represented by brown bullhead (benthivorous fish), while Trophic Level 3 was represented by largemouth bass (piscivorous fish). Both species are known to live in the KIH, are subject to PCB-driven consumption restrictions and occupy different feeding guilds.

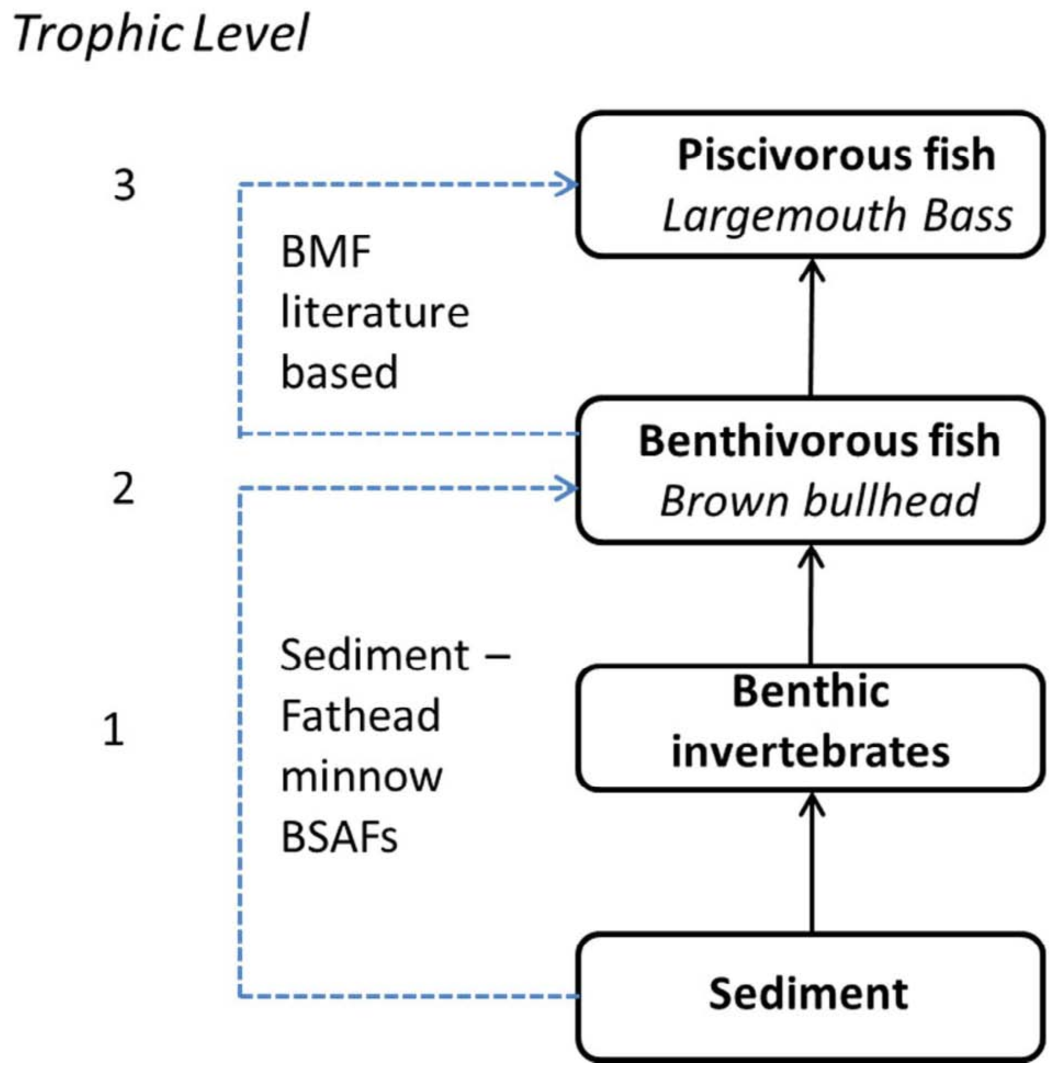


Figure V-4: Simplified food web model including three trophic levels for the KIH.

Brown bullhead and largemouth bass (as well as other fish species) are regularly collected in the KIH for analysis as part of the OMOE Sport Fish Contaminant Monitoring Program. Sport fish consumption restrictions for total PCBs for the general population begin at levels of >0.153 µg/g (restriction to four meals per month); complete restriction is advised for filet concentrations greater than >1.22 µg/g (OMOE 2013). Both species currently have food consumption restrictions in place for the KIH because of PCBs (OMOE 2013).

The relationship between PCB concentrations in the fish and sediment was established on the basis of the results of fathead minnow laboratory bioaccumulation tests using KIH sediments. These results were selected for use in the SeQO calculations because the experiments provided measures of biota-sediment accumulation factors

(BSAFs) that are specific to fish in the KIH. These tests exposed juvenile fathead minnows to sediments collected from seven locations in the KIH covering a range of PCB sediment concentrations (20 ppb – 660 ppb) for 21 days. A 21-day test provides a reasonable estimate of contaminant uptake by resident fish when the sediment concentration is known. The sediment fathead minnow data are presented in Watson-Leung (2004).

The fathead minnow data were used to estimate (a) sediment-fathead minnow regression equation for the KIH and (b) site-specific BSAFs.

a. Sediment-fathead minnow regression equation

An empirical sediment-biota regression equation was developed to establish the relationship between PCBs in sediments and uptake by fathead minnows (Sed-FM). Total organic carbon (TOC) normalized sediment PCB concentrations (ng PCB/g TOC dw) were plotted against the lipid-normalized fathead minnow PCB concentrations (ng PCB/g lipid ww — corrected for pre-exposure PCB concentration) on a log scale (Figure V-5).

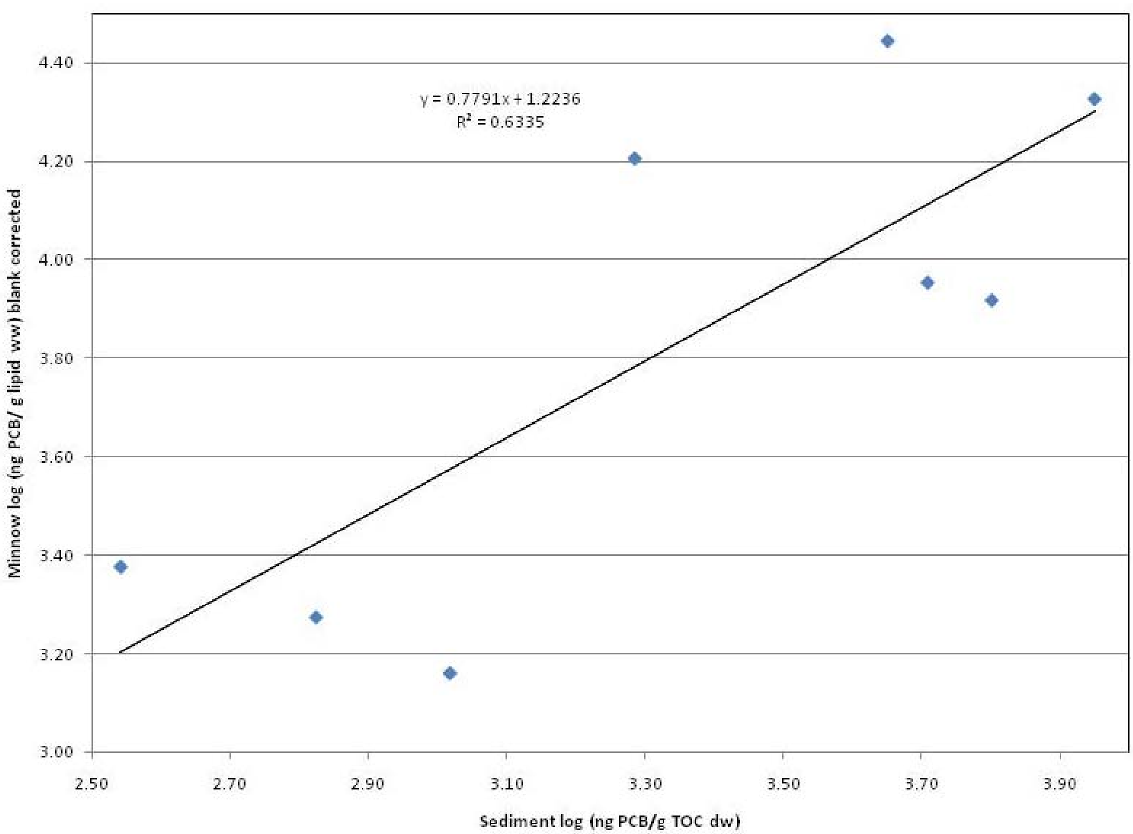


Figure V-5: Log-normalized relationship between PCBs in KIH sediment and fathead minnows as established through a sediment-fish bioassay.

b. Site-specific BSAFs

BSAFs are parameters that describe the accumulation of sediment-associated contaminants into tissues of ecological receptors (Burkhard 2009). They are commonly derived from paired chemical concentration data in sediments and biota and used to model biological uptake in aquatic ecosystems. BSAFs generally depend on a number of site-specific parameters such as trophic level, dietary composition, sediment organic carbon and lipid percentage. Individual biota sediment accumulation factors were calculated for each of the seven locations used in the fathead minnow laboratory bioaccumulation assays using the BSAF equation presented in Appendix I. All BSAFs calculated from the PCB concentrations in tissue and sediment from the Great Cataraqui River were greater than 1, indicating that contaminants are accumulating to a higher degree in the biota than in the sediments. The minimum (BSAF = 1.3), average (BSAF = 3.8) and maximum (BSAF = 8.3) calculated fathead minnow BSAFs were used in the SeQO calculations to provide an estimate of PCB uptake from the sediments for benthivorous fish (e.g., brown bullhead).

BSAFs are normalized to fish lipid contents and sediment organic carbon concentrations. The SeQO calculations used the average lipid content for fish samples collected from the KIH (2%), which is similar to that reported from other studies. The average sediment TOC concentration for samples located in the southern KIH (8%; n = 31) was used for organic carbon normalization.

To calculate the concentration of PCBs in piscivorous fish (largemouth bass), a biomagnification factor (BMF) from the literature was used for transfer of PCBs from benthivorous fish to piscivorous fish. The literature review was based on a compilation of 172 studies investigating PCB BMFs for various aquatic species at different trophic levels (Milani and Grapentine 2006). Whole body PCB tissue concentrations derived for brown bullhead were multiplied by a minimum (BMF_{min} = 1.1), average ($BMF_{average}$ = 4.6) and maximum BMF (BMF_{max} = 12.6) to calculate the concentrations in the largemouth bass.

SeQOs were calculated for the range of BSAFs and BMFs for both brown bullhead and largemouth bass. The calculated SeQOs were validated using measured data for the KIH to evaluate which method best approximated the relationship between fish and sediment concentrations.

c. Spatially weighted average concentrations

Because human and ecological receptors are mobile, actual exposures to CoCs in sediments were averaged over space. This approach is also appropriate to address risk through fish consumption, as fish are exposed to sediments throughout their home range. Spatially weighted average concentrations (SWACs) of CoCs in surface sediments were calculated using geospatial techniques and compared to the SeQOs. The approach assumes that receptors are exposed equally to sediments throughout the area used for spatial averaging.

The selection of the area used for the SWAC calculations was based on receptor exposure scenarios presented in the KIH HHERA (Chapter IV). The following areas were used:

1. The entire area of the southern KIH (As, PCBs, PAHs). This scenario assumed that human receptors were exposed equally throughout the harbour for the incidental ingestion and dermal contact pathways for As and PAHs. It was also used to address risks through the fish consumption pathway (PCBs), as sport fish are mobile throughout the KIH.

2. The SMA near the Rowing Club and along the western shoreline of the KIH (As). These areas were selected because high concentrations of As and Hg are found close to the Woolen Mill and Rowing Club, and the scenario accounts for this localized exposure, especially via Emma Martin Park (see Chapter IV, Section F). The SWAC scenarios were calculated for the same Emma Martin Park/Rowing Club SMA as presented in Chapter IV as well as for a larger SMA along the western shoreline that accounts for planned future development and increased public access to the waterfront in this area. The boundaries of the SMAs are shown in Appendix B, Map V-1.

3. Home ranges of the ecological receptors identified as showing potential risk in the KIH ecological risk assessment. These include the mallard duck home range for Cr and the mink home range for PCBs. SWAC calculations for PCBs were also performed for the brown bullhead home range, which is a conservative scenario that assumes that brown bullhead are fished preferentially from the most contaminated portion of the harbour.

To calculate the area of the harbour requiring management for each CoC, the following procedure was used. First, Thiessen polygons were used to map existing sediment concentrations (0–50 cm depth). Thiessen polygons are derived from a set of sample location points and bound an area in which any given location is nearest to the associated sample point relative to all other sample points. This interpolation method assigns the interpolated value equal to the nearest sample value to the polygon. Secondly, polygons with the highest concentration were removed and replaced with the 95 percent upper confidence limit (95UCL) of KIH background concentrations until the SWAC was equal to the SeQO. The equation used to calculate the SWAC for a particular area is presented in Appendix I.

C. Summary of SeQOs for Individual CoCs

Results for SeQOs developed using the methodology described above for the exposure scenarios and pathways presenting risk in Chapter IV are summarized in Table V-4. Human health scenarios are represented by the most sensitive receptor (toddler), as SeQOs for the toddler are protective of all other human receptors. SeQOs for ecological health are presented only for receptors that were determined to be at risk in the KIH HERA (Chapter IV). The results and area for management for each CoC are discussed in more detail in the following sections.

Table V-4: Summary of risk-based SeQOs to address CoCs posing potential risk to human and ecological receptors in the KIH for the exposure scenarios in the HHERA (Chapter IV)

CoC	Exposure pathway	Receptor	SeQO [ppm]
As	Cancer risk; incidental sediment ingestion and dermal contact	Toddler	6
Sb	Non-cancer risk; incidental sediment ingestion and dermal contact	Toddler	6.9
PAHs	Cancer risk; incidental sediment ingestion and dermal contact — wading	Toddler	0.007
PAHs	Cancer risk; incidental sediment ingestion and dermal contact — no wading	Toddler	0.1
Cr(III)	Food ingestion	Mallard duck	1160
PCBs	Non-cancer risk; fish consumption	Toddler	0.64
PCBs	Fish consumption	Mink	0.64

1. Arsenic

The risk-based SeQO for As based on cancer risk for the toddler receptor was calculated to be 6 ppm. Sediments along most of the western shoreline of the KIH exceed the SeQO, with the highest concentrations located in the vicinity of the Woolen Mill and Rowing Club (Map II-10, Appendix B). Map V-2 (Appendix B) indicates the area of sediments that would need to be managed to reduce the SWAC to 6 pm, assuming that human receptors may be exposed equally to sediments throughout the southern KIH. This scenario would remove sediments near the shore in the vicinity of the Woolen Mill and the Rowing Club.

Given the localized elevated concentrations of As and the recreational use of the western shoreline, SWACs calculated using the entire southern KIH may not be sufficiently protective of human receptors using only the western shoreline for recreational activities. To account for this, SWAC calculations were carried out for two SMA: the Rowing Club area and the western shoreline area where direct access to the waterfront is possible or planned through future development (Appendix B, Map V-1). The areas requiring management to achieve the SeQO of 6 ppm for these two scenarios are shown in Appendix B, Maps V-3 to V-4. Although Hg concentrations in sediments did not pose unacceptable risk to human receptors when background exposure was included (see Chapter IV, Section F), the highest Hg concentrations are found in this area of the KIH and would be addressed under these As management scenarios. The final delineation of the SMA boundaries should be determined in consultation with stakeholders and should consider future planned development of this area to address potential changes in access and recreational use of the waterfront.

2. Antimony

The SeQO for Sb to address potential risks to toddler receptors through dermal exposure and incidental sediment ingestion was calculated as 6.9 ppm. As discussed in Section II.G of Chapter IV, there is high uncertainty associated with the Sb data set as many samples were below the analytical limits of detection. Given this uncertainty and the fact that the SeQO was lower than the limits of detection in many cases, the SWAC procedure was not appropriate to address Sb contamination in the KIH. However, the available data indicate that Sb concentrations exceeding the SeQO are localized to a few small areas that are generally not accessible from the shoreline (Map II-12, Appendix B) and are co-located with other CoCs in the KIH, such as Cr and PCBs. Sediment management scenarios for these latter CoCs would address Sb contamination as well.

3. Polycyclic Aromatic Hydrocarbons

PAHs in the KIH pose cancer risk to humans, and this is solely attributable to the dermal exposure pathway. Risk-based SeQOs for PAHs were developed to address potential risks to toddler receptors through dermal exposure and used two exposure scenarios: indirect dermal contact (i.e., no wading; SeQO = 0.1 ppm) and direct dermal contact with sediments through recreational wading activities (SeQO = 0.007 ppm). Calculations using a dermal-specific slope factor were carried out according to guidance obtained from Health Canada in a personal communication (Lindsay Smith-Munoz), as the sample calculations provided in Health Canada (2010a) were not appropriate for the dermal slope factor provided in Health Canada (2010b). The calculations were adapted from Knafla et al. (2011). The risk calculated in this way is considerable, whether the high-sediment-loading exposure pathway of wading is included or not. The high risk is attributable to a number of factors, most notably the assumption that the per-animal slope factor (for mice) is directly applicable to humans on a per-body basis, based on the assumption that interspecies variability (between mice and humans) does not apply. US EPA is considering establishing a dermal cancer slope factor in the revised version (currently in draft form for public review) of its Integrated Risk Information System (IRIS) toxicological assessment of benzo[a]pyrene (B[a]P) (US EPA 2013), but the equation for the cancer slope factor includes an interspecies scaling component ($\left[\frac{Body\ weight(human)}{Body\ weight\ (mouse)}\right]^{3/4}$) that gives a slope factor of 0.005 µg/day (compare with the CSF in Knafla et al. (2006) of 0.58 µg/day).

The risk calculated in this way may be overly conservative, as can be seen by the calculation of SeQOs using the same methods. The SeQOs, which are similar to the low values obtained in Knafla et al, (2011), 0.0046 to 0.035 mg/kg of B[a]P, are substantially lower than both background PAH concentrations in KIH (95UCL of 2.9 mg/kg) and provincial sediment guidelines (4 mg/kg). The Knafla et al. (2011) derived values are lower than Ontario background sediment concentrations (0.37 mg/kg) and the most conservative of Ontario soil standards (0.05 mg/kg, full depth background site condition standards; OMOE 2011a) as well as being lower than or comparable to the CCME Interim Sediment Quality Guideline of 0.0319 mg/kg. Exceedance of PAH sediment quality guidelines is common in Great Lakes harbours, and while the Health Canada risk-based approach of deriving cleanup criteria may be protective of human health, it does not constitute the most practical approach.

One possible approach to address potential human health risks through dermal contact with PAHs in sediments would be the management of sediments adjacent to the western shoreline where the waterfront is accessible to the public and subject to recreational use. The highest PAH concentrations in the KIH are found along the western shoreline and exceed background values for most of this area (Map II-14, Appendix B). Map V-5 (Appendix B) presents two possible scenarios for shoreline management: a 5 m buffer from the shore (assumed to be the maximum area used for wading) and a 25 m buffer from the shore (assumed to be the maximum area used for recreational swimming). Management of sediment in these areas would account for recreational use of the western shoreline, which is likely to increase with establishment of a waterfront pathway and residential development.

Several other possibilities exist for identifying sediment management areas for PAHs. A cost-benefit analysis could be completed to examine the benefits of hot spot remediation for PAHs, provided that sources are addressed. Sediment management areas could also be designated based on risk to benthic invertebrate communities, as was implemented for the Randle Reef sediment remediation project in Hamilton Harbour. However, the latter approach would not address potential risks to humans through PAH exposure. Further consultation with the KIH stakeholders is necessary to determine which approach is most suited for the KIH.

4. Chromium (Cr(III))

The risk-based SeQO for Cr(III) to address potential risks to mallard ducks through food ingestion was 1160 ppm. The calculations were based on a diet composed of 50% macrophytes and 50% benthic invertebrates and used the home range of the mallard duck (9.2 hectares (ha)) for the SWAC procedure. The area of the KIH requiring management for Cr under this scenario is shown in Appendix B, Map V-6. This scenario would address the highest concentrations of Cr in the KIH sediments, which are found adjacent to the former Davis Tannery property (Map II-6, Appendix B).

5. Polychlorinated Biphenyls

Table V-5 shows the PCB SeQOs calculated for protection of human and ecological health using several different approaches, as described in Section IV.C. Interestingly, almost identical fish tissue PCB concentration targets were calculated for the toddler receptor and for mink. As a result, the SeQOs presented in Table V-5 are applicable to both receptors. Sediment management goals range between 0.2 and 1.9 ppm for protection of human health and mink.

Table V-5: Summary of SeQOs for PCBs to address potential risks through fish consumption for the toddler and mink receptors, calculated using four different PCB sediment-biota uptake scenarios

Sediment-biota uptake scenario	Brown bullhead SeQO [ppm]	Largemouth bass SeQO [ppm]
Minimum BSAF	1.9	1.3
Intermediate BSAF	0.64	0.43
Maximum BSAF	0.30	0.20
Sediment-to-fathead minnow uptake equation	1.4	0.75

To assess the performance of the modelled PCB pathway, a comparison among the different sediment-biota uptake methods was completed to verify which model best reflects actual uptake of PCBs from sediments into biota. The mean of measured PCB concentrations in fish tissue collected in the impacted area of the KIH was used to predict sediment concentrations using maximum, minimum and intermediate BSAFs as well as the sediment-fathead minnow equation. The predicted sediment concentrations were then compared with the mean of measured sediment concentrations. The comparison between measured and estimated concentrations suggests that using the intermediate BSAF best approximates the actual uptake of PCBs into biological tissue in the KIH for brown bullhead, while the sediment-to-fathead minnow uptake equation provides the best fit for largemouth bass. The PCB SeQOs for the validated methods range from 0.64 ppm (brown bullhead) to 0.75 ppm (largemouth bass). The most conservative of the validated PCB SeQOs (0.64 ppm) was selected for the SWAC modelling procedure. There are localized exceedances of this SeQO in the KIH sediments, with the highest PCB concentrations found in a small area immediately south of Belle Park (Map II-13, Appendix B).

SWAC calculations for PCBs were performed for three areas, as follows:

1. The entire southern KIH, assuming that sport fish are mobile throughout this area
2. The home range of a brown bullhead, assuming that sport anglers are fishing this species from the most contaminated area of the harbour
3. The home range of a mink

Under the first scenario, no management of PCB-contaminated sediments is required to address potential human health risks through fish consumption as the SWAC is below the SeQO. The home ranges of brown bullhead and mink are very similar in size and the SWAC procedure for scenarios 2 and 3 identifies the same area for management. Map V-7 (Appendix B) shows the area for sediment management to address potential human and ecological health risks from PCBs under scenarios 2 and 3. The management area would address the elevated hotspot of PCB contamination located south of Belle Park. If the model assumptions regarding biological uptake for the KIH are realistic, remediation of this area of the harbour should eventually result in declines in fish tissue PCB concentrations to levels that pose acceptable risks to human and wildlife consumers of fish.

D. Summary Map Displaying Overlapped Area of Sediment for Removal

The overlap of the area requiring management actions for As, PAHs, Cr and PCBs within the KIH is shown in Map V-8 (Appendix B). The management scenarios presented in Map V-8 include the following:

1. As: 6 ppm SWAC, special management area on western shoreline
2. Cr: 1160 ppm SWAC, mallard duck home range
3. PAHs: shoreline management area (25 m buffer zone)
4. PCBs: 0.64 ppm SWAC, brown bullhead and mink home ranges

These management scenarios were selected to be protective of human and ecological receptors throughout the KIH and also address localized human and ecological exposure to hotspots of sediment contamination.

Sediment volumes requiring management were calculated using an estimated depth of 35 cm for sediment removal for most of the harbour. In the southwestern part of the KIH, in areas adjacent to the Kingscourt storm sewer, core depth data indicate that contaminants are found at depths of up to 80 cm; as a result, dredging to a depth of greater than 50 cm would be required in this portion to ensure that all CoCs are removed. The total area to be removed corresponds to 26 ha and the estimated total volume to be remediated is 91,000 m^3.

V. RESIDUAL RISK AND UNCERTAINTY ANALYSES

A. Residual Risks and Risk Reduction

The management strategy developed in this report is anticipated to reduce risks to human and ecological receptors of the KIH. The analysis in this section quantifies residual risks associated with the management scenarios presented in Map V-8.

To calculate risk reduction under the proposed management scenarios, baseline HQs (as calculated in Chapter IV) were compared to post-remediation HQs derived using the SeQOs, and the percent risk reduction was calculated for each receptor and CoC. Background exposure was incorporated for As and PCBs (see Section II.F, Chapter IV). Risks from consumption of fish to human and ecological receptors for PCBs were assessed assuming a fish tissue PCB concentration corresponding to an SeQO of 0.64 ppm. For Cr, risks to mallard ducks from consumption of food items (macrophytes and benthic invertebrates) were evaluated using the uptake models presented in Section IV.C that correspond to an SeQO of 1160 ppm of Cr. Residual risks and risk reduction could not be evaluated for the PAH shoreline management scenario as the management scenario was not derived using the SWAC modelling procedure.

Risk reduction and residual risks to the toddler, mallard duck and mink receptors for the As, Cr and PCB management scenarios are summarized in Table V-6. Cells are shaded where the HHERA did not identify unacceptable risks under current KIH exposure.

Table V-6: Risk reduction and residual risks to human and wildlife receptors for sediment management scenarios for As, Cr and PCBs shown in Map V-8

Receptor	Risk reduction	As	Cr	PCBs
Toddler	Baseline HQ	1.2		1.1
	Residual HQ	0.5		0.96
	Risk reduction (%)	58		11
Mallard duck	Baseline HQ		2.3	
	Residual HQ		1.0	
	Risk reduction (%)		57	
Mink	Baseline HQ			1.6
	Residual HQ			1.0
	Risk reduction (%)			38

Management scenarios for As and Cr result in relatively large risk reductions (57 to 58%). These management scenarios would also address Hg contamination in the harbour, which is largely co-located with As contamination. However, the results suggest that there would be limited benefit to the PCB management scenario given the relatively small reductions in risk and the relatively patchy distribution of PCB contamination in the KIH. In addition, although mink are confirmed to be present in the harbour, there is limited suitable habitat and it may not be appropriate to determine sediment management scenarios based on potential risks to mink. Final decisions on management scenarios will be determined through stakeholder consultation.

B. Uncertainty Analyses

Uncertainty is an important component of risk assessment and therefore the uncertainty associated with risk-based SeQOs has to be discussed. The following section discusses data gaps and identifies factors that contribute to uncertainty in the risk assessment. Sources of uncertainty encompass the validity of the food web model, volume calculation, determination of areas for sediment management and remedy effectiveness.

1. Validity of the Food Web Bioaccumulation/Biomagnification Model

Food web models are simplified quantitative illustrations of transport and uptake of chemical compounds in an ecosystem. Assumptions that are associated with some degree of uncertainty are related to modelling of PCB biomagnification and Cr bioaccumulation. Parameters such as the variability of the calculated BSAFs (PCBs), the regression equation (Cr), limitations to the literature-derived toxicity thresholds, the selection of the receptors of concern, the variability of the home range of receptors and local diet of the receptors are sources of uncertainty. While it is beyond the scope of this report to quantify all of the uncertainty, the factors considered most important are discussed briefly.

The greatest contributor to uncertainty in predicting trophic transfer is the range of BSAFs and BMFs. A sensitivity analysis was performed using low, average and high BSAFs and BMFs to determine sediment management goals for PCBs. The predicted PCB SeQOs ranged from 0.017 ppm to 1.9 ppm, indicating that there was a high degree of uncertainty associated with the derivation of PCB sediment management goals. To address this uncertainty, validation of the modelling scenarios using measured concentrations of PCBs in the KIH fish and sediments was used to determine which BSAFs and BMFs best approximated actual biological uptake for the KIH. Comparison of modelled values with site-specific measured data suggests that the minimum BSAF tends to underestimate biological uptake and would therefore be less conservative, while the maximum BSAF tends to overestimate actual uptake and is too conservative. The intermediate BSAF seems to represent measured concentrations with acceptable accuracy. Differences between the SeQOs calculated using the intermediate BSAFs and the Sed-FM sediment to fathead minnow regression equations are small, although the Sed-FM equation better represents the largemouth bass uptake. The average BSAF of 3.8 used for the KIH criteria calculations is comparable to other BSAFs published in the scientific literature (Niimi 1996).

Exposure estimates for Cr were developed using direct measurements of Cr concentrations in macrophytes and indigenous invertebrates of the KIH. The use of uptake factors is based on the assumption that concentrations of chemicals in organisms are a linear function of the concentrations in sediments. There is high uncertainty associated with the indigenous invertebrate Cr uptake equation because of low sample size, poor representation of the concentration range and the fact that the organisms were not depurated and may therefore represent an overestimate of the bioavailable Cr. We have reviewed alternative approaches to this; either they are not feasible or they are not available in the literature or they would require assumptions that would introduce more uncertainties. The site-specific invertebrate uptake equation developed for Cr was checked against published equations for both depurated and non-depurated organisms

(Oak Ridge National Laboratory 1998). Results suggest a similar range of SeQOs, indicating that the regression equation based on non-depurated organisms represents a robust approximation.

2. Characterization of CoCs in Sediments

The spatial coverage of sediment samples for Cr and PCBs within the impacted area of the KIH is robust and data are sufficient to characterize the horizontal extent of contamination. The spatial density in the sampling location is higher along the shoreline, where historical sources used to discharge into the KIH and where contaminant concentrations tend to be highest.

Good spatial coverage is also indicated by the small area of the Thiessen polygons along the shorelines of Belle Park and the former Davis Tannery property. Thiessen polygons tend to become larger with distance from the shoreline; therefore, the uncertainty associated with a single measurement increases. For PCBs, the higher levels in small polygons indicate that hotspots are well defined. Since uncertainty increases with larger Thiessen polygons, it is more likely that concentrations in larger polygons represent overestimations for PCBs, as PCBs generally show a high variability of concentrations across the KIH. For Cr, concentrations in polygons characterize actual concentrations well. A gradient of decreasing concentrations can be seen from the southwest to the southeast.

Generally, the uncertainty related to spatial coverage of chemical concentrations is low, because the impacted area of the KIH is well defined.

3. Calculation of Sediment Volume

Sediment volumes were calculated using information obtained from cores on the vertical extent of the contamination in the sediments. The vertical extent of contaminants for Cr ranged from 15 to 50 cm. For PCBs, only limited depth information was available, and this represents a source of uncertainty. Depth information on PCB concentrations in cores located at the edges of the areas warranting sediment management for PCBs is also scarce, making it challenging to calculate residual risk. Sediment volumes warranting management decisions were calculated conservatively using a maximum depth of 50 cm.

Depth data and stratigraphies were obtained from a limited number of cores. In most cores, the contamination at depth was limited to the gyttja layer. The gyttja layer extends to a depth of 25 to 40 cm and is generally thinner than the maximum depth of 50 cm applied for volume calculation. Therefore, as a practical consideration for sediment management, it is recommended that the sediments be removed down to the peat/clay layer. The area in the southwestern part of the KIH where the Kingscourt storm sewer discharges is an exception, as contaminants appear to extend into the peat.

The limited number of core samples contributes to uncertainty for volume calculations. Contaminant depth information is especially needed for the area where the Kingscourt storm sewer discharges in order to better characterize the maximum depth. Since these areas are difficult to access, confirmatory sampling during remediation would ensure that contaminants at levels in excess of the SeQOs were being removed. Overall, the volume of 91,000 m^3 is likely to be a conservative estimate because it is based on maximum CoC depths of 35 cm throughout the harbour and of 50 cm in the area close to the Kingscourt storm sewer outflow, where contamination extends to greater depths.

4. Calculation of Areas Warranting Management

Many different combinations of Thiessen polygons could have been selected to calculate the SWAC to achieve a given SeQO. Contiguous polygons with the highest concentrations starting from shoreline areas of the KIH were chosen preferentially until the SeQO was met. This approach ensured that the areas of highest contamination would be removed from the KIH and also took into account practical considerations for dredging design. However, alternative removal scenarios could have been created to achieve the management objectives; this creates some uncertainty in the definition of areas requiring management.

5. Remedy Effectiveness

The assumption that remedies are 100 percent effective is not likely to be found to be true, as certain remedies will leave some residual contamination. For example, Patmont and Palermo (2007) discuss that residuals generated from dredging result in residual contamination of a magnitude of 2 to 9% of the contaminant mass originally targeted for removal. Thus, the extent of management areas may be underestimated if dredging is selected as a remedial option. Several approaches were used to reduce the possibility of residual contamination. First, the SWAC modelling procedure incorporated contamination to a depth of 50 cm; for a particular location with multiple samples at depth, the highest measured concentration was used. Second, the boundaries of management areas presented in Map V-8 were smoothed and extended by 1 m to account for imprecise dredging cut lines. Third, residual contamination is best addressed in the remedial action plan (RAP) through a confirmatory sampling program and a follow-up remedial strategy if necessary (e.g., additional dredging passes; thin-layer capping with clean material). The next section outlines some considerations for RAP design that may be incorporated to address some of the areas of uncertainty discussed in this section.

VI. CONSIDERATIONS FOR RAP DESIGN

The next step for the KIH is to develop a remedial action plan for the sediment management areas presented in this chapter. To address uncertainties discussed in Section V.B, the following activities should be considered when developing the RAP:

1. **Further sampling to characterize sediment concentrations of CoCs in areas where spatial coverage is poor**

SWAC modelling procedures are based on the sequential removal and replacement of Thiessen polygons with 95UCL background concentrations until the desired SeQO is achieved. The size of the Thiessen polygon is inversely related to sampling spatial coverage: polygons are larger where spatial coverage is relatively poor. Additional sediment sampling to increase spatial coverage would provide more precise interpolation of sediment concentrations and provide a better estimate of the management area required to meet the SeQOs.

2. **Further depth sampling to improve volume estimates for sediment management**

As discussed in section V.B, there is a fair amount of uncertainty in the volume estimated due to the limited number of core samples. The collection of more sediment cores to examine contaminant depth profiles throughout the sediment management areas would enable more precise estimates of sediment volumes that require management.

3. **Development of a confirmatory sampling program following management action, with follow-up remedial actions if confirmatory sampling indicates that the SeQOs have not been achieved**

Confirmatory sampling programs are important to evaluate remedy effectiveness, particularly for management strategies such as dredging where some contamination is commonly left behind because of limitations of dredging techniques. This residual contamination is best addressed by a confirmatory sampling program to measure remedy effectiveness. Follow-up remedial strategies such as additional dredging passes can be used to address residual contamination as part of the RAP.

4. **Collection of additional baseline information to evaluate the effectiveness of risk management/remedial actions**

Given that the proposed management scenario for the KIH is based on the reduction of human health and ecological risks to acceptable levels, demonstrating that the management actions are effective is important. Current project baseline includes a large dataset of contaminant concentrations in sediment and fish. A limited dataset is available for contaminant concentrations in benthic invertebrates, which represent the main exposure pathway presenting risk to mallard ducks for Cr (via ingestion of food items). Consideration should be given in the RAP to ensuring that sufficient baseline information is available to evaluate the effectiveness of the RAP strategy and to collecting additional baseline information if necessary.

VII. Conclusions and Recommendations

A risk management and sediment remediation strategy for the KIH was developed to address the risks posed by contaminated sediments and biological contamination in the southwest portion of the KIH. The KIH was designated as Class 1, High Priority for Action based on the ASCS.

Causation for ecological impairment in the KIH was demonstrated through a strength-of-evidence analysis. No major potential ongoing sources of contaminants into the KIH were found. It is recommended that any remedial actions for the river sediments occur in conjunction with stormwater management for the Kingscourt storm sewer, measures to address combined sewer overflows into the KIH, and the cleanup of the Orchard Street Marsh. Potential impacts and mitigation measures as they relate to species at risk identified in the KIH and to fish habitat will have to be addressed as part of the environmental assessment for remedial activities.

A remedial options analysis for the KIH identified dredging as the preferred remedial strategy to treat contaminated sediments in the KIH. A practical limit for vertical removal of sediment may be defined based on the transition between organic gyttja sediment and underlying clay or peat. In the southwest corner of the harbour, at the mouth of the Kingscourt storm sewer discharge, dredging into the peat layer is required as the most elevated contaminant concentrations occur in the upper layers of peat, at depths approximately 55 to 60 cm below the sediment-water interface.

A risk-based approach was used to develop site-specific SeQOs for those ecological and human receptors and CoCs determined to pose potential risk in the KIH HHERA. Risk-based SeQOs to address risks to the toddler through incidental sediment ingestion and dermal contact with sediments were calculated for As (SeQO = 6 ppm), Sb (SeQO = 6.9 ppm), and PAHs (SeQO = 0.007 to 0.1 ppm). As achievement of the PAH risk-based SeQOs is not feasible, a shoreline management area along the western shoreline was designated based on recreational use (wading and swimming) and PAH contaminant profiles. Risk-based SeQOs for Cr (SeQO = 1160 ppm) were calculated to address potential risks to mallard ducks from food ingestion. A food web model was used to calculate risk-based SeQOs for PCBs (SeQO = 0.64 ppm) to address risks to toddler receptors and mink through fish consumption, and the model incorporated estimates of background exposure. However, given the uncertainties inherent in the food web modelling and the relatively small risk reduction, sediment management for PCBs may not be warranted. The total area warranting sediment management to achieve acceptable risks to human and wildlife consumers of fish corresponds to 27 ha. The estimated total volume of sediments to be remediated is 91,000 m^3.

The next step for the KIH is to develop and implement a remedial action plan (FCSAP, Step 8). Federal legislative requirements include a comprehensive EA, including consideration of fish habitat and SARA species. An archaeological assessment of the area should also be completed. Considerations for RAP design that would address areas of uncertainty include further depth sampling and development of a confirmatory sampling program with follow-up remedial strategies if necessary.

VIII. REFERENCES

Asquini, A., M. McLeod and C. Sollows (Asquini et al.). 2007. "Remediation of Sediment Contamination in the Cataraqui River, Kingston Inner Harbour." Undergraduate thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

Azimuth Consulting Group. 2012. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Prepared for Environment Canada.

Benoit, N. and D. Burniston. 2010. Cataraqui River Project Trackdown: Follow-up Study on Success of Remediation Efforts in the Cataraqui River 2006.

Benoit, N. and A. Dove. 2006. Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 Monitoring Programs. Technical Report. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Burbridge, D.J. 2010. "Contaminated Sediments in the Kingston Inner Harbour: Assessing Ecological Effects, Evaluating and Minimizing Remediation Impacts." MSc thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON. 244 pages.

Burkhard, L. 2009. Estimation of Biota Sediment Accumulation Factor (BSAF) from Paired Observations of Chemical Concentrations in Biota and Sediment. Prepared for the US Environmental Protection Agency. February 2009.

Canadian Council of Ministers of the Environment (CCME). 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.

Castro, V. 2011. Memorandum regarding Belle Park Landfill (closed), environmental operations and monitoring 2010. To Craig Dobiech, senior environmental officer, Kingston District office, Ontario Ministry of the Environment, Eastern Region. October 12, 2011.

CH2MHill and XCG. 2010. Pollution Control Plan Update for the City of Kingston. Final report. Prepared for Utilities Kingston.

Chapman, P. M. 2011. Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP). Final Report. Prepared by Golder Associates Ltd., Burnaby, BC, Canada for Fisheries and Oceans Canada.

Chapman, P.M. and H. Holler. 2006. "Should the Sediment Quality Triad Become a Tetrad, a Pentad, or Possibly even a Hexad?" *Journal of Soils and Sediments* 6, no. 1: 4–8.

City of Kingston, Sustainability and Growth, Environment Division. 2011. Interoffice memorandum regarding Belle Park South Shore Shallow Groundwater Monitoring Program. From David Matheson to Paul MacLatchy. March 3, 2011.

City of Kingston and Ontario Ministry of the Environment (OMOE). 2005. Project Trackdown, Cataraqui River, Kingston, Ontario: Assessment of PCB's in nearshore groundwater. Final report.

Contaminated Sites Management Working Group (CSMWG). 1999. A Federal Approach to Contaminated Sites. Prepared by Dillon Consulting Ltd., Ottawa, ON.

Derry, A., A. Dove, R. Fletcher and N. Benoit (Dove et al.). 2003. PCB Source Trackdown in the Cataraqui River: 2001 Findings. Technical Memorandum. Prepared for the Ontario Ministry of Environment, Eastern Region, Kingston, ON.

Diamond, M.L., D. Mackay, D.J. Poulton and F.A. Stride (Diamond et al.). 1994. "Development of a mass balance model of the fate of 17 chemicals in the Bay of Quinte." *Journal of Great Lakes Research* 20: 643–666.

Environmental Sciences Group and Franz Environmental Inc. 2013. FCSAP Long-term Monitoring Planning Guidance. Prepared for Fisheries and Oceans Canada and Environment Canada, March 2013.

ENVIRON. 2006. Sediment Remedial Alternatives Analysis Report: Study Area 7, Jersey City, New Jersey. Prepared for Honeywell International Inc., Morristown, NJ. December 2006.

Environment Canada and Ontario Ministry of the Environment (OMOE). 2008. Canada-Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment. Prepared by Peter Chapman (Golder Associates Ltd.) with the COA Sediment Task Group on behalf of Environment Canada and the Ontario Ministry of the Environment under the Canada-Ontario Agreement (COA 2002). March 2008.

Fisheries and Oceans Canada (DFO). 1986. Policy for the Management of Fish Habitat. Ottawa, ON.

Franz Environmental Inc. 2009. FCSAP Aquatic Sites Classification System (2009) Draft Detailed User Guidance Manual. Prepared for Fisheries and Oceans Canada.

Golder Associates. 2010. Identification and Evaluation of Protocols for the Derivation of Human Heath Sediment Quality Guidelines. Prepared for Health Canada. Burnaby, BC.

Golder Associates. 2012. Implementation of the Canada–Ontario Decision-making Framework for Assessment of Great Lakes Contaminated Sediment — Kingston Inner Harbour: Framework Step 6 (Detailed Quantitative Assessment). Submitted to Public Works and Government Services Canada. Report number 11-1122-0154. 497 pages.

Hamilton, T. 2002. "Are Kingston sediments toxic to fish? Effects of PAH and PCBs from Kingston Inner Harbour sediments on rainbow trout." Undergraduate thesis, Department of Biology, Queen's University, Kingston, ON.

Health Canada. 2008. Guidelines for Canadian Drinking Water Quality — Summary Table. Prepared by Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment.

Health Canada. 2009. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Complex Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRAchem). Version 1.0. Prepared by the Contaminated Sites Division Safe Environments Programme. February 2009.

Health Canada. 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA). Version 2.0. Prepared by the Contaminated Sites Division Safe Environments Directorate. September 2010.

Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-specific Factors. Version 2.0. Prepared by the Contaminated Sites Division Safe Environments Directorate. September 2010.

Knafla, A., S. Petrovic, M. Richardson, J. Campbell and C. Rowat (Knafla et al.). 2011. "Development and application of a skin cancer slope factor for exposures to benzo[a]pyrene in soil." *Regulatory Toxicology and Pharmacology* 59: 101–110.

Knafla, A., K.A. Phillipps, R.W. Brecher, S. Petrovic and M. Richardson (Knafla et al.). 2006. "Development of a dermal cancer slope factor for benzo[a]pyrene." *Regulatory Toxicology and Pharmacology* 45: 159–168.

Labencki, T. 2008. An Assessment of Polychlorinated Biphenyls (PCBs) in the Hamilton Harbour Area of Concern (AOC) in Support of the Beneficial Use Impairment (BUI): Restrictions on Fish and Wildlife Consumption. Prepared by the Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch.

Magar, V.S., K. Merritt, M. Hennig, M. Sorensen and R.J. Wenning (Magar et al.). 2008. "Approaches used for remedy selection at contaminated sites." *Real Time and Deliberative Decision Making*. NATO Science for Peace and Security Series 4: 357–377.

Manion, N. 2007. "Determining the distribution and fate of mercury in sediment of the Cataraqui River at Kingston, Ontario." Unpublished MSc thesis, Department of Biology, Queen's University, Kingston, ON.

Milani, D. and L. Grapentine. 2006. The Assessment of Sediment PCB Contamination and Biological Impairments in Lyon Creek East (Niagara River Area of Concern). Prepared by Environment Canada. NWRI Contribution No. 06-414, March 2006.

Milley, S. 2010. “A brownfield redevelopment case study: Assessment of the environmental conditions and remediation options using life cycle assessment for the former Davis Tannery property, Kingston, Ontario.” Master’s thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

National Research Council (NRC). 2007. Sediment Dredging at Superfund Megasites: Assessing the Effectiveness. Committee on Sediment Dredging at Superfund Megasites. National Academy Press, Washington, DC.

Niimi, A.J. 1996. “Evaluation of PCBs and PCDD/Fs retention by aquatic organisms.” *Science of the Total Environment* 196: 123–150.

Oak Ridge National Laboratory. 1998. Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation. Prepared for the U.S. Department of Energy Office of Environmental Management.

Ontario Ministry of the Environment (OMOE). 2013. Guide to Eating Ontario Sport Fish 2013–2014 — 27th Edition, revised. Queen’s Printer for Ontario.

Ontario Ministry of the Environment (OMOE). 2011a. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, revised version. Prepared by Standards Development Branch. PIBS 7386e01. 571 pages. April 15, 2011. Available at http://www.ene.gov.on.ca/environment/en/resources/STDPROD_086519.html.

Ontario Ministry of the Environment (OMOE). 2011b. Report by Mr. Frank Crossley on the Hydrological Assessment of Emma Martin Park/Rowing Club Conducted in July 2011.

Palermo, M., S. Maynord, J. Miller and D. Reible (Palermo et al.). 1998. Assessment and Remediation of Contaminated Sediments (ARCS) Program: Guidance for *In Situ* Subaqueous Capping of Contaminated Sediments. EPA/905/B-96/004. US Environmental Protection Agency Great Lakes National Program Office, Chicago, IL.

Patmont, C. and M. Palermo. 2007. “Case studies environmental dredging residuals and management implications.” Paper D-066 in *Remediation of Contaminated Sediments — 2007: Proceedings of the 4th International Conference on Remediation of Contaminated Sediments,* January 2007, Savannah, GA. Battelle Press, Columbus, OH.

Rafferty, S.D., V.S. Blazer, A.E. Pinkney, J.L. Grazio, E.C. Obert, and L. Broughton. 2009. “A historical perspective on the ‘fish tumours and other deformities’ beneficial use impairment at Great Lakes Areas of Concern.” *Journal of Great Lakes Research* 35: 496–506.

Space and Naval Warfare Systems Command (SPAWAR). 2003. Implementation Guide for Assessing and Managing Contaminated Sediment at Navy Facilities. Prepared for Naval Facilities Engineering Command 20374-5065, Washington, DC.

Space and Naval Warfare Systems Center Pacific (SSC Pacific) and ENVIRON International Corporation (SSC Pacific and ENVIRON). 2010. Long-term Monitoring Strategies for Contaminated Sediment Management. Final Guidance Document. 108 pages.

Suter, G.W., S.B. Norton and S.M. Cormier (Suter et al.). 2002. “A methodology for inferring the causes of observed impairments in aquatic ecosystems.” *Environmental Toxicology and Chemistry* 21, no. 6: 1101–1111.

Tinney, M. 2006. “Site investigation and ecological risk assessment of the Kingston Inner Harbour.” Unpublished MSc thesis, Department of Chemistry and Chemical Engineering, Royal Military College of Canada, Kingston, ON.

United States Environmental Protection Agency (US EPA). 1997. Integrated Risk Information System (IRIS) Summary: Polychlorinated biphenyls (PCBs) (CASRN 1336-36-3). Available from http://www.epa.gov/NCEA/iris/subst/0294.htm. Accessed March 16, 2010.

United States Environmental Protection Agency (US EPA). 2000. Guidance for the Data Quality Objectives Process, EPA QA/G-4. EPA/600/R-96/055. Office of Environmental Information, Washington, DC. August 2000.

United States Environmental Protection Agency (US EPA). 2005. Contaminated Site Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012. Office of Solid Waste and Emergency Response,

United States Environmental Protection Agency (US EPA). 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4. EPA/240/B 06/001. Office of Environmental Information, Washington, DC.

United States Environmental Protection Agency (US EPA). 2013. Toxicological Review of Benzo[a]pyrene (CASRN 50-32-8) in Support of Summary Information on the Integrated Risk Information System (IRIS). Public Comment Draft. EPA/635/R13/138a. Office of Research and Development. August 2013. Available from http://cfpub.epa.gov/ncea/ iris_drafts/recordisplay.cfm?deid=66193. Accessed December 2013.

Watson-Leung, T. 2004. Laboratory Sediment Toxicity and Bioaccumulation Tests: Report on Cataraqui River Sediments 2002. Technical Memorandum. Appendix J to: Derry et al. 2003.

Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour

Appendices

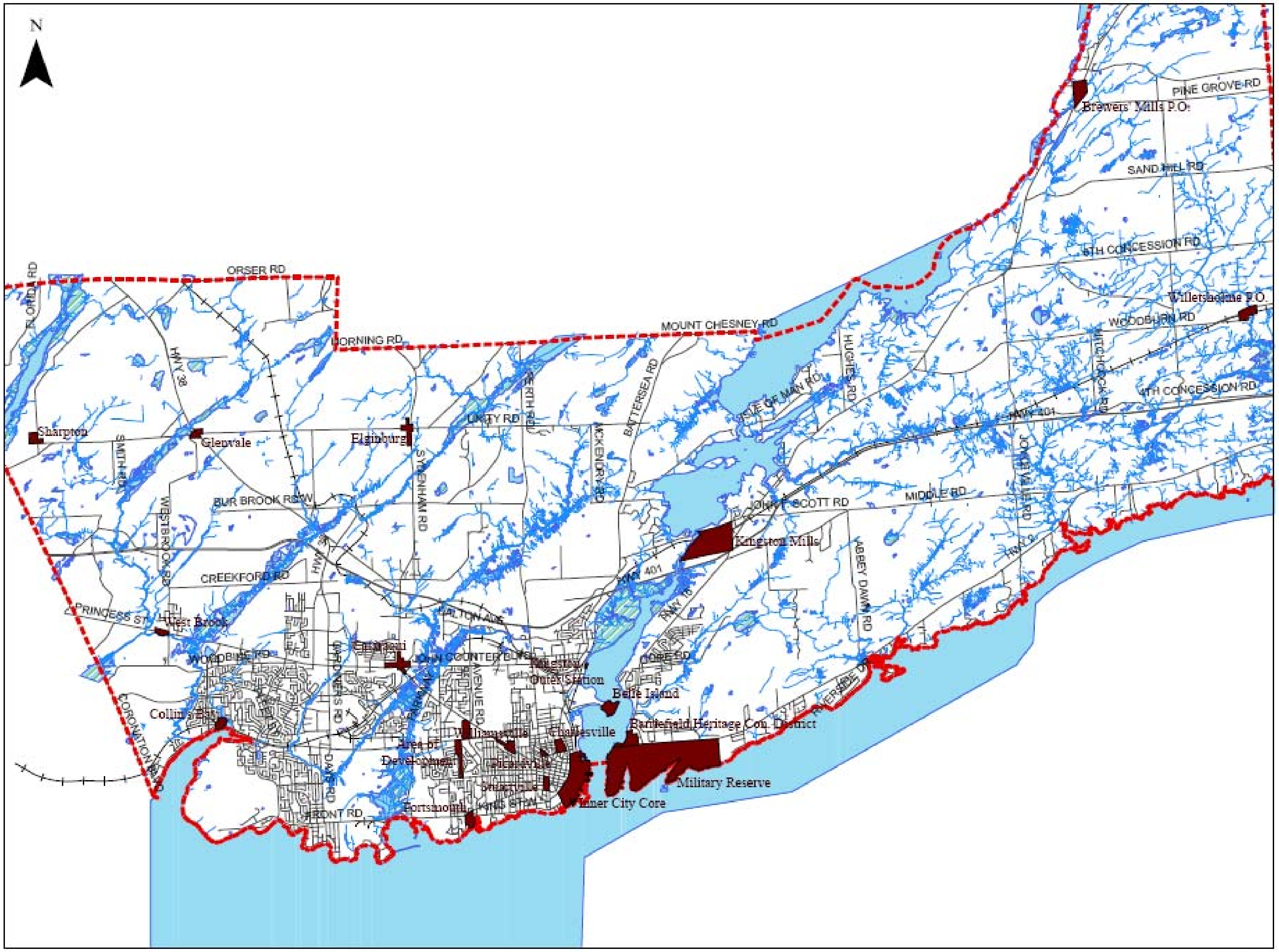
Prepared by

Environmental Sciences Group
Royal Military College
Kingston, Ontario

APPENDIX A: SELECTED FIGURES AND TABLES FROM REFERENCED DOCUMENTS

Contents

Archaeological Services Inc., 2008a



ARCHAEOLOGICAL MASTER PLAN

City of Kingston

Figure 1: Location of Archaeologically Sensitive Areas

ASA
Roadway
Railway
Stream or Drainage Ditch
Marshes
Rivers, Lakes and Ponds

ARCHAEOLOGICAL SERVICES INC.

DATE: MARCH 31, 2008
DRAWN BY: S.F.

0 0.5 1 2 3 4 5 Kilometers

Blancher, 1984

Table 6: Significant plant species in the Cataraqui Marsh area and their location (UTM grid reference). Status as follows: NR - nationally rare; PR - provincially rare; PU - provincially uncommon; RR - regionally rare (from Catling 1983).

Species	Grid Reference	Status
Alisma gramineum	834023, 828012	PU
Amphicarpa bracteata var. *comosa*	844043	RR
Anemone quinquefolia	845040, 848037	RR
Aster ericoides	818008	RR
Bidens beckii	836034, 837034	PU
Carex amphibola var. *turgida*	831007	PU, RR
Carex artitecta	845040, 846039	PR
Carex brevior	848043	RR
Carex prairea	848043	RR
Cinna arundinacea	850039	PR
Cyperus rivularis	827005	RR
Dentaria X *maxima*	838029	RR
Dryopteris goldiana	851039	PU
Epilobium glandulosum	845040	RR
Galium tinctorium	833035	RR
Hierchloa odorata	825034	RR
Impatiens pallida	851039	RR
Jeffersonia diphylla	825034, 823031	NR, PR
Juncus secundus	844046	NR, PR
Leersia virginica	836024	RR
Najas guadalupensis	844044, 839035	RR, PU
Potamogeton epihydrus var. *ramosus*	834034	RR
Quercus muhlenbergii	824033	NR, PR
Rubus cf. *flagellaris*	845046	RR
Solidago hispida	847048	RR
Utricularia gibba	828030	RR, PU
Utricularia minor	825025, 826024	RR
Zannichellia palustris	826005	RR

Table 12: List of mammal species observed or reported (*) in the Cataraqui Marsh area.

Short-tailed Shrew	Blarina brevicauda
Masked Shrew	Sorex cinereus
Little Brown Myotis	Myotis lucifugus
Raccoon	Procyon lotor
Longtail Weasel	Mustela frenata
Ermine	Mustela erminea *
Mink	Mustela vison
River Otter	Lutra canadensis
Striped Skunk	Mephitis mephitis
Coyote	Canis latrans *
Red Fox	Vulpes vulpes
Woodchuck	Marmota monax
Eastern Chipmunk	Tamias striatus
Eastern Grey Squirrel	Squirus carolinensis
Red Squirrel	Tamiasciurus hudsonicus
Beaver	Castor canadensis
White-footed Mouse	Peromyscus leucopus
Meadow Vole	Microtus pennsylvanicus
Muskrat	Ondatra zibethicus
Norway Rat	Rattus norvegicus *
Meadow Jumping Mouse	Zapus hudsonius
Porcupine	Erethizon dorsatum
European Hare	Lepus europaeus
Eastern Cottontail	Sylvilagus floridanus
Whitetail Deer	Odocoileus virginianus

Table 16: Fish species observed or reported in the Cataraqui River. Sp= observed spawning; YOY = young-of –the-year- fish observed. YOY? Refers to several species which are indistinguishable at a very early age.

Order PETROMYZONTIFORMES Family Petromyzontidae			
Ichthyomyzon unicuspis		Silver Lamprey	
Order LEPISOSTEIFORMES Family Lepisosteidae			
Lepisosteus osseus		Longnose Gar	
Order AMIIFORMES Family Amiidae			
Amia calva		Bowfin	YOY
Order CLUPEIFORMES Family Clupeidae			
Alosa pseudoharengus		Alewife	
Dorosoma cepedianum		Gizzard Shad	
Family Salmonidae			
Oncorhynchus sp.		Salmon	
Family Umbridae			
Umbra limi		Central Mudminnow (CMM)	
Family Esocidae			
Esox lucius		Northern Pike (NP)	Sp
Esox masquinongy		Muskellunge	
Order CYPRINIFORMES Family Cyprinidae			
Chrosomos eos	(RBD)	Northern Redbelly Dace	YOY?
Cyprinus carpio		Carp	Sp
Notemigonus crysoleucas		Golden Shiner (GSh)	YOY?
Notropis atherinoides		Emerald Shiner (EMSh)	YOY?
Notropis hudsonius		Spottail Shiner	YOY?
Pimephales notatus		Bluntnose Minnow (BNM)	YOY?
Family Catostomidae			
Catostomus commersoni		White Sucker	
Family Ictaluridae			
Ictalurus natalis		Yellow Bullhead	
Ictalurus nebulosus		Brown Bullhead (BB)	YOY
Ictalurus punctatus		Channel Catfish	
Order ANGUILLIFORMES Family Anguillidae			
Anguilla rostrata		American Eel	
Order CYPRINODONTIFORMES Family Cyprinodontidae			
Fundulus diaphanus		Banded Killifish (KILL)	
Order ATHERINIFORMES Family Atherinidae			
Labidesthes sicculus		Brook Silverside (BSS)	

Table 16 cont'd: Fish species observed or reported in the Cataraqui River. Sp= observed spawning; YOY = young-of –the-year- fish observed. YOY? Refers to several species which are indistinguishable at a very early age.

Order GASTEROSTEIFORMES	Family Gasterosteidae		
Culaea inconstans		Brook Stickleback (BKST)	
Order PERCIFORMES	Family Percichthyidae		
Morone americana		White Perch	
Morone chrysops		White Bass (WHB)	YOY
	Family Centrarchidae		
Ambloplites rupestris		Rock Bass (RB)	Sp, YOY
Lepomis gibbosus	(PKS)	Pumpkinseed Sunfish	Sp, YOY
Lepomis macrochirus		Bluegill (BG)	Sp, YOY
Lepomis m. x g. hybrid		Pumpkinseed x Bluegill	
Micropterus dolomieui		Smallmouth Bass (SMB)	Sp
Micropterus salmoides		Largemouth Bass (LMB)	Sp, YOY
Pomoxis nigromaculatus		Black Crappie (BC)	Sp, YOY
	Family Percidae		
Perca flavescens		Yellow Perch (PER)	Sp
Stizostedion vitreum		Walleye	Sp
Etheostoma nigrum		Johnny Darter (JD)	

Table 20: Annotated list of reptiles and amphibians observed in the Cataraqui Marsh area in 1983.

<u>Chelydra serpentina</u> Snapping Turtle
Numerous nests found along the edges of the CNR tracks and Highway 401 though turtles seen only infrequently within the marsh.

<u>Sternotherus odoratus</u> Stinkpot
Two turtles seen swimming in marshy parts of the Cataraqui

River near Highway 401. This turtle is likely much more abundant than this figure indicates.

<u>Graptemys geographica</u> Map Turtle
Reported by P. Catling from the river north of Highway 401 though none were seen in 1983. The absence of rocks or stumps surrounded by water, in addition to the narrow width of the river and the amount of boat traffic here combine to make this a poor location for this shy turtle.

<u>Chrysemys picta marginata</u> Midland Painted Turtle
Very abundant throughout the marsh area, frequently seen sunning on the edge of the cattails. Nests along Highway 401 and on islands in the marsh.

<u>Emydoidea blandingi</u> Blanding's Turtle
Two freshly dead turtles by the side of Highway 401 were the only evidence of this turtle's presence.

<u>Natrix sipedon sipedon</u> Northern Water Snake
Commonly seen sunning either along Highway 401 or out in the middle of the marsh.

<u>Storeria dekayi dekayi</u> Northern Brown Snake
Present in surrounding upland areas in unknown numbers

<u>Thamnophis sirtalis sirtalis</u> Eastern Garter Snake
Very abundant in a variety of habitats surrounding the marsh but particularly along Highway 401.

<u>Lampropeltis triangulum triangulum</u> Eastern Milk Snake
Present along the edge of Highway 401 where they appeared to be denning.

<u>Plethodon cinereus cinereus</u> Red-backed Salamander
Very abundant along the limestone cliffs on both sides of the Cataraqui River.

<u>Bufo americanus</u> American Toad
Seen occasionally along the edges of the marsh.

<u>Hyla crucifer</u> Spring Peeper
Heard in large numbers at the edge of the marsh southeast of Highway 401.

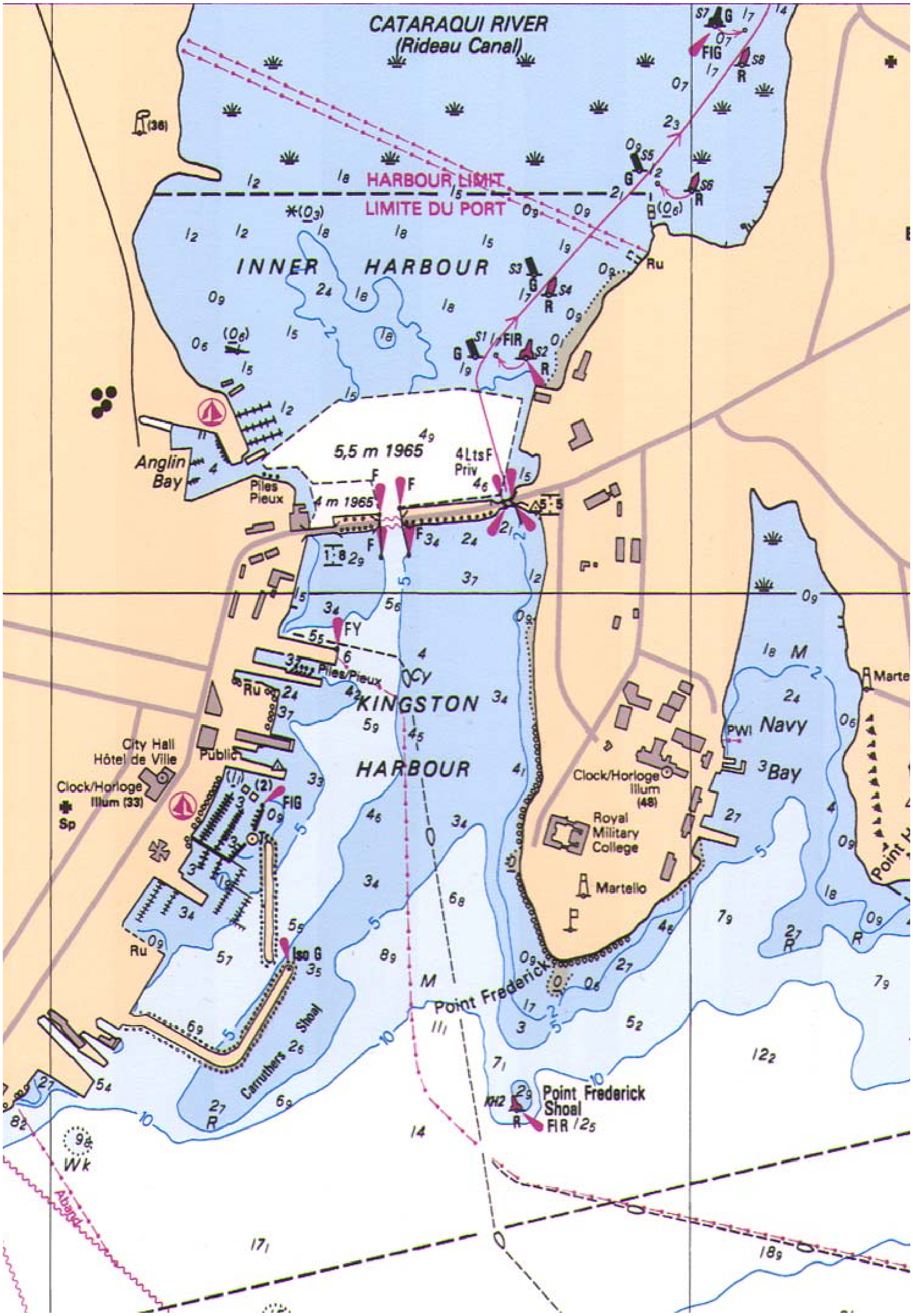
<u>Pseudacris triseriata triseriata</u> Western Chorus Frog
Present in a sedge meadow near the woodlot cut off to the south of Highway 401, and also in ponds above the eastern limestone ridge.

<u>Rana catesbeiana</u> Bullfrog
Present in all streams running through the marsh, though not in great numbers in any of them.

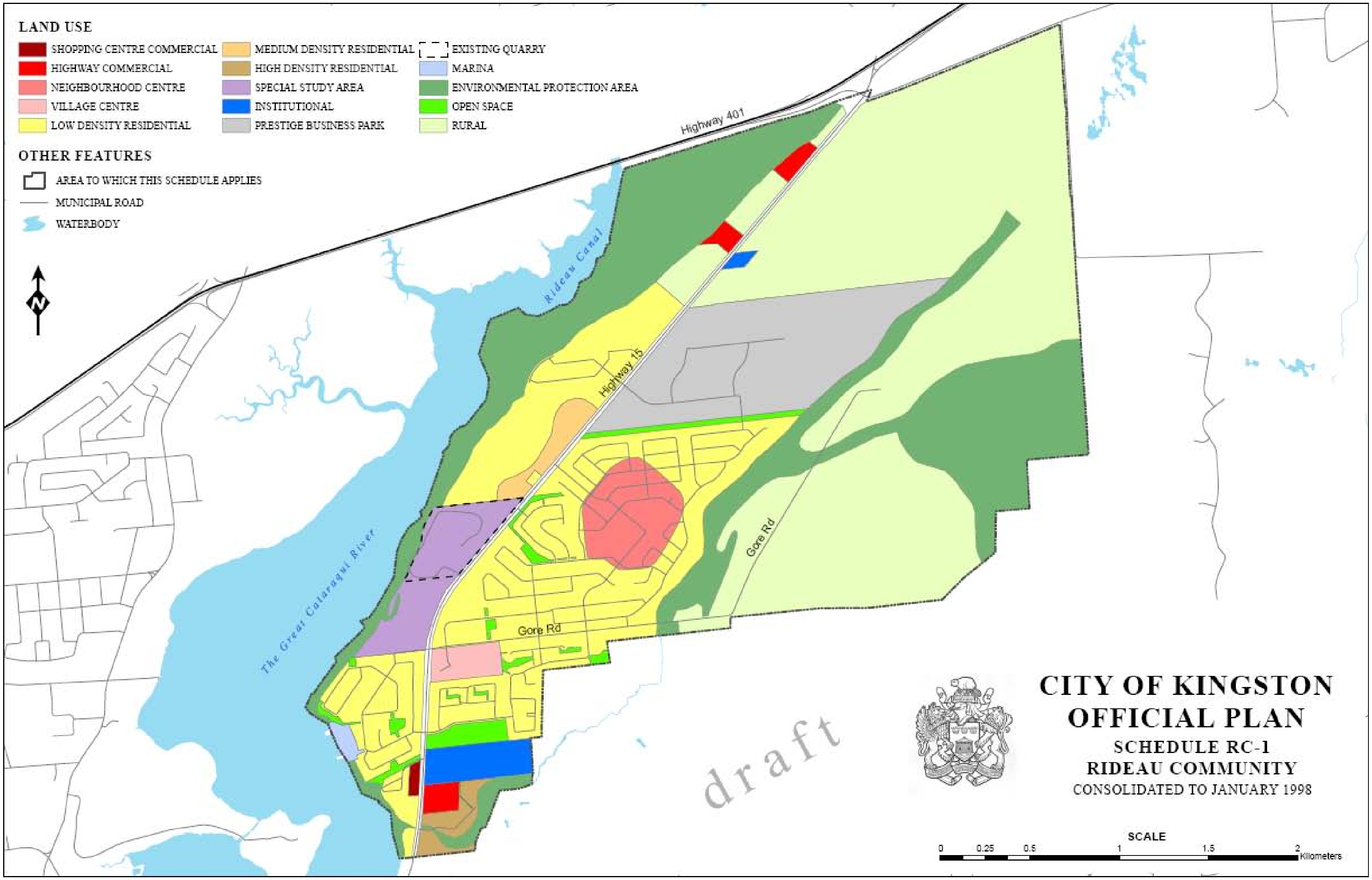
<u>Rana clamitans melanota</u> Green Frog
Present in the marsh in unknown numbers on both sides of the river south of Highway 401.

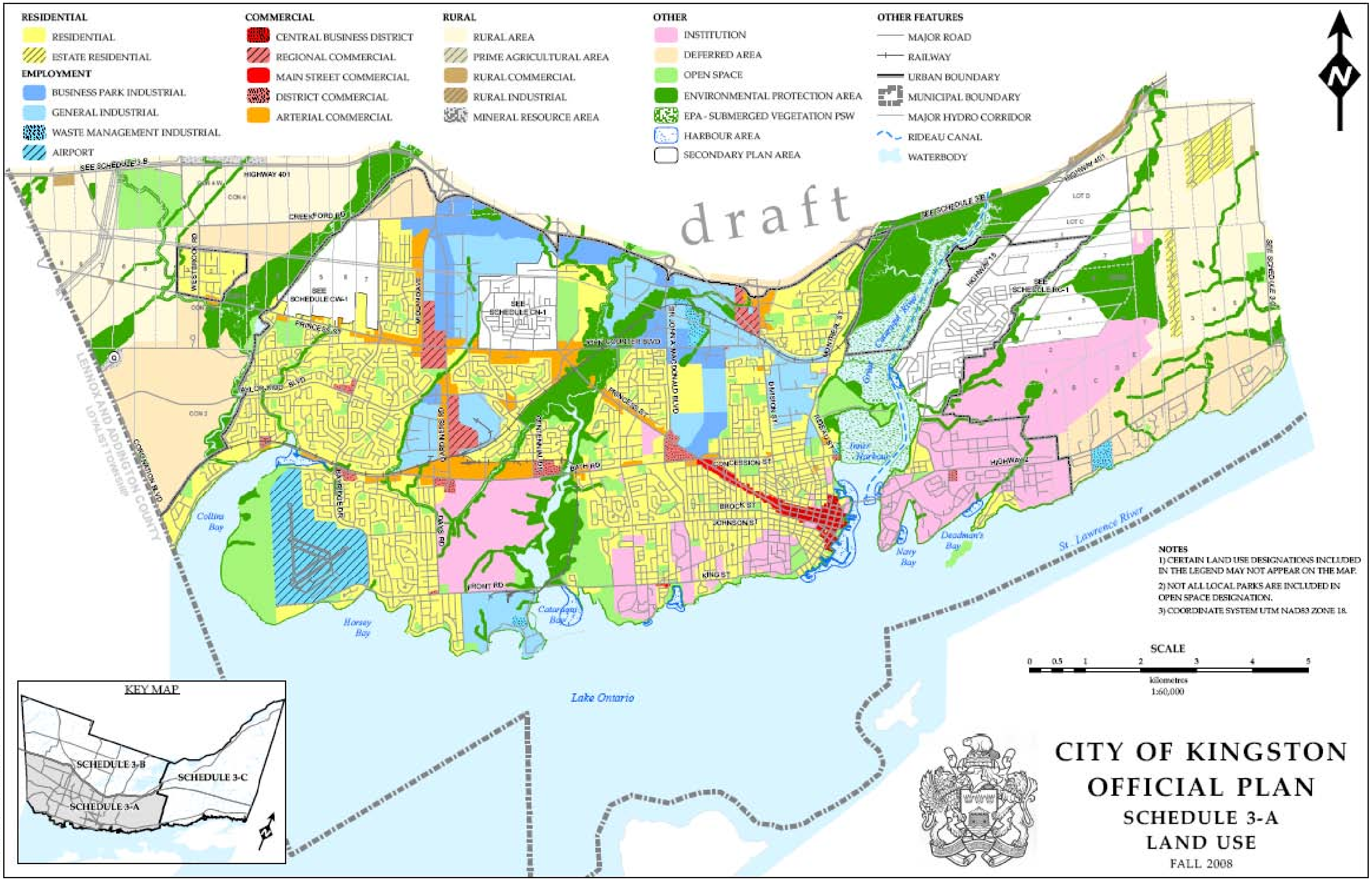
<u>Rana pipiens</u> Leopard Frog
Abundant breeder throughout the marsh and along the river shores.

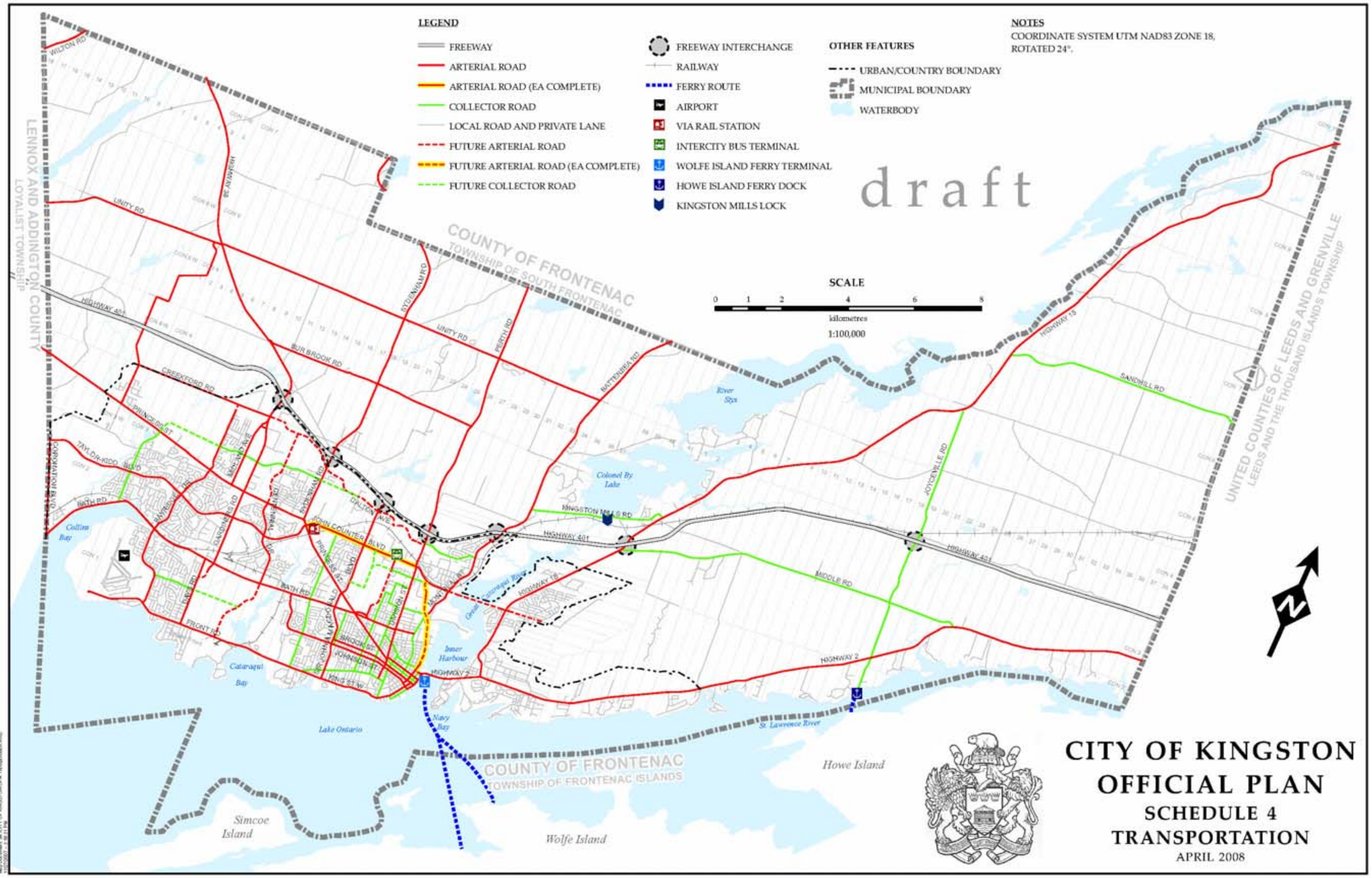
Canadian Hydrographic Service, 1990

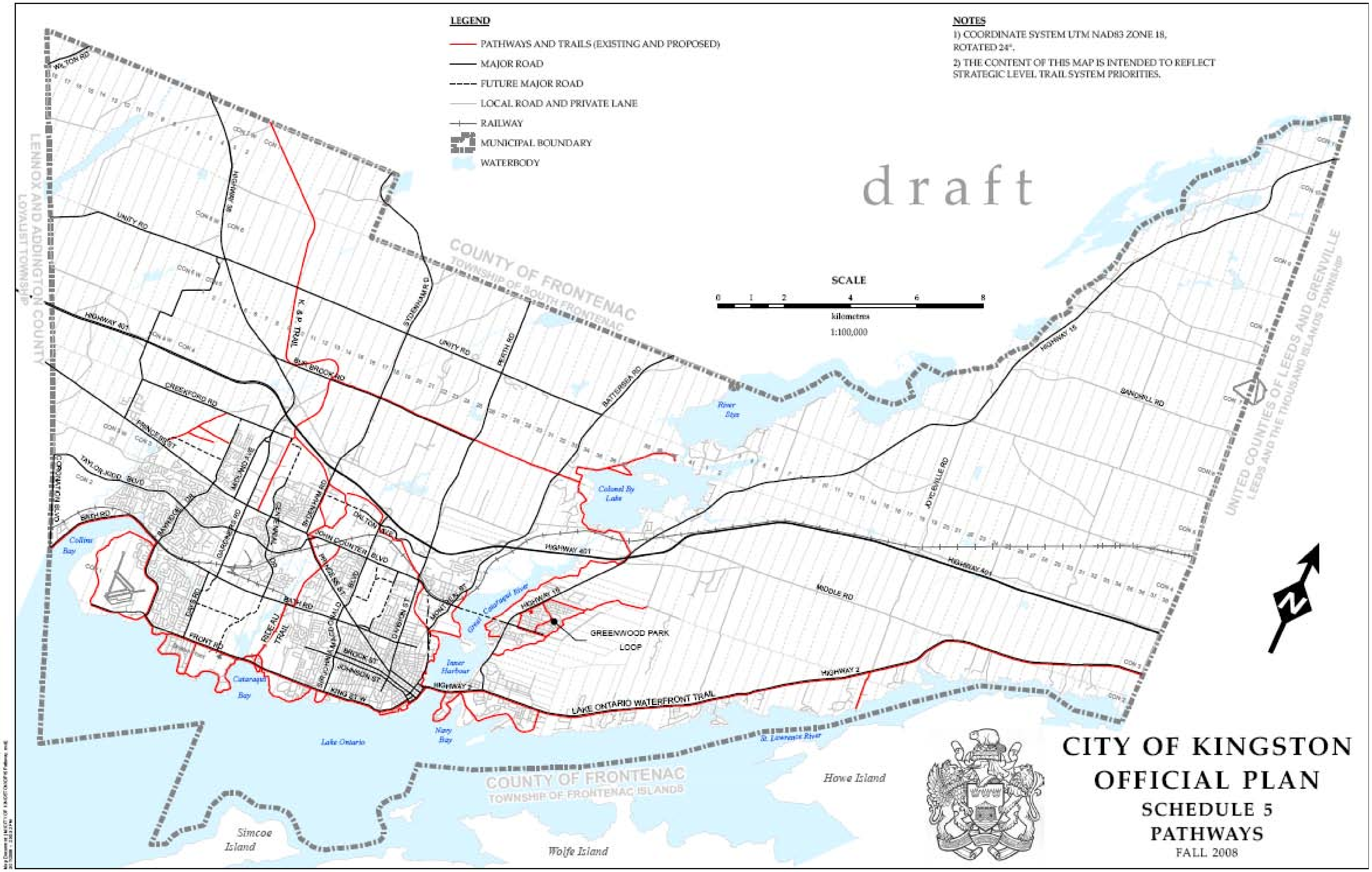

CATARAQUI RIVER
(Rideau Canal)
HARBOUR LIMIT
LIMITE DU PORT
INNER HARBOUR
Anglin Bay
Piles
Pieux
5,5 m 1965
4 m 1965
4LtsF
Priv
KINGSTON HARBOUR
City Hall
Hôtel de Ville
Clock/Horloge
Illum (33)
Public
Clock/Horloge
Illum
(48)
Royal
Military
College
Martello
Navy Bay
Point Frederick
Carruthers Shoal
Point Frederick
Shoal
Aband
Wk

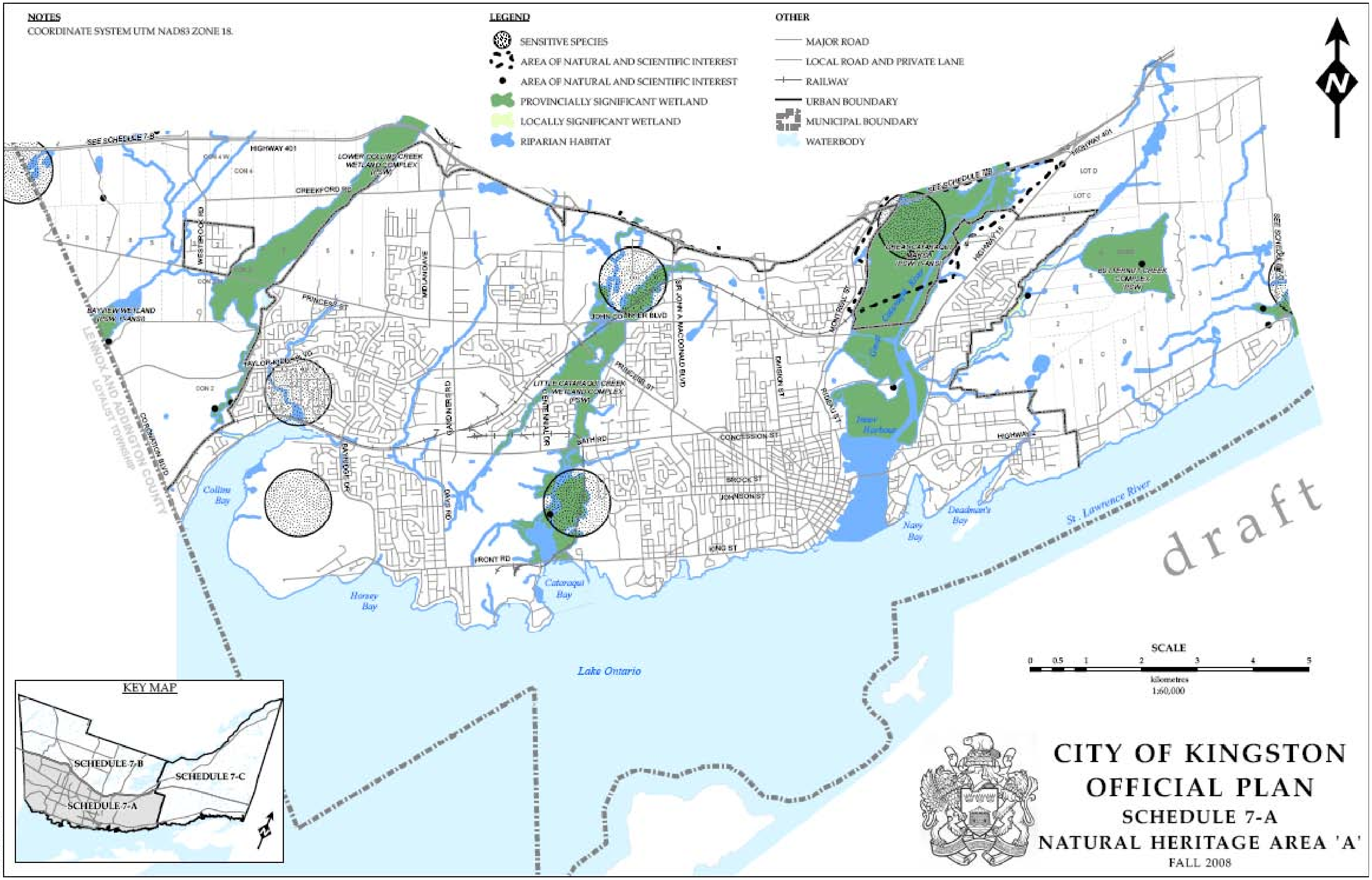
City of Kingston, 2010

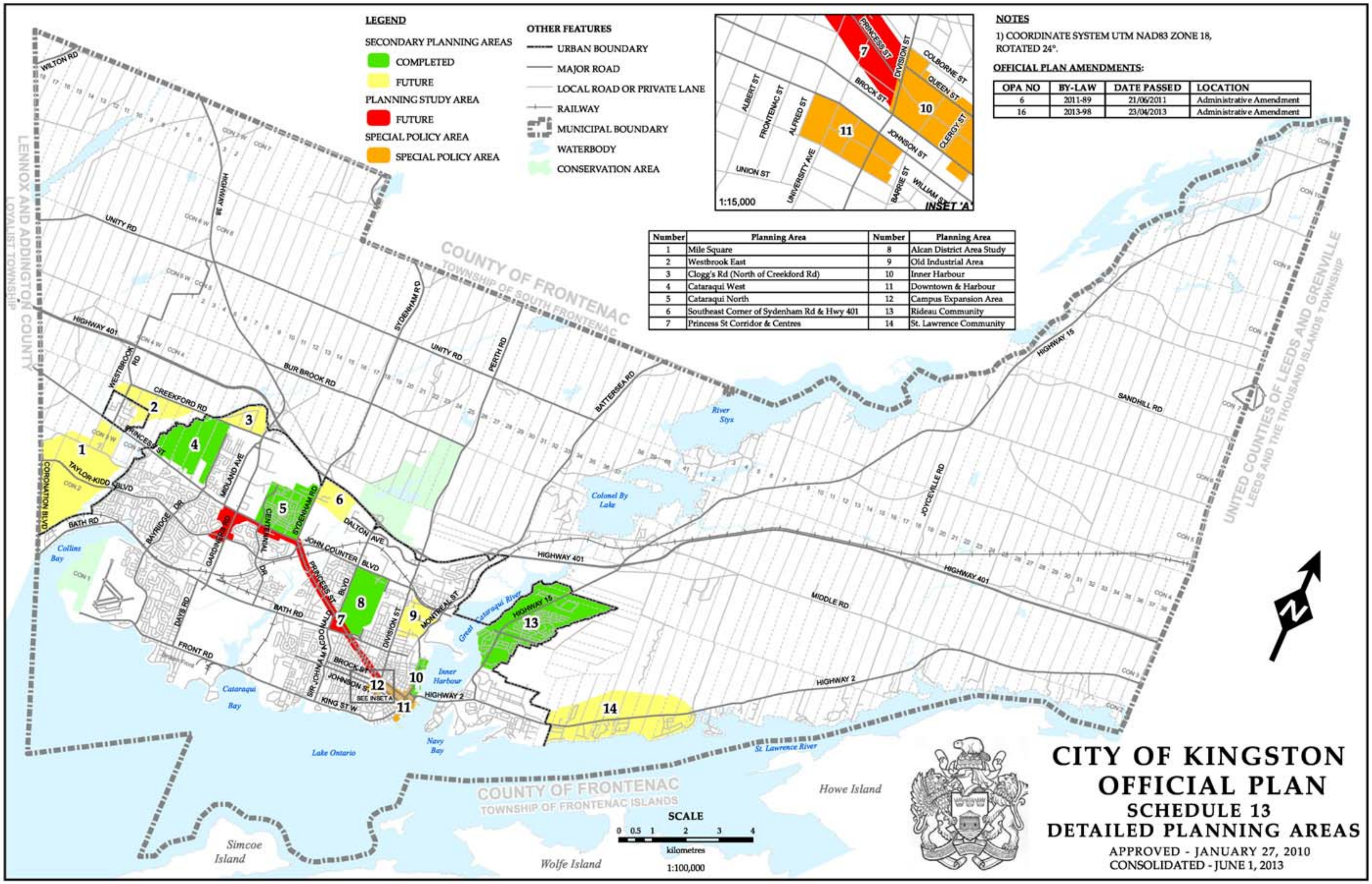

LAND USE
SHOPPING CENTRE COMMERCIAL
HIGHWAY COMMERCIAL
NEIGHBOURHOOD CENTRE
VILLAGE CENTRE
LOW DENSITY RESIDENTIAL
MEDIUM DENSITY RESIDENTIAL
HIGH DENSITY RESIDENTIAL
SPECIAL STUDY AREA
INSTITUTIONAL
PRESTIGE BUSINESS PARK
EXISTING QUARRY
MARINA
ENVIRONMENTAL PROTECTION AREA
OPEN SPACE
RURAL
OTHER FEATURES
AREA TO WHICH THIS SCHEDULE APPLIES
MUNICIPAL ROAD
WATERBODY
N
Highway 401
Rideau Canal
Highway 15
The Great Cataraqui River
Gore Rd
Gore Rd
draft
CITY OF KINGSTON
OFFICIAL PLAN
SCHEDULE RC-1
RIDEAU COMMUNITY
CONSOLIDATED TO JANUARY 1998
SCALE
0 0.25 0.5 1 1.5 2 Kilometers


RESIDENTIAL
RESIDENTIAL
ESTATE RESIDENTIAL
EMPLOYMENT
BUSINESS PARK INDUSTRIAL
GENERAL INDUSTRIAL
WASTE MANAGEMENT INDUSTRIAL
AIRPORT
COMMERCIAL
CENTRAL BUSINESS DISTRICT
REGIONAL COMMERCIAL
MAIN STREET COMMERCIAL
DISTRICT COMMERCIAL
ARTERIAL COMMERCIAL
RURAL
RURAL AREA
PRIME AGRICULTURAL AREA
RURAL COMMERCIAL
RURAL INDUSTRIAL
MINERAL RESOURCE AREA
OTHER
INSTITUTION
DEFERRED AREA
OPEN SPACE
ENVIRONMENTAL PROTECTION AREA
EPA - SUBMERGED VEGETATION PSW
HARBOUR AREA
SECONDARY PLAN AREA
OTHER FEATURES
MAJOR ROAD
RAILWAY
URBAN BOUNDARY
MUNICIPAL BOUNDARY
MAJOR HYDRO CORRIDOR
RIDEAU CANAL
WATERBODY
draft
HIGHWAY 401
PRINCESS ST
BATH RD
CONCESSION ST
BROCK ST
JOHNSON ST
KING ST
FRONT RD
HIGHWAY 2
HIGHWAY 15
SEE SCHEDULE CW-1
SEE SCHEDULE CN-1
SEE SCHEDULE RC-1
LENNOX AND ADDINGTON COUNTY
LOYALIST TOWNSHIP
Collins Bay
Horsey Bay
Cataraqui Bay
Inner Harbour
Navy Bay
Deadman's Bay
St. Lawrence River
Lake Ontario
NOTES
1) CERTAIN LAND USE DESIGNATIONS INCLUDED IN THE LEGEND MAY NOT APPEAR ON THE MAP.
2) NOT ALL LOCAL PARKS ARE INCLUDED IN OPEN SPACE DESIGNATION.
3) COORDINATE SYSTEM UTM NAD83 ZONE 18.
SCALE
0 0.5 1 2 3 4 5
kilometres
1:60,000
KEY MAP
SCHEDULE 3-B
SCHEDULE 3-C
SCHEDULE 3-A
CITY OF KINGSTON
OFFICIAL PLAN
SCHEDULE 3-A
LAND USE
FALL 2008


LEGEND
FREEWAY
ARTERIAL ROAD
ARTERIAL ROAD (EA COMPLETE)
COLLECTOR ROAD
LOCAL ROAD AND PRIVATE LANE
FUTURE ARTERIAL ROAD
FUTURE ARTERIAL ROAD (EA COMPLETE)
FUTURE COLLECTOR ROAD
FREEWAY INTERCHANGE
RAILWAY
FERRY ROUTE
AIRPORT
VIA RAIL STATION
INTERCITY BUS TERMINAL
WOLFE ISLAND FERRY TERMINAL
HOWE ISLAND FERRY DOCK
KINGSTON MILLS LOCK
OTHER FEATURES
URBAN/COUNTRY BOUNDARY
MUNICIPAL BOUNDARY
WATERBODY
NOTES
COORDINATE SYSTEM UTM NAD83 ZONE 18, ROTATED 24°.
draft
SCALE
kilometres
1:100,000
COUNTY OF FRONTENAC
TOWNSHIP OF SOUTH FRONTENAC
LENNOX AND ADDINGTON COUNTY
LOYALIST TOWNSHIP
UNITED COUNTIES OF LEEDS AND GRENVILLE
LEEDS AND THE THOUSAND ISLANDS TOWNSHIP
COUNTY OF FRONTENAC
TOWNSHIP OF FRONTENAC ISLANDS
HIGHWAY 401
UNITY RD
HIGHWAY 15
SANDHILL RD
MIDDLE RD
HIGHWAY 2
KINGSTON MILLS RD
JOHN COUNTER BLVD
BATH RD
FRONT RD
PRINCESS ST
TAYLOR-KIDD BLVD
River Styx
Colonel By Lake
Collins Bay
Cataraqui Bay
Inner Harbour
Navy Bay
Lake Ontario
St. Lawrence River
Howe Island
Wolfe Island
Simcoe Island
CITY OF KINGSTON
OFFICIAL PLAN
SCHEDULE 4
TRANSPORTATION
APRIL 2008


LEGEND
PATHWAYS AND TRAILS (EXISTING AND PROPOSED)
MAJOR ROAD
FUTURE MAJOR ROAD
LOCAL ROAD AND PRIVATE LANE
RAILWAY
MUNICIPAL BOUNDARY
WATERBODY
NOTES
1) COORDINATE SYSTEM UTM NAD83 ZONE 18, ROTATED 24°.
2) THE CONTENT OF THIS MAP IS INTENDED TO REFLECT STRATEGIC LEVEL TRAIL SYSTEM PRIORITIES.
draft
SCALE
0 1 2 4 6 8
kilometres
1:100,000
COUNTY OF FRONTENAC
TOWNSHIP OF SOUTH FRONTENAC
LENNOX AND ADDINGTON COUNTY
LOYALIST TOWNSHIP
UNITED COUNTIES OF LEEDS AND GRENVILLE
LEEDS AND THE THOUSAND ISLANDS TOWNSHIP
COUNTY OF FRONTENAC
TOWNSHIP OF FRONTENAC ISLANDS
HIGHWAY 401
HIGHWAY 15
HIGHWAY 2
K & P TRAIL
LAKE ONTARIO WATERFRONT TRAIL
GREENWOOD PARK LOOP
Colonel By Lake
Lake Ontario
Howe Island
Wolfe Island
Simcoe Island
CITY OF KINGSTON
OFFICIAL PLAN
SCHEDULE 5
PATHWAYS
FALL 2008

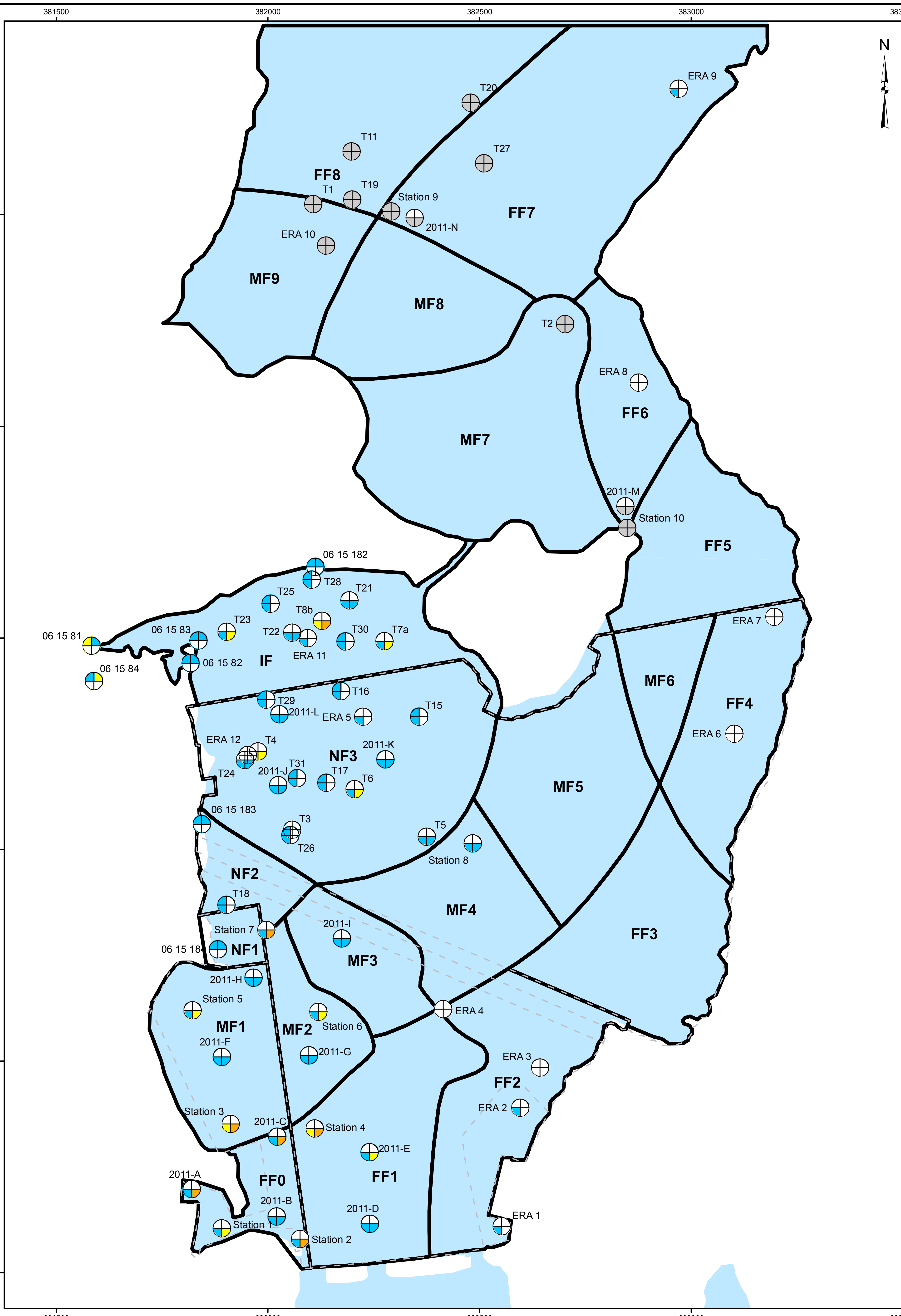

NOTES
COORDINATE SYSTEM UTM NAD83 ZONE 18.
LEGEND
SENSITIVE SPECIES
AREA OF NATURAL AND SCIENTIFIC INTEREST
AREA OF NATURAL AND SCIENTIFIC INTEREST
PROVINCIALLY SIGNIFICANT WETLAND
LOCALLY SIGNIFICANT WETLAND
RIPARIAN HABITAT
OTHER
MAJOR ROAD
LOCAL ROAD AND PRIVATE LANE
RAILWAY
URBAN BOUNDARY
MUNICIPAL BOUNDARY
WATERBODY
Lake Ontario
St. Lawrence River
Collins Bay
Cataraqui Bay
Navy Bay
Deadman's Bay
Inner Harbour
SCALE
0 0.5 1 2 3 4 5
kilometres
1:60,000
KEY MAP
SCHEDULE 7-B
SCHEDULE 7-C
SCHEDULE 7-A
draft
CITY OF KINGSTON
OFFICIAL PLAN
SCHEDULE 7-A
NATURAL HERITAGE AREA 'A'
FALL 2008



OPA NO	BY-LAW	DATE PASSED	LOCATION
6	2011-89	21/06/2011	Administrative Amendment
16	2013-98	23/04/2013	Administrative Amendment

Number	Planning Area	Number	Planning Area
1	Mile Square	8	Alcan District Area Study
2	Westbrook East	9	Old Industrial Area
3	Clogg's Rd (North of Creekford Rd)	10	Inner Harbour
4	Cataraqui West	11	Downtown & Harbour
5	Cataraqui North	12	Campus Expansion Area
6	Southeast Corner of Sydenham Rd & Hwy 401	13	Rideau Community
7	Princess St Corridor & Centres	14	St. Lawrence Community

Golder Associates, 2012



LEGEND

Sediment Toxicity - Survival

Hexagenia (21 day) | C. tentans (10 day)
H. azteca | C. tentans (20 day)

- <20% Reduction
- 20-50% Reduction
- > 50% Reduction
- Reference
- No Value

200 0 200

SCALE 1:8,500 METRES

DRAFT

REFERENCE

Projection: UTM Zone 18 Datum: NAD 83

PROJECT

PWGSC
KINGSTON INNER HARBOUR
KINGSTON, ONTARIO

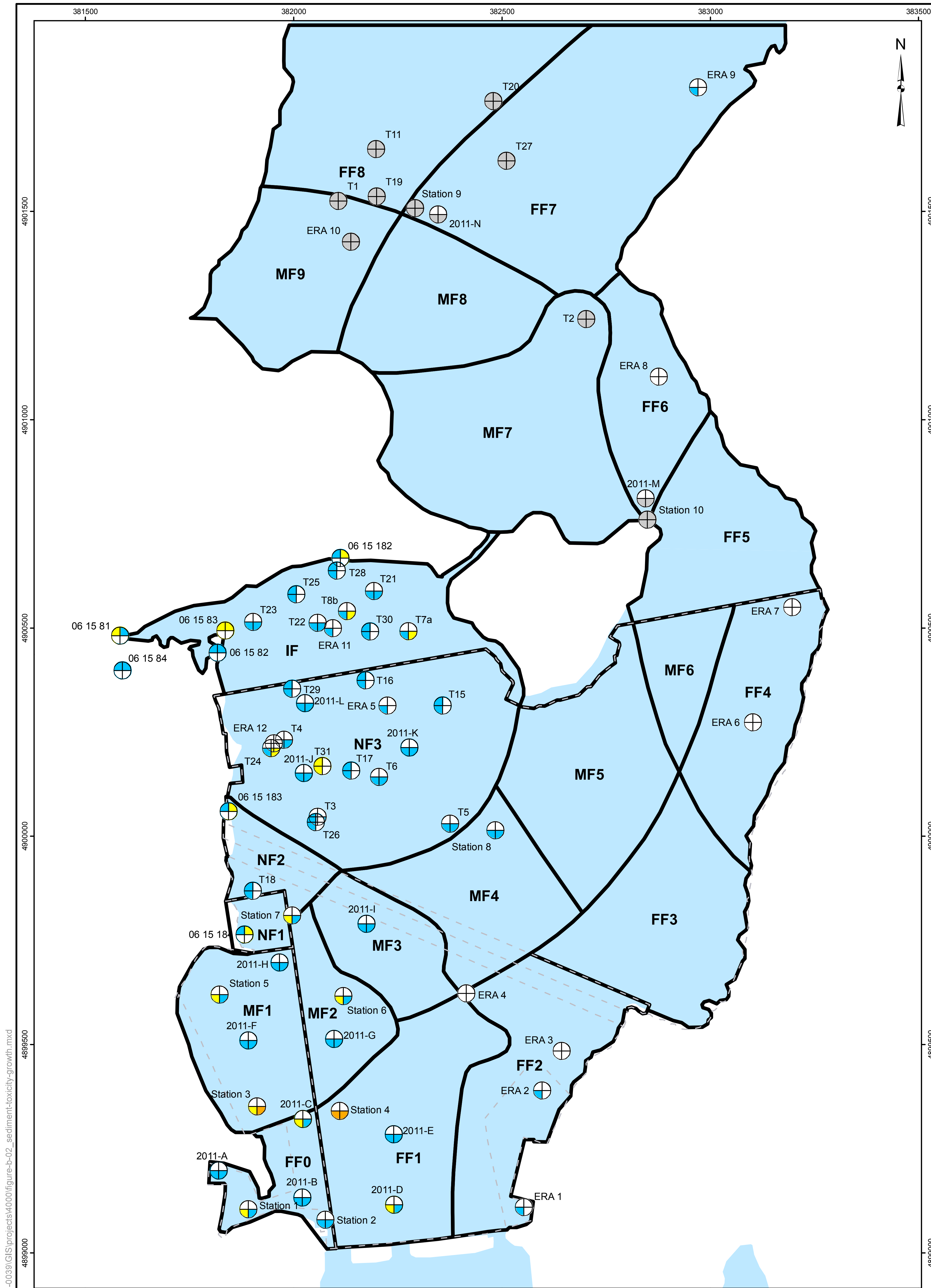
TITLE

SEDIMENT TOXICITY - SURVIVAL

Golder Associates
Greater Vancouver Office, B.C.

PROJECT No. 11-1122-0154			PHASE No. 4000	
DESIGN	VM	31JAN12	SCALE AS SHOWN	REV. 0
GIS	DSC	01FEB12	**FIGURE B-1**	
CHECK				
REVIEW				

N:\Bur-Graphics\Projects\2010\1421\10-1421-0039\GIS\projects\4000\figure-b-01_sediment-toxicity-survival.mxd



LEGEND

Sediment Toxicity - Growth

Hexagenia (21 day) | C. tentans (10 day)
H. azteca | C. tentans (20 day)

- <20% Reduction
- 20-50% Reduction
- > 50% Reduction
- Reference
- No Value

200 0 200

SCALE 1:8,500 METRES

DRAFT

REFERENCE

Projection: UTM Zone 18 Datum: NAD 83

PROJECT

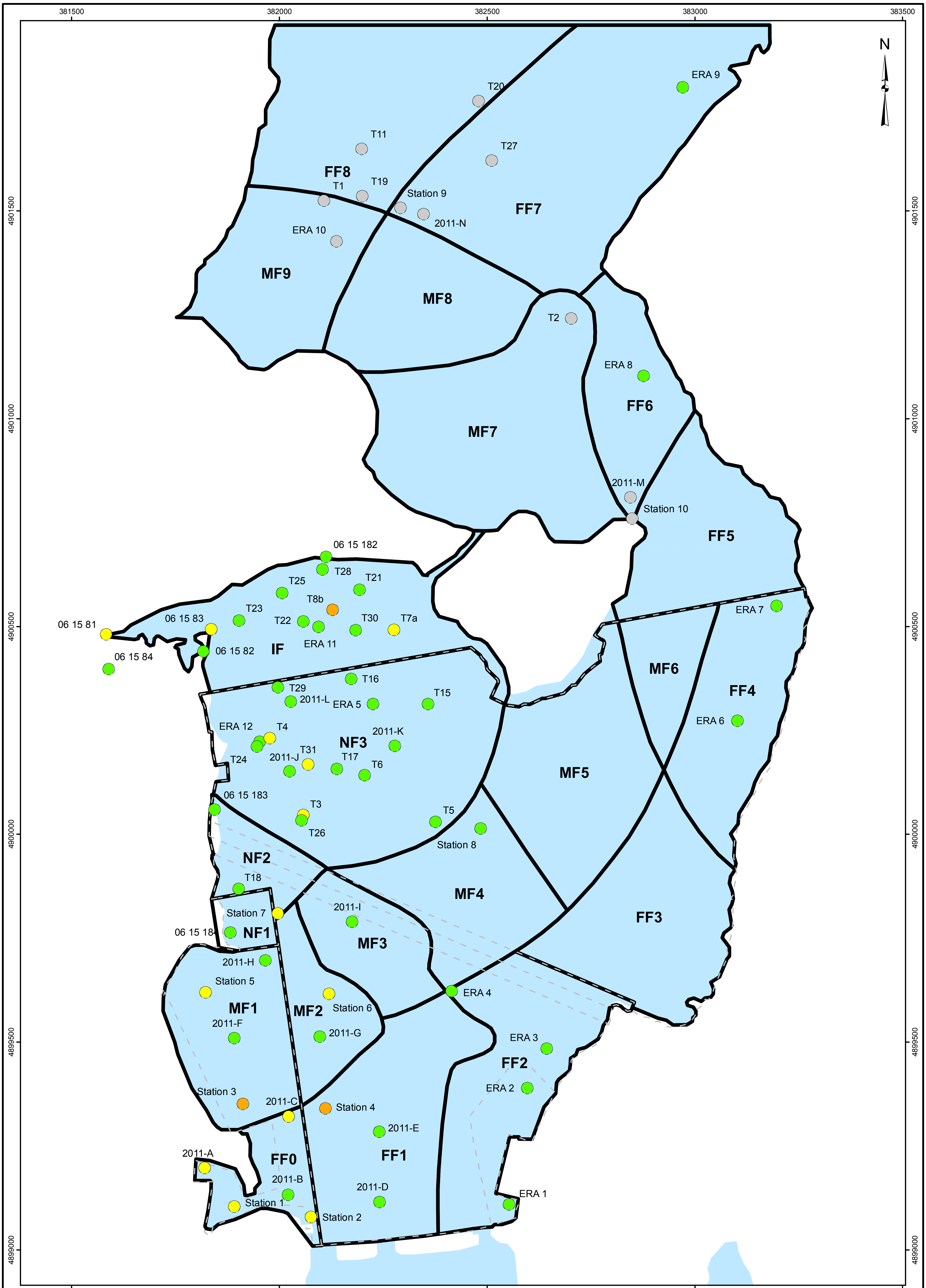
PWGSC
KINGSTON INNER HARBOUR
KINGSTON, ONTARIO

TITLE

SEDIMENT TOXICITY - GROWTH

Golder Associates
Greater Vancouver Office, B.C.

PROJECT No. 11-1122-0154			PHASE No. 4000	
DESIGN	VM	31JAN12	SCALE AS SHOWN	REV. 0
GIS	DSC	01FEB12	**FIGURE B-2**	
CHECK				
REVIEW				



LEGEND

Overall Toxicity

- Significant: Multiple tests/endpoints exhibit major toxicological effects
- Potential: Multiple tests/endpoints exhibit minor toxicological effects and/or one test/endpoint exhibits major effects
- Negligible: Minor toxicological effects observed in no more than one endpoint
- Reference

200 0 200

SCALE 1:8,500 METRES

REFERENCE

Projection: UTM Zone 18 Datum: NAD 83

DRAFT

PROJECT

PWGSC
KINGSTON INNER HARBOUR
KINGSTON, ONTARIO

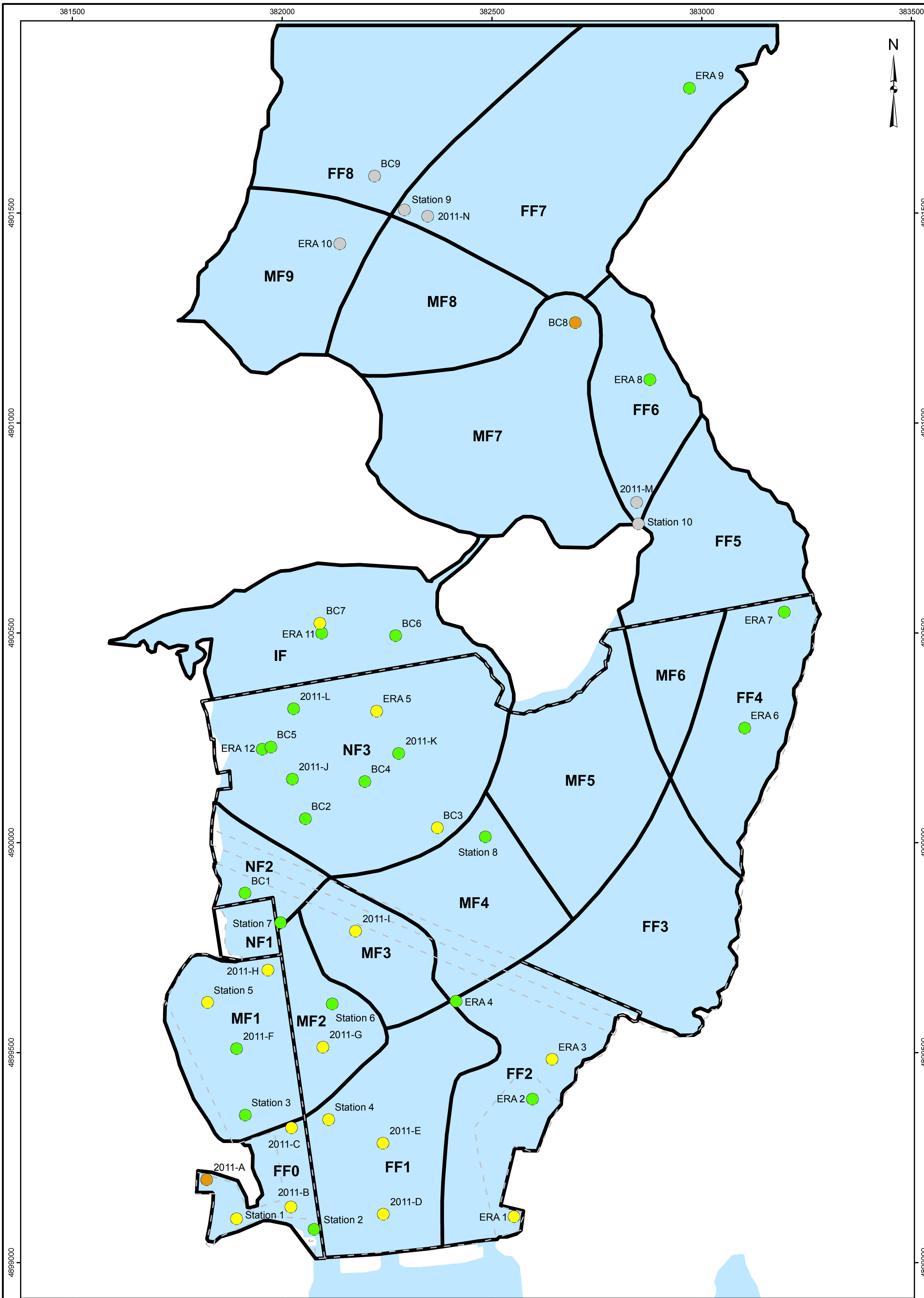
TITLE

SITE SPECIFIC ORDINAL RANKINGS FOR WOE CATEGORIZATIONS FOR TOXICITY

Golder Associates
Greater Vancouver Office, B.C.

PROJECT No. 11-1122-0154			PHASE No. 4000	
DESIGN	VM	31JAN12	SCALE AS SHOWN	REV. 0
GIS	DSC	01FEB12	**FIGURE B-3**	
CHECK				
REVIEW				

N:\Bur-Graphics\Projects\2010\1421\10-1421-0039\GIS\projects\4000\figure-b-03_overall-toxicity.mxd



N:\Bur-Graphics\Projects\2011\1122\11-1122-0154\GIS\Mapping\MXD\WaterQuality\figure-b-08_overall-benthic-community.mxd

LEGEND

Benthic Community

- Significant: Multiple significant differences in benthic indices
- Potential: Multiple slight differences in more than one index and/or one major difference
- Negligible: Equivalent to reference station or slight difference in no more than one index
- Reference

200 0 200

SCALE 1:8,500 METRES

REFERENCE

Projection: UTM Zone 18 Datum: NAD 83

PROJECT

PWGSC
KINGSTON INNER HARBOUR
KINGSTON, ONTARIO

TITLE

SITE SPECIFIC ORDINAL RANKINGS FOR WOE CATEGORIZATIONS FOR THE BENTHIC COMMUNITY

Golder Associates
Greater Vancouver Office, B.C.

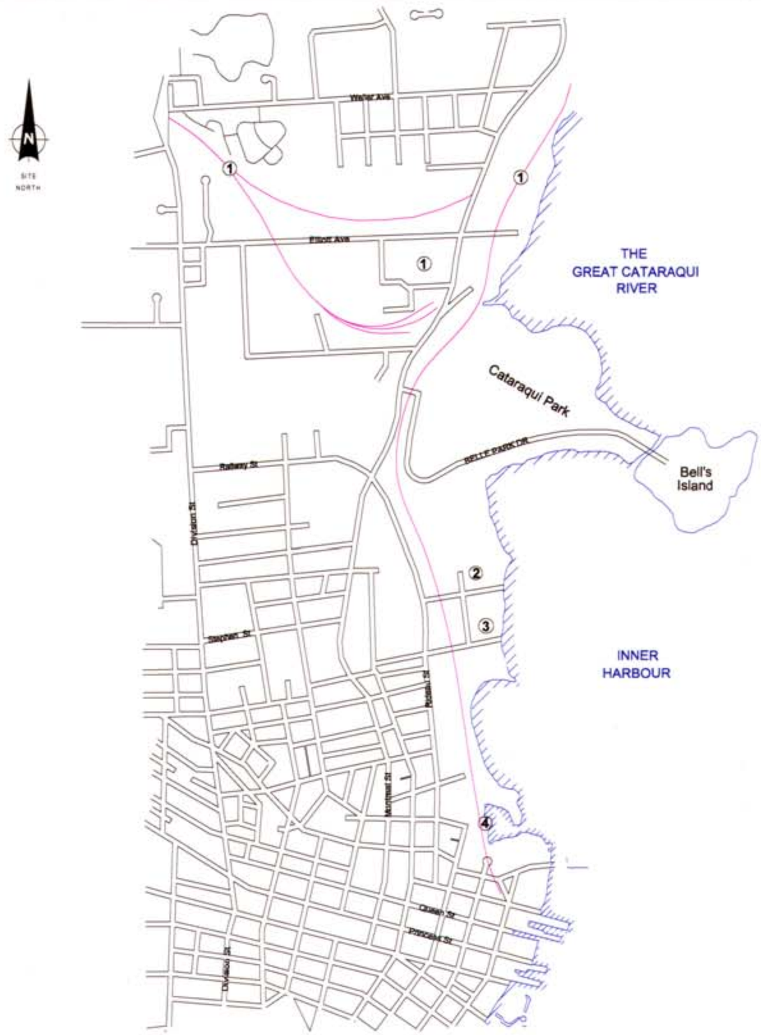
PROJECT No. 11-1122-0154			PHASE No. 4000	
DESIGN	SS	05JAN12	SCALE AS SHOWN	REV. 0
GIS	MH	16FEB12	**FIGURE B-8**	
CHECK				
REVIEW				

Hodson, 1998a

Table 8. Species of fish endemic to the Great Cataraqui River (A. Keast, as quoted in Blancher (1989)).

Fish Species		Included in Commercial Fishing Permit NP 5211	Captured by P. Hodson in 1984 Experimental Sampling
Bowfin	*Amia calva*	X	X
Log perch	*Percina caprodes*		
Common shiner	*Notropis cornutus*		
Golden shiner	*Notemigonus crysoleucus*		
Central Mudminnow	*Umbra limi*		
Stickleback	*Eucalia inconstans*		
Brown Bullhead	*Ictalurus nebulosus*	X	X
Yellow Bullhead	*Ictalurus natalis*	X	
Gizzard Shad	*Dorosoma cepedianum*		X
Alewife	*Alosa pseudoharengus*	X	
American eel	*Anguilla rostrata*	X	
Carp	*Cyprinus carpio*	X	X
White sucker	*Catastomus commersoni*	X	
Muskellunge	*Esox masquinongy*		
Northern pike	*Esox lucius*		X
Yellow pickerel	*Stizostedion vitreum*		X
White perch	*Morone americana*	X	
White bass	*Morone chrysops*	X	
Yellow perch	*Perca flavescans*	X	
Bluegill	*Lepomis macrochirus*	X	
Pumpkinseed	*Lepomis gibbosus*	X	
Black crappie	*Pomoxis nigromaculatus*		
Rock bass	*Ambloplites rupestris*	X	
Largemouth bass	*Micropterus salmoides*		
Smallmouth bass	*Micropterus dolomieui*		X
Freshwater drum	*Ambloplites rupestris*	X	

Malroz, 1999



Legend:

1. **Grand Trunk Railway**
2. **Frontenac Smelting Works**
3. **Tannery**
4. **Planing Mill**

Historic information from: C.R. Allen, c1880
City of Kingston Ont. Scale 10 chains to an inch

Note: historic features superimposed on map of Study Area showing current features

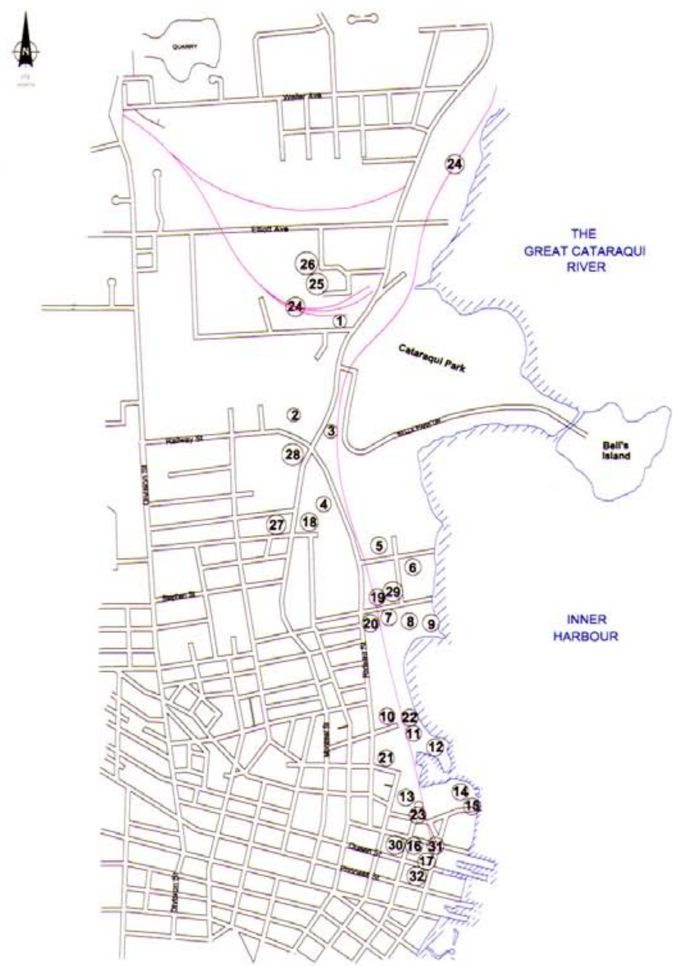
Inner Harbour (West Shore)
Industrial Land Uses
Circa 1880

Environmental Impact Study
Cataraqui Park, Kingston, Ontario

MALROZ

Date: 99/08
File: 218/733/S-2/

Figure:
2.3



Legend:

1. CN Rail storage
2. K-D Mfg.Co.Ltd.
3. Elders Beverage Ltd.
4. C.E. MacPherson Ltd.
5. Kingston Tannery A. Davis and Sons Ltd.
6. Dye Chemical Co. of Canada Inc.
7. Canadian Oil Company Limited
8. City Service Oil Co. Ltd.
9. Hield Bros. (Canada) Ltd.
10. Imperial Oil Limited
11. Shell Oil Co. of Canada Ltd.
12. Canadian Dredge and Dock Co Ltd.
13. CNR (freight sheds and sidings)
14. James Sowards Coal Co. Ltd
15. Knapp's Boats
16. Drury's Fuel and Builders Supplies Ltd.
17. Crawford Coal and Fuel Co.
18. Direct Winters Transport Ltd.
19. Rosen Fuels Ltd.
20. National Grocers Co. Ltd.
21. Anglin Company Limited
22. CPR Turn Yard
23. Millard and Lumb Limited
24. CNR Rail Lines
25. Frontenac Floor and Wall Tile Ltd.
26. Monarch Battery MFG. Co. Ltd.
27. Dept. of Highways (Ontario) Warehouse
28. I. Cohen & Co. (scrap iron storage)
29. McColl & Frontenac Oil Co. Ltd.
30. Public Utilities Commission Electric, Gas & Water Departments
31. Tweed Milling Co. Ltd. (Grist Mill)
32. W.B. Dalton & Sons Ltd.

Historic information from: 1947 Underwriters Survey Bureau Fire Insurance Maps.

Note: historic features superimposed on map of Study Area showing current features

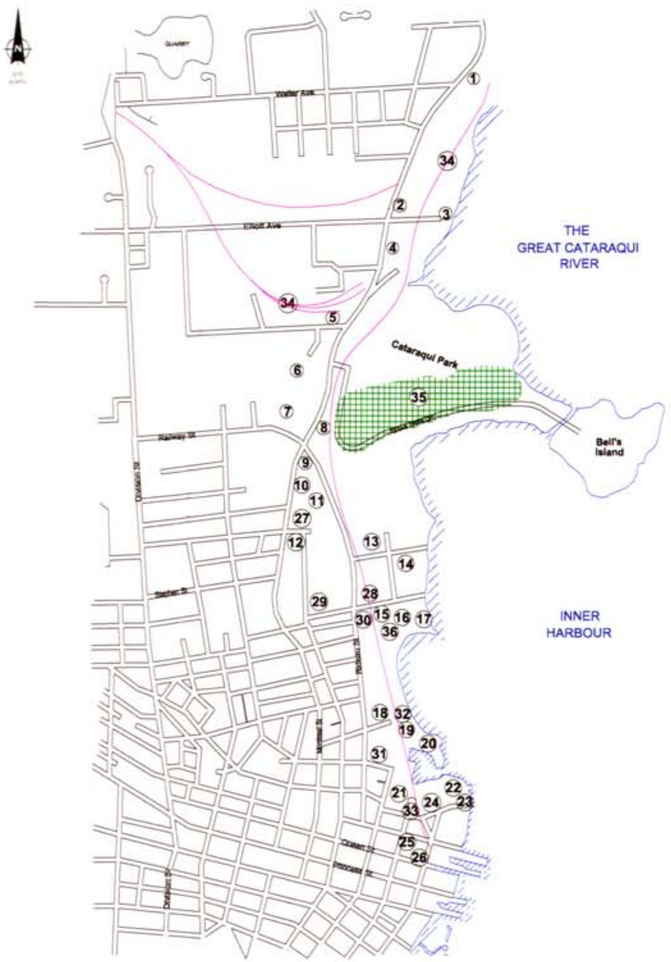
Inner Harbour (West Shore)
Commercial/Industrial Land Uses 1947

Environmental Impact Study
Cataraqui Park, Kingston, Ontario

MALROZ

Figure: **2.4**

Date: 99/08
File: 218/733/S-2/



Legend:

1. F.C. Clancy Fuel Co.
2. N.J. Pollitt Lumber
3. Music's Marina
4. Chown Ltd.
5. Griffith Lumber Ltd.
6. Leduc Bros. Contractors
7. K-D Mfg.Co.Ltd.
8. Elders Beverage Ltd.
9. Bell Telephone Co. of Canada
10. W.H. Keeler Welding Ltd
11. C.E. MacPherson Ltd.
12. Cleland Iron Works
13. A. Davis and Sons Ltd.
14. Dye Chemical Co. of Canada Inc.
15. Canadian Oil Company Limited
16. City Service Oil Co. Ltd.
17. Hield Bros. (Canada) Ltd.
18. Imperial Oil Limited
19. Shell Oil Co. of Canada Ltd.
20. Canadian Dredge and Dock Co Ltd.
21. CNR (freight sheds and sidings)
22. James Sowards Coal Co. Ltd
23. Knapp's Boats
24. Morris Coal Co.
25. Drury's Fuel and Builders Supplies Ltd.
26. Crawford Coal and Fuel Co.
27. Direct Winters Transport Ltd.
28. Rosen Fuels Ltd.
29. Brewers Warehouse Ltd.
30. National Grocers Co. Ltd.
31. Anglin Company Limited
32. CPR Turn Yard
33. Millard and Lumb Limited
34. CNR Rail Lines
35. City of Kingston Waste Disposal Site
36. Supertest Petroleum Corp. Ltd.

Historic information from: 1963 Underwriters Survey Bureau Fire Insurance Maps.

Note: historic features superimposed on map of Study Area showing current features

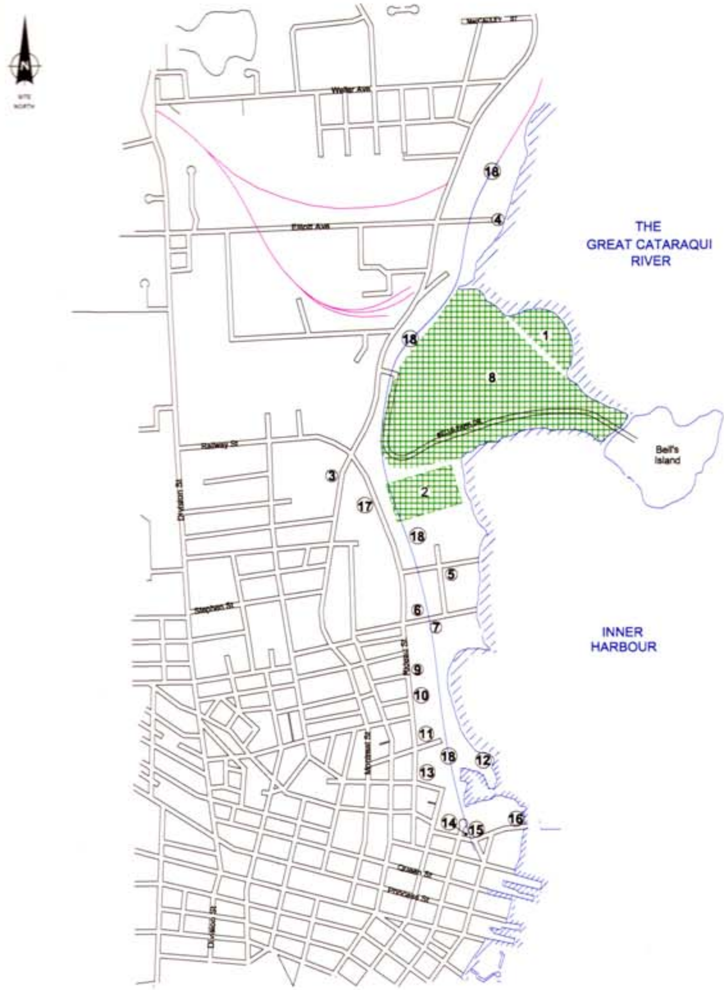
Inner Harbour (West Shore)
Commercial/Industrial Land Uses 1963

Environmental Impact Study
Cataraqui Park, Kingston, Ontario

MALROZ

Date: 99/08
File: 218/733/S-2/

Figure:
2.5



Legend:

1. Federal Dredged Sediments Disposal Site (closed)
2. Arcom Waste Disposal Site (closed)
3. I. Cohen & Co.
4. Music's Marina
5. Dyeco (food colour and chemical manufacturing)
6. Rosen Fuels Ltd.
7. Harold's Demolition
8. City of Kingston Waste Disposal Site (closed)
9. Newton Electric
10. Quintal and England Roofing and Sheet Metal
11. Imperial Oil Limited
12. Canadian Dredge and Dock Co Ltd.
13. S. Anglin Company Limited
14. Millard and Lumb Ltd.
15. CPR Railway Siding
16. Dept. Of National Defence (tender repair facility)
17. C.E. MacPherson Ltd.
18. CNR Rail Lines

Historic Information from:
Totten Sims Hubicki (1984)

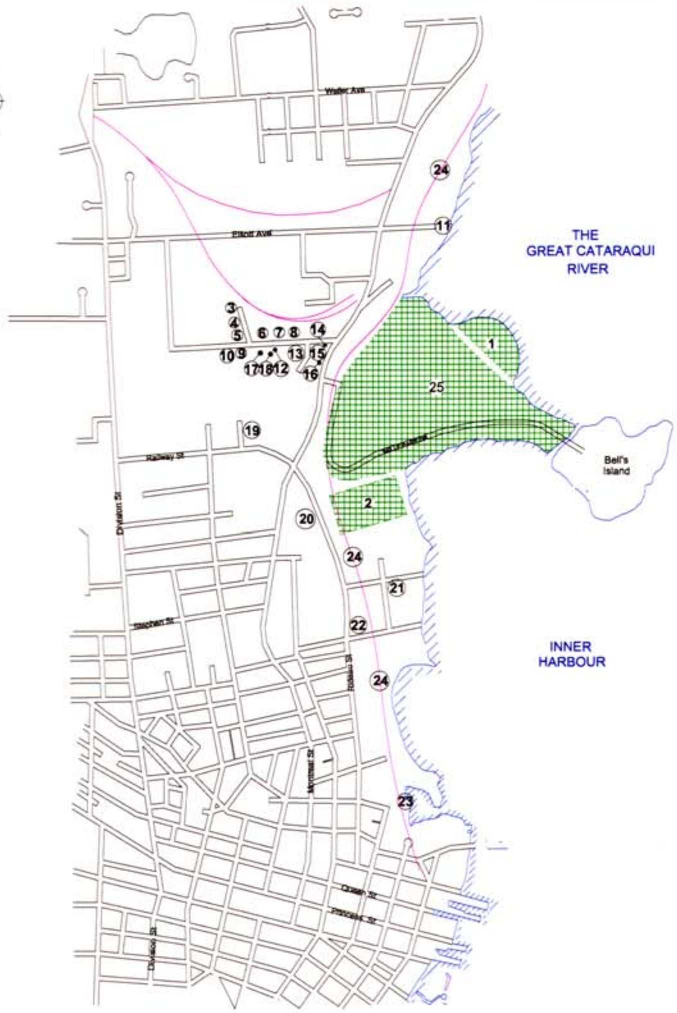
Note: historic features superimposed on map of Study Area showing current features

Inner Harbour (West Shore)
Commercial/Industrial Land Uses 1984

Environmental Impact Study
Cataraqui Park, Kingston, Ontario

MALROZ
Date: 99/08
File: 218/733/S-2/

Figure:
2.6



Legend:

1. Federal Dredged Sediments Disposal Site (closed)
2. Arcom Waste Disposal Site (closed)
3. Malette Electric Ltd.
4. George A. Wright and Sons, General Services Inc.
5. V.J. Mc Mullen Pipeline Welding and Fabricating Ltd.
6. Taugher Controls Ltd.
7. Loach Engineering
8. Albert's Welding and Machining
9. Geo. A. Wright and Sons (Fabricators / Machinists)
10. Limestone Auto Body
11. Music's Marina
12. York Automotive
    Derue Mechanical
    Croxford Machine and Tool
13. Rogan Kitchen and Counter Tops
14. Independent Alternator and Starter
15. Home Bakery Of Kingston
16. H.V. Construction
    Valeira Construction
17. Jensen Building Ltd.
18. Universal Radiator Service Ltd.
19. Weston Bakery
20. C.E. MacPherson Ltd.
21. Dyeco (food colour and chemical manufacturing)
22. Rosen Fuels Ltd.
23. Kingston Marina
24. CNR Rail Line
25. City of Kingston Waste Disposal Site (closed)

Inner Harbour (West Shore)
Commercial/Industrial Land Uses 1997

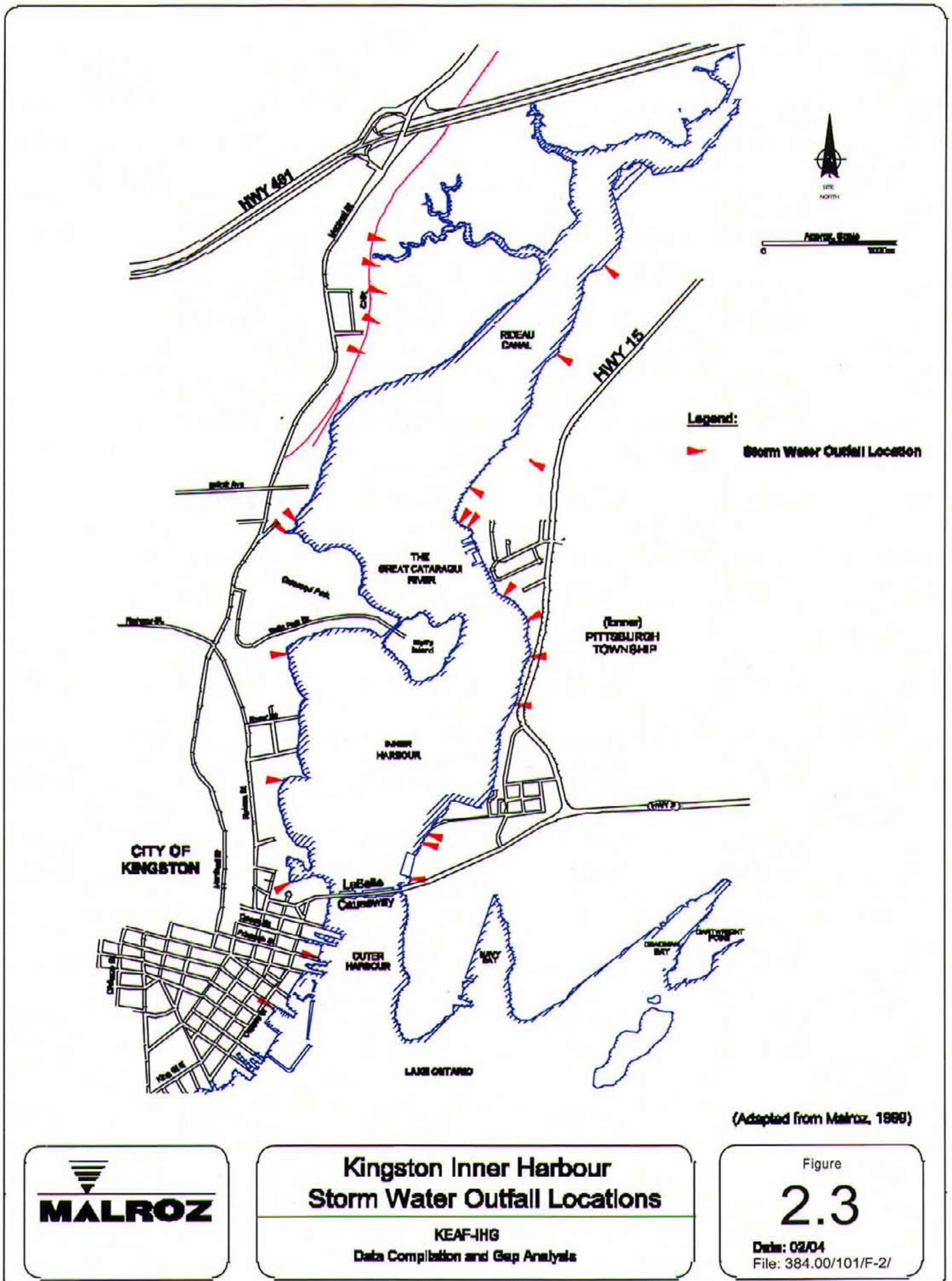
Environmental Impact Study
Cataraqui Park, Kingston, Ontario

MALROZ

Date: 99/08
File: 218/733/S-2/

Figure:
2.7

Malroz, 2003


HWY 401
RIDEAU CANAL
HWY 15
Legend:
Storm Water Outfall Location
THE GREAT CATARAQUI RIVER
(former) PITTSBURGH TOWNSHIP
INNER HARBOUR
CITY OF KINGSTON
LaSalle Causeway
OUTER HARBOUR
LAKE ONTARIO
(Adapted from Malroz, 1999)
MALROZ
Kingston Inner Harbour
Storm Water Outfall Locations
KEAF-IHG
Data Compilation and Gap Analysis
Figure
2.3
Date: 02/04
File: 384.00/101/F-2/

Ontario Ministry of Natural Resources, 2009

Peterborough District Wetland Report

February 10, 2009

Wetland Name: Greater Cataraqui Marsh

Wetland FMF ID: 1251547458

Area Team: Kingston

Edition: Third Edition

Significance: Provincial

Last Evaluated: 2004-MAR

Size (ha): 504

Zone: 18

Easting: 380000

Northing: 4903000

Scoring System: Southern Ontario

Biological Component: 204

Hydrological Component: 73

Social Component: 219

Special Features Component: 250

Total Score: 746

Vegetation Description:

A Provincially significant, Coastal wetland, composed of only one wetland type (100% marsh) (Mudal and Krannitz, 1990).

Vegetation Communities:

Vegetation Communities (Mudal and Krannitz, 1990):
One Form
M1: robust emergents- cattail;
M2: narrow-leaved emergents- grasses;
W1: submergents- milfoil;

Two Forms
M3: robust emergents- cattail, bulrush; narrow-leaved emergents- grasses, sedges;
M4: robust emergents- cattail; free-floating plants- Frogbit;
M5: narrow-leaved emergents- grasses; ground cover- mint, jewelweed;
M6: robust emergents- cattail; ground cover- Purple Loosestrife;
M7: narrow-leaved emergents- sedges, grasses; robust emergents- cattail;
M8: narrow-leaved emergents- Reed Canary Grass; tall shrubs- dogwood;
W2: submergents- milfoil; floating plants- waterlilies;
W3: floating plants- waterlilies; submergents- milfoil;
W4: submergents- milfoil; free-floating plants- duckweed;

Three Forms
M9: robust emergents- cattail; free-floating plants- Frogbit; narrow-leaved emergents- grasses;
M10: robust emergents- cattail; narrow-leaved emergents- grasses, sedges; ground cover- joe-pye weed;
M11: robust emergents- cattail; narrow-leaved emergents- grasses, sedges; broad-leaved emergents- arrowhead;
M12: narrow-leaved emergents- grasses; robust emergents- cattail; ground cover- boneset;
M13: narrow-leaved emergents- Sparganium spp.; submergents- milfoil; robust emergents- Typha spp.;

Four Forms
M14: robust emergents- cattail; narrow-leaved emergents- grasses; ground cover- Marsh Fern; mosses;

Land Formation:

Soils (Mudal and Krannitz, 1990): 20% clays, loams or silts and 80% organic;
Site Type (Mudal and Krannitz, 1990): 100% riverine;

Land Uses:

Offsite Information:

Diversity of Surrounding Habitat (Mudal and Krannitz, 1990):
pasture, abandoned agricultural land, deciduous forest, coniferous forest, urban or cottage development, pits, quarries or mining waste disposal, open lake or deep river, fence rows with cover or shelterbelts, terrain undulating or hilly with ravines, creeks;

Hydrologically connected by surface water to other wetlands, or open water within 1.5 km (Mudal and Krannitz, 1990).

Threats to Communities:

Impairment of natural quality intense in some areas or severe localized water pollution- roads, utility corridor, buildings, channelization, drainage, filling, water pollution, boat wake, periodic erosion (Mudal and Krannitz,

Biological Diversity:

Breeding or Feeding Habitat for a Provincially Significant Animal Species (Mudal and Krannitz, 1990):
Northern Harrier and Marsh Wren (both- field obsv.), Common Tern, Caspian Tern, Least Bittern, Pied-billed Grebe (all- Kingston Field Naturalists, referenced);

Provincially Significant Plant Species (Mudal and Krannitz, 1990):
Alisma gramineum (field obsv.);

Regionally Significant Species (Mudal and Krannitz, 1990):
Virginia Rail, Green Heron, Swamp Sparrow (all- field obsv.);

Breeding or Feeding Habitat for a Provincially Significant Animal Species (Blancher and Deacon, 1983):
Black Tern, Marsh Wren, Least Bittern, Long-tailed Weasel (all- field obsv.);

Provincially Significant Plant Species (Blancher and Deacon, 1983):
Alisma gramineum, Bidens beckii, Najas guadalupensis, Utricularia gibba (all- Catling, 1983, referenced);

Regionally Significant Species (Blancher and Deacon, 1983):
Epilobium glandulosum, Galium tinctorium, Potamogeton epihydrus, Utricularia minor (all- Catling, 1983, referenced);

Ecological Values:

Nesting of colonial waterbirds- currently nesting Black Tern (R. Snetsinger, field obsv. & Kingston Field Naturalists, referenced) (Mudal and Krannitz, 1990).
Good winter cover for aquatic furbearers (Mudal and Krannitz, 1990).
Waterfowl staging- national significance (Mudal and Krannitz, 1990).
Waterfowl production- regional significance (Mudal and Krannitz, 1990).
Migratory passerine and/ or shorebird stopover area- high significance (Mudal and Krannitz, 1990).
Significance for fish spawning and rearing- regional significance (Mudal and Krannitz, 1990).
Nesting of colonial waterbirds- currently nesting Black Tern (Catling, 1983, referenced) (Blancher and Deacon, 1983).
Waterfowl staging- regional significance (Blancher and Deacon, 1983).
Waterfowl production- regional significance (Blancher and Deacon, 1983).
Significance for fish spawning and rearing- regional significance - Northern Pike, and baitfish (Blancher and Deacon, 1983).

Recreational Activity (Mudal and Krannitz, 1990):
Hunting- high, Nature Appreciation or Study- high, Fishing- high, Canoeing/ Boating- high;

Landuse in Catchment Basin (Mudal and Krannitz, 1990):
mainly forested and/ or less than 40% agriculture;1990).

Other

Resource Products (Mudal and Krannitz, 1990):
Wild Rice (field obsv. & Catling 1985, referenced), Bullfrogs and Snapping Turtles (both- field obsv.), Furbearers- Muskrat, Raccoon, Beaver, Mink (all- field obsv.), and River Otter (Dr. A. Crowder, Queen's University, referenced);

Resource Products (Blancher and Deacon, 1983):
Wild Rice (Catling, 1983, pers. obsv., referenced), Bullfrogs and Snapping Turtles (both- field obsv.),

Ownership Information:

100% Public- unrestricted activities (Mudal and Krannitz, 1990).

Directions:

Kingston Conc. 4, Lots 33-36 (Mudal and Krannitz, 1990).

Agency:

Evaluated By:

Mudal and Krannitz

Record Last Updated:

02/11/2000

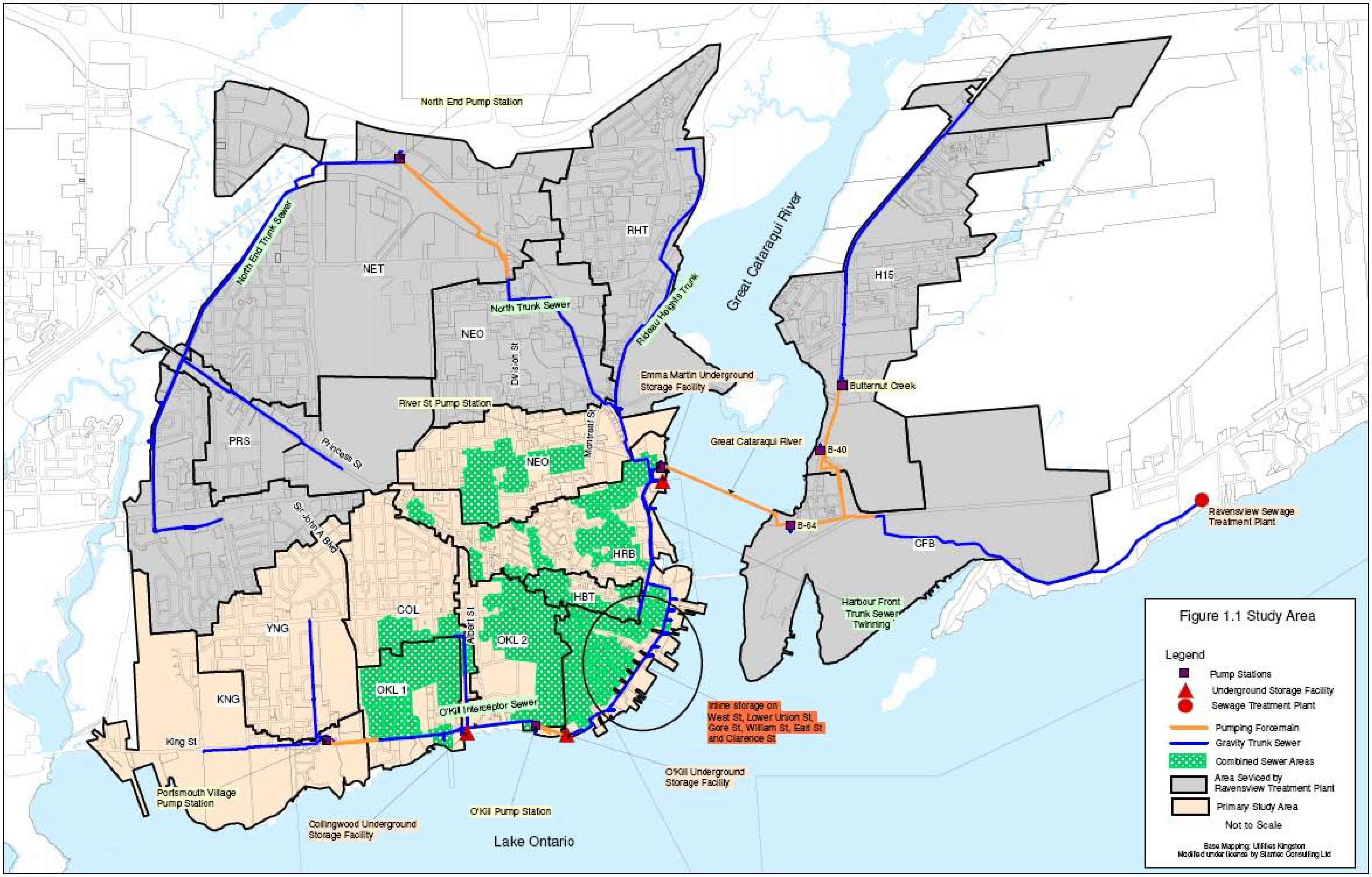
Updated By:

Charlotte Whal

Wetland Name: Greater Cataraqui Marsh
Significance: Provincial

Wetland FMF ID: 1251547458
Wetland ID: W1838152900131

Stantec Consulting Ltd.


North End Pump Station
North End Trunk Sewer
NET
RHT
Great Cataraqui River
H15
North Trunk Sewer
NEO
Division St
Rideau Heights Trunk
Emma Martin Underground Storage Facility
Butternut Creek
River St Pump Station
Montreal St
PRS
Princess St
Great Cataraqui River
B-40
NEO
Sir John A Blvd
B-64
Ravensview Sewage Treatment Plant
CFB
HRB
HBT
COL
Albert St
YNG
OKL 2
Harbour Front Trunk Sewer Twinning
OKL 1
KNG
O'Kill Interceptor Sewer
Inline storage on West St, Lower Union St, Gore St, William St, Earl St and Clarence St
King St
O'Kill Underground Storage Facility
Portsmouth Village Pump Station
O'Kill Pump Station
Collingwood Underground Storage Facility
Lake Ontario
Figure 1.1 Study Area
Legend
Pump Stations
Underground Storage Facility
Sewage Treatment Plant
Pumping Forcemain
Gravity Trunk Sewer
Combined Sewer Areas
Area Serviced by Ravensview Treatment Plant
Primary Study Area
Not to Scale
Base Mapping: Utilities Kingston
Modified under license by Stantec Consulting Ltd

APPENDIX B: MAPS

List of Maps

Legend

- Parks Canada Boundary
- Roads
- Buildings
- Land
- Marsh
- Water

Title: Map II-1: Kingston Inner Harbour Geographical Features and Landuse

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

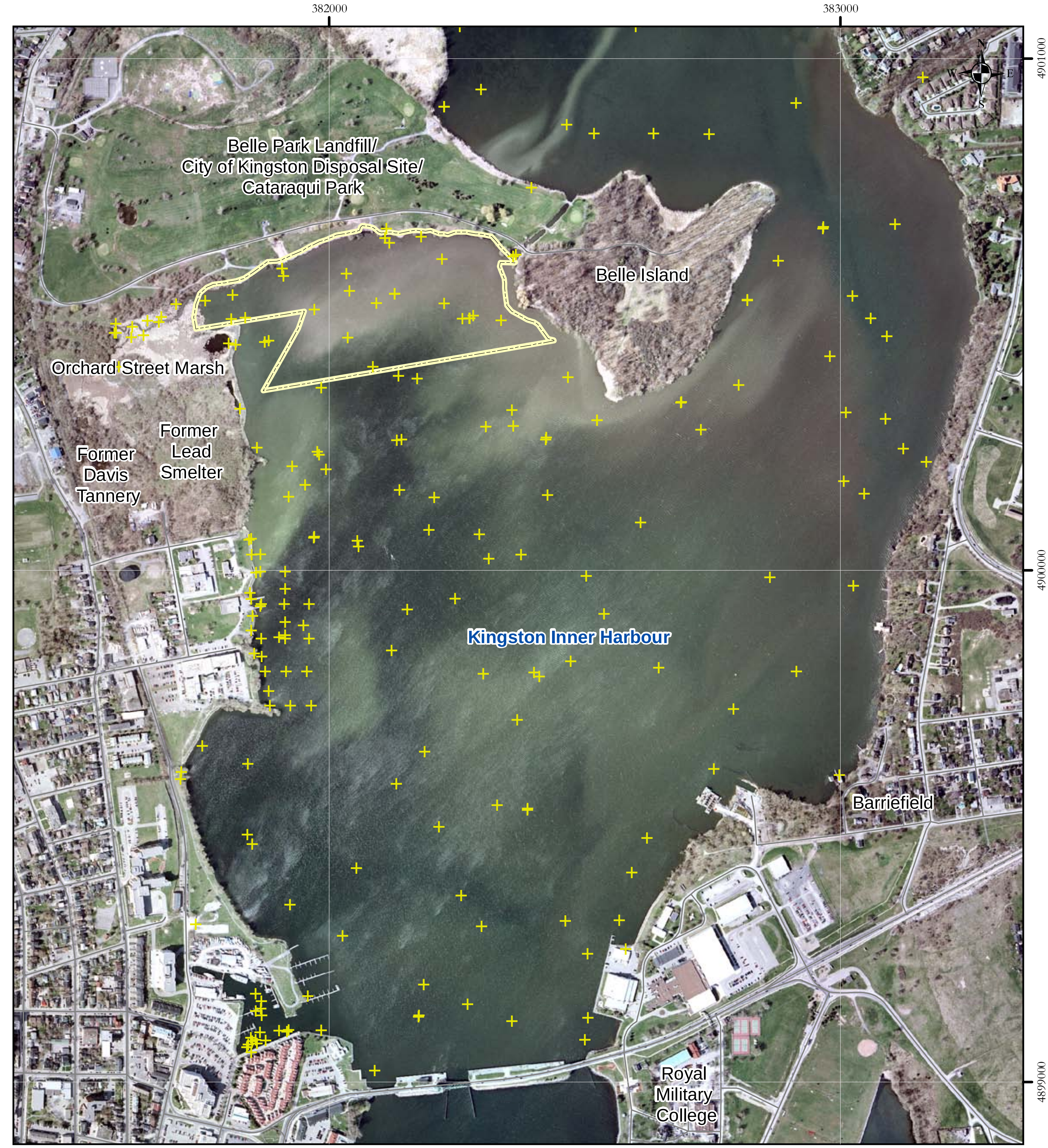
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-1

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_1_Landuse_Nov_2013.mxd



Legend

- Sample Locations
- Parks Canada Boundary
- Roads

Title: Map II-2: Location of Sediment Samples in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-2

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_2_SampleLoc_Nov_2013.mxd

Legend

Core Sample Locations

- 2003
- 2005
- 2006
- 2008
- 2010
- Parks Canada Boundary
- Roads

Title: Map II-3: Core Sample Locations in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

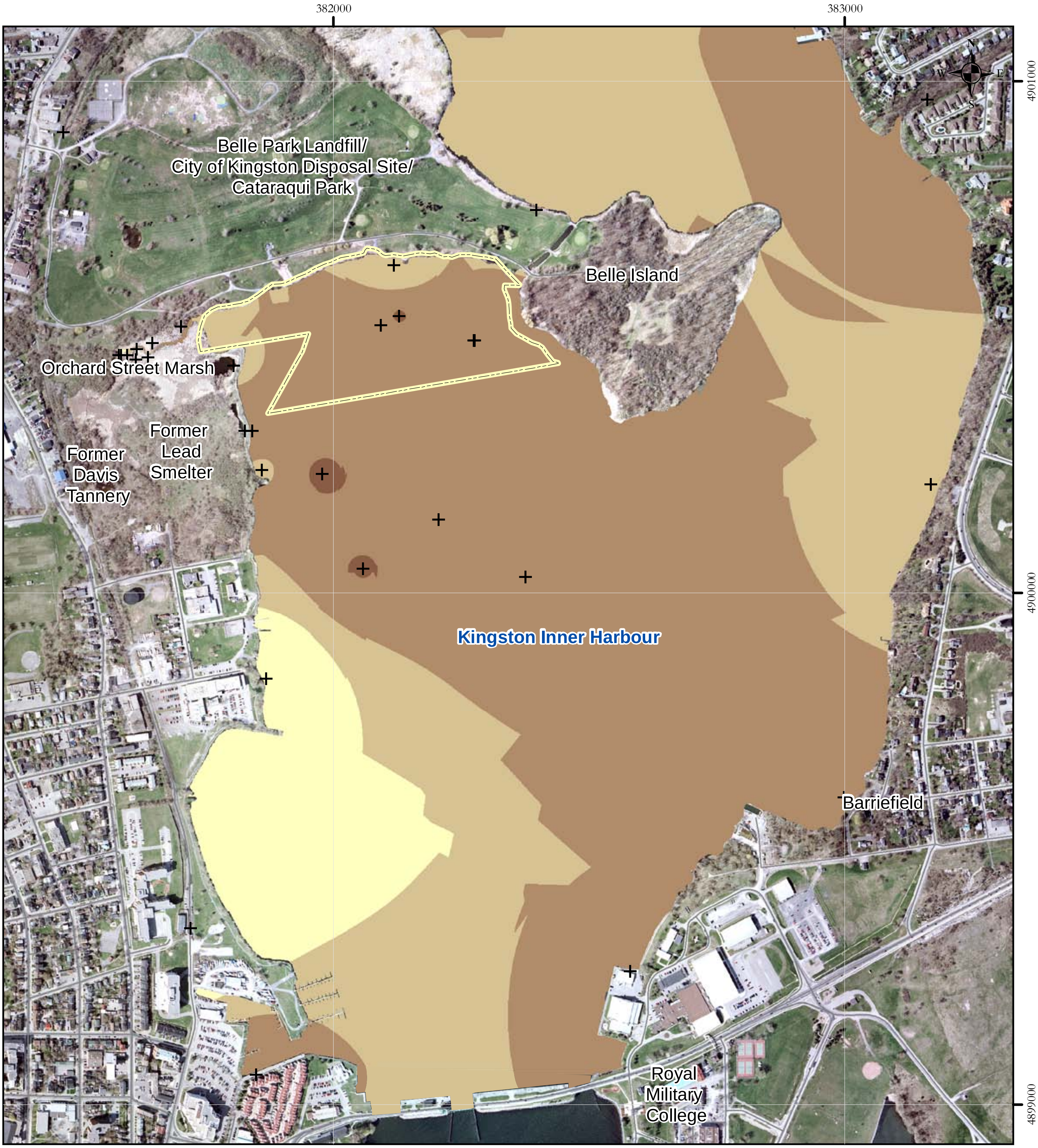
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-3

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_3_Core_Nov_2013.mxd



Legend

- KIH Grain Size Sample
- Parks Canada Boundary
- Roads

Grain Size

- <63 Silty Sand
- 63-81 Sandy Silt
- 82-96 Clayey Silt
- >97 Silty Clay

Title: Map II-4: Distribution of Fine-Grained Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transversal Mercator (UTM) - Zone 18

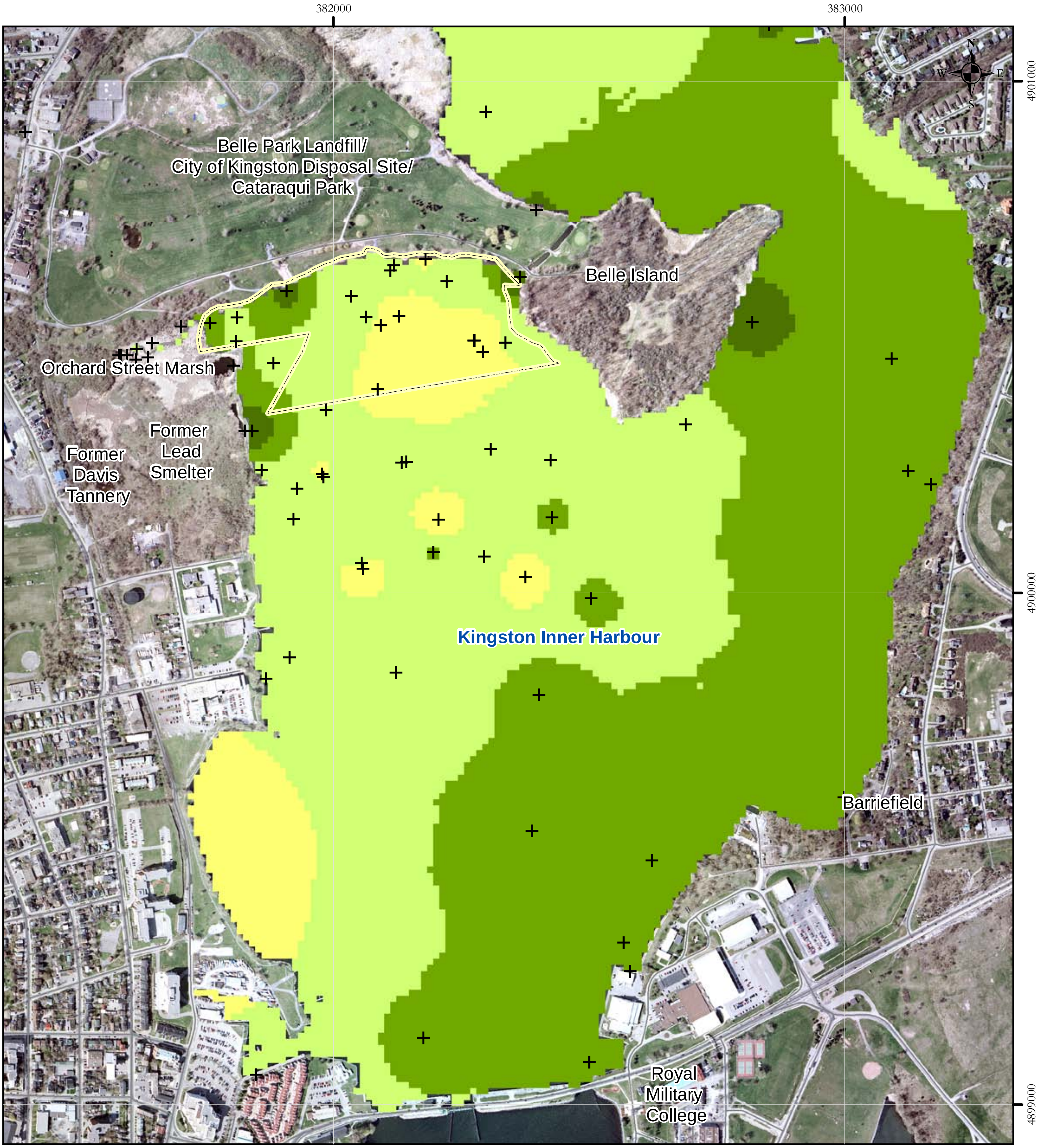
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-4

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_4_GrainSize_Nov_2013.mxd



Legend

- + KIH TOC Sample
- Parks Canada Boundary
- Roads

Total Organic Carbon(%)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 25

Title: Map II-5: TOC Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Date: November 2013

Meters
200 100 0 200

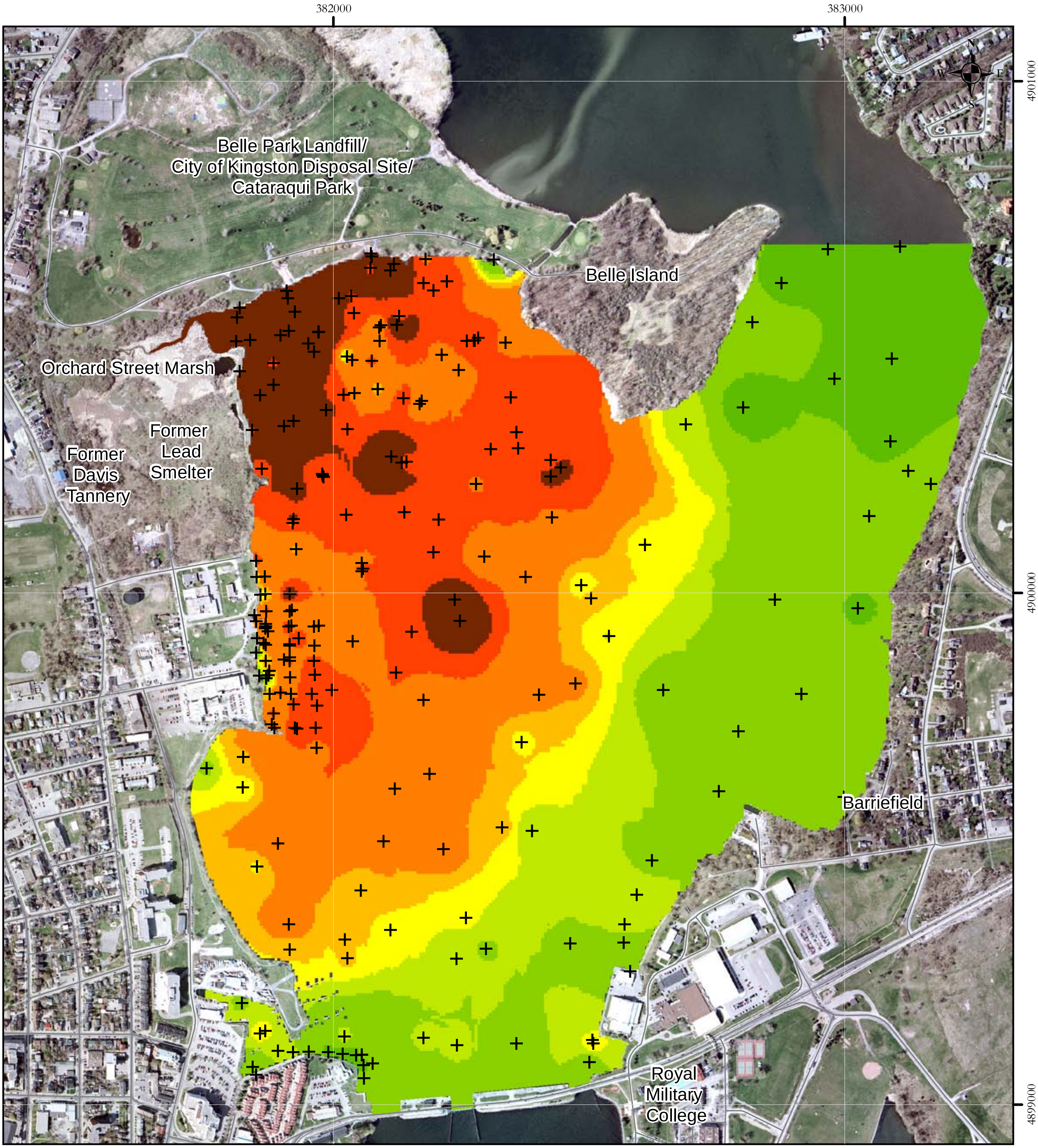
Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Map II-5

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_5_TOC_Nov_2013.mxd



Legend

+ KIH Cr Sample

Roads

Chromium Concentrations

- < 37.7ppm (< ISQG)
- 37.7-90ppm (< PEL)
- 90-180ppm (< 2PEL)
- 180-270ppm (< 3PEL)
- 270-360ppm (< 4PEL)
- 360-450ppm (< 5PEL)
- 450-900ppm (< 10PEL)
- 900-1350ppm (< 15 PEL)
- 1350 - 25000ppm

Title: Map II-6: Cr Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

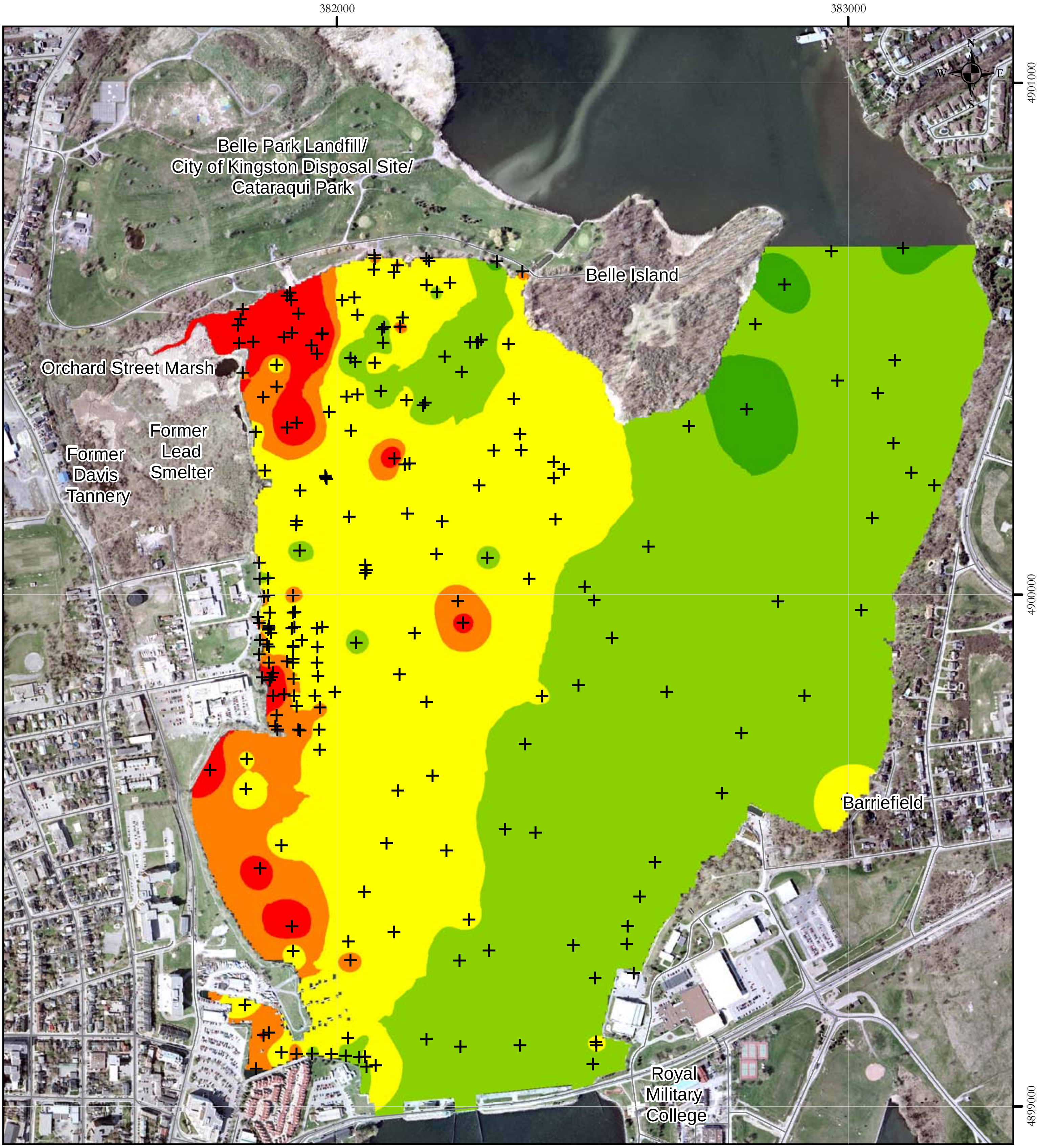
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-6

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_6_Cr_Nov_2013.mxd



Legend

+ KIH Pb Sample

Roads

Lead Concentrations

- <35 ppm
- 35-91.3 ppm (< PEL)
- 91.3-183 ppm (< 2xPEL)
- 183-274 ppm (< 3xPEL)
- 274-365 ppm (< 4xPEL)

Title: Map II-7: Pb Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

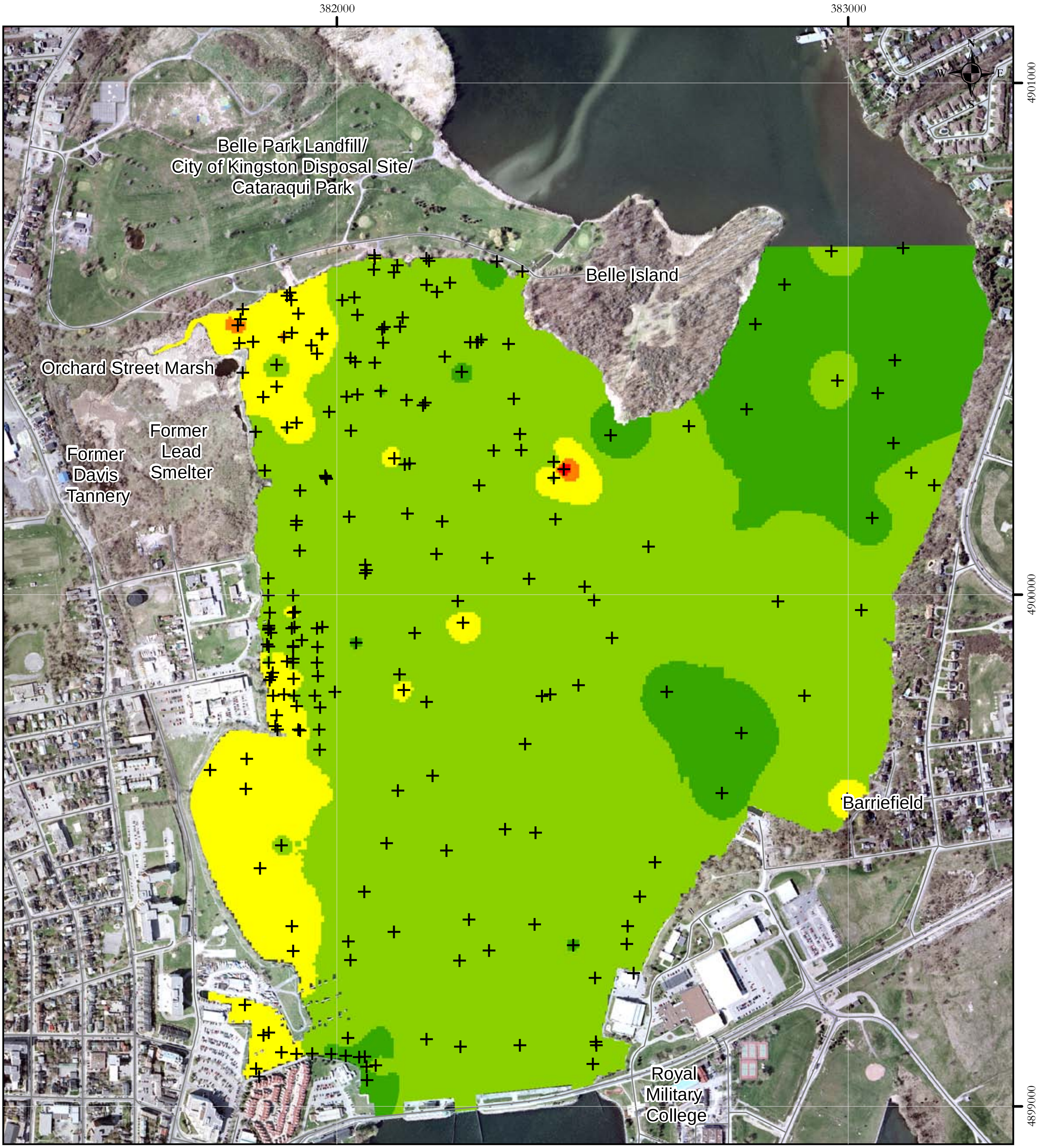
Datum
North American Datum 1983 (NAD83)

Date: November 2013

200 100 0 200 Meters

Map II-7

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_7_Pb_Nov_2013.mxd



Legend

+ KIH Zn Sample	Zinc Concentrations
Roads	< 123 ppm (< ISQG)
	123-315 ppm (< PEL)
	315-630 ppm (< 2x PEL)
	630-945 ppm (< 3x PEL)
	945-1800 ppm (<6x PEL)

Title: Map II-8: Zn Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

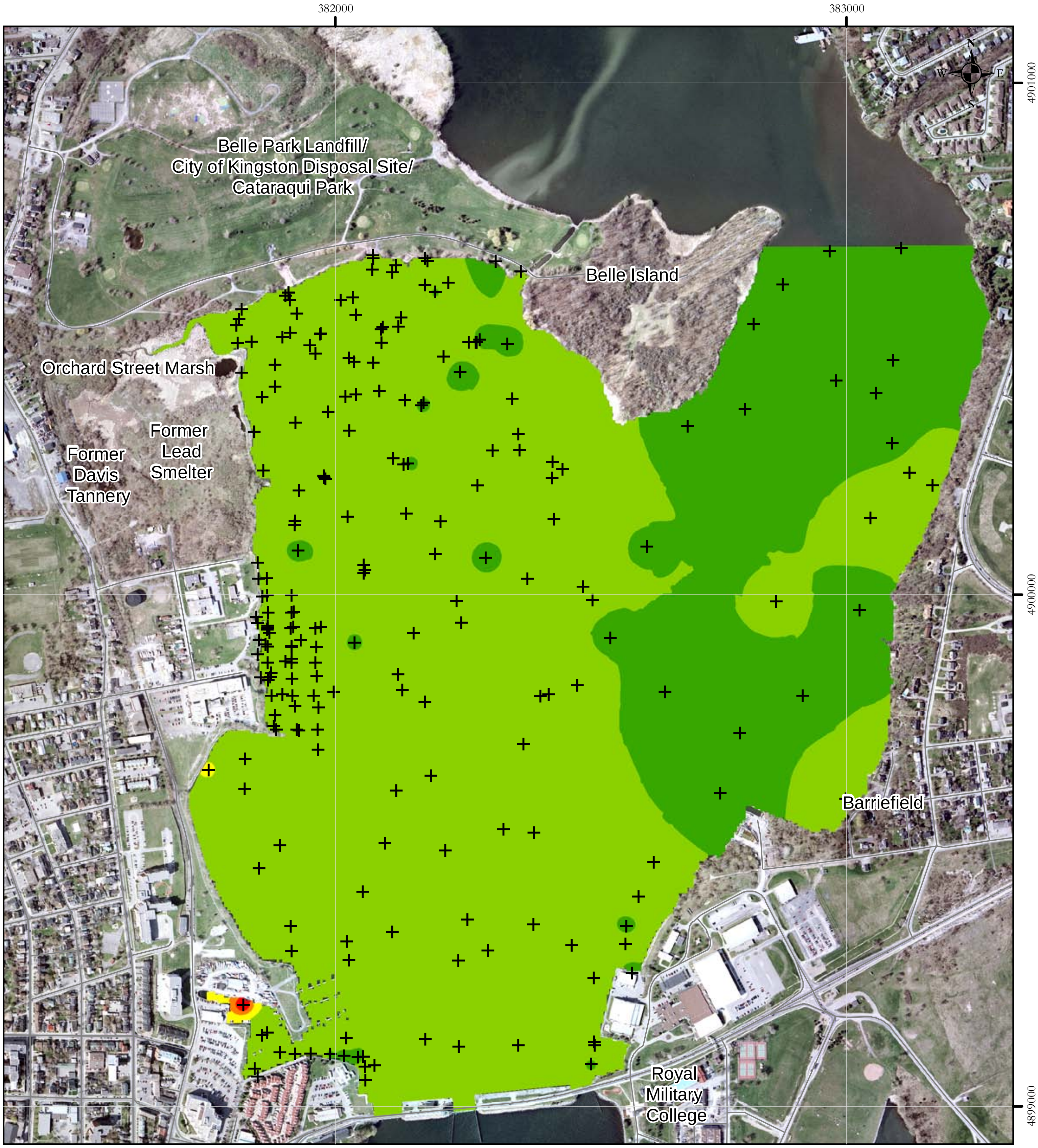
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-8

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_8_Zn_Nov_2013.mxd



Legend

- + KIH Cu Sample
- Roads

Copper Concentrations

- <35.7 ppm (<ISQG)
- 35.7-197 ppm (<PEL)
- 197-394 ppm (<2xPEL)
- 394-591 ppm (<3xPEL)
- 591-788 ppm (<4xPEL)

Title: Map II-9: Cu Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

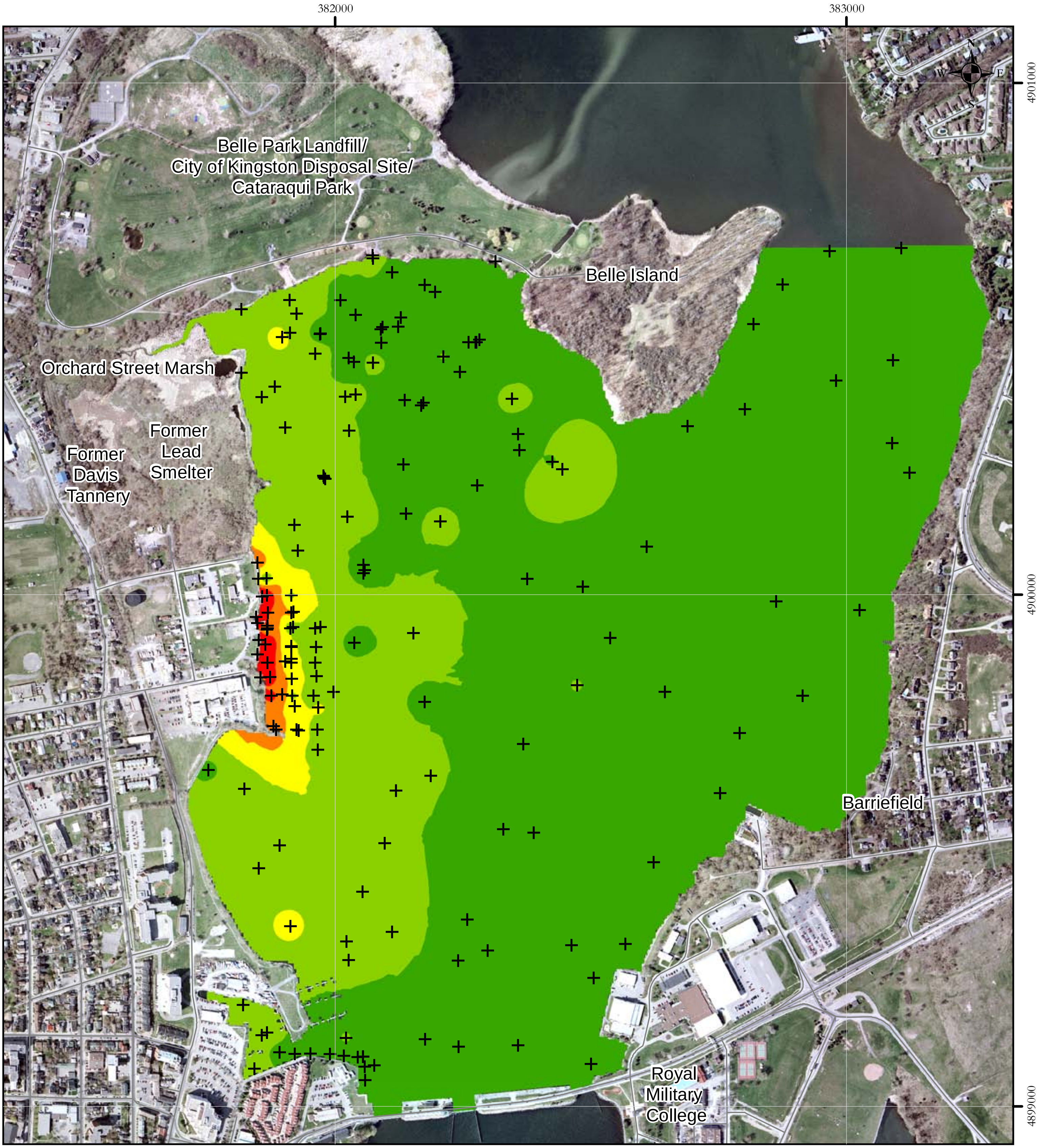
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-9

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_9_Cu_Nov_2013.mxd



Legend

- + KIH As Sample
- Roads

Arsenic Concentrations

- < 5.9 ppm (ISQG)
- 5.9-17 ppm (PEL)
- 17-34 ppm (<2xPEL)
- 34-68 ppm (<4xPEL)
- >68 ppm (>4xPEL)

Title: Map II-10: As Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

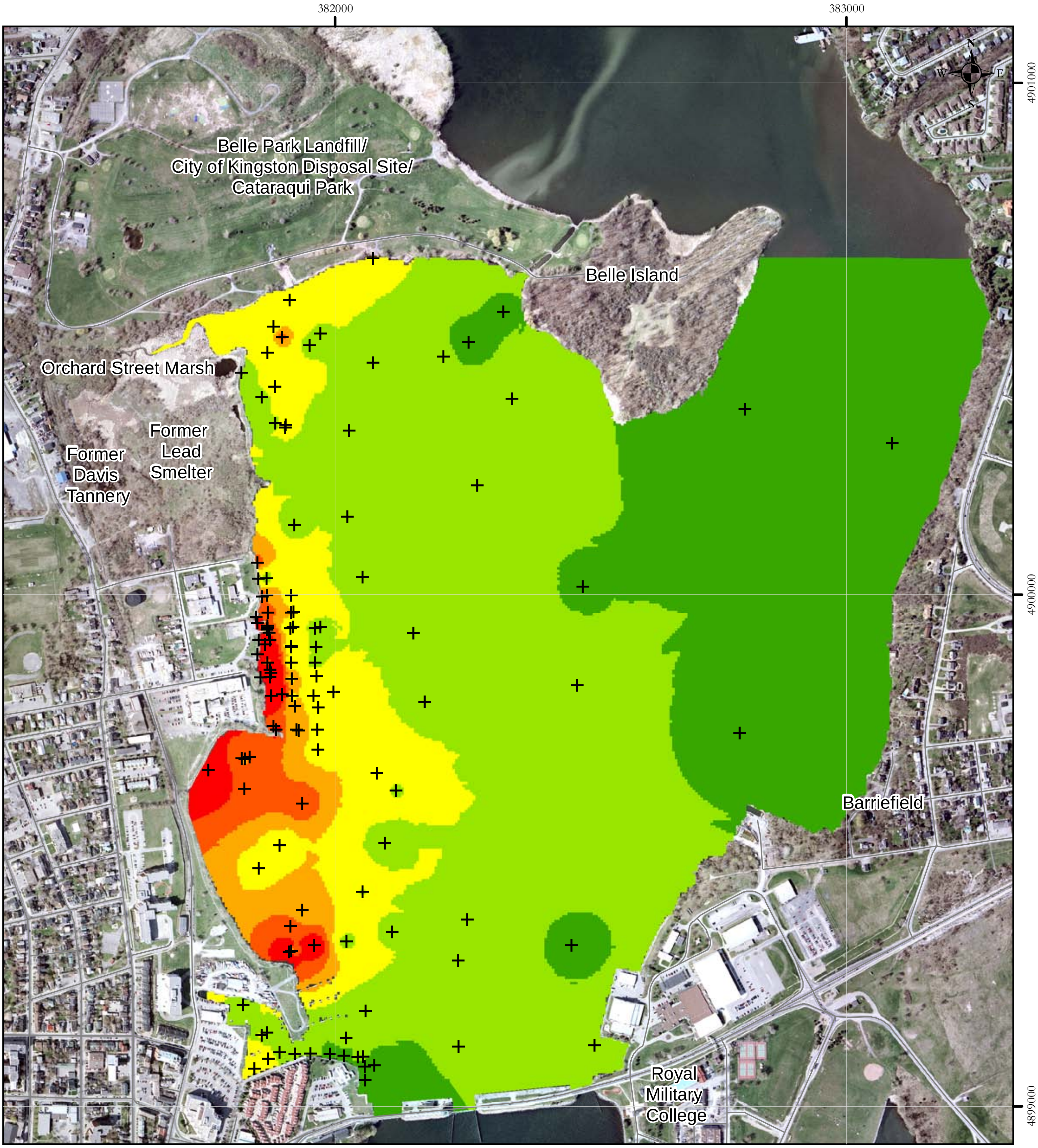
Datum
North American Datum 1983 (NAD83)

Date: November 2013

200 100 0 200 Meters

Map II-10

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_10_As_Nov_2013.mxd



Legend

KIH Hg Sample	Mercury Concentration
Roads	< 0.17ppm (ISQG)
	0.17-0.49ppm (PEL)
	0.49-0.97ppm (2xPEL)
	0.97-1.45ppm (3xPEL)
	1.45-1.95ppm (4xPEL)
	>1.95ppm (>4xPEL)

Title: Map II-11: Hg Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

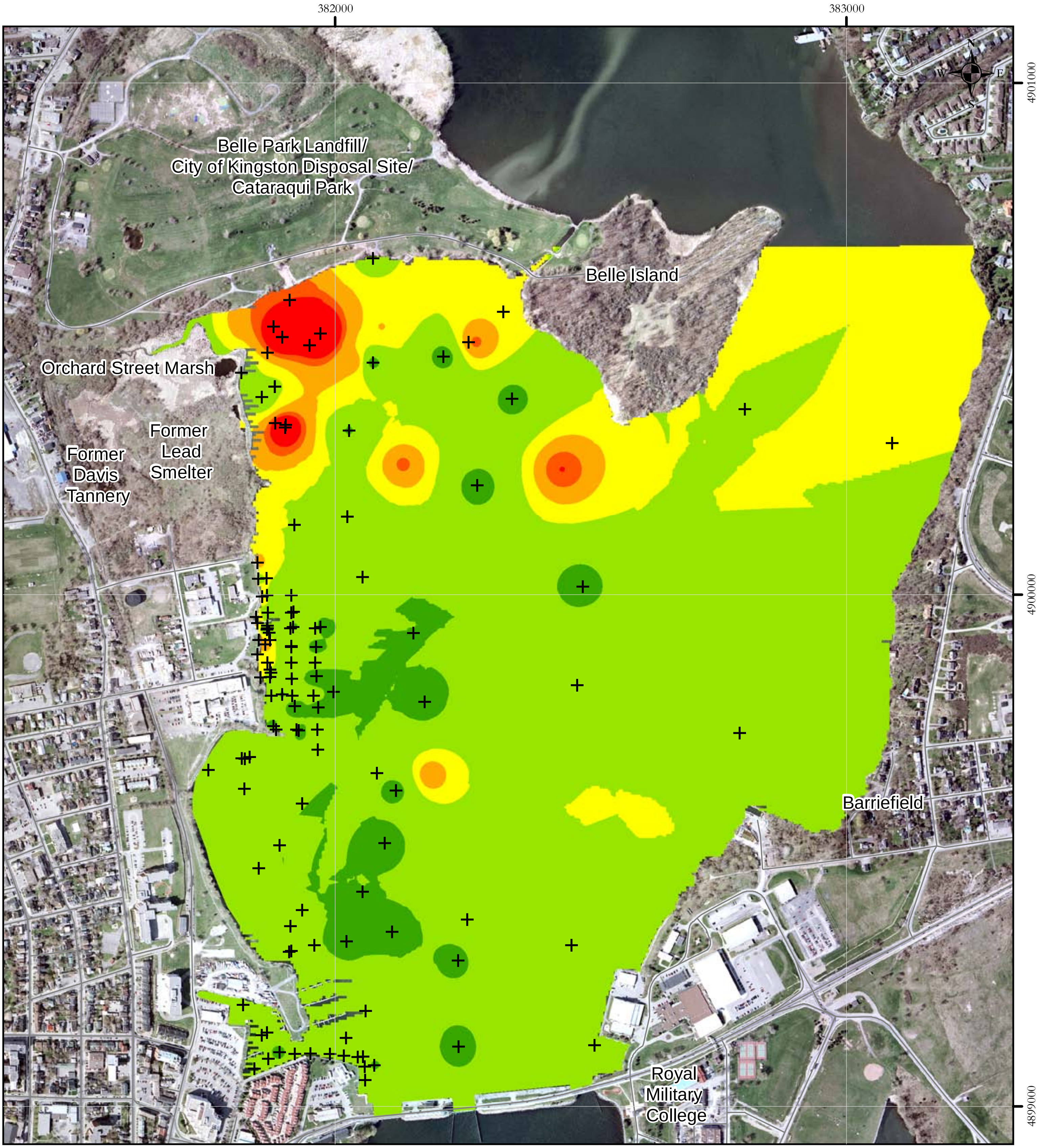
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-11

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_11_Hg_Nov_2013.mxd



Legend

- + KIH Hg Sample
- Roads

Antimony Concentrations

- 0-1 ppm (Near Water Standard)
- 1-5
- 5-10
- 10-20 (CCME Soil Standard)
- 20-30
- 30+

Title: Map II-12: Sb Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

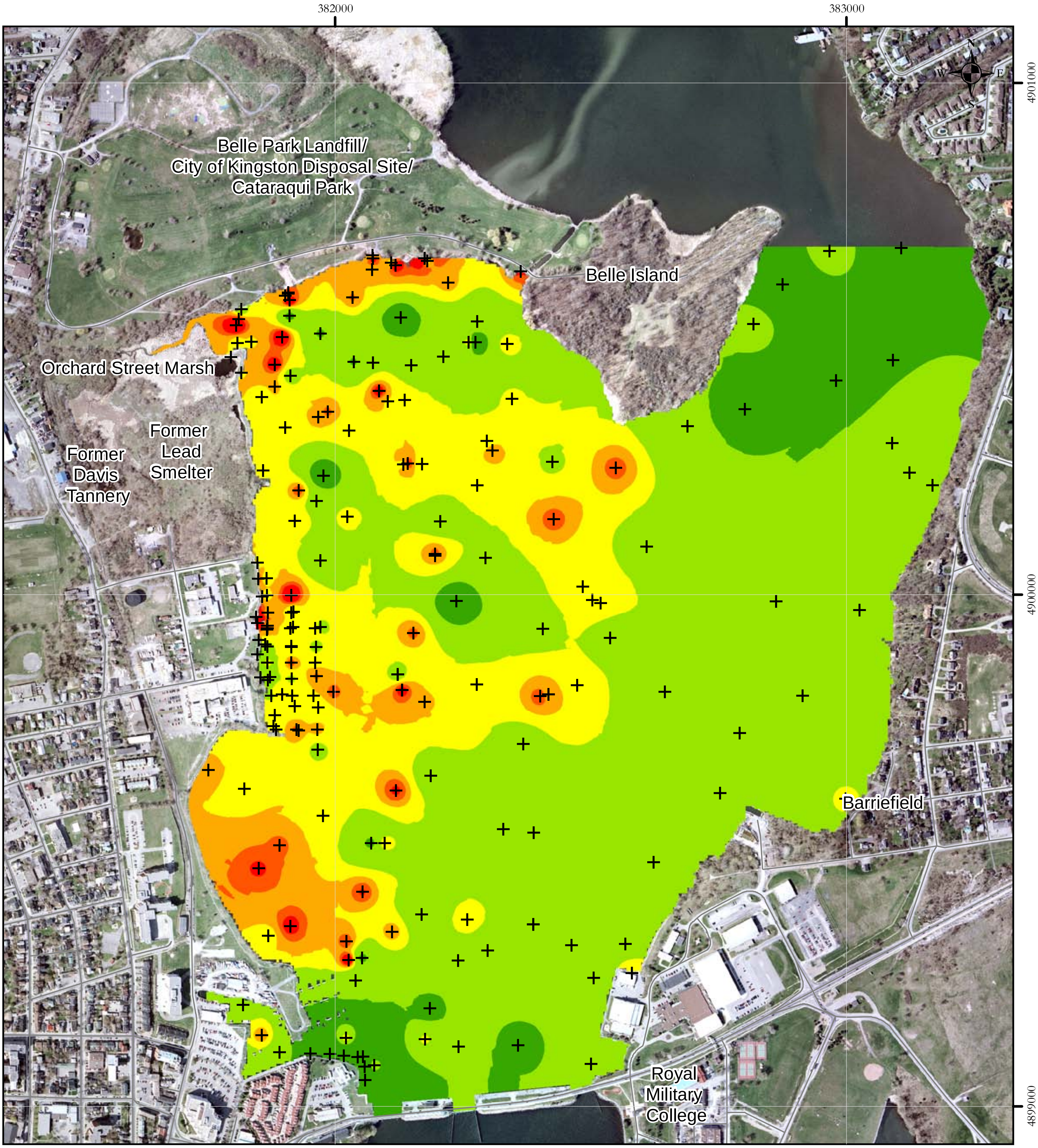
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-12

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_12_Sb_Nov_2013.mxd



Legend

- + KIH PCB Sample
- Roads

Polychlorinated Biphenyl Concentrations

- < 34.1 ppb (ISQG)
- 34-277 ppb (PEL)
- 277-554 (2x PEL)
- 554-831 (3x PEL)
- 831-1,108 (4x PEL)
- 1108-8100 (29x PEL)

Title: Map II-13: PCB Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

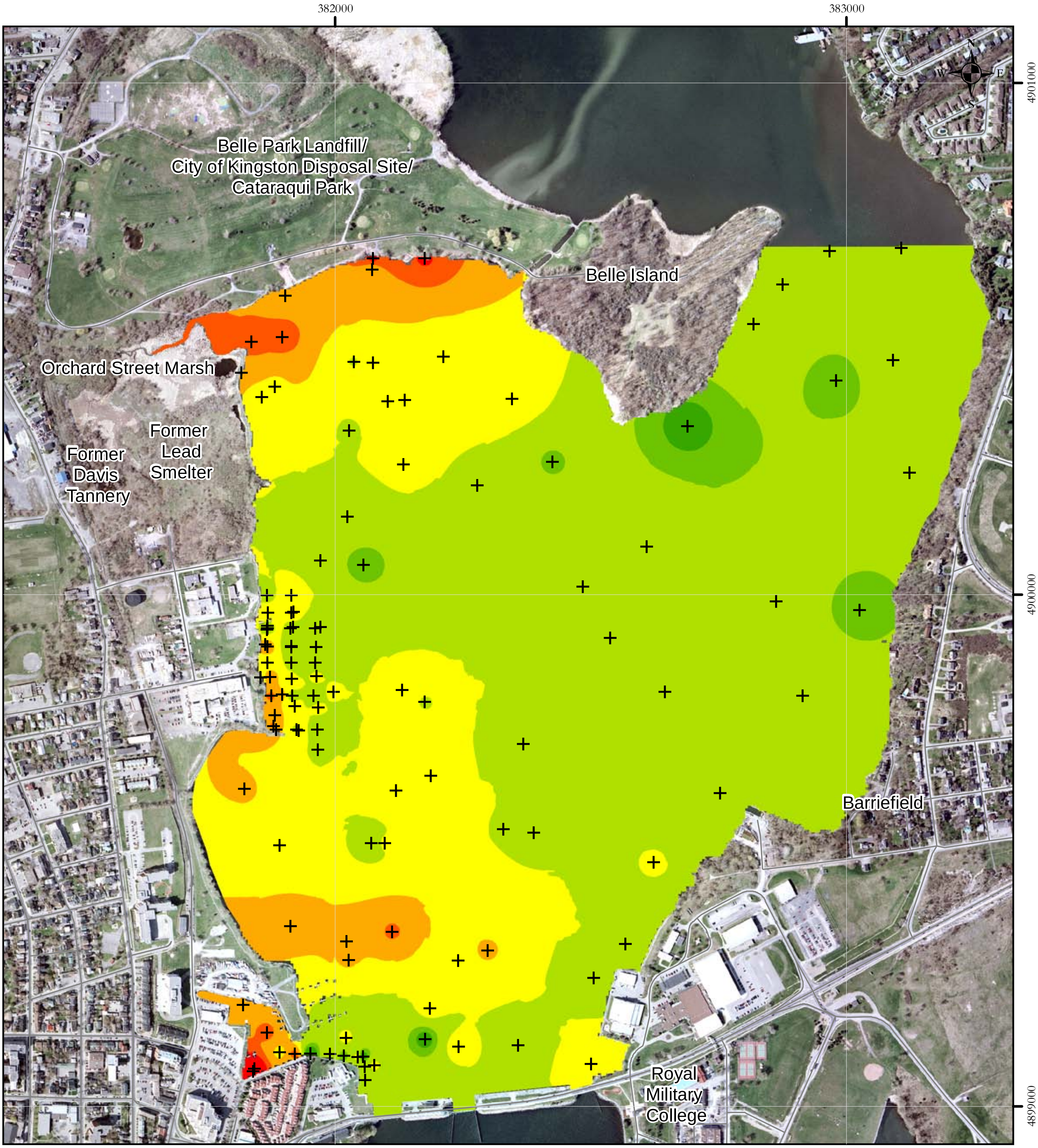
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-13

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_13_PCB_Nov_2013.mxd



Legend

- + KIH PAH Sample
- Roads

Polycyclic Aromatic Hydrocarbon Concentrations

- 0-500 ppb
- 500-1000 ppb
- 1000-4000 ppb (LEL)
- 4000-10000 ppb
- 10000-25000 ppb
- 25000-50000 ppb
- 50000-175000 ppb

Title: Map II-14: PAH Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

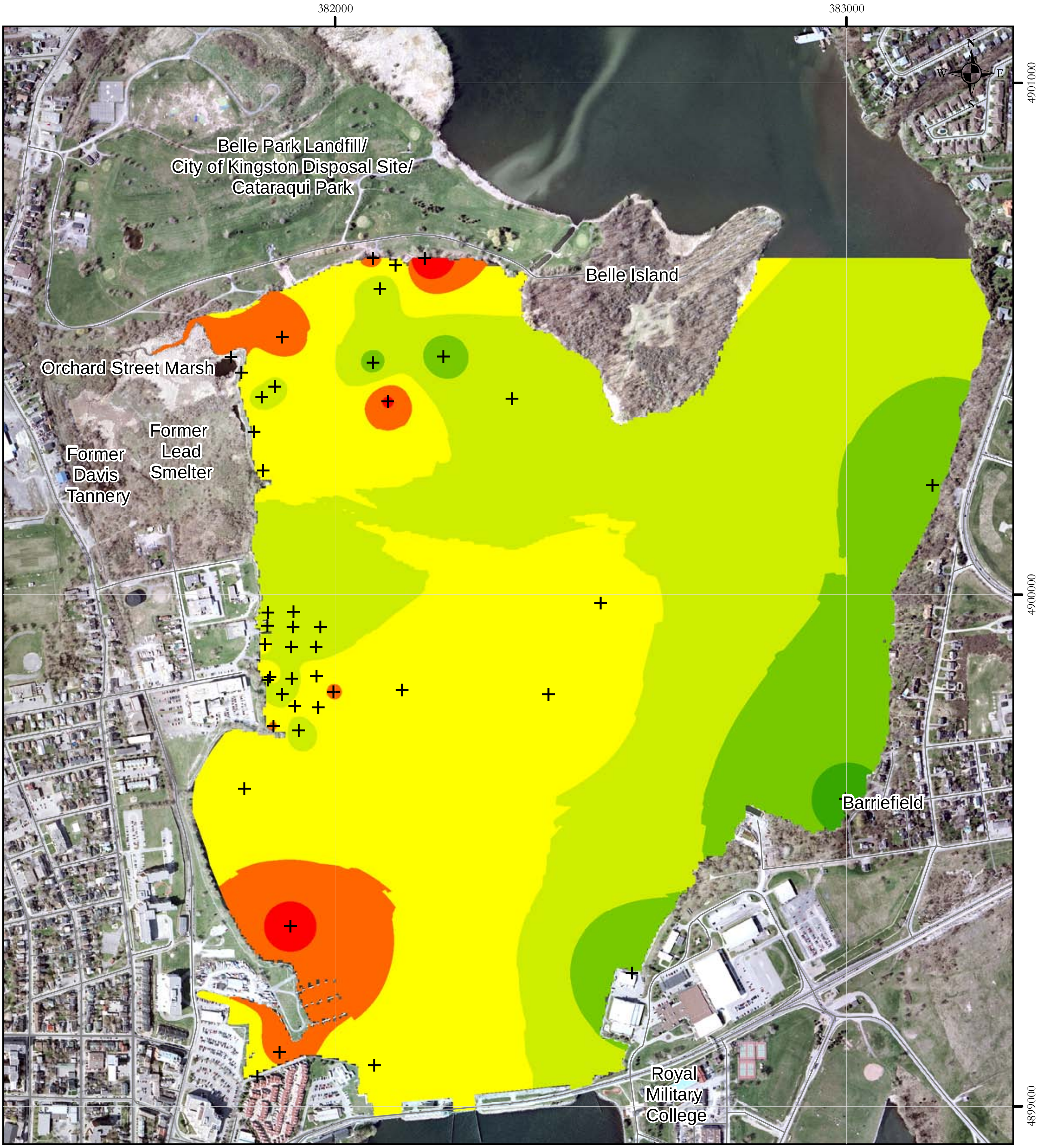
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
200 100 0 200

Map II-14

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_14_PAH_Nov_2013.mxd



Legend

+ KIH DDT Sample	DDT Concentrations
Roads	0-1.19 ppb (ISQG)
	1.19-4.77 ppb (PEL)
	4.77-10 ppb
	10-20 ppb
	20-40 ppb
	40+ ppb

Title: Map II-15: DDT Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Date: November 2013

Meters
200 100 0 200

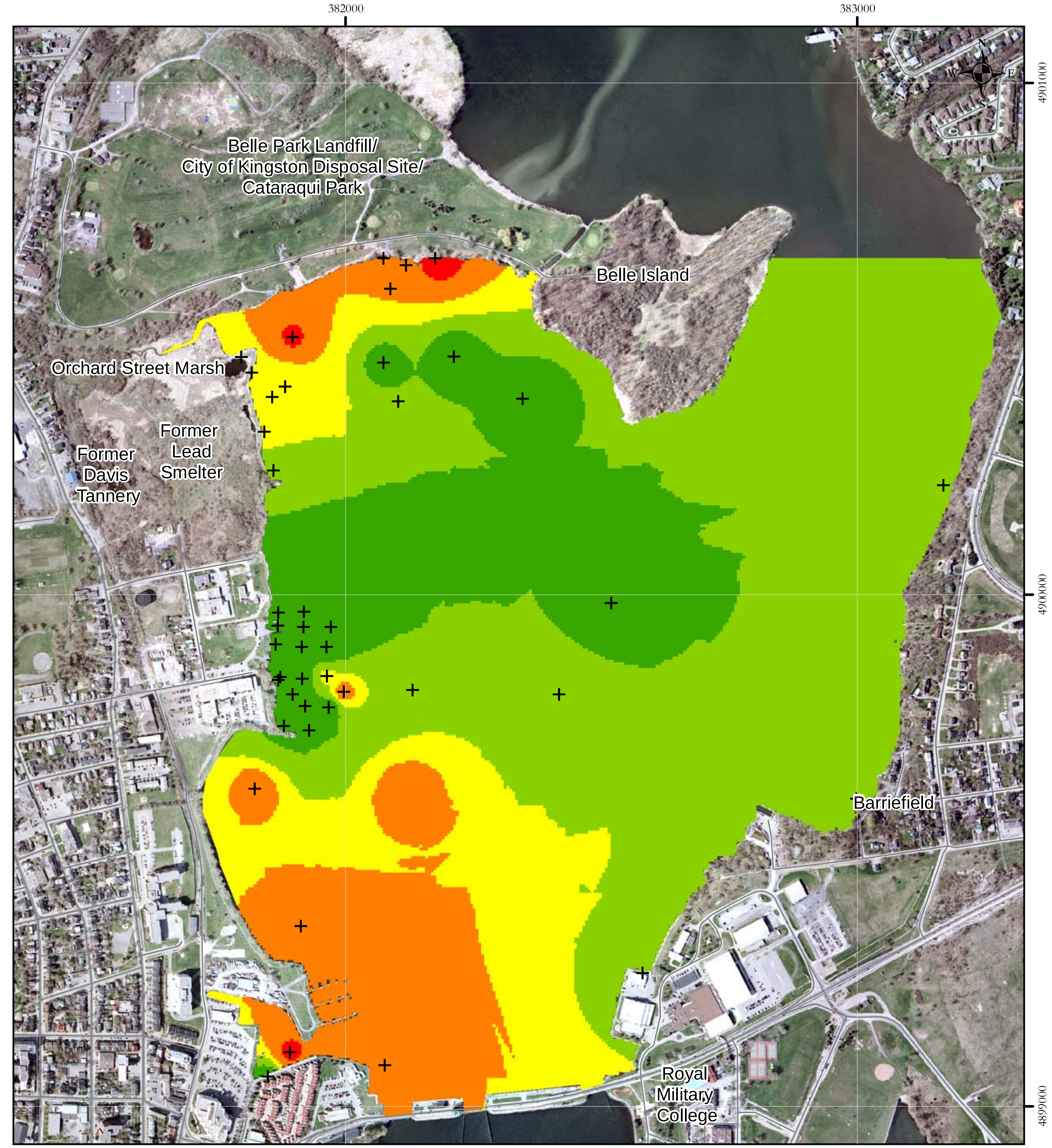
Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Map II-15

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_15_DDT_Nov_2013.mxd



Legend

+ KIH Chlordane Sample

Roads

Chlordane Concentrations

- 0-2 ppb
- 2-4.5 ppb (ISQG)
- 4.5-8.87 ppb (PEL)
- 8.87-20 ppb
- 20+ ppb

Title: Map II-16: Chlordane Concentrations of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

200 100 0 200 Meters

Map II-16

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\Final Report\KIH_16_Chlordane_Nov_2013.mxd

MAP III-1: KINGSTON INNER HARBOUR - MACROPHYTE LOCATION DATA

Legend

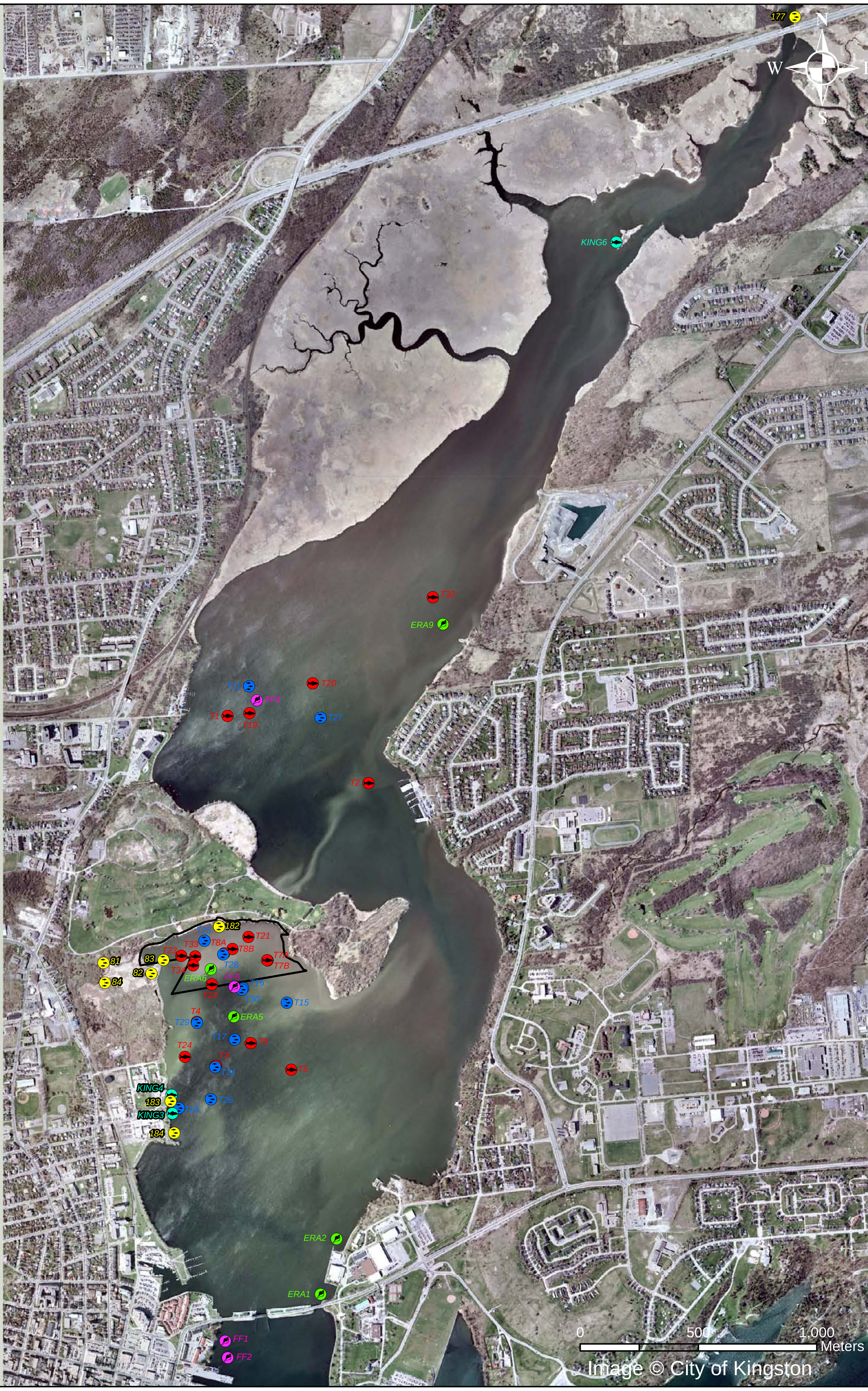
	Data Source
ERA	Tinney 2006
SSM	This Report

Parks Canada Boundary

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 24 2010

MAP III-10: KINGSTON INNER HARBOUR - TOXICITY SAMPLE LOCATIONS



Legend

Legend	Data Source
Chironomus riparius, Hyalella azteca, Hexagenia, and Tubifex	This Report
Chironomus tentans and Hyalella azteca	This Report
Fathead Minnow	Scheider 2009
Hexagenia, Chironomus tentans, and Fathead Minnow	Benoit and Dove 2006
Hyalella azteca	Tinney 2006
Hyalella azteca	ESG 2003
Parks Canada Boundary	

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 25 2010

MAP III-2: KINGSTON INNER HARBOUR - CATTAIL LOCATION DATA

Legend

Cattail Sampling Location

ParksCanadaBoundary

Data Source

This Report

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 24 2010

MAP III-3: KINGSTON INNER HARBOUR - INVERTEBRATE LOCATION DATA

Legend	Data Source
Benthic Invertebrates	Benoit and Dove, 2006
Benthic Invertebrates	This Report
Hyalella Lab Uptake	This Report
Caged Mussels	Scheider 2009
Caged Mussels	Derry et al., 2003
Parks Canada Boundary	

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 25 2010

MAP III-4: KINGSTON INNER HARBOUR - Cr IN FIELD INVERTEBRATES

Legend

Average invertebrate [Cr] ppm dw

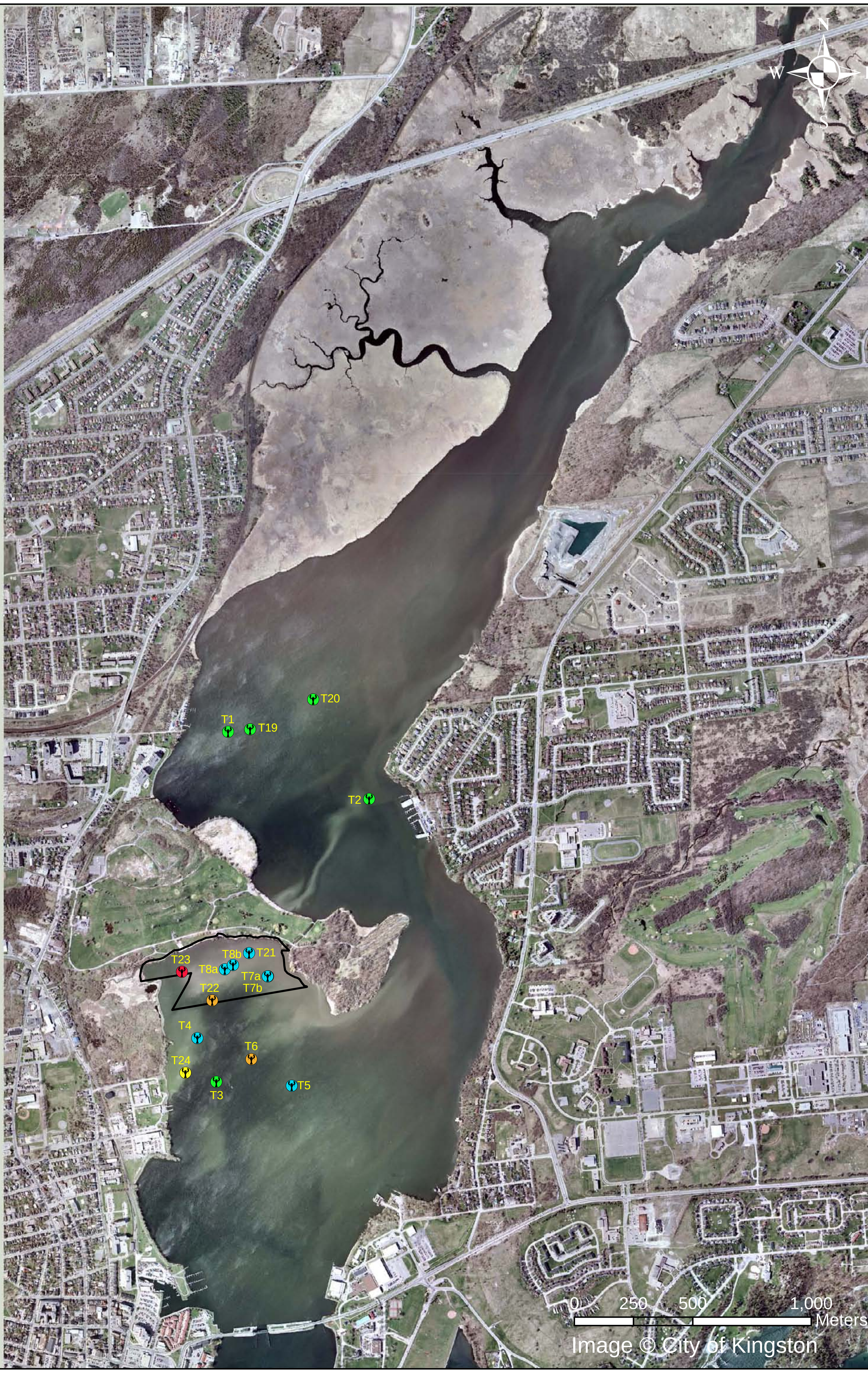
- 0-50 ppm
- 50-100 ppm
- >100 ppm
- Parks Canada Boundary

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4

Date: February 24 2010

MAP III-5: KINGSTON INNER HARBOUR - LAB HYALELLA Cr UPTAKE



Legend

Hyalella [Cr] ppm dw

- 0-2 ppm
- 2-5 ppm
- 5-10 ppm
- 10-25 ppm
- > 25 ppm
- Parks Canada Boundary

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 24 2010

MAP III-6: KINGSTON INNER HARBOUR
DIOXINS, FURANS, AND DLPCBs IN CRUSTACEANS (SOURCE; BENOIT AND DOVE, 2006)

Legend

Tissue concentrations of DLPCB + dioxins and furans (pg/g TEQ ww)

- 0-10 pg/g
- 10-20 pg/g
- 20-30 pg/g
- 30-50 pg/g
- Parks Canada Boundary

CCME DLPCB guideline = 0.79 pg TEQ/g ww

CCME Dioxins and Furans guideline = 0.71 pg TEQ/g ww

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 24 2010

MAP III-7: KINGSTON INNER HARBOUR - FISH LOCATION DATA

Legend

		Data Source
(yellow circle)	Juvenile Yellow Perch	Scheider 2009
(green circle)	Minnow Lab Uptake	Benoit and Dove, 2006
(red hatch)	Sport Fish Area	This Report
(black line)	Parks Canada Boundary	

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 24 2010

MAP III-8: KINGSTON INNER HARBOUR AVERAGE FISH PCB CONCENTRATIONS

Legend

Juvenile Yellow Perch

- >50 ppb PCB
- 50 - 100 ppb PCB
- 100 - 200 ppb PCB
- 200 - 300 ppb PCB
- 300 - 400 ppb PCB

SPORT FISH

Parks Canada Boundary

IJC tissue residue guideline = 100 ppb ww

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4

Date: February 23 2010

MAP III-9: KINGSTON INNER HARBOUR
AVERAGE FISH MERCURY CONCENTRATIONS (SOURCE: SCHEIDER 2009)

Legend

Juvenile Yellow Perch

- >20 ppb Hg
- 20 - 33 ppb Hg
- 33 - 50 ppb Hg
- 50 - 100 ppb Hg
- Parks Canada Boundary

CCME methylmercury tissue residue guideline = 33 ppb ww

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 23 2010

MAP III-11: KINGSTON INNER HARBOUR - BEAST ANALYSIS

Legend

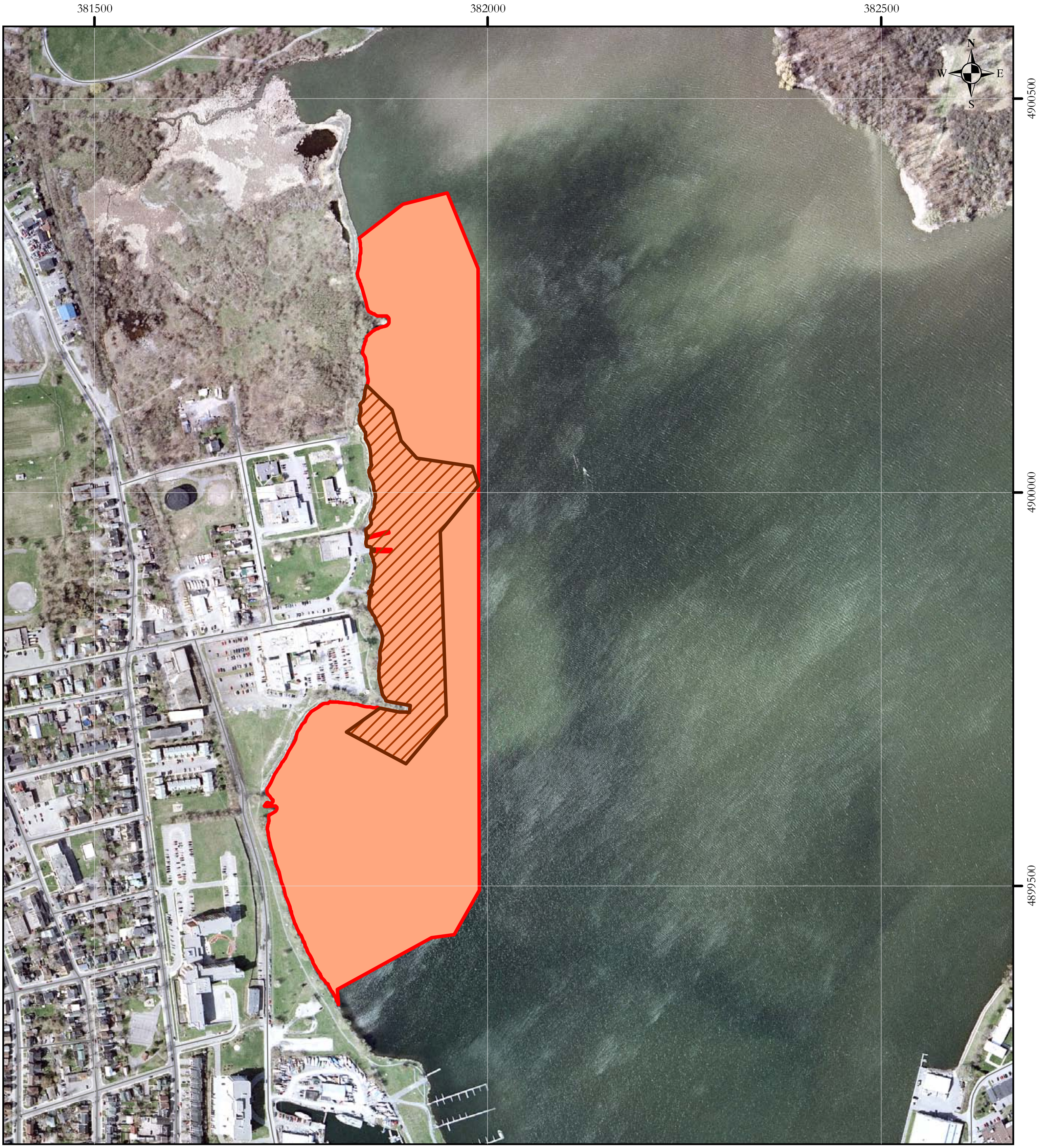
- Unstressed
- Pontentially Stressed
- Stressed
- Severely Stressed
- Parks Canada Boundary

KINGSTON

ENVIRONMENTAL SCIENCES GROUP • ESG •

Projection: Universal Transverse Mercator
Datum: NAD 1983 Zone 18
Source: Environmental Services Group (ESG)
Base Layers from the City of Kingston
GIS Technician: Jeffrey Donald

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7K 7B4
Date: February 26 2010



Legend

- Area of Special Consideration (Rowing Club)
- Area of Special Consideration (Western Shoreline)

MAP V-1: Management Areas of Special Consideration Kingston Inner Harbour, Western Shoreline

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
100 50 0 100

Map V-1

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-1_SMA_Dec_2013.mxd

Legend

+ KIH Arsenic Sample

Thiessen Polygon used to calculate SWAC = 6ppm for Arsenic

Area warranting management for Arsenic

Map V-2: Arsenic SWAC of 6 of Surface Sediments in Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

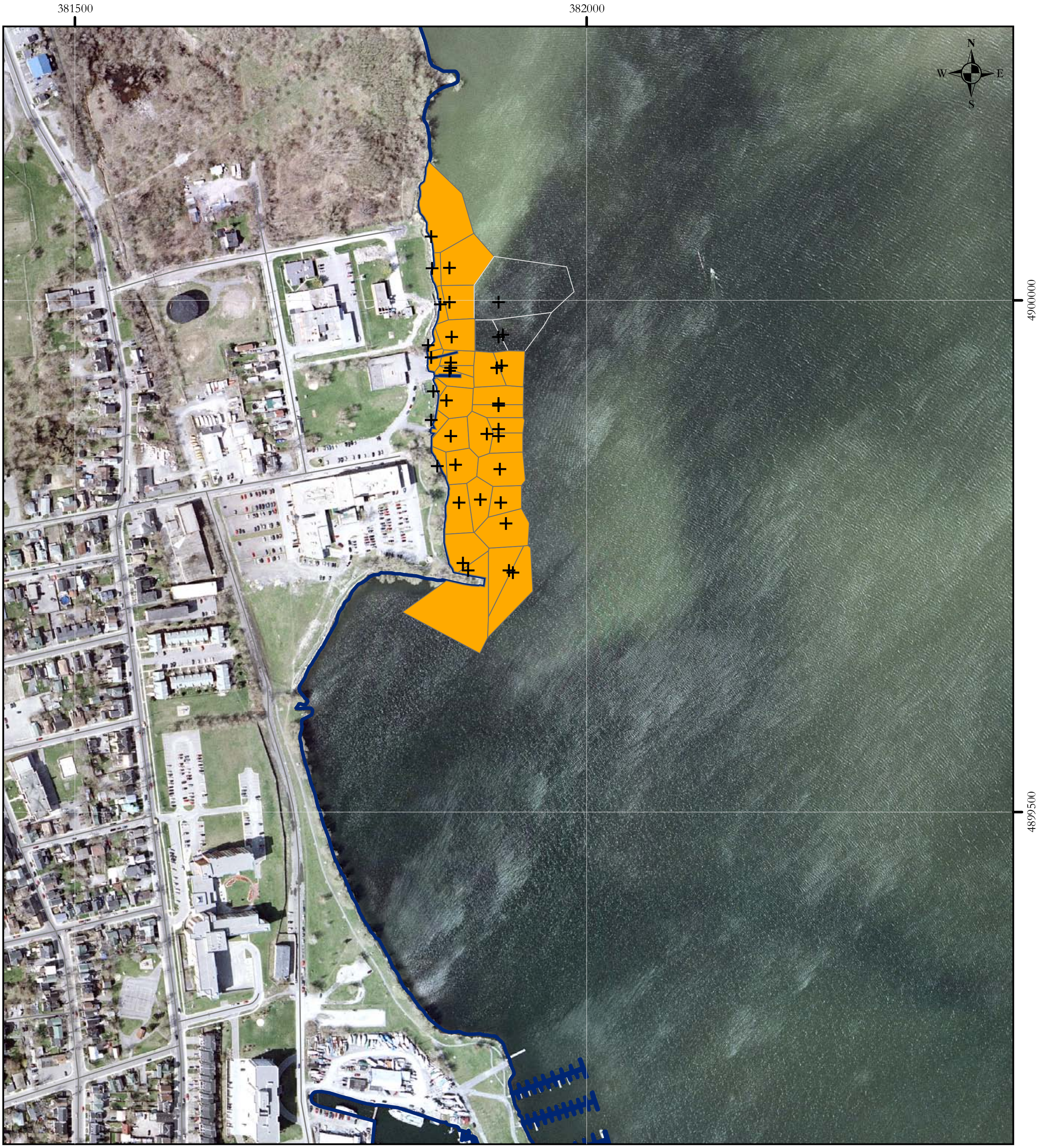
Datum
North American Datum 1983 (NAD83)

Date: November 2013

150 75 0 150 Meters

Map V-2

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-2_As_Dec_2013.mxd



Legend

- KIH Arsenic Sample
- Thiessen Polygon used to calculate SWAC = 6ppm for Arsenic
- Area warranting management for Arsenic

Map V-3: Arsenic SWAC of 6ppm of Surface Sediments in Kingston Inner Harbour, Rowing Club Special Management Area

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Date: November 2013

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

100 50 0 100 Meters

Map V-3

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-3_As_Dec_2013.mxd

Legend

- + KIH Arsenic Sample
- Thiessen Polygon used to calculate SWAC = 6ppm for Arsenic
- Area warranting management for Arsenic

Map V-4: Arsenic SWAC of 6ppm of Surface Sediments in
Kingston Inner Harbour, Western Shoreline Special Management Area

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
100 50 0 100

Map V-4

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-4_As_Dec_2013.mxd

Legend

- 5 m buffer zone - wading area
- 25 m buffer zone - swimming area

Map V-5: Shoreline Management Areas for PAHs

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters: 100 50 0 100 200

Map V-5

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-5_Shoreline_Dec_2013.mxd

Legend

+ KIH Chromium Sample

Thiessen Polygon used to calculate SWAC = 1164ppm for Chromium

Area warranting management for Chromium

Map V-6: Chromium SWAC of 1164 ppm of Surface Sediments in Kingston Inner Harbour, Mallard Duck Home Range of 9.2 Ha

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Date: November 2013

Meters 150 75 0 150

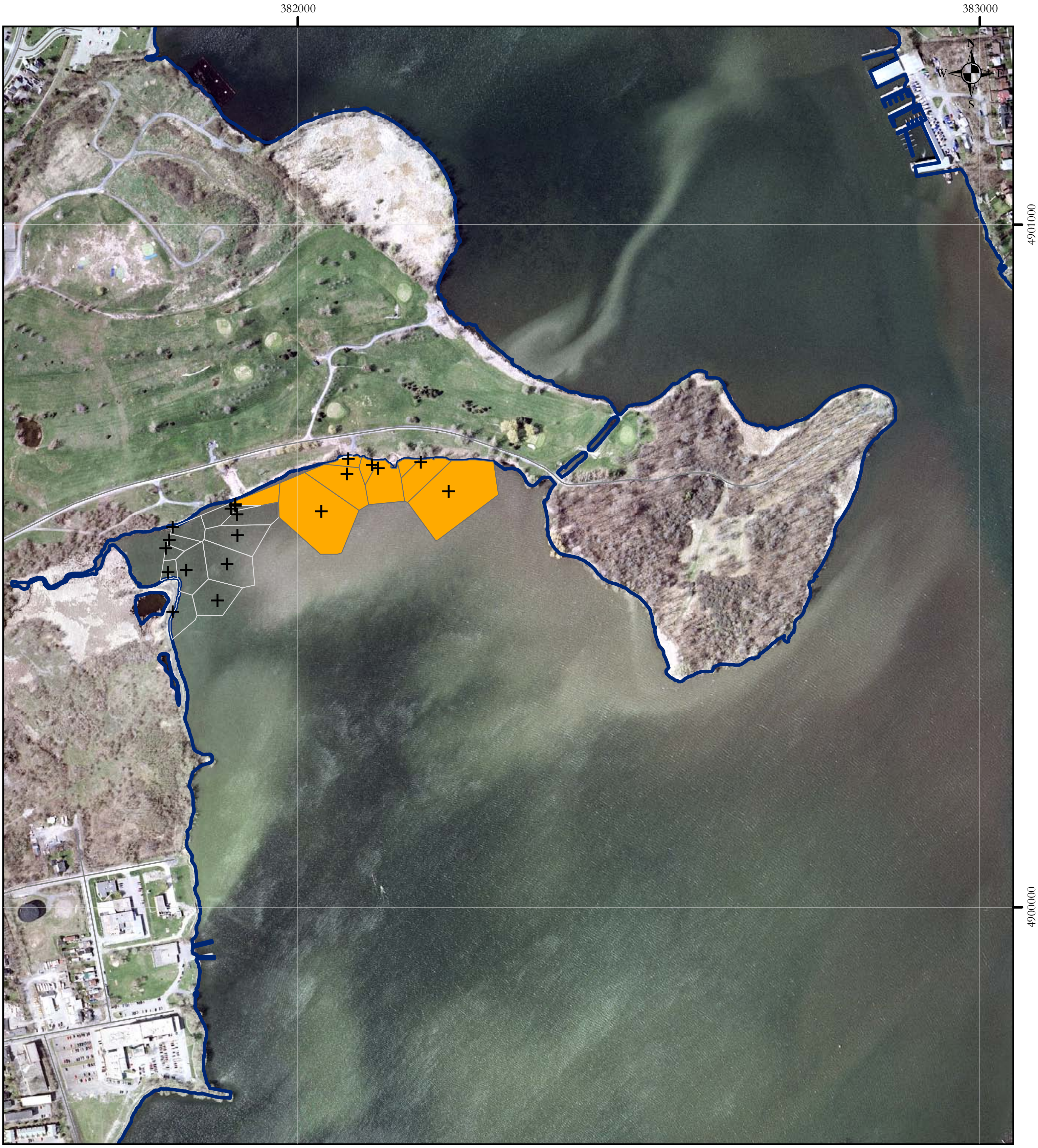
Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Map V-6

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-6_Cr_Dec_2013.mxd



Legend

- \+ KIH PCB Sample
- Thiessen Polygon used to calculate SWAC = 643ppb for PCB
- Area warranting management for PCB

Map V-7: PCB SWAC of 643 ppb of Surface Sediments in Kingston Inner Harbour Brown Bullhead and Mink Home Ranges

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

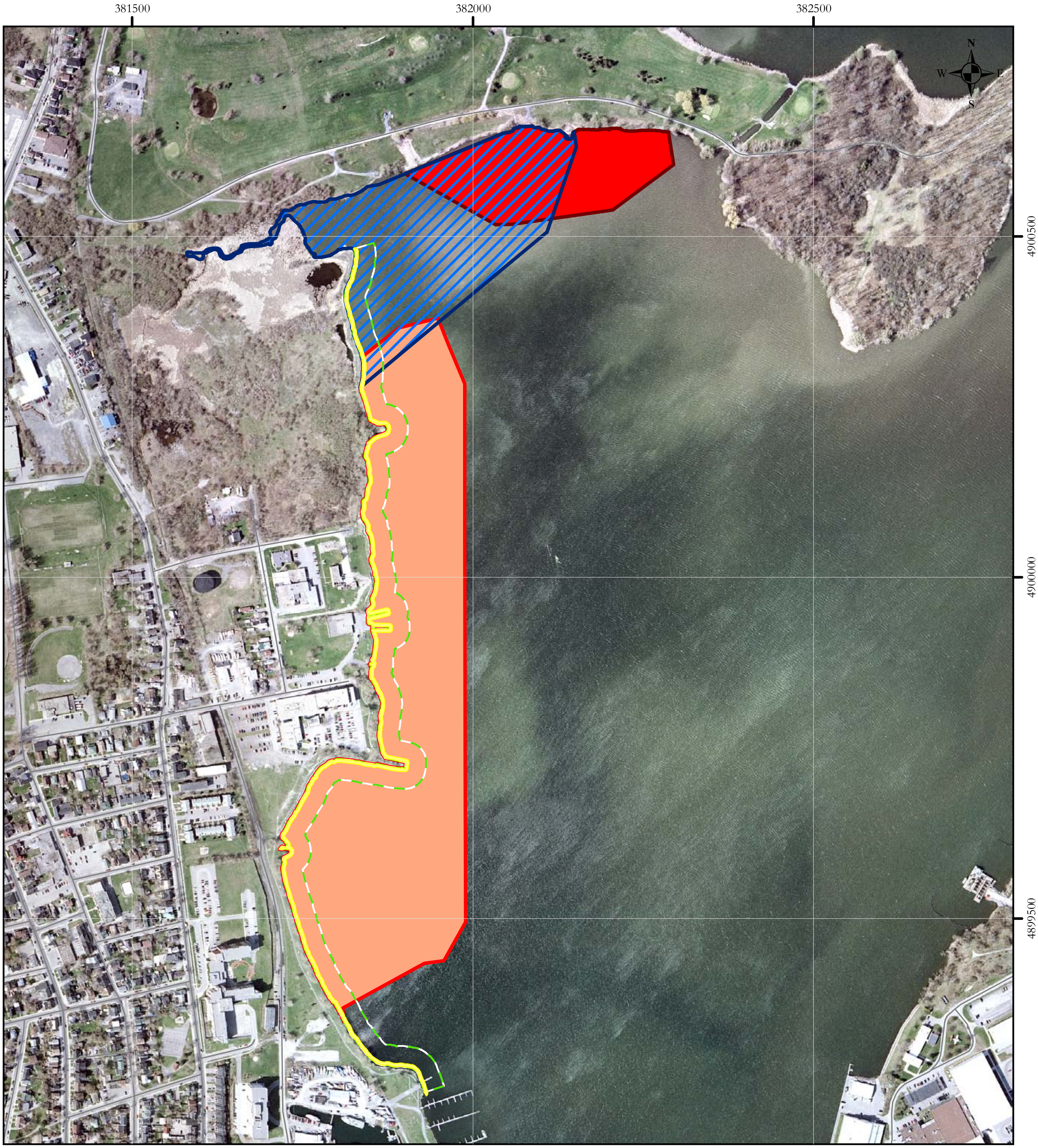
Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
150 75 0 150

Map V-7

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-7_PCB_BullHead_Dec_2013.mxd



Legend

- Management Area for PAHs - 5 m buffer
- Management Area for PAHs - 25 m buffer
- Cr (1164 ppm SWAC Scenario)
- As (6 ppm SWAC - Special Management Western Shoreline)
- PCB (Brown Bullhead and Mink 643 ppb SWAC Scenario)

Map V-8: Management Areas of Contaminants of Concern Kingston Inner Harbour

Environmental Sciences Group
The Royal Military College of Canada
PO Box 17000 Stn Forces
Kingston, Ontario K7L 7B4

Data Resources
Government of Canada
Environmental Sciences Group

Projection
Universal Transverse Mercator (UTM) - Zone 18

Datum
North American Datum 1983 (NAD83)

Date: November 2013

Meters
100 50 0 100 200

MapV-8

J:\Projects\Inner Harbour\Inner Harbour-2013\MXD\SWAC\KIH_V-8_COC_Dec_2013.mxd

APPENDIX C: METHODS

Table of Contents

A. Analyses Conducted at Analytical Services Unit (ASU), Queen's University, and Analytical Sciences Group (ASG), RMC

1. Digestion of Various Matrices for Inorganic Elements

Analyses were conducted by the Analytical Services Unit, Queen's University, Kingston, Ontario. Each sample was clearly labelled and stored in a secured area (before and after analysis) at a temperature appropriate for the analytical method.

a. Sediment

Samples were air-dried and ground to a fine powder with a mortar and pestle. Large stones were removed, as they would not be expected to contain any anthropogenic environmental contaminants. Approximately 0.5 g of powdered sample was heated with 2 mL of nitric acid and 6 mL of hydrochloric acid overnight so that the volume was reduced to 1–2 mL. Distilled deionized water was then added to the solution for a total volume of 25 mL. Although not all metals may be brought into solution by this procedure (some may be locked into silicate minerals), metals that are released are considered to be of greater environmental significance than a true total metals.

b. Plant and Tissue

The majority of the plant digests and analyses for total metal concentrations were conducted by the Analytical Services Unit (ASU), Queen's University, Kingston. A 0.5 g (± 0.0001 g) portion of the dried plant sample was weighed into a clean, dry Vycor® crucible, which was then placed in a Fisher Scientific ISOTEMP programmable muffle furnace. The furnace was programmed to ash the samples with the following heating regime: (1) 150°C for 20 minutes, (2) 250°C for 60 minutes, (3) 500°C for 3 hours, and 4) room temperature until the next morning. The ashed samples were removed from the furnace the next day. A few drops of 18 MΩ distilled dionized water (DDW) were added to wet the ash, followed by the addition of nitric (HNO_3) and hydrochloric (HCl) acids to digest the ashed sample. Following the acid digestion, hydrogen peroxide (H_2O_2) was added to the samples and the volume was reduced to 1 mL. The samples were then made up to 12.5 mL with 18 MΩ DDW. All reagents used were reagent grade.

2. Inorganic Elements by Inductively Coupled Plasma Atomic Emission Spectroscopy

Analyses were conducted by the Analytical Services Unit, Queen's University, Kingston, Ontario. Each sample was clearly labelled and stored in a secured area (before and after analysis) at a temperature appropriate for the analytical method.

Concentrations of inorganic elements were measured using a Varian VISTA AX CCD Simultaneous ICP-AES. Samples were analyzed in batches of up to 36, which comprised up to 28 samples, 2 blanks, 4 duplicates and 2 samples of reference material (NRC MESS-3 or SS-2). A minimum of one SS-2 sample is run each day if samples are analysed for Cd.

3. Polychlorinated Biphenyls in Sediment and Plants

Analyses were conducted by the Analytical Sciences Group, Royal Military College of Canada, Kingston, Ontario. Each sample was clearly labelled and stored at low temperatures in a secured area before and after analysis.

4. Sample Preparation

a. <u>Sediments</u>

All samples were thoroughly homogenized before they were weighed out for analysis. Sediment samples were subsampled for determination of wet/dry weight ratio. Accurately weighed samples of wet sediment (10 g) to which the surrogate standard decachlorobiphenyl (DCBP), sodium sulphate (40 g) and Ottawa sand (20 g) were added, were extracted three times for 20 minutes with 50 mL of dichloromethane on an orbital shaker. Accurately weighed samples of sediment that could not be extracted by shaker were extracted by Soxhlet for 4 hours at 4–6 cycles per hour with 250 mL of dichloromethane. In both cases, the extract was then concentrated by rotoevaporation to which approximately 1 mL, and 5 mL of hexane was added and evaporated to 1 mL. This was repeated twice more, resulting in 1 mL of hexane solvent, which was then applied to a florisil column for cleanup. The column was thoroughly rinsed with hexane and the eluate containing the PCBs diluted to 10 mL. A 2 mL GC vial was filled in preparation for analysis.

An alternative extraction method used for solid samples was pressurized solvent extraction (PSE). Extractions were performed according to ASG Procedure 02-38 "Extraction by PSE." An Applied Separations PSE system capable of six simultaneous extractions was used in conjunction with 33 mL stainless steel extraction vessels, frits, and filters. Each vessel was filled to a depth of approximately 1 cm with florisil cleanup reagent, to which a mixture of 2 g of diatomaceous earth, 10 g sediment, and appropriate surrogate spikes were added. The remaining void was filled with Ottawa sand and glass wool. Six extraction vessels containing samples, blanks, or controls were placed in the automated PSE system. Extraction proceeded according to the following parameters: solvent hexane, static temperature of 100^{o}C, static time of 5 minutes, and 1 extraction cycle. The extracts were flushed to 45 mL collection vessels using a 3 minute solvent flush and 2 minute nitrogen gas flush.

b. Plants (Parts per Million/ECD Analysis)

All samples were spiked with an aliquot of decachlorobiphenyl (DCBP), a surrogate standard, prior to analysis by gas chromatography (GC) with electron capture detection (ECD). The samples were extracted with dichloromethane in a Soxhlet apparatus. The extracts were concentrated in a rotoevaporator and the solvent was exchanged for hexane, which was then eluted through a florisil column to facilitate sample cleanup.

Plant samples were laid out to air dry overnight and then ground using a Waring commercial blender. All the samples were thoroughly homogenized before sampling for analysis. Prior to extraction, DCBP, sodium sulphate (40 g), and Ottawa sand (20 g) were added to each accurately weighed plant sample (1–2 g). The samples were extracted by Soxhlet with 250 mL of dichloromethane for 4 hours at 4–6 cycles per hour. The extract was then concentrated by rotoevaporation to approximately 1 mL, and 5 mL of hexane was added and evaporated to 1 mL. This was repeated twice more, resulting in 1 mL of hexane solvent, which was then applied to a florisil column for cleanup. The column was thoroughly rinsed with hexane and the eluate containing the PCBs was diluted to 10 mL. A GC vial (2 mL) was then filled and the sample analyzed by GC/ECD.

5. Analysis of Sediment and Plants

All samples were analyzed by gas chromatography (GC) with electron capture detection (ECD), using an HP/Agilent 6890 Plus Gas Chromatograph equipped with a ^{63}Ni Electron Capture Detector (GC/ECD), a SGE HT-8 fused silica capillary column (10 m, 0.1 mm i.d. x 0.1 μm film thickness) and HP ChemStation software. The conditions were as follows: Sample volume 0.5 μL, splitless injection, temperature programmed ramp and constant helium carrier gas pressure. Nitrogen was used as a makeup gas for the ECD. All values were reported as μg/g dry weight (ppm).

a. Ultra-low Sediment

Samples requiring ultra-low detection limit analysis were similarly treated, using Soxhlet or PSE extraction techniques. In each case, the samples were concentrated to a known volume of approximately 0.5 mL. A 0.5 μL injection volume was used for GC analysis. All values were reported as ng/g dry weight (ppb).

6. Polychlorinated Biphenyl Aroclors in Sediment, Plants, and Tissue

All samples were thoroughly homogenized before sampling for the analysis. Soil samples were subsampled for the determination of wet/dry weight ratio. Accurately weighed samples of wet soil (10 g), to which the surrogate standard CLB-2 (^{13}C-labelled PCB congener 155), sodium sulphate (40 g) and Ottawa sand (20 g) were added, were extracted by Soxhlet for 4 hours at 4–6 cycles per hour using 250 mL of dichloromethane. The extract was then concentrated by rotoevaporation to approximately 1 mL. Hexane (5 mL) was added and again evaporated to 1 mL. This was repeated twice more, resulting in 1 mL of hexane solvent, which was then applied to a florisil column for cleanup. The column was thoroughly rinsed with hexane, and the eluate containing the PCBs diluted to 10 mL. A GC vial (2 mL) was then filled in preparation for analysis.

An alternative extraction method used for soil samples was pressurized solvent extraction (PSE). Extractions were performed according to ASG Procedure 02-38 “Extraction by PSE.” An Applied Separations PSE system capable of six simultaneous extractions was used in conjunction with 33 mL stainless steel extraction vessels, frits, and filters. Each vessel was filled to a depth of approximately 1 cm with florisil cleanup reagent, to which a mixture of 2 g of diatomaceous earth, 10 g soil, and appropriate surrogate spikes was added. The remaining void was filled with Ottawa sand and glass wool. Six extraction vessels containing samples, blanks, or controls were placed in the automated PSE system. Extraction proceeded according to the following parameters: solvent hexane, static temperature of 100^{o}C, static time of 5 minutes, and 1 extraction cycle. The extracts were flushed to 45 mL collection vessels, using a 3 minute solvent flush and 2 minute nitrogen gas flush. The samples were analyzed by gas chromatography (GC) with mass selective detection (MS), using an Agilent 6890 Plus Gas Chromatograph equipped with an Agilent 5973 MS Detector, an SGE HT-8 fused silica capillary column or equivalent (50 m, 0.22 mm i.d. x 0.25 μm film thickness) and

MSD ChemStation software. The conditions were as follows: sample volume 1 μL, splitless injection, temperature programmed ramp and constant helium carrier gas pressure. Data were collected in single ion monitoring mode with one primary and three secondary ions. Data selection criteria were based on compound retention time and on the relative intensity of primary and secondary ions for standard reference congeners and extracted samples. Calibration standards containing known concentrations of all 209 PCB congeners were used for congener quantitation. Similar Aroclor standards were used to obtain total Aroclor concentrations. Control samples, duplicates, and blanks were extracted for 10% of the samples. All values were reported as ng/g dry weight (ppb).

7. Polychlorinated Biphenyls Congeners/Aroclors in Plants — Part per Billion/GC-MS

Analyses were conducted by the Analytical Sciences Group, Royal Military College of Canada, Kingston, Ontario. Each sample was clearly labelled and stored at low temperatures in a secured area before and after analysis.

Plant samples were laid out to air-dry overnight and then ground using a Waring commercial blender. All samples were thoroughly homogenized before being sub-sampled for analysis. Prior to extraction, CLB-2 (^{13}C-labelled PCB congener 155), sodium sulphate (40 g) and Ottawa sand (20 g) were added to each accurately weighed plant sample (1–2 g). Extraction was by the Soxhlet method over a period of 4 hours at 4–6 cycles per hour, with 250 mL of dichloromethane.

An alternative extraction method used for plant samples was pressurized solvent extraction (PSE). Extractions were performed according to ASG Procedure 02-38 “Extraction by PSE.” An Applied Separations PSE system capable of six simultaneous extractions was used in conjunction with 33-mL stainless steel extraction vessels, frits, and filters. Each vessel was filled to a depth of approximately 1 cm with Ottawa sand, to which a mixture of 2 g of diatomaceous earth, 10 g plant, and appropriate surrogate spikes were added. The remaining void was filled with Ottawa sand and glass wool. Six extraction vessels containing samples, blanks, or controls were placed in the automated PSE system. Extraction proceeded according to the following parameters: solvent hexane, static temperature of 100^{o}C, static time of 5 minutes, and 1 extraction cycle. The extracts were flushed to 45 mL collection vessels using a 3 minute solvent flush and 2 minute nitrogen gas flush.

By either extraction technique, the extraction was subsampled for gravimetric lipid determination. The remaining extract was concentrated by rotoevaporation and evaporation to an approximate volume less than 1 mL. The fraction was applied to a florisil cleanup column and the eluate was concentrated and reconstituted in dichloromethane. When pesticide analysis was not required, the process was repeated and the samples were washed with aqueous sulphuric acid, then dried and spiked with internal standards. Further dichloromethane was added to afford a final volume of 0.5 mL or 10 mL, depending on the required detection limit. When pesticide analysis was required, the extract was concentrated, reconstituted in dichloromethane/hexane, and passed down a prepared 1 m chromatography column containing a BIO RAD S-X3 size exclusion stationary phase. The fraction containing PCB congeners and surrogate was determined by precalibration. The appropriate fraction was collected and concentrated to 0.5 mL or 10 mL, depending on the detection limit.

The samples were analyzed by gas chromatography (GC) with mass selective detection (MS), using an Agilent 6890 Plus Gas Chromatograph equipped with an Agilent 5973 MS Detector, an SGE HT-8 fused silica capillary column or equivalent (50 m, 0.22 mm i.d. x 0.25 μm film thickness) and MSD ChemStation software. The conditions were as follows: sample volume 1 μL, splitless injection, temperature programmed ramp, and constant helium carrier gas pressure. Data were collected in single ion monitoring mode with one primary and three secondary ions. Data selection criteria were based on compound retention time and on the relative intensity of primary and secondary ions for standard reference congeners and extracted samples. Calibration standards containing known concentrations of all 209 PCB congeners were used for congener quantitation. Similar Aroclor standards were used to obtain total Aroclor concentrations. Control samples, duplicates, and blanks were extracted for 10% of the samples. All values were reported as ng/g dry weight (ppb).

8. Analysis of Hexavalent Chromium

The hexavalent chromium in the sample, in the soluble forms CrO_4^{2-}, $Cr_2O_7^{2-}$, and chromic acid, reacts with diphenylcarbohydrazide to form a CrO_4^{2-} diphenyl-carbohydrazide complex, which can be detected spectrophotometrically. Standards were prepared with potassium chromate and diluted in deionized distilled water and 0.5 N sulphuric acid to a working range of 0.05 to 20 µg of Cr VI. A 2 mL aliquot of the water samples was added to approximately 15 ml of 0.5 N sulphuric acid. Diphenylcarbohydrazide solution (0.5 mL) was added to each sample and standard, and then made up to 25 mL volume with 0.5 N sulphuric acid. The flasks were shaken and the colour allowed to develop for a few minutes. The absorbance of the samples and standards was read at 450 nm on a Beckman UV/VIS spectrophotometer, and a graph of Cr VI concentration (µg) versus absorbance was plotted. The resulting calibration line was used to determine the mass of soluble Cr, in µg, in each sample. Soil samples to be analyzed for hexavalent chromium were air-dried overnight and then ground. A 1 g sub-sample was shaken with 20 mL of 0.5 N sulphuric acid in a round-bottomed flask. If the extract was turbid it was filtered with a 0.4 µm Millipore filter. A 2 mL aliquot of the extract was then analyzed in the same way as a water sample.

B. Sediment Sampling

Two standard sediment sampling techniques were used during the investigation and are described below.

1. Surface Sediment Sampling

A Ponar Grab sampler was used to collect surface sediments samples from the bottom of the harbour. Sampling locations were predetermined on mapping software and sampling points uploaded to a portable GPS unit. The boat was anchored and positioned as close to the sampling location as possible. The Ponar Grab apparatus was then lowered over the side of the boat. To collect the sample, a weight was dropped to trigger the bottom hinges to shut, thus trapping the sample in the device. Approximately three Ponar Grabs of sediments were collected at each site and stored in a 40 L cooler to account for heterogeneity in sediments. To homogenize the samples, the sediments were stirred for several minutes using a stainless steel scoop. Subsamples of sediments were then transferred into small Whirlpaks and/or 125 ml amber bottles using the stainless steel scoop. The scoop was decontaminated with water and wiped off between each sample. At the end of each day, the samples were transported to ESG where they were catalogued into the ESG Analytical Database and stored in a refrigerator at 4°C. Chain of Custody reports were prepared for all collected samples and used to track the movement of the samples as they were processed for analysis.

2. Collection of Sediment Cores

The depth of sedimentary contaminants can be determined by collection of sediment cores. Core sampling locations were predetermined on mapping software and sampling points uploaded to a portable GPS unit. As the project developed, the sampling locations were purposely chosen to fill in gaps in the data. Once in the correct area, the boat was anchored and positioned as close to the sampling location as possible.

Two different coring techniques were used: (i) Kajak-Brinkhurst (KLB) gravity core and (ii) the percussion corer.

a. <u>Kajak-Brinkhurst device</u>

The KLB corer retrieves the top layer of the sediment with minimum disturbance. This type of coring device is recommended for soft substrates such as silt or clays. The procedure for retrieving samples using the gravity core involves first lowering the apparatus vertically into the water via a rope. The device is lowered until it rests on the bottom and the plunger is released, plugging the top of the core and allowing the sample to be raised to the surface. The gravity core is useful in providing a fast sample from the surface of the sediment, however the cores are unable to get into the hard underlying clay layer found in the Kingston Inner Harbour and samples were limited to 30–40 centimetres in depth. It was therefore necessary to use another technique so that the extent of the contamination into the clay layer could be studied.

b. <u>Percussion corer</u>

The percussion core is able to collect sediment cores up to 1.5 metres in depth, and therefore permitted samples to be collected into the underlying clay layer. The core is lowered over the side of the boat vertically until it rests on the bottom of the riverbed. The core is then pounded into the hard underlying layer with a hammer device located at top of the apparatus. When the core cannot be pounded any further into the sediment, the top of the core is then plugged and raised to the surface. The core is taped and carefully brought back to shore in the vertical position for analysis. One issue with the percussion corer is that the top layer of sediment from the core is sometimes disturbed when the core is being hammered. For this reason, a gravity core was also collected from each sampling location so that they could be compared to ensure that minimal disturbance had occurred to the upper surface layers.

c. <u>Sectioning of cores</u>

The cores were transported back to land in an upright position and then sectioned into 5 cm samples using a sediment extruder and samples were placed in a sterile numbered Whirlpak for laboratory analysis. To prevent cross-contamination, the extruding tray and scraper were rinsed thoroughly between each sample. As the samples were being sectioned, notes were taken regarding the stratigraphy of the core (i.e. the sediment types in the core and the depths at which the sediment type changed). Also noted was the presence of benthic invertebrates and any indication of smeared sediment on the inside wall of the tube. The samples were stored in refrigeration until analyzed.

APPENDIX D: DATA TABLES

LIST OF TABLES

LIST OF TABLES, CONT'D

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012)

Sample #	Report Locator	Depth (cm)	Easting	Northing
1. Sediment Samples				
06-17042	s9	2.5	381867	4900472
06-17044	S8	2.5	381882	4900335
06-17060	C1 percussion	2.5	382507	4899119
06-17061	C1 percussion	7.5	382507	4899119
06-17062	C1 percussion	12.5	382507	4899119
06-17063	C1 percussion	17.5	382507	4899119
06-17064	C1 percussion	22.5	382507	4899119
06-17065	C1 percussion	27.5	382507	4899119
06-17066	C1 percussion	32.5	382507	4899119
06-17067	C1 percussion	37.5	382507	4899119
06-17068	C1 percussion	42.5	382507	4899119
06-17069	C1 percussion	47.5	382507	4899119
06-17070	C1 percussion	52.5	382507	4899119
06-17071	C1 percussion	57.5	382507	4899119
06-17072	C1 percussion	62.5	382507	4899119
06-17073	C1 percussion	67.5	382507	4899119
06-17074	C1 percussion	72.5	382507	4899119
06-17075	C1 percussion	77.5	382507	4899119
06-17076	C1 percussion	82.5	382507	4899119
06-17077	C1 percussion	87.5	382507	4899119
06-17078	C1 percussion	92.5	382507	4899119
06-17079	C1 percussion	97.5	382507	4899119
06-17080	C1 percussion	102.5	382507	4899119
06-17081	C1KLB	2.5	382507	4899119
06-17081d	C1KLB	2.5	382507	4899119
06-17081d2	C1KLB	2.5	382507	4899119
06-17082	C1KLB	7.5	382507	4899119
06-17083	C1KLB	12.5	382507	4899119
06-17083b	C1KLB	12.5	382507	4899119
06-17084	C1KLB	17.5	382507	4899119
06-17084d	C1KLB	17.5	382507	4899119
06-17085	C1KLB	22.5	382507	4899119
06-17085d	C1KLB	22.5	382507	4899119
06-17086	C1KLB	27.5	382507	4899119
06-17086d	C1KLB	27.5	382507	4899119
06-17086d2	C1KLB	22.5	382507	4899119
06-17087	C7 KLB	2.5	382123	4900523
06-17088	C7 KLB	7.5	382123	4900523
06-17088b	C7 KLB	12.5	382123	4900523
06-17089	C7 KLB	17.5	382123	4900523
06-17089	C7 KLB	22.5	382123	4900523

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012) (cont'd)

06-17090	C7 KLB	27.5	382123	4900523
06-17091	C7 KLB	32.5	382123	4900523
06-17091d	C7 KLB	32.5	382123	4900523
06-17093	C7 KLB	2.5	382123	4900523
06-17094	C7 KLB	7.5	382123	4900523
06-17095	C7 KLB	12.5	382123	4900523
06-17096	C7 KLB	17.5	382123	4900523
06-17097	C7 KLB	22.5	382123	4900523
06-17098	C7 KLB	27.5	382123	4900523
06-17099	C7 KLB	32.5	382123	4900523
06-17100	C3 Percussion	2.5	382237	4899987
06-17101	C3 Percussion	7.5	382237	4899987
06-17102	C3 Percussion	12.5	382237	4899987
06-17102d	C3 Percussion	12.5	382237	4899987
06-17103	C3 Percussion	17.5	382237	4899987
06-17104	C3 Percussion	22.5	382237	4899987
06-17105	C3 Percussion	27.5	382237	4899987
06-17106	C3 Percussion	32.5	382237	4899987
06-17107	C3 Percussion	37.5	382237	4899987
06-17108	C3 Percussion	42.5	382237	4899987
06-17109	C3 Percussion	47.5	382237	4899987
06-17110	C4 percussion	2.5	381902	4900326
06-17111	C4 percussion	7.5	381902	4900326
06-17112	C4 percussion	12.5	381902	4900326
06-17113	C4 percussion	17.5	381902	4900326
06-17114	C4 percussion	22.5	381902	4900326
06-17115	C4 percussion	27.5	381902	4900326
06-17116	C4 percussion	32.5	381902	4900326
06-17116d	C4 percussion	32.5	381902	4900326
06-17117	C4 percussion	37.5	381902	4900326
06-17120	C4 percussion	52.5	381902	4900326
06-17121	C4 percussion	57.5	381902	4900326
06-17122	C4 percussion	62.5	381902	4900326
06-17123	C4 KLB	2.5	381902	4900326
06-17124	C4 KLB	7.5	381902	4900326
06-17124d	C4 KLB	7.5	381902	4900326
06-17125	C4 KLB	12.5	381902	4900326
06-17126	C4 KLB	17.5	381902	4900326
06-17127	C4 KLB	22.5	381902	4900326
06-17128	C5 KLB	2.5	382113	4900266
06-17129	C5 KLB	7.5	382113	4900266
06-17130	C5 KLB	12.5	382113	4900266
06-17131	C5 KLB	17.5	382113	4900266
06-17132	C5 KLB	22.5	382113	4900266

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012) (cont'd)

06-17133	C5 KLB	27.5	382113	4900266
06-17135	C5 Percussion	7.5	382113	4900266
06-17135d	C5 Percussion	7.5	382113	4900266
06-17137	C5 Percussion	17.5	382113	4900266
06-17138	C5 Percussion	22.5	382113	4900266
06-17139	C5 Percussion	27.5	382113	4900266
06-17140	C5 Percussion	32.5	382113	4900266
06-17141	C5 Percussion	37.5	382113	4900266
06-17141b	C5 Percussion	37.5	382113	4900266
06-17141c	C5 Percussion	37.5	382113	4900266
06-17142	C5 Percussion	42.5	382113	4900266
06-17143	C5 Percussion	47.5	382113	4900266
06-17144	C5 Percussion	52.5	382113	4900266
06-17145	C5 Percussion	57.5	382113	4900266
06-17146	C6 Percussion	2.5	382444	4900245
06-17148	C6 Percussion	12.5	382444	4900245
06-17149	C6 Percussion	17.5	382444	4900245
06-17149b	C6 Percussion	17.5	382444	4900245
06-17149c	C6 Percussion	17.5	382444	4900245
06-17150	C6 Percussion	22.5	382444	4900245
06-17150b	C6 Percussion	22.5	382444	4900245
06-17151	C6 Percussion	27.5	382444	4900245
06-17152	C6 Percussion	32.5	382444	4900245
06-17153	C6 KLB	2.5	382444	4900245
06-17154	C6 KLB	7.5	382444	4900245
06-17155	C6 KLB	12.5	382444	4900245
06-17156	C6 KLB	17.5	382444	4900245
06-17157	C6 KLB	22.5	382444	4900245
06-17158	C6 KLB	27.5	382444	4900245
06-17160	C2 Percussion	2.5	382569	4899352
06-17161	C2 Percussion	7.5	382569	4899352
06-17162	C2 Percussion	12.5	382569	4899352
06-17163	C2 Percussion	17.5	382569	4899352
06-17164	C2 Percussion	22.5	382569	4899352
06-17165	C2 Percussion	27.5	382569	4899352
06-17166	C2 Percussion	32.5	382569	4899352
06-17166d	C2 Percussion	32.5	382569	4899352
06-17167	C2 Percussion	37.5	382569	4899352
06-17167d	C2 Percussion	37.5	382569	4899352
06-17168	C2 Percussion	42.5	382569	4899352
06-17169	C2 Percussion	47.5	382569	4899352
06-17170	C2 Percussion	52.5	382569	4899352
06-17171	C2 Percussion	57.5	382569	4899352
06-17172	C2 Percussion	62.5	382569	4899352

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012) (cont'd)

06-17180	C2 Percussion	2.5	382569	4899352
06-17181	C2 Percussion	7.5	382569	4899352
06-17182	C2 Percussion	12.5	382569	4899352
06-17183	C2 Percussion	17.5	382569	4899352
06-17184	C2 Percussion	22.5	382569	4899352
06-17185	C2 Percussion	27.5	382569	4899352
06-17186	C8 KLB	2.5	381971	4900510
06-17187	C8 KLB	7.5	381971	4900510
06-17188	C8 KLB	12.5	381971	4900510
06-17189	C8 KLB	17.5	381971	4900510
06-17190	C7 Percussion	2.5	382123	4900523
06-17190d	C7 Percussion	2.5	382123	4900523
06-17191	C7 Percussion	7.5	382123	4900523
06-17192	C7 Percussion	12.5	382123	4900523
06-17193	C7 Percussion	17.5	382123	4900523
06-17193d	C7 Percussion	17.5	382123	4900523
06-17194	C7 Percussion	22.5	382123	4900523
06-17195	C7 Percussion	27.5	382123	4900523
06-17196	C7 Percussion	32.5	382123	4900523
06-17197	C7 Percussion	37.5	382123	4900523
06-17198	C7 Percussion	42.5	382123	4900523
06-17199	C7 Percussion	47.5	382123	4900523
06-17200	C7 Percussion	52.5	382123	4900523
06-17201	C7 Percussion	57.5	382123	4900523
06-17202	C7 Percussion	62.5	382123	4900523
06-17203	C7 Percussion	67.5	382123	4900523
06-17204	C7 Percussion	72.5	382123	4900523
06-17205	C8 Percussion	2.5	381971	4900510
06-17206	C8 Percussion	7.5	381971	4900510
06-17207	C8 Percussion	12.5	381971	4900510
06-17208	C8 Percussion	17.5	381971	4900510
06-17209	C8 Percussion	22.5	381971	4900510
06-17210	C8 Percussion	27.5	381971	4900510
06-17211	C8 Percussion	32.5	381971	4900510
06-17212	C8 Percussion	37.5	381971	4900510
06-17213	C8 Percussion	42.5	381971	4900510
06-17214	C8 Percussion	47.5	381971	4900510
06-17215	C8 Percussion	52.5	381971	4900510
06-17216	C8 Percussion	57.5	381971	4900510
06-17217	C8 Percussion	62.5	381971	4900510
06-17218	C8 Percussion	67.5	381971	4900510
06-17219	C8 Percussion	72.5	381971	4900510
06-17220	C8 Percussion	77.5	381971	4900510
06-17221	C8 Percussion	82.5	381971	4900510

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012) (cont'd)

06-17222	C8 Percussion	87.5	381971	4900510
06-17265	T3	2.5	382057	4900047
06-17267	T4	2.5	381977	4900232
07-29644	T7	2.5	382276	4900493
07-29646	T8	2.5	382092	4900523
07-29647	T6	2.5	382205	4900143
07-29648	T9	2.5	382360	4900282
07-29649	T5	2.5	382375	4900031
08-29891	T15	2.5	382358	4900314
08-29892	T14	2.5	382282	4900498
08-29893	T13	2.5	382040	4900546
08-29895	T16	2.5	382172	4900375
08-29898	T17	2.5	382138	4900158
08-29900	T18	2.5	381902	4899869
08-42000	T7	2.5	382274	4900493
08-42004	T8	2.5	382128	4900541
08-42012	Station BIV5	2.5	382111	4900630
08-42041	Station BC1	2.5	381914	4899874
08-42046	Station BC2	2.5	382055	4900058
08-42051	Station BC3	2.5	381980	4900226
08-42064	Cat4	2.5	382313	4900651
08-42068	Cat3	2.5	382073	4900663
08-42076	Cat1	2.5	381816	4900557
08-42104	C1 15-20	17.5	382026	4900462
08-42113	C4 0-5	7.5	381920	4900136
08-42116	C4 15-20	22.5	381920	4900136
08-42140	SSM9	0-10	382090	4900492
08-42141	SSM1	0-10	381924	4900549
08-42143	SSM3	0-10	382175	4900605
08-42146	SSM6	0-10	382244	4900435
08-42147	SSM7	0-10	382019	4900387
09-25600		0-10	382040	4900391
09-25601		0-10	381978	4900229
09-25602		0-10	381927	4900085
09-25605		0-10	382055	4900042
09-25606		0-10	382037	4899905
09-25610		0-10	381912	4900512
09-25611		0-10	382195	4900591
09-25612		0-10	382010	4900575
09-25613		0-10	382089	4900518
09-25614		0-10	382168	4900369
09-25706	C20	0-10	381961	4900471
09-25705	C8	0-10	381970	4900509
10-20498	sed15	0-10	381935	4899383

Table D-II-1: Site Location, Date, GPS Coordinates for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012) (cont'd)

10-20501	sed16	0-10	381818	4899680
10-20502	sed17	0-10	381935	4899591
10-20503	sed18	0-10	382082	4899651
10-20492	sed20	0-10	382053	4900034
12-01609	ABA-1 (AB-02)	0-10	381951	4899103
12-01610	ABA-1 (AB-02)	0-10	381951	4899103
12-01614	ABA-2 (AB-03)	0-10	381989	4899102
12-01615	ABA-2 (AB-03)	0-10	381989	4899102
12-01618	ABA-3 (AB-04)	0-10	382017	4899099
12-01619	ABA-3 (AB-04)	0-10	382017	4899099
12-01622	ABA-4 (AB-05)	0-10	382044	4899096
12-01623	ABA-4 (AB-05)	0-10	382044	4899096
12-01626	ABA-7 (AB-06)	0-10	382058	4899077
12-01627	ABA-7 (AB-06)	0-10	382058	4899077
12-01630	ABA-8 (AB-07)	0-10	382059	4899051
12-01631	ABA-8 (AB-07)	0-10	382059	4899051
12-01634	ABA-5 (AB-08)	0-10	382054	4899097
12-01635	ABA-5 (AB-08)	0-10	382054	4899097
12-01636	ABA-5 (AB-08)	0-10	382054	4899097

Table D-II-2: Grain Size and Total Organic Carbon (TOC) for Sediment Samples Collected by ESG in the Kingston Inner Harbour (2006-2012)

Sample #	Report Locator	Depth [cm]	Clay [%]	Sand [%]	Silt [%]	TOC [%]
1. Sediment Samples						
06-17265	T3	0-5	57	40	3.7	6.5
06-17267	T4	0-5	57	41	2.2	6.0
07-29644	T7a	0-5	33	55	13	4.2
07-29646	T8a	0-5	38	54	8.0	4.1
07-29647	T6	0-5	36	53	11	5.6
07-29649	T5	0-5	36	50	14	
08-42000	T7b	0-5	45	49	5.7	
08-42041	BC1	0-5				9.2
08-42046	BC2	0-5				8.1
08-42051	BC3	0-5				8.9
12-01610		0-10				7.6
12-01615		0-10				3.7
12-01619		0-10				6.8
12-01623		0-10				8.0
12-01627		0-10				2.2
12-01631		0-10				18
12-01634		0-10				15

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
			[cm]	Easting	Northing	[ppm]
CCME ISQG						*37.3*
CCME PEL						***90***
Ontario SQG - LEL						**26**
1. Jaagumagi, 1991						
AQ1		1990	2.5	381842	4899073	*86*
AQ2		1990	2.5	381921	4899102	***190***
AQ3		1990	2.5	381866	4899143	***290***
2. Totten Sims Hubicki Associates, 1992						
T10		1985	0.0	381866	4900031	***800***
T11		1985	0.0	382152	4899924	***1300***
T12		1985	0.0	382473	4899823	***480***
T13		1985	0.0	382791	4899729	***110***
T14		1985	0.0	381752	4899657	***160***
T15		1985	0.0	381850	4899465	***350***
T16		1985	0.0	382053	4899419	***410***
T17		1985	0.0	382258	4899365	***300***
T18		1985	0.0	382462	4899315	***170***
T19		1985	0.0	381856	4899139	***330***
T6		1985	0.0	381911	4900575	***15000***
T7		1985	0.0	382261	4900493	***940***
T8		1985	0.0	382801	4900362	*63*
T9		1985	0.0	383089	4900296	*77*
3. Derry et al, 2003						
31	SE-1	2001	0.5	381868	4899833	*82*
37	SE-7	2001	0.5	381859	4900242	***1200***
38	SE-8	2001	0.5	382580	4899260	***94***
39	SE-9	2001	0.5	382998	4899601	***97***
40	SE-10	2001	0.5	383168	4900213	***97***
47	SE-17	2001	0.5	382118	4900643	***3100***
54	SE-24	2001	0.5	381848	4899058	***120***
56	SE-26	2001	0.5	381841	4900318	***1300***
63	Duplicate of 31	2001	0.5	381868	4899833	*79*
A3		2001	2.5	382503	4899989	***380***
A4		2001	2.5	382427	4900147	***840***
A5		2001	2.5	382307	4900281	***1200***
A6		2001	2.5	382086	4900398	***390***
A7		2001	2.5	381985	4900357	***1700***
G3		2001	2.5	382401	4899801	***480***
G4		2001	2.5	382122	4899844	***920***
K10		2001	2.5	382086	4900398	***440***
K11		2001	2.5	382180	4900652	***820***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
				Easting	Northing	
			[cm]			[ppm]
K12		2001	2.5	381908	4900590	***9900***
K12		2001	2.5	381908	4900590	***5300***
K13		2001	2.5	381811	4900538	***5900***
S10		2001	2.5	382221	4900609	***1300***
S11		2001	2.5	381928	4900203	***1600***
S12		2001	2.5	382142	4900256	***960***
S13		2001	2.5	382336	4900489	***860***
S14		2001	2.5	381921	4900144	***1700***
S15		2001	2.5	382195	4900079	***1100***
S16		2001	2.5	382294	4900071	***530***
S7		2001	2.5	381809	4900491	***4800***
S8		2001	2.5	381882	4900449	***1100***
S9		2001	2.5	382034	4900580	***1300***
4. ESG , 2002						
FF6		2002	2.5	382136	4900380	**1200**
5. MOE Benoit, 2006						
06 15 083		2003	5.0	381836	4900494	***8600***
06 15 085		2003	5.0	381726	4901247	*42*
06 15 0182		2003	5.0	382072	4900635	***1100***
06 15 0183		2003	5.0	381867	4899898	***670***
06 15 0184		2003	5.0	381882	4899764	***1000***
L7A		2003	5.0	381848	4900062	***1140***
L8A		2003	5.0	381849	4900031	***267***
L9A		2003	5.0	381857	4899996	***149***
L9B		2003	15	381857	4899996	***263***
L10A		2003	5.0	381845	4899956	***261***
L10B		2003	15	381845	4899956	***149***
L11A		2003	5.0	381848	4899944	***752***
L11B		2003	15	381848	4899944	***1020***
L12A		2003	5.0	381850	4899911	***637***
L12B		2003	15	381850	4899911	***548***
L13A		2003	5.0	381848	4899883	*83*
L13B		2003	15	381848	4899883	*73*
L14A		2003	5.0	381854	4899838	*65*
L14B		2003	15	381854	4899838	**31**
RC-1		2003	1.0	381866	4899998	***349***
RC-2		2003	1.0	381914	4899998	***770***
RC-2		2003	5.0	381914	4899998	***902***
RC-2		2003	15	381914	4899998	***1320***
RC-2		2003	25	381914	4899998	***2580***
RC-3		2003	1.0	381867	4899934	***619***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
				Easting	Northing	
			[cm]			[ppm]
RC-4		2003	1.0	381912	4899934	***740***
RC-4		2003	5.0	381912	4899934	***933***
RC-4		2003	15	381912	4899934	***1110***
RC-4		2003	25	381912	4899934	***1760***
RC-5		2003	1.0	381961	4899934	***788***
RC-6		2003	1.0	381867	4899867	***503***
RC-7		2003	1.0	381914	4899867	***845***
RC-7		2003	5.0	381914	4899867	***1030***
RC-7		2003	15	381914	4899867	***1020***
RC-8		2003	1.0	381961	4899867	***947***
RC-9		2003	1.0	381875	4899802	***397***
RC-10		2003	1.0	381916	4899802	***853***
RC-11		2003	1.0	381957	4899802	***1050***
RC-12		2003	1.0	381884	4899736	***991***
RC-13		2003	1.0	381924	4899736	***1050***
RC-14		2003	1.0	381965	4899736	***1130***
RC-15		2003	1.0	381914	4899964	***534***
RC-16		2003	1.0	381866	4899931	***710***
RC-17		2003	1.0	381914	4899899	***1040***
RC-18		2003	1.0	381867	4899934	***644***
6. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	***113***
04-24249	ERA2	2004	2.5	382567	4899317	***129***
04-24254	ERA3	2004	2.5	382622	4899477	***162***
04-24259	ERA4	2004	2.5	382388	4899535	***189***
04-24264	ERA5	2004	2.5	382133	4900254	***1480***
04-24269	ERA6	2004	2.5	383123	4900238	***102***
04-24283	ERA8	2004	2.5	382851	4901111	*48*
04-24284	ERA8	2004	2.5	382851	4901111	*43*
04-24295	SED11	2004	2.5	382753	4899612	***129***
04-24296	SED12	2004	2.5	382914	4899802	***104***
04-24297	SED13	2004	2.5	383025	4899970	*87*
04-24301	SED16	2004	2.5	382979	4900418	*89*
04-24302	SED17	2004	2.5	382862	4899987	***123***
04-24303	SED18	2004	2.5	382609	4900093	***307***
04-24304	SED19	2004	2.5	382538	4899915	***268***
04-24305	SED20	2004	2.5	382645	4899810	***109***
04-24306	SED21	2004	2.5	382368	4899708	***341***
04-24307	SED22	2004	2.5	382329	4899541	***406***
04-24308	SED23	2004	2.5	382298	4899304	***167***
04-24309	SED24	2004	2.5	382505	4899251	***125***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cr**
				Easting	**Northing**	
			[cm]			**[ppm]**
05-17280	Core3	2005	2.5	381932	4899911	***696***
05-17281	Core3	2005	7.5	381932	4899911	***881***
05-17282	Core3	2005	12.5	381932	4899911	***1065***
05-17283	Core3	2005	17.5	381932	4899911	***987***
05-17284	Core3	2005	22.5	381932	4899911	***1011***
05-17285	Core3	2005	27.5	381932	4899911	***1204***
05-17286	Core3	2005	32	381932	4899911	***1321***
05-17287	Core4	2005	2.5	381921	4900336	***993***
05-17288	Core4	2005	7.5	381921	4900336	***1395***
05-17289	Core4	2005	12.5	381921	4900336	***1818***
05-17290	Core4	2005	17.5	381921	4900336	***2754***
05-17291	Core4	2005	22.5	381921	4900336	***5617***
05-17292	Core4	2005	27.5	381921	4900336	***12204***
05-17293	Core4	2005	31.5	381921	4900336	***4416***
05-17294	Core5	2005	2.5	382215	4899499	***303***
05-17295	Core5	2005	7.5	382215	4899499	***365***
05-17296	Core5	2005	12.5	382215	4899499	***462***
05-17297	Core5	2005	17.5	382215	4899499	***611***
05-17298	Core5	2005	37.5	382215	4899499	***418***
05-17299	Core6	2005	2.5	382246	4899945	***679***
05-17300	Core6	2005	7.5	382246	4899945	***907***
05-17301	Core6	2005	12.5	382246	4899945	***1363***
05-17302	Core6	2005	17.5	382246	4899945	***1242***
05-17303	Core6	2005	22.5	382246	4899945	***2438***
05-17304	Core6	2005	27.5	382246	4899945	***3423***
05-17305	Core6	2005	32.5	382246	4899945	***1648***
05-17306	Core6	2005	36.5	382246	4899945	***955***
05-17311	Core1	2005	2.5	382506	4899126	***125***
05-17312	Core1	2005	7.5	382506	4899126	***133***
05-17313	Core1	2005	12.5	382506	4899126	***132***
05-17314	Core1	2005	17.5	382506	4899126	***148***
05-17315	Core1	2005	22.5	382506	4899126	***172***
05-17316	Core1	2005	27.5	382506	4899126	***244***
05-17317	Core1	2005	32.5	382506	4899126	***187***
05-17351	SED37	2005	2.5	382689	4900329	***225***
05-17352	SED38	2005	2.5	382424	4900259	***1023***
05-17353	Core7	2005	2.5	383047	4900149	***92***
05-17354	Core7	2005	7.5	383047	4900149	***105***
05-17355	Core7	2005	12.5	383047	4900149	***95***
05-17356	Core7	2005	17.5	383047	4900149	***105***
05-17357	Core7	2005	22.5	383047	4900149	***132***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
			[cm]	Easting	Northing	[ppm]
05-17358	Core7	2005	27.5	383047	4900149	***110***
05-17388	Core8	2005	2.5	382424	4900227	***668***
05-17389	Core8	2005	7.5	382424	4900227	***749***
05-17390	Core8	2005	12.5	382424	4900227	***954***
05-17391	Core8	2005	17.5	382424	4900227	***1181***
05-17392	Core8	2005	22.5	382424	4900227	***1541***
05-17393	Core8	2005	26	382424	4900227	***1460***
05-17421	SED39	2005	2.5	382026	4899286	***380***
05-17422	SED40	2005	2.5	382175	4899130	***208***
05-17436	Core2	2005	2.5	382592	4899410	***113***
05-17437	Core2	2005	7.5	382592	4899410	***129***
05-17438	Core2	2005	12.5	382592	4899410	***140***
05-17439	Core2	2005	17.5	382592	4899410	***161***
05-17440	Core2	2005	22.5	382592	4899410	***235***
05-17441	Core2	2005	27.5	382592	4899410	***198***
05-17442	Core2	2005	31.5	382592	4899410	***616***
05-30029	ERA11	2005	2.5	382036	4900455	***763***
05-30056	SED28	2005	2.5	382187	4899646	***744***
05-30058	SED26	2005	2.5	382357	4899119	***126***
7. ESG, 2006						
06-17060	C1 percussion	2006	2.5	382507	4899119	***<100***
06-17061	C1 percussion	2006	7.5	382507	4899119	***<100***
06-17062	C1 percussion	2006	12.5	382507	4899119	***<100***
06-17063	C1 percussion	2006	17.5	382507	4899119	***187***
06-17064	C1 percussion	2006	22.5	382507	4899119	***182***
06-17065	C1 percussion	2006	27.5	382507	4899119	***172***
06-17066	C1 percussion	2006	32.5	382507	4899119	***280***
06-17067	C1 percussion	2006	37.5	382507	4899119	***373***
06-17068	C1 percussion	2006	42.5	382507	4899119	***189***
06-17069	C1 percussion	2006	47.5	382507	4899119	***222***
06-17070	C1 percussion	2006	52.5	382507	4899119	***<100***
06-17071	C1 percussion	2006	57.5	382507	4899119	***<100***
06-17072	C1 percussion	2006	62.5	382507	4899119	***174***
06-17073	C1 percussion	2006	67.5	382507	4899119	***<100***
06-17074	C1 percussion	2006	72.5	382507	4899119	***<100***
06-17075	C1 percussion	2006	77.5	382507	4899119	***198***
06-17076	C1 percussion	2006	82.5	382507	4899119	***<100***
06-17077	C1 percussion	2006	87.5	382507	4899119	***<100***
06-17078	C1 percussion	2006	92.5	382507	4899119	***<100***
06-17079	C1 percussion	2006	97.5	382507	4899119	***<100***
06-17080	C1 percussion	2006	102.5	382507	4899119	***<100***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
			[cm]	Easting	Northing	[ppm]
06-17081	C1KLB	2006	2.5	382507	4899119	***169***
06-17081d	C1KLB	2006	2.5	382507	4899119	***<100***
06-17081d2	C1KLB	2006	2.5	382507	4899119	***<100***
06-17082	C1KLB	2006	7.5	382507	4899119	***409***
06-17083	C1KLB	2006	12.5	382507	4899119	***<100***
06-17083b	C1KLB	2006	12.5	382507	4899119	***<100***
06-17084	C1KLB	2006	17.5	382507	4899119	***136***
06-17084d	C1KLB	2006	17.5	382507	4899119	***150***
06-17085	C1KLB	2006	22.5	382507	4899119	***134***
06-17085d	C1KLB	2006	22.5	382507	4899119	***268***
06-17086	C1KLB	2006	27.5	382507	4899119	***<100***
06-17086d	C1KLB	2006	27.5	382507	4899119	***207***
06-17086d2	C1KLB	2006	22.5	382507	4899119	***190***
06-17087	C7 KLB	2006	2.5	382123	4900523	***954***
06-17088	C7 KLB	2006	7.5	382123	4900523	***<100***
06-17088b	C7 KLB	2006	12.5	382123	4900523	***752***
06-17089	C7 KLB	2006	17.5	382123	4900523	***186***
06-17089	C7 KLB	2006	22.5	382123	4900523	***<100***
06-17090	C7 KLB	2006	27.5	382123	4900523	***<100***
06-17091	C7 KLB	2006	32.5	382123	4900523	***353***
06-17091d	C7 KLB	2006	32.5	382123	4900523	***227***
06-17093	C7 KLB	2006	2.5	382123	4900523	***1004***
06-17094	C7 KLB	2006	7.5	382123	4900523	***641***
06-17095	C7 KLB	2006	12.5	382123	4900523	***287***
06-17096	C7 KLB	2006	17.5	382123	4900523	***219***
06-17097	C7 KLB	2006	22.5	382123	4900523	***235***
06-17098	C7 KLB	2006	27.5	382123	4900523	***8102***
06-17099	C7 KLB	2006	32.5	382123	4900523	***5860***
06-17100	C3 Percussion	2006	2.5	382237	4899987	***615***
06-17101	C3 Percussion	2006	7.5	382237	4899987	***962***
06-17102	C3 Percussion	2006	12.5	382237	4899987	***1417***
06-17102d	C3 Percussion	2006	12.5	382237	4899987	***1332***
06-17103	C3 Percussion	2006	17.5	382237	4899987	***1846***
06-17104	C3 Percussion	2006	22.5	382237	4899987	***552***
06-17105	C3 Percussion	2006	27.5	382237	4899987	***<LOD***
06-17106	C3 Percussion	2006	32.5	382237	4899987	***<LOD***
06-17107	C3 Percussion	2006	37.5	382237	4899987	***<LOD***
06-17108	C3 Percussion	2006	42.5	382237	4899987	***<LOD***
06-17109	C3 Percussion	2006	47.5	382237	4899987	***<LOD***
06-17110	C4 percussion	2006	2.5	381902	4900326	***983***
06-17111	C4 percussion	2006	7.5	381902	4900326	***1061***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
			[cm]	Easting	Northing	[ppm]
06-17112	C4 percussion	2006	12.5	381902	4900326	***1328***
06-17113	C4 percussion	2006	17.5	381902	4900326	***1785***
06-17114	C4 percussion	2006	22.5	381902	4900326	***2304***
06-17115	C4 percussion	2006	27.5	381902	4900326	***2844***
06-17116	C4 percussion	2006	32.5	381902	4900326	***3800***
06-17116d	C4 percussion	2006	32.5	381902	4900326	***4146***
06-17117	C4 percussion	2006	37.5	381902	4900326	***1146***
06-17120	C4 percussion	2006	52.5	381902	4900326	***<100***
06-17121	C4 percussion	2006	57.5	381902	4900326	***<100***
06-17122	C4 percussion	2006	62.5	381902	4900326	***<100***
06-17123	C4 KLB	2006	2.5	381902	4900326	***1307***
06-17124	C4 KLB	2006	7.5	381902	4900326	***1863***
06-17124d	C4 KLB	2006	7.5	381902	4900326	***1889***
06-17125	C4 KLB	2006	12.5	381902	4900326	***2501***
06-17126	C4 KLB	2006	17.5	381902	4900326	***3377***
06-17127	C4 KLB	2006	22.5	381902	4900326	***251***
06-17128	C5 KLB	2006	2.5	382113	4900266	***1195***
06-17129	C5 KLB	2006	7.5	382113	4900266	***1334***
06-17130	C5 KLB	2006	12.5	382113	4900266	***1454***
06-17131	C5 KLB	2006	17.5	382113	4900266	***2028***
06-17132	C5 KLB	2006	22.5	382113	4900266	***6157***
06-17133	C5 KLB	2006	27.5	382113	4900266	***6287***
06-17135	C5 Percussion	2006	7.5	382113	4900266	***1504***
06-17135d	C5 Percussion	2006	7.5	382113	4900266	***1373***
06-17137	C5 Percussion	2006	17.5	382113	4900266	***4256***
06-17138	C5 Percussion	2006	22.5	382113	4900266	***6621***
06-17139	C5 Percussion	2006	27.5	382113	4900266	***3371***
06-17140	C5 Percussion	2006	32.5	382113	4900266	***1919***
06-17141	C5 Percussion	2006	37.5	382113	4900266	***323***
06-17141b	C5 Percussion	2006	37.5	382113	4900266	***307***
06-17141c	C5 Percussion	2006	37.5	382113	4900266	***837***
06-17142	C5 Percussion	2006	42.5	382113	4900266	***<100***
06-17143	C5 Percussion	2006	47.5	382113	4900266	***<100***
06-17144	C5 Percussion	2006	52.5	382113	4900266	***<100***
06-17145	C5 Percussion	2006	57.5	382113	4900266	***244***
06-17146	C6 Percussion	2006	2.5	382444	4900245	***720***
06-17148	C6 Percussion	2006	12.5	382444	4900245	***1038***
06-17149	C6 Percussion	2006	17.5	382444	4900245	***1321***
06-17149b	C6 Percussion	2006	17.5	382444	4900245	***1531***
06-17149c	C6 Percussion	2006	17.5	382444	4900245	***1209***
06-17150	C6 Percussion	2006	22.5	382444	4900245	***1480***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cr**
				Easting	**Northing**	
			[cm]			**[ppm]**
06-17150b	C6 Percussion	2006	22.5	382444	4900245	***1567***
06-17151	C6 Percussion	2006	27.5	382444	4900245	***389***
06-17152	C6 Percussion	2006	32.5	382444	4900245	***<100***
06-17153	C6 KLB	2006	2.5	382444	4900245	***487***
06-17154	C6 KLB	2006	7.5	382444	4900245	***645***
06-17155	C6 KLB	2006	12.5	382444	4900245	***990***
06-17156	C6 KLB	2006	17.5	382444	4900245	***1258***
06-17157	C6 KLB	2006	22.5	382444	4900245	***1387***
06-17158	C6 KLB	2006	27.5	382444	4900245	***1360***
06-17160	C2 Percussion	2006	2.5	382569	4899352	***<100***
06-17161	C2 Percussion	2006	7.5	382569	4899352	***<100***
06-17162	C2 Percussion	2006	12.5	382569	4899352	***183***
06-17163	C2 Percussion	2006	17.5	382569	4899352	***142***
06-17164	C2 Percussion	2006	22.5	382569	4899352	***<100***
06-17165	C2 Percussion	2006	27.5	382569	4899352	***<100***
06-17166	C2 Percussion	2006	32.5	382569	4899352	***<100***
06-17166d	C2 Percussion	2006	32.5	382569	4899352	***<100***
06-17167	C2 Percussion	2006	37.5	382569	4899352	***<100***
06-17167d	C2 Percussion	2006	37.5	382569	4899352	***<100***
06-17168	C2 Percussion	2006	42.5	382569	4899352	***<100***
06-17169	C2 Percussion	2006	47.5	382569	4899352	***<100***
06-17170	C2 Percussion	2006	52.5	382569	4899352	***<100***
06-17171	C2 Percussion	2006	57.5	382569	4899352	***<100***
06-17172	C2 Percussion	2006	62.5	382569	4899352	***<100***
06-17180	C2 Percussion	2006	2.5	382569	4899352	***<100***
06-17181	C2 Percussion	2006	7.5	382569	4899352	***<100***
06-17182	C2 Percussion	2006	12.5	382569	4899352	***<100***
06-17183	C2 Percussion	2006	17.5	382569	4899352	***137***
06-17184	C2 Percussion	2006	22.5	382569	4899352	***132***
06-17185	C2 Percussion	2006	27.5	382569	4899352	***246***
06-17186	C8 KLB	2006	2.5	381971	4900510	***3500***
06-17187	C8 KLB	2006	7.5	381971	4900510	***3747***
06-17188	C8 KLB	2006	12.5	381971	4900510	***3332***
06-17189	C8 KLB	2006	17.5	381971	4900510	***11700***
06-17190	C7 Percussion	2006	2.5	382123	4900523	***895***
06-17190d	C7 Percussion	2006	2.5	382123	4900523	***812***
06-17191	C7 Percussion	2006	7.5	382123	4900523	***1053***
06-17192	C7 Percussion	2006	12.5	382123	4900523	***584***
06-17193	C7 Percussion	2006	17.5	382123	4900523	***211***
06-17193d	C7 Percussion	2006	17.5	382123	4900523	***264***
06-17194	C7 Percussion	2006	22.5	382123	4900523	***199***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cr**
			[cm]	**Easting**	**Northing**	**[ppm]**
06-17195	C7 Percussion	2006	27.5	382123	4900523	***1228***
06-17196	C7 Percussion	2006	32.5	382123	4900523	***3455***
06-17197	C7 Percussion	2006	37.5	382123	4900523	***252***
06-17198	C7 Percussion	2006	42.5	382123	4900523	***<100***
06-17199	C7 Percussion	2006	47.5	382123	4900523	***<100***
06-17200	C7 Percussion	2006	52.5	382123	4900523	***<100***
06-17201	C7 Percussion	2006	57.5	382123	4900523	***<100***
06-17202	C7 Percussion	2006	62.5	382123	4900523	***<100***
06-17203	C7 Percussion	2006	67.5	382123	4900523	***<100***
06-17204	C7 Percussion	2006	72.5	382123	4900523	***<100***
06-17205	C8 Percussion	2006	2.5	381971	4900510	***4294***
06-17206	C8 Percussion	2006	7.5	381971	4900510	***3757***
06-17207	C8 Percussion	2006	12.5	381971	4900510	***4543***
06-17208	C8 Percussion	2006	17.5	381971	4900510	***3835***
06-17209	C8 Percussion	2006	22.5	381971	4900510	***3371***
06-17210	C8 Percussion	2006	27.5	381971	4900510	***3220***
06-17211	C8 Percussion	2006	32.5	381971	4900510	***5700***
06-17212	C8 Percussion	2006	37.5	381971	4900510	***41000***
06-17213	C8 Percussion	2006	42.5	381971	4900510	***42737***
06-17214	C8 Percussion	2006	47.5	381971	4900510	***38766***
06-17215	C8 Percussion	2006	52.5	381971	4900510	***33800***
06-17216	C8 Percussion	2006	57.5	381971	4900510	***6854***
06-17217	C8 Percussion	2006	62.5	381971	4900510	***228***
06-17218	C8 Percussion	2006	67.5	381971	4900510	***114***
06-17219	C8 Percussion	2006	72.5	381971	4900510	***82***
06-17220	C8 Percussion	2006	77.5	381971	4900510	***<100***
06-17221	C8 Percussion	2006	82.5	381971	4900510	***<100***
06-17222	C8 Percussion	2006	87.5	381971	4900510	***<100***
06-17265	T3	2006	2.5	382057	4900047	***1025***
06-17267	T4	2006	2.5	381977	4900232	***1045***
8. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	***426***
CAT 3		2006	1.5	381918	4899966	***678***
CAT 4		2006	1.5	381917	4899936	***497***
CAT 5		2006	1.5	381971	4899936	***703***
CAT 6		2006	1.5	381962	4899897	***752***
CAT 7		2006	1.5	381914	4899897	***750***
CAT 8		2006	1.5	381863	4899902	***392***
CAT 9		2006	1.5	381872	4899839	***398***
CAT 10		2006	1.5	381915	4899835	***869***
CAT 11		2006	1.5	381963	4899840	***1060***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cr**
			[cm]	**Easting**	**Northing**	**[ppm]**
CAT 12		2006	1.5	381896	4899805	***1080***
CAT 13		2006	1.5	381921	4899782	***926***
CAT 14		2006	1.5	381967	4899779	***1070***
CAT 15		2006	1.5	381879	4899743	***499***
CAT 16		2006	1.5	381928	4899734	***896***
CAT 17		2006	1.5	381868	4899964	***1070***
CAT 18		2006	1.5	382074	4900453	***972***
CAT 19		2006	1.5	382211	4900465	***723***
CAT 20		2006	1.5	382346	4900382	***1170***
CAT 21		2006	1.5	381856	4900386	***1950***
CAT 22		2006	1.5	382074	4900657	***7760***
CAT 24		2006	1.5	381744	4901241	***58***
CAT 26		2006	1.5	381816	4900433	***1670***
CAT 27		2006	0-10	381896	4900503	***10600***
CAT 28		2006	11-25	381896	4900503	***14300***
CAT 29		2006	26-33	381896	4900503	***33100***
CAT 32		2006	0-10	381882	4900406	***1460***
CAT 32		2006	11-25	381882	4900406	***2020***
CAT 32		2006	26-46	381882	4900406	***3720***
9. ESG, 2007-2009						
07-29644	T7	2007	2.5	382276	4900493	***1210***
07-29646	T8	2007	2.5	382092	4900523	***496***
07-29647	T6	2007	2.5	382205	4900143	***1199***
07-29648	T9	2007	2.5	382360	4900282	***1026***
07-29649	T5	2007	2.5	382375	4900031	***777***
08-29891	T15	2008	2.5	382358	4900314	***1059***
08-29892	T14	2008	2.5	382282	4900498	***933***
08-29893	T13	2008	2.5	382040	4900546	***879***
08-29895	T16	2008	2.5	382172	4900375	***658***
08-29898	T17	2008	2.5	382138	4900158	***1056***
08-29900	T18	2008	2.5	381902	4899869	***759***
08-42000	T7	2008	2.5	382274	4900493	***1002***
08-42004	T8	2008	2.5	382128	4900541	***815***
08-42012	Station BIV5	2008	2.5	382111	4900630	***1425***
08-42041	Station BC1	2008	2.5	381914	4899874	***653***
08-42046	Station BC2	2008	2.5	382055	4900058	***826***
08-42051	Station BC3	2008	2.5	381980	4900226	***1360***
08-42064	Cat4	2008	2.5	382313	4900651	***74***
08-42068	Cat3	2008	2.5	382073	4900663	***1559***
08-42076	Cat1	2008	2.5	381816	4900557	***3595***
08-42104	C1 15-20	2008	17.5	382026	4900462	***187***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cr
			[cm]	Easting	Northing	[ppm]
08-42116	C4 15-20	2008	22.5	381920	4900136	***790***
08-42140	SSM9	2008	5.0	382090	4900492	***735***
08-42141	SSM1	2008	5.0	381924	4900549	***5488***
08-42143	SSM3	2008	5.0	382175	4900605	***1297***
08-42146	SSM6	2008	5.0	382244	4900435	***786***
08-42147	SSM7	2008	5.0	382019	4900387	***962***
09-25600		2009	5.0	382040	4900391	***844***
09-25601		2009	5.0	381978	4900229	***988***
09-25602		2009	5.0	381927	4900085	***430***
09-25605		2009	5.0	382055	4900042	***855***
09-25606		2009	5.0	382037	4899905	***555***
09-25610		2009	5.0	381912	4900512	***7450***
09-25611		2009	5.0	382195	4900591	***986***
09-25612		2009	5.0	382010	4900575	***2333***
09-25613		2009	5.0	382089	4900518	***925***
09-25614		2009	5.0	382168	4900369	***720***
09-25706	C20	2009	5.0	381961	4900471	***11283***
09-25705	C8	2009	5.0	381970	4900509	***5689***
10. MOE, 2009						
KING1		2009	5.0	381914	4899303	***370***
KING2		2009	5.0	381823	4899679	***430***
KING3		2009	5.0	381874	4899847	***700***
KING4		2009	5.0	381871	4899925	***360***
KING5		2009	5.0	381950	4900487	***5100***
11. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	***220***
Station 2		2010	5.0	382076	4899080	***150***
Station 3		2010	5.0	381912	4899352	***630***
Station 4		2010	5.0	382111	4899341	***340***
Station 5		2010	5.0	381822	4899620	***300***
Station 6		2010	5.0	382119	4899617	***770***
Station 7		2010	5.0	381996	4899810	***960***
Station 8		2010	5.0	382484	4900015	***310***
12. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	***170***
2011-B		2011	5.0	382021	4899133	***280***
2011-C		2011	5.0	382022	4899322	***370***
2011-D		2011	5.0	382241	4899116	***200***
2011-E		2011	5.0	382240	4899285	***200***
2011-F		2011	5.0	381891	4899510	***910***
2011-G		2011	5.0	382097	4899514	***510***

Table D-II-3: Chromium Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cr**
			[cm]	**Easting**	**Northing**	**[ppm]**
2011-H		2011	5.0	381966	4899697	***830***
2011-I		2011	5.0	382175	4899790	***580***
2011-J		2011	5.0	382024	4900152	***1000***
2011-K		2011	5.0	382278	4900213	***870***
2011-L		2011	5.0	382027	4900320	***900***
13. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	***162***
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	***76***
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	***60***
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	***50***
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	***59***
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	***124***
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	***124***
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	***144***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Pb
			[cm]	Easting	Northing	[ppm]
CCME ISQG						*35*
CCME PEL						***91***
Ontario SQG - LEL						**31**
1. Jaagumagi, 1991						
AQ1		1990	2.5	381842	4899073	***260***
AQ2		1990	2.5	381921	4899102	***290***
AQ3		1990	2.5	381866	4899143	***210***
2. Totten Sims Hubicki Associates, 1992						
T10		1985	0.0	381866	4900031	*85*
T11		1985	0.0	382152	4899924	***150***
T12		1985	0.0	382473	4899823	*78*
T13		1985	0.0	382791	4899729	*43*
T14		1985	0.0	381752	4899657	***440***
T15		1985	0.0	381850	4899465	***330***
T16		1985	0.0	382053	4899419	***130***
T17		1985	0.0	382258	4899365	***100***
T18		1985	0.0	382462	4899315	*59*
T19		1985	0.0	381856	4899139	***300***
T6		1985	0.0	381911	4900575	***990***
T7		1985	0.0	382261	4900493	*82*
T8		1985	0.0	382801	4900362	14
T9		1985	0.0	383089	4900296	*39*
3. Brooks et al, 1998						
E3		1998	0.0	381871	4901152	***93***
E5		1998	0.0	382219	4700888	*60*
G5		1998	0.0	383058	4900393	*69*
K10		1998	0.0	382363	4900631	***227***
K11		1998	0.0	382175	4900657	***298***
K12		1998	0.0	381902	4900584	***437***
K13		1998	0.0	381806	4900526	***1087***
4. Derry et al, 2003						
31	SE-1	2001	0.5	381868	4899833	***840***
37	SE-7	2001	0.5	381859	4900242	***120***
38	SE-8	2001	0.5	382580	4899260	*46*
39	SE-9	2001	0.5	382998	4899601	***130***
40	SE-10	2001	0.5	383168	4900213	*40*
47	SE-17	2001	0.5	382118	4900643	***200***
54	SE-24	2001	0.5	381848	4899058	***93***
56	SE-26	2001	0.5	381841	4900318	***150***
63	Duplicate of 31	2001	0.5	381868	4899833	***440***
A3		2001	2.5	382503	4899989	*82*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
				Easting	**Northing**	
			[cm]			**[ppm]**
A4		2001	2.5	382427	4900147	***120***
A5		2001	2.5	382307	4900281	***130***
A6		2001	2.5	382086	4900398	*60*
A7		2001	2.5	381985	4900357	***180***
G3		2001	2.5	382401	4899801	***93***
G4		2001	2.5	382122	4899844	***150***
K10		2001	2.5	382086	4900398	*82*
K11		2001	2.5	382180	4900652	*77*
K12		2001	2.5	381908	4900590	***470***
K12		2001	2.5	381908	4900590	***420***
K13		2001	2.5	381811	4900538	***440***
S10		2001	2.5	382221	4900609	***160***
S11		2001	2.5	381928	4900203	***140***
S12		2001	2.5	382142	4900256	*86*
S13		2001	2.5	382336	4900489	***120***
S14		2001	2.5	381921	4900144	***180***
S15		2001	2.5	382195	4900079	***130***
S16		2001	2.5	382294	4900071	*78*
S7		2001	2.5	381809	4900491	***380***
S8		2001	2.5	381882	4900449	***110***
S9		2001	2.5	382034	4900580	***95***
5. ESG , 2002						
FF6		2002	2.5	382136	4900380	***111***
6. MOE Benoit, 2006						
06 15 083		2003	5	381836	4900494	***510***
06 15 085		2003	5	381726	4901247	***170***
06 15 0182		2003	5	382072	4900635	***100***
06 15 0183		2003	5	381867	4899898	***150***
06 15 0184		2003	5	381882	4899764	***250***
L10A		2003	5	381845	4899956	***94***
L10B		2003	15	381845	4899956	*58*
L11A		2003	5	381848	4899944	***331***
L11B		2003	15	381848	4899944	***248***
L12A		2003	5	381850	4899911	***234***
L12B		2003	15	381850	4899911	***314***
L13A		2003	5	381848	4899883	***158***
L13B		2003	15	381848	4899883	*39*
L14A		2003	5	381854	4899838	***731***
L14B		2003	15	381854	4899838	***106***
L7A		2003	5	381848	4900062	***191***
L8A		2003	5	381849	4900031	*55*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
			[cm]	**Easting**	**Northing**	**[ppm]**
L9A		2003	5	381857	4899996	***366***
L9B		2003	15	381857	4899996	***109***
RC-1		2003	1	381866	4899998	***121***
RC-10		2003	1	381916	4899802	***154***
RC-11		2003	1	381957	4899802	***155***
RC-12		2003	1	381884	4899736	***284***
RC-13		2003	1	381924	4899736	***188***
RC-14		2003	1	381965	4899736	***177***
RC-15		2003	1	381914	4899964	***234***
RC-16		2003	1	381866	4899931	***178***
RC-17		2003	1	381914	4899899	***180***
RC-18		2003	1	381867	4899934	***188***
RC-2		2003	1	381914	4899998	***130***
RC-2		2003	5	381914	4899998	***137***
RC-2		2003	15	381914	4899998	***159***
RC-2		2003	25	381914	4899998	***244***
RC-3		2003	1	381867	4899934	***185***
RC-4		2003	1	381912	4899934	***126***
RC-4		2003	5	381912	4899934	***139***
RC-4		2003	15	381912	4899934	***145***
RC-4		2003	25	381912	4899934	***179***
RC-5		2003	1	381961	4899934	***175***
RC-6		2003	1	381867	4899867	***153***
RC-7		2003	1	381914	4899867	***137***
RC-7		2003	5	381914	4899867	***135***
RC-7		2003	15	381914	4899867	***113***
RC-8		2003	1	381961	4899867	***143***
RC-9		2003	1	381875	4899802	***491***
7. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	*47*
04-24249	ERA2	2004	2.5	382567	4899317	*61*
04-24254	ERA3	2004	2.5	382622	4899477	*61*
04-24259	ERA4	2004	2.5	382388	4899535	*57*
04-24264	ERA5	2004	2.5	382133	4900254	***144***
04-24269	ERA6	2004	2.5	383123	4900238	*47*
04-24283	ERA8	2004	2.5	382851	4901111	27
04-24284	ERA8	2004	2.5	382851	4901111	23
04-24295	SED11	2004	2.5	382753	4899612	*44*
04-24296	SED12	2004	2.5	382914	4899802	*46*
04-24297	SED13	2004	2.5	383025	4899970	*44*
04-24301	SED16	2004	2.5	382979	4900418	*54*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Pb
			[cm]	Easting	Northing	[ppm]
04-24302	SED17	2004	2.5	382862	4899987	*50*
04-24303	SED18	2004	2.5	382609	4900093	*68*
04-24304	SED19	2004	2.5	382538	4899915	*62*
04-24305	SED20	2004	2.5	382645	4899810	*38*
04-24306	SED21	2004	2.5	382368	4899708	*65*
04-24307	SED22	2004	2.5	382329	4899541	*76*
04-24308	SED23	2004	2.5	382298	4899304	*57*
04-24309	SED24	2004	2.5	382505	4899251	*57*
05-17280	Core3	2005	2.5	381932	4899911	***116***
05-17281	Core3	2005	7.5	381932	4899911	***136***
05-17282	Core3	2005	12.5	381932	4899911	***176***
05-17283	Core3	2005	17.5	381932	4899911	***137***
05-17284	Core3	2005	22.5	381932	4899911	***130***
05-17285	Core3	2005	27.5	381932	4899911	***146***
05-17286	Core3	2005	32	381932	4899911	***157***
05-17287	Core4	2005	2.5	381921	4900336	***142***
05-17288	Core4	2005	7.5	381921	4900336	***158***
05-17289	Core4	2005	12.5	381921	4900336	***166***
05-17290	Core4	2005	17.5	381921	4900336	***286***
05-17291	Core4	2005	22.5	381921	4900336	***487***
05-17292	Core4	2005	27.5	381921	4900336	***1036***
05-17293	Core4	2005	31.5	381921	4900336	***518***
05-17294	Core5	2005	2.5	382215	4899499	*68*
05-17295	Core5	2005	7.5	382215	4899499	*91*
05-17296	Core5	2005	12.5	382215	4899499	***122***
05-17297	Core5	2005	17.5	382215	4899499	***135***
05-17298	Core5	2005	37.5	382215	4899499	***120***
05-17299	Core6	2005	2.5	382246	4899945	*88*
05-17300	Core6	2005	7.5	382246	4899945	***114***
05-17301	Core6	2005	12.5	382246	4899945	***162***
05-17302	Core6	2005	17.5	382246	4899945	***169***
05-17303	Core6	2005	22.5	382246	4899945	***265***
05-17304	Core6	2005	27.5	382246	4899945	***327***
05-17305	Core6	2005	32.5	382246	4899945	***156***
05-17306	Core6	2005	36.5	382246	4899945	***125***
05-17311	Core1	2005	2.5	382506	4899126	*41*
05-17312	Core1	2005	7.5	382506	4899126	*48*
05-17313	Core1	2005	12.5	382506	4899126	*46*
05-17314	Core1	2005	17.5	382506	4899126	*48*
05-17315	Core1	2005	22.5	382506	4899126	*59*
05-17316	Core1	2005	27.5	382506	4899126	*90*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
			[cm]	**Easting**	**Northing**	**[ppm]**
05-17317	Core1	2005	32.5	382506	4899126	***97***
05-17351	SED37	2005	2.5	382689	4900329	*45*
05-17352	SED38	2005	2.5	382424	4900259	***100***
05-17353	Core7	2005	2.5	383047	4900149	*40*
05-17354	Core7	2005	7.5	383047	4900149	*35*
05-17355	Core7	2005	12.5	383047	4900149	*35*
05-17356	Core7	2005	17.5	383047	4900149	*40*
05-17357	Core7	2005	22.5	383047	4900149	*37*
05-17358	Core7	2005	27.5	383047	4900149	*38*
05-17388	Core8	2005	2.5	382424	4900227	***102***
05-17389	Core8	2005	7.5	382424	4900227	***114***
05-17390	Core8	2005	12.5	382424	4900227	***101***
05-17391	Core8	2005	17.5	382424	4900227	***135***
05-17392	Core8	2005	22.5	382424	4900227	***167***
05-17393	Core8	2005	26	382424	4900227	***152***
05-17421	SED39	2005	2.5	382026	4899286	***217***
05-17422	SED40	2005	2.5	382175	4899130	*60*
05-17436	Core2	2005	2.5	382592	4899410	*43*
05-17437	Core2	2005	7.5	382592	4899410	*47*
05-17438	Core2	2005	12.5	382592	4899410	*55*
05-17439	Core2	2005	17.5	382592	4899410	*63*
05-17440	Core2	2005	22.5	382592	4899410	*79*
05-17441	Core2	2005	27.5	382592	4899410	*72*
05-17442	Core2	2005	31.5	382592	4899410	***148***
05-30029	ERA11	2005	2.5	382036	4900455	*86*
05-30056	SED28	2005	2.5	382187	4899646	***133***
05-30058	SED26	2005	2.5	382357	4899119	*45*
8. ESG, 2006						
06-17060	C1 percussion	2006	2.5	382507	4899119	*55*
06-17061	C1 percussion	2006	7.5	382507	4899119	*38*
06-17062	C1 percussion	2006	12.5	382507	4899119	*49*
06-17063	C1 percussion	2006	17.5	382507	4899119	*89*
06-17064	C1 percussion	2006	22.5	382507	4899119	***108***
06-17065	C1 percussion	2006	27.5	382507	4899119	***97***
06-17066	C1 percussion	2006	32.5	382507	4899119	***120***
06-17067	C1 percussion	2006	37.5	382507	4899119	***141***
06-17068	C1 percussion	2006	42.5	382507	4899119	***99***
06-17069	C1 percussion	2006	47.5	382507	4899119	*73*
06-17070	C1 percussion	2006	52.5	382507	4899119	*61*
06-17071	C1 percussion	2006	57.5	382507	4899119	*48*
06-17072	C1 percussion	2006	62.5	382507	4899119	*63*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Pb
			[cm]	Easting	Northing	[ppm]
06-17073	C1 percussion	2006	67.5	382507	4899119	*57*
06-17074	C1 percussion	2006	72.5	382507	4899119	*59*
06-17075	C1 percussion	2006	77.5	382507	4899119	*58*
06-17076	C1 percussion	2006	82.5	382507	4899119	*53*
06-17077	C1 percussion	2006	87.5	382507	4899119	28
06-17078	C1 percussion	2006	92.5	382507	4899119	*36*
06-17079	C1 percussion	2006	97.5	382507	4899119	18
06-17080	C1 percussion	2006	102.5	382507	4899119	*77*
06-17081	C1KLB	2006	2.5	382507	4899119	*67*
06-17081d	C1KLB	2006	2.5	382507	4899119	*62*
06-17081d2	C1KLB	2006	2.5	382507	4899119	*58*
06-17082	C1KLB	2006	7.5	382507	4899119	*81*
06-17083	C1KLB	2006	12.5	382507	4899119	**32**
06-17083b	C1KLB	2006	12.5	382507	4899119	*60*
06-17084	C1KLB	2006	17.5	382507	4899119	*75*
06-17084d	C1KLB	2006	17.5	382507	4899119	*64*
06-17085	C1KLB	2006	22.5	382507	4899119	*89*
06-17085d	C1KLB	2006	22.5	382507	4899119	*89*
06-17086	C1KLB	2006	27.5	382507	4899119	***97***
06-17086d	C1KLB	2006	27.5	382507	4899119	***100***
06-17086d2	C1KLB	2006	22.5	382507	4899119	*91*
06-17087	C7 KLB	2006	2.5	382123	4900523	***112***
06-17088	C7 KLB	2006	7.5	382123	4900523	*40*
06-17088b	C7 KLB	2006	12.5	382123	4900523	*89*
06-17089	C7 KLB	2006	17.5	382123	4900523	*47*
06-17089	C7 KLB	2006	22.5	382123	4900523	10
06-17090	C7 KLB	2006	27.5	382123	4900523	*36*
06-17091	C7 KLB	2006	32.5	382123	4900523	*42*
06-17091d	C7 KLB	2006	32.5	382123	4900523	*46*
06-17093	C7 KLB	2006	2.5	382123	4900523	***103***
06-17094	C7 KLB	2006	7.5	382123	4900523	***94***
06-17095	C7 KLB	2006	12.5	382123	4900523	*56*
06-17096	C7 KLB	2006	17.5	382123	4900523	*44*
06-17097	C7 KLB	2006	22.5	382123	4900523	*43*
06-17098	C7 KLB	2006	27.5	382123	4900523	***360***
06-17099	C7 KLB	2006	32.5	382123	4900523	***324***
06-17100	C3 Percussion	2006	2.5	382237	4899987	***117***
06-17101	C3 Percussion	2006	7.5	382237	4899987	***146***
06-17102	C3 Percussion	2006	12.5	382237	4899987	***156***
06-17102d	C3 Percussion	2006	12.5	382237	4899987	***165***
06-17103	C3 Percussion	2006	17.5	382237	4899987	***230***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Pb
			[cm]	Easting	Northing	[ppm]
06-17104	C3 Percussion	2006	22.5	382237	4899987	***131***
06-17105	C3 Percussion	2006	27.5	382237	4899987	*46*
06-17106	C3 Percussion	2006	32.5	382237	4899987	*50*
06-17107	C3 Percussion	2006	37.5	382237	4899987	17
06-17108	C3 Percussion	2006	42.5	382237	4899987	20
06-17109	C3 Percussion	2006	47.5	382237	4899987	*53*
06-17110	C4 percussion	2006	2.5	381902	4900326	***142***
06-17111	C4 percussion	2006	7.5	381902	4900326	***161***
06-17112	C4 percussion	2006	12.5	381902	4900326	***176***
06-17113	C4 percussion	2006	17.5	381902	4900326	***226***
06-17114	C4 percussion	2006	22.5	381902	4900326	***239***
06-17115	C4 percussion	2006	27.5	381902	4900326	***269***
06-17116	C4 percussion	2006	32.5	381902	4900326	***315***
06-17116d	C4 percussion	2006	32.5	381902	4900326	***361***
06-17117	C4 percussion	2006	37.5	381902	4900326	***138***
06-17120	C4 percussion	2006	52.5	381902	4900326	12
06-17121	C4 percussion	2006	57.5	381902	4900326	13
06-17122	C4 percussion	2006	62.5	381902	4900326	20
06-17123	C4 KLB	2006	2.5	381902	4900326	***176***
06-17124	C4 KLB	2006	7.5	381902	4900326	***223***
06-17124d	C4 KLB	2006	7.5	381902	4900326	***235***
06-17125	C4 KLB	2006	12.5	381902	4900326	***252***
06-17126	C4 KLB	2006	17.5	381902	4900326	***319***
06-17127	C4 KLB	2006	22.5	381902	4900326	*36*
06-17128	C5 KLB	2006	2.5	382113	4900266	***142***
06-17129	C5 KLB	2006	7.5	382113	4900266	***164***
06-17130	C5 KLB	2006	12.5	382113	4900266	***168***
06-17131	C5 KLB	2006	17.5	382113	4900266	***194***
06-17132	C5 KLB	2006	22.5	382113	4900266	***423***
06-17133	C5 KLB	2006	27.5	382113	4900266	***650***
06-17137	C5 Percussion	2006	17.5	382113	4900266	***305***
06-17138	C5 Percussion	2006	22.5	382113	4900266	***667***
06-17139	C5 Percussion	2006	27.5	382113	4900266	***313***
06-17140	C5 Percussion	2006	32.5	382113	4900266	***256***
06-17141	C5 Percussion	2006	37.5	382113	4900266	***129***
06-17141b	C5 Percussion	2006	37.5	382113	4900266	***140***
06-17141c	C5 Percussion	2006	37.5	382113	4900266	***103***
06-17142	C5 Percussion	2006	42.5	382113	4900266	*62*
06-17143	C5 Percussion	2006	47.5	382113	4900266	*50*
06-17144	C5 Percussion	2006	52.5	382113	4900266	26
06-17145	C5 Percussion	2006	57.5	382113	4900266	*51*

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Pb
			[cm]	Easting	Northing	[ppm]
06-17146	C6 Percussion	2006	2.5	382444	4900245	***101***
06-17148	C6 Percussion	2006	12.5	382444	4900245	***105***
06-17149	C6 Percussion	2006	17.5	382444	4900245	***149***
06-17149b	C6 Percussion	2006	17.5	382444	4900245	***170***
06-17149c	C6 Percussion	2006	17.5	382444	4900245	***159***
06-17150	C6 Percussion	2006	22.5	382444	4900245	***148***
06-17150b	C6 Percussion	2006	22.5	382444	4900245	***171***
06-17151	C6 Percussion	2006	27.5	382444	4900245	*48*
06-17152	C6 Percussion	2006	32.5	382444	4900245	15
06-17153	C6 KLB	2006	2.5	382444	4900245	*84*
06-17154	C6 KLB	2006	7.5	382444	4900245	*79*
06-17155	C6 KLB	2006	12.5	382444	4900245	***118***
06-17156	C6 KLB	2006	17.5	382444	4900245	***129***
06-17157	C6 KLB	2006	22.5	382444	4900245	***160***
06-17158	C6 KLB	2006	27.5	382444	4900245	***168***
06-17160	C2 Percussion	2006	2.5	382569	4899352	*52*
06-17161	C2 Percussion	2006	7.5	382569	4899352	*62*
06-17162	C2 Percussion	2006	12.5	382569	4899352	*63*
06-17163	C2 Percussion	2006	17.5	382569	4899352	*72*
06-17164	C2 Percussion	2006	22.5	382569	4899352	*47*
06-17165	C2 Percussion	2006	27.5	382569	4899352	*40*
06-17166	C2 Percussion	2006	32.5	382569	4899352	*42*
06-17166d	C2 Percussion	2006	32.5	382569	4899352	*38*
06-17167	C2 Percussion	2006	37.5	382569	4899352	*50*
06-17167d	C2 Percussion	2006	37.5	382569	4899352	*51*
06-17168	C2 Percussion	2006	42.5	382569	4899352	**34**
06-17169	C2 Percussion	2006	47.5	382569	4899352	24
06-17170	C2 Percussion	2006	52.5	382569	4899352	30
06-17171	C2 Percussion	2006	57.5	382569	4899352	24
06-17172	C2 Percussion	2006	62.5	382569	4899352	**31**
06-17180	C2 Percussion	2006	2.5	382569	4899352	**35**
06-17181	C2 Percussion	2006	7.5	382569	4899352	*62*
06-17182	C2 Percussion	2006	12.5	382569	4899352	*57*
06-17183	C2 Percussion	2006	17.5	382569	4899352	*67*
06-17184	C2 Percussion	2006	22.5	382569	4899352	*79*
06-17185	C2 Percussion	2006	27.5	382569	4899352	*90*
06-17186	C8 KLB	2006	2.5	381971	4900510	***320***
06-17187	C8 KLB	2006	7.5	381971	4900510	***297***
06-17188	C8 KLB	2006	12.5	381971	4900510	***298***
06-17189	C8 KLB	2006	17.5	381971	4900510	***767***
06-17190	C7 Percussion	2006	2.5	382123	4900523	***102***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth [cm]	UTM, NAD 84 Easting	UTM, NAD 84 Northing	Pb [ppm]
06-17190d	C7 Percussion	2006	2.5	382123	4900523	***113***
06-17191	C7 Percussion	2006	7.5	382123	4900523	***110***
06-17192	C7 Percussion	2006	12.5	382123	4900523	*78*
06-17193	C7 Percussion	2006	17.5	382123	4900523	*41*
06-17193d	C7 Percussion	2006	17.5	382123	4900523	*48*
06-17194	C7 Percussion	2006	22.5	382123	4900523	*43*
06-17195	C7 Percussion	2006	27.5	382123	4900523	***102***
06-17196	C7 Percussion	2006	32.5	382123	4900523	***205***
06-17197	C7 Percussion	2006	37.5	382123	4900523	28
06-17198	C7 Percussion	2006	42.5	382123	4900523	8
06-17199	C7 Percussion	2006	47.5	382123	4900523	11
06-17200	C7 Percussion	2006	52.5	382123	4900523	5.9
06-17201	C7 Percussion	2006	57.5	382123	4900523	13
06-17202	C7 Percussion	2006	62.5	382123	4900523	8.2
06-17203	C7 Percussion	2006	67.5	382123	4900523	19
06-17204	C7 Percussion	2006	72.5	382123	4900523	<LOD
06-17205	C8 Percussion	2006	2.5	381971	4900510	***327***
06-17206	C8 Percussion	2006	7.5	381971	4900510	***308***
06-17207	C8 Percussion	2006	12.5	381971	4900510	***381***
06-17208	C8 Percussion	2006	17.5	381971	4900510	***358***
06-17209	C8 Percussion	2006	22.5	381971	4900510	***313***
06-17210	C8 Percussion	2006	27.5	381971	4900510	***256***
06-17211	C8 Percussion	2006	32.5	381971	4900510	***440***
06-17212	C8 Percussion	2006	37.5	381971	4900510	***220***
06-17213	C8 Percussion	2006	42.5	381971	4900510	***3246***
06-17214	C8 Percussion	2006	47.5	381971	4900510	***3107***
06-17215	C8 Percussion	2006	52.5	381971	4900510	***2940***
06-17216	C8 Percussion	2006	57.5	381971	4900510	***708***
06-17217	C8 Percussion	2006	62.5	381971	4900510	24
06-17218	C8 Percussion	2006	67.5	381971	4900510	22
06-17219	C8 Percussion	2006	72.5	381971	4900510	14
06-17220	C8 Percussion	2006	77.5	381971	4900510	10
06-17221	C8 Percussion	2006	82.5	381971	4900510	17
06-17222	C8 Percussion	2006	87.5	381971	4900510	11
06-17265	T3	2006	2.5	382057	4900047	***123***
06-17267	T4	2006	2.5	381977	4900232	***126***
9. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	***109***
CAT 3		2006	1.5	381918	4899966	***107***
CAT 4		2006	1.5	381917	4899936	*73*
CAT 5		2006	1.5	381971	4899936	***108***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
			[cm]	**Easting**	**Northing**	**[ppm]**
CAT 6		2006	1.5	381962	4899897	***118***
CAT 7		2006	1.5	381914	4899897	***114***
CAT 8		2006	1.5	381863	4899902	***219***
CAT 9		2006	1.5	381872	4899839	***445***
CAT 10		2006	1.5	381915	4899835	***174***
CAT 11		2006	1.5	381963	4899840	***160***
CAT 12		2006	1.5	381896	4899805	***316***
CAT 13		2006	1.5	381921	4899782	***168***
CAT 14		2006	1.5	381967	4899779	***197***
CAT 15		2006	1.5	381879	4899743	***241***
CAT 16		2006	1.5	381928	4899734	***205***
CAT 17		2006	1.5	381868	4899964	***187***
CAT 18		2006	1.5	382074	4900453	***121***
CAT 19		2006	1.5	382211	4900465	*75*
CAT 20		2006	1.5	382346	4900382	***107***
CAT 21		2006	1.5	381856	4900386	***210***
CAT 22		2006	1.5	382074	4900657	***377***
CAT 24		2006	1.5	381744	4901241	***170***
CAT 26		2006	1.5	381816	4900433	***266***
CAT 27		2006	0-10	381896	4900503	***664***
CAT 28		2006	11-25	381896	4900503	***840***
CAT 29		2006	26-33	381896	4900503	***1850***
CAT 32		2006	0-10	381882	4900406	***236***
CAT 32		2006	11-25	381882	4900406	***270***
CAT 32		2006	26-46	381882	4900406	***270***
10. ESG, 2007-2009						
07-29644	T7	2007	2.5	382276	4900493	*74*
07-29646	T8	2007	2.5	382092	4900523	*55*
07-29647	T6	2007	2.5	382205	4900143	***141***
07-29648	T9	2007	2.5	382360	4900282	***104***
07-29649	T5	2007	2.5	382375	4900031	***108***
08-29891	T15	2008	2.5	382358	4900314	***98***
08-29892	T14	2008	2.5	382282	4900498	*71*
08-29893	T13	2008	2.5	382040	4900546	***105***
08-29895	T16	2008	2.5	382172	4900375	*68*
08-29898	T17	2008	2.5	382138	4900158	***135***
08-29900	T18	2008	2.5	381902	4899869	***282***
08-42000	T7	2008	2.5	382274	4900493	*80*
08-42004	T8	2008	2.5	382128	4900541	*82*
08-42012	Station BIV5	2008	2.5	382111	4900630	***119***
08-42041	Station BC1	2008	2.5	381914	4899874	***115***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
			[cm]	**Easting**	**Northing**	**[ppm]**
08-42046	Station BC2	2008	2.5	382055	4900058	***108***
08-42051	Station BC3	2008	2.5	381980	4900226	***152***
08-42064	Cat4	2008	2.5	382313	4900651	22
08-42068	Cat3	2008	2.5	382073	4900663	*77*
08-42076	Cat1	2008	2.5	381816	4900557	***426***
08-42104	C1 15-20	2008	17.5	382026	4900462	27
08-42116	C4 15-20	2008	22.5	381920	4900136	***118***
08-42140	SSM9	2008	5.0	382090	4900492	*80*
08-42141	SSM1	2008	5.0	381924	4900549	***379***
08-42143	SSM3	2008	5.0	382175	4900605	***101***
08-42146	SSM6	2008	5.0	382244	4900435	*71*
08-42147	SSM7	2008	5.0	382019	4900387	***110***
09-25600		2009	5.0	382040	4900391	***104***
09-25601		2009	5.0	381978	4900229	***113***
09-25602		2009	5.0	381927	4900085	*64*
09-25605		2009	5.0	382055	4900042	***102***
09-25606		2009	5.0	382037	4899905	*70*
09-25610		2009	5.0	381912	4900512	***417***
09-25611		2009	5.0	382195	4900591	*78*
09-25612		2009	5.0	382010	4900575	***176***
09-25613		2009	5.0	382089	4900518	*87*
09-25614		2009	5.0	382168	4900369	*72*
09-25706	C20	2009	5.0	381961	4900471	***542***
09-25705	C8	2009	5.0	381970	4900509	***420***
11. MOE, Scheider Memo 2009						
KING1		2009	5.0	381914	4899303	***160***
KING2		2009	5.0	381823	4899679	***170***
KING3		2009	5.0	381874	4899847	***510***
KING4		2009	5.0	381871	4899925	***120***
KING5		2009	5.0	381950	4900487	***430***
12. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	***120***
Station 2		2010	5.0	382076	4899080	***140***
Station 3		2010	5.0	381912	4899352	***510***
Station 4		2010	5.0	382111	4899341	***110***
Station 5		2010	5.0	381822	4899620	***150***
Station 6		2010	5.0	382119	4899617	***130***
Station 7		2010	5.0	381996	4899810	***140***
Station 8		2010	5.0	382484	4900015	*68*
13. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	***160***

Table D-II-4: Lead Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Pb**
				Easting	**Northing**	
			[cm]			**[ppm]**
2011-B		2011	5.0	382021	4899133	***110***
2011-C		2011	5.0	382022	4899322	***130***
2011-D		2011	5.0	382241	4899116	*69*
2011-E		2011	5.0	382240	4899285	*71*
2011-F		2011	5.0	381891	4899510	***150***
2011-G		2011	5.0	382097	4899514	***100***
2011-H		2011	5.0	381966	4899697	***140***
2011-I		2011	5.0	382175	4899790	***94***
2011-J		2011	5.0	382024	4900152	***130***
2011-K		2011	5.0	382278	4900213	***110***
2011-L		2011	5.0	382027	4900320	***110***
14. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	*69*
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	***159***
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	*54*
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	25
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	*80*
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	***133***
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	***133***
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	***198***

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
CCME ISQG						*123*
CCME PEL						***315***
Ontario SQG - LEL						**120**
		1. Jaagumagi, 1991				
AQ1		1990	2.5	381842	4899073	*290*
AQ2		1990	2.5	381921	4899102	*310*
AQ3		1990	2.5	381866	4899143	*300*
		2. Totten Sims Hubicki Associates, 1992				
T10		1985	0.0	381866	4900031	*140*
T11		1985	0.0	382152	4899924	*180*
T12		1985	0.0	382473	4899823	*140*
T13		1985	0.0	382791	4899729	100
T14		1985	0.0	381752	4899657	***490***
T15		1985	0.0	381850	4899465	*260*
T16		1985	0.0	382053	4899419	*180*
T17		1985	0.0	382258	4899365	*150*
T18		1985	0.0	382462	4899315	**120**
T19		1985	0.0	381856	4899139	*280*
T6		1985	0.0	381911	4900575	***370***
T7		1985	0.0	382261	4900493	*130*
T8		1985	0.0	382801	4900362	89
T9		1985	0.0	383089	4900296	99
		3. Brooks et al, 1998				
E3		1998	0.0	381871	4901152	*149*
E5		1998	0.0	382219	4700888	*182*
G1		1998	0.0	382387	4899355	*156*
G3		1998	0.0	382417	4899805	*142*
G4		1998	0.0	382131	4899813	*270*
G5		1998	0.0	383058	4900393	105
K9		1998	0.0	382535	4900311	60
K10		1998	0.0	382363	4900631	*242*
K11		1998	0.0	382175	4900657	*223*
K12		1998	0.0	381902	4900584	*311*
K13		1998	0.0	381806	4900526	***737***
		4. Derry et al, 2003				
31	SE-1	2001	0.5	381868	4899833	***360***
37	SE-7	2001	0.5	381859	4900242	*150*
38	SE-8	2001	0.5	382580	4899260	*140*
39	SE-9	2001	0.5	382998	4899601	*260*
40	SE-10	2001	0.5	383168	4900213	*140*
47	SE-17	2001	0.5	382118	4900643	*170*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
54	SE-24	2001	0.5	381848	4899058	***370***
56	SE-26	2001	0.5	381841	4900318	*200*
63	Duplicate of 31	2001	0.5	381868	4899833	***350***
A3		2001	2.5	382503	4899989	*140*
A4		2001	2.5	382427	4900147	*160*
A5		2001	2.5	382307	4900281	*160*
A6		2001	2.5	382086	4900398	**120**
A7		2001	2.5	381985	4900357	*190*
G3		2001	2.5	382401	4899801	*150*
G4		2001	2.5	382122	4899844	*220*
K10		2001	2.5	382086	4900398	*190*
K11		2001	2.5	382180	4900652	*140*
K12		2001	2.5	381908	4900590	***320***
K12		2001	2.5	381908	4900590	***420***
K13		2001	2.5	381811	4900538	***420***
S10		2001	2.5	382221	4900609	*180*
S11		2001	2.5	381928	4900203	*170*
S12		2001	2.5	382142	4900256	110
S13		2001	2.5	382336	4900489	*150*
S14		2001	2.5	381921	4900144	*190*
S15		2001	2.5	382195	4900079	*160*
S16		2001	2.5	382294	4900071	*130*
S7		2001	2.5	381809	4900491	***320***
S8		2001	2.5	381882	4900449	*140*
S9		2001	2.5	382034	4900580	*130*
5. ESG , 2002						
FF6		2002	2.5	382136	4900380	*172*
6. MOE Benoit, 2006						
06 15 083		2003	5	381836	4900494	***430***
06 15 085		2003	5	381726	4901247	*260*
06 15 0182		2003	5	382072	4900635	*140*
06 15 0183		2003	5	381867	4899898	*230*
06 15 0184		2003	5	381882	4899764	*310*
RC-1		2003	1	381866	4899998	**122**
RC-10		2003	1	381916	4899802	*193*
RC-11		2003	1	381957	4899802	*187*
RC-12		2003	1	381884	4899736	***334***
RC-13		2003	1	381924	4899736	*231*
RC-14		2003	1	381965	4899736	*207*
RC-15		2003	1	381914	4899964	***404***
RC-16		2003	1	381866	4899931	*240*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
RC-17		2003	1	381914	4899899	*222*
RC-18		2003	1	381867	4899934	*204*
RC-2		2003	1	381914	4899998	*158*
RC-2		2003	5	381914	4899998	*160*
RC-2		2003	15	381914	4899998	*162*
RC-2		2003	25	381914	4899998	*217*
RC-3		2003	1	381867	4899934	*203*
RC-4		2003	1	381912	4899934	*155*
RC-4		2003	5	381912	4899934	*163*
RC-4		2003	15	381912	4899934	*148*
RC-4		2003	25	381912	4899934	*169*
RC-5		2003	1	381961	4899934	*160*
RC-6		2003	1	381867	4899867	*197*
RC-7		2003	1	381914	4899867	*167*
RC-7		2003	5	381914	4899867	*147*
RC-7		2003	15	381914	4899867	118
RC-8		2003	1	381961	4899867	*173*
RC-9		2003	1	381875	4899802	***426***
7. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	*135*
04-24249	ERA2	2004	2.5	382567	4899317	*158*
04-24254	ERA3	2004	2.5	382622	4899477	*144*
04-24259	ERA4	2004	2.5	382388	4899535	*140*
04-24264	ERA5	2004	2.5	382133	4900254	*195*
04-24269	ERA6	2004	2.5	383123	4900238	*145*
04-24283	ERA8	2004	2.5	382851	4901111	94
04-24284	ERA8	2004	2.5	382851	4901111	91
04-24295	SED11	2004	2.5	382753	4899612	115
04-24296	SED12	2004	2.5	382914	4899802	*136*
04-24297	SED13	2004	2.5	383025	4899970	*132*
04-24301	SED16	2004	2.5	382979	4900418	*140*
04-24302	SED17	2004	2.5	382862	4899987	*140*
04-24303	SED18	2004	2.5	382609	4900093	*143*
04-24304	SED19	2004	2.5	382538	4899915	*141*
04-24305	SED20	2004	2.5	382645	4899810	114
04-24306	SED21	2004	2.5	382368	4899708	*141*
04-24307	SED22	2004	2.5	382329	4899541	*159*
04-24308	SED23	2004	2.5	382298	4899304	*142*
04-24309	SED24	2004	2.5	382505	4899251	*157*
05-17280	Core3	2005	2.5	381932	4899911	*163*
05-17281	Core3	2005	7.5	381932	4899911	*193*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
05-17282	Core3	2005	12.5	381932	4899911	*217*
05-17283	Core3	2005	17.5	381932	4899911	*196*
05-17284	Core3	2005	22.5	381932	4899911	*174*
05-17285	Core3	2005	27.5	381932	4899911	*188*
05-17286	Core3	2005	32	381932	4899911	*196*
05-17287	Core4	2005	2.5	381921	4900336	*196*
05-17288	Core4	2005	7.5	381921	4900336	*174*
05-17289	Core4	2005	12.5	381921	4900336	*174*
05-17290	Core4	2005	17.5	381921	4900336	*225*
05-17291	Core4	2005	22.5	381921	4900336	*284*
05-17292	Core4	2005	27.5	381921	4900336	***406***
05-17293	Core4	2005	31.5	381921	4900336	*287*
05-17294	Core5	2005	2.5	382215	4899499	*142*
05-17295	Core5	2005	7.5	382215	4899499	*168*
05-17296	Core5	2005	12.5	382215	4899499	*175*
05-17297	Core5	2005	17.5	382215	4899499	*207*
05-17298	Core5	2005	37.5	382215	4899499	*207*
05-17299	Core6	2005	2.5	382246	4899945	*144*
05-17300	Core6	2005	7.5	382246	4899945	*171*
05-17301	Core6	2005	12.5	382246	4899945	*210*
05-17302	Core6	2005	17.5	382246	4899945	*204*
05-17303	Core6	2005	22.5	382246	4899945	*260*
05-17304	Core6	2005	27.5	382246	4899945	*305*
05-17305	Core6	2005	32.5	382246	4899945	*188*
05-17306	Core6	2005	36.5	382246	4899945	*162*
05-17311	Core1	2005	2.5	382506	4899126	*129*
05-17312	Core1	2005	7.5	382506	4899126	*146*
05-17313	Core1	2005	12.5	382506	4899126	*138*
05-17314	Core1	2005	17.5	382506	4899126	*144*
05-17315	Core1	2005	22.5	382506	4899126	*149*
05-17316	Core1	2005	27.5	382506	4899126	*168*
05-17317	Core1	2005	32.5	382506	4899126	*167*
05-17351	SED37	2005	2.5	382689	4900329	*127*
05-17352	SED38	2005	2.5	382424	4900259	*159*
05-17353	Core7	2005	2.5	383047	4900149	119
05-17354	Core7	2005	7.5	383047	4900149	105
05-17355	Core7	2005	12.5	383047	4900149	105
05-17356	Core7	2005	17.5	383047	4900149	119
05-17357	Core7	2005	22.5	383047	4900149	111
05-17358	Core7	2005	27.5	383047	4900149	111
05-17388	Core8	2005	2.5	382424	4900227	*166*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
				Easting	**Northing**	
			[cm]			[ppm]
05-17389	Core8	2005	7.5	382424	4900227	*190*
05-17390	Core8	2005	12.5	382424	4900227	*154*
05-17391	Core8	2005	17.5	382424	4900227	*185*
05-17392	Core8	2005	22.5	382424	4900227	*217*
05-17393	Core8	2005	26	382424	4900227	*185*
05-17421	SED39	2005	2.5	382026	4899286	*197*
05-17422	SED40	2005	2.5	382175	4899130	*159*
05-17436	Core2	2005	2.5	382592	4899410	*125*
05-17437	Core2	2005	7.5	382592	4899410	*135*
05-17438	Core2	2005	12.5	382592	4899410	*142*
05-17439	Core2	2005	17.5	382592	4899410	*151*
05-17440	Core2	2005	22.5	382592	4899410	*164*
05-17441	Core2	2005	27.5	382592	4899410	*151*
05-17442	Core2	2005	31.5	382592	4899410	*252*
05-30029	ERA11	2005	2.5	382036	4900455	*157*
05-30056	SED28	2005	2.5	382187	4899646	*202*
05-30058	SED26	2005	2.5	382357	4899119	*129*
		8. ESG, 2006				
06-17060	C1 percussion	2006	2.5	382507	4899119	108
06-17061	C1 percussion	2006	7.5	382507	4899119	78
06-17062	C1 percussion	2006	12.5	382507	4899119	93
06-17063	C1 percussion	2006	17.5	382507	4899119	*145*
06-17064	C1 percussion	2006	22.5	382507	4899119	*136*
06-17065	C1 percussion	2006	27.5	382507	4899119	*134*
06-17066	C1 percussion	2006	32.5	382507	4899119	*145*
06-17067	C1 percussion	2006	37.5	382507	4899119	*187*
06-17068	C1 percussion	2006	42.5	382507	4899119	*123*
06-17069	C1 percussion	2006	47.5	382507	4899119	*123*
06-17070	C1 percussion	2006	52.5	382507	4899119	105
06-17071	C1 percussion	2006	57.5	382507	4899119	86
06-17072	C1 percussion	2006	62.5	382507	4899119	93
06-17073	C1 percussion	2006	67.5	382507	4899119	86
06-17074	C1 percussion	2006	72.5	382507	4899119	89
06-17075	C1 percussion	2006	77.5	382507	4899119	84
06-17076	C1 percussion	2006	82.5	382507	4899119	105
06-17077	C1 percussion	2006	87.5	382507	4899119	82
06-17078	C1 percussion	2006	92.5	382507	4899119	91
06-17079	C1 percussion	2006	97.5	382507	4899119	83
06-17080	C1 percussion	2006	102.5	382507	4899119	80
06-17081	C1KLB	2006	2.5	382507	4899119	*157*
06-17081d	C1KLB	2006	2.5	382507	4899119	*129*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
06-17081d2	C1KLB	2006	2.5	382507	4899119	*137*
06-17082	C1KLB	2006	7.5	382507	4899119	*133*
06-17083	C1KLB	2006	12.5	382507	4899119	81
06-17083b	C1KLB	2006	12.5	382507	4899119	105
06-17084	C1KLB	2006	17.5	382507	4899119	114
06-17084d	C1KLB	2006	17.5	382507	4899119	107
06-17085	C1KLB	2006	22.5	382507	4899119	*146*
06-17085d	C1KLB	2006	22.5	382507	4899119	*144*
06-17086	C1KLB	2006	27.5	382507	4899119	*134*
06-17086d	C1KLB	2006	27.5	382507	4899119	*148*
06-17086d2	C1KLB	2006	22.5	382507	4899119	*158*
06-17087	C7 KLB	2006	2.5	382123	4900523	*153*
06-17088	C7 KLB	2006	7.5	382123	4900523	37
06-17088b	C7 KLB	2006	12.5	382123	4900523	119
06-17089	C7 KLB	2006	17.5	382123	4900523	100
06-17089	C7 KLB	2006	22.5	382123	4900523	<LOD
06-17090	C7 KLB	2006	27.5	382123	4900523	99
06-17091	C7 KLB	2006	32.5	382123	4900523	98
06-17091d	C7 KLB	2006	32.5	382123	4900523	94
06-17093	C7 KLB	2006	2.5	382123	4900523	*126*
06-17094	C7 KLB	2006	7.5	382123	4900523	*136*
06-17095	C7 KLB	2006	12.5	382123	4900523	113
06-17096	C7 KLB	2006	17.5	382123	4900523	118
06-17097	C7 KLB	2006	22.5	382123	4900523	105
06-17098	C7 KLB	2006	27.5	382123	4900523	*200*
06-17099	C7 KLB	2006	32.5	382123	4900523	*168*
06-17100	C3 Percussion	2006	2.5	382237	4899987	*148*
06-17101	C3 Percussion	2006	7.5	382237	4899987	*167*
06-17102	C3 Percussion	2006	12.5	382237	4899987	*162*
06-17102d	C3 Percussion	2006	12.5	382237	4899987	*159*
06-17103	C3 Percussion	2006	17.5	382237	4899987	*190*
06-17104	C3 Percussion	2006	22.5	382237	4899987	*150*
06-17105	C3 Percussion	2006	27.5	382237	4899987	89
06-17106	C3 Percussion	2006	32.5	382237	4899987	83
06-17107	C3 Percussion	2006	37.5	382237	4899987	68
06-17108	C3 Percussion	2006	42.5	382237	4899987	79
06-17109	C3 Percussion	2006	47.5	382237	4899987	67
06-17110	C4 percussion	2006	2.5	381902	4900326	*149*
06-17111	C4 percussion	2006	7.5	381902	4900326	*167*
06-17112	C4 percussion	2006	12.5	381902	4900326	*178*
06-17113	C4 percussion	2006	17.5	381902	4900326	*189*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
06-17114	C4 percussion	2006	22.5	381902	4900326	*200*
06-17115	C4 percussion	2006	27.5	381902	4900326	*208*
06-17116	C4 percussion	2006	32.5	381902	4900326	*228*
06-17116d	C4 percussion	2006	32.5	381902	4900326	*237*
06-17117	C4 percussion	2006	37.5	381902	4900326	100
06-17120	C4 percussion	2006	52.5	381902	4900326	35
06-17121	C4 percussion	2006	57.5	381902	4900326	45
06-17122	C4 percussion	2006	62.5	381902	4900326	56
06-17123	C4 KLB	2006	2.5	381902	4900326	*177*
06-17124	C4 KLB	2006	7.5	381902	4900326	*202*
06-17124d	C4 KLB	2006	7.5	381902	4900326	*195*
06-17125	C4 KLB	2006	12.5	381902	4900326	*212*
06-17126	C4 KLB	2006	17.5	381902	4900326	*230*
06-17127	C4 KLB	2006	22.5	381902	4900326	68
06-17128	C5 KLB	2006	2.5	382113	4900266	*176*
06-17129	C5 KLB	2006	7.5	382113	4900266	*194*
06-17130	C5 KLB	2006	12.5	382113	4900266	*160*
06-17131	C5 KLB	2006	17.5	382113	4900266	*185*
06-17132	C5 KLB	2006	22.5	382113	4900266	*258*
06-17133	C5 KLB	2006	27.5	382113	4900266	***351***
06-17137	C5 Percussion	2006	17.5	382113	4900266	*207*
06-17138	C5 Percussion	2006	22.5	382113	4900266	***352***
06-17139	C5 Percussion	2006	27.5	382113	4900266	*223*
06-17140	C5 Percussion	2006	32.5	382113	4900266	*196*
06-17141	C5 Percussion	2006	37.5	382113	4900266	112
06-17141b	C5 Percussion	2006	37.5	382113	4900266	114
06-17141c	C5 Percussion	2006	37.5	382113	4900266	*162*
06-17142	C5 Percussion	2006	42.5	382113	4900266	79
06-17143	C5 Percussion	2006	47.5	382113	4900266	72
06-17144	C5 Percussion	2006	52.5	382113	4900266	58
06-17145	C5 Percussion	2006	57.5	382113	4900266	65
06-17146	C6 Percussion	2006	2.5	382444	4900245	*143*
06-17148	C6 Percussion	2006	12.5	382444	4900245	*146*
06-17149	C6 Percussion	2006	17.5	382444	4900245	*181*
06-17149b	C6 Percussion	2006	17.5	382444	4900245	*186*
06-17149c	C6 Percussion	2006	17.5	382444	4900245	*196*
06-17150	C6 Percussion	2006	22.5	382444	4900245	***2460***
06-17150b	C6 Percussion	2006	22.5	382444	4900245	***1788***
06-17151	C6 Percussion	2006	27.5	382444	4900245	***1853***
06-17152	C6 Percussion	2006	32.5	382444	4900245	*210*
06-17153	C6 KLB	2006	2.5	382444	4900245	114

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
				Easting	**Northing**	
			[cm]			[ppm]
06-17154	C6 KLB	2006	7.5	382444	4900245	*140*
06-17155	C6 KLB	2006	12.5	382444	4900245	*190*
06-17156	C6 KLB	2006	17.5	382444	4900245	*159*
06-17157	C6 KLB	2006	22.5	382444	4900245	*157*
06-17158	C6 KLB	2006	27.5	382444	4900245	*187*
06-17160	C2 Percussion	2006	2.5	382569	4899352	107
06-17161	C2 Percussion	2006	7.5	382569	4899352	116
06-17162	C2 Percussion	2006	12.5	382569	4899352	*144*
06-17163	C2 Percussion	2006	17.5	382569	4899352	*124*
06-17164	C2 Percussion	2006	22.5	382569	4899352	94
06-17165	C2 Percussion	2006	27.5	382569	4899352	99
06-17166	C2 Percussion	2006	32.5	382569	4899352	94
06-17166d	C2 Percussion	2006	32.5	382569	4899352	105
06-17167	C2 Percussion	2006	37.5	382569	4899352	99
06-17167d	C2 Percussion	2006	37.5	382569	4899352	97
06-17168	C2 Percussion	2006	42.5	382569	4899352	101
06-17169	C2 Percussion	2006	47.5	382569	4899352	82
06-17170	C2 Percussion	2006	52.5	382569	4899352	88
06-17171	C2 Percussion	2006	57.5	382569	4899352	96
06-17172	C2 Percussion	2006	62.5	382569	4899352	78
06-17180	C2 Percussion	2006	2.5	382569	4899352	81
06-17181	C2 Percussion	2006	7.5	382569	4899352	*123*
06-17182	C2 Percussion	2006	12.5	382569	4899352	119
06-17183	C2 Percussion	2006	17.5	382569	4899352	120
06-17184	C2 Percussion	2006	22.5	382569	4899352	*124*
06-17185	C2 Percussion	2006	27.5	382569	4899352	*154*
06-17186	C8 KLB	2006	2.5	381971	4900510	*180*
06-17187	C8 KLB	2006	7.5	381971	4900510	*176*
06-17188	C8 KLB	2006	12.5	381971	4900510	*203*
06-17189	C8 KLB	2006	17.5	381971	4900510	***374***
06-17190	C7 Percussion	2006	2.5	382123	4900523	*154*
06-17190d	C7 Percussion	2006	2.5	382123	4900523	*147*
06-17191	C7 Percussion	2006	7.5	382123	4900523	*148*
06-17192	C7 Percussion	2006	12.5	382123	4900523	*128*
06-17193	C7 Percussion	2006	17.5	382123	4900523	*125*
06-17193d	C7 Percussion	2006	17.5	382123	4900523	106
06-17194	C7 Percussion	2006	22.5	382123	4900523	107
06-17195	C7 Percussion	2006	27.5	382123	4900523	*142*
06-17196	C7 Percussion	2006	32.5	382123	4900523	*157*
06-17197	C7 Percussion	2006	37.5	382123	4900523	57
06-17198	C7 Percussion	2006	42.5	382123	4900523	16

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
06-17199	C7 Percussion	2006	47.5	382123	4900523	13
06-17200	C7 Percussion	2006	52.5	382123	4900523	12
06-17201	C7 Percussion	2006	57.5	382123	4900523	14
06-17202	C7 Percussion	2006	62.5	382123	4900523	15
06-17203	C7 Percussion	2006	67.5	382123	4900523	11
06-17204	C7 Percussion	2006	72.5	382123	4900523	8
06-17205	C8 Percussion	2006	2.5	381971	4900510	*214*
06-17206	C8 Percussion	2006	7.5	381971	4900510	*217*
06-17207	C8 Percussion	2006	12.5	381971	4900510	*232*
06-17208	C8 Percussion	2006	17.5	381971	4900510	*243*
06-17209	C8 Percussion	2006	22.5	381971	4900510	*223*
06-17210	C8 Percussion	2006	27.5	381971	4900510	*189*
06-17211	C8 Percussion	2006	32.5	381971	4900510	*259*
06-17212	C8 Percussion	2006	37.5	381971	4900510	***580***
06-17213	C8 Percussion	2006	42.5	381971	4900510	***539***
06-17214	C8 Percussion	2006	47.5	381971	4900510	***579***
06-17215	C8 Percussion	2006	52.5	381971	4900510	***822***
06-17216	C8 Percussion	2006	57.5	381971	4900510	*187*
06-17217	C8 Percussion	2006	62.5	381971	4900510	<15
06-17218	C8 Percussion	2006	67.5	381971	4900510	<LOD
06-17219	C8 Percussion	2006	72.5	381971	4900510	<LOD
06-17220	C8 Percussion	2006	77.5	381971	4900510	<LOD
06-17221	C8 Percussion	2006	82.5	381971	4900510	10
06-17222	C8 Percussion	2006	87.5	381971	4900510	6
06-17265	T3	2006	2.5	382057	4900047	*180*
06-17267	T4	2006	2.5	381977	4900232	*188*
9. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	*178*
CAT 3		2006	1.5	381918	4899966	*192*
CAT 4		2006	1.5	381917	4899936	*135*
CAT 5		2006	1.5	381971	4899936	*189*
CAT 6		2006	1.5	381962	4899897	*170*
CAT 7		2006	1.5	381914	4899897	*185*
CAT 8		2006	1.5	381863	4899902	*244*
CAT 9		2006	1.5	381872	4899839	***442***
CAT 10		2006	1.5	381915	4899835	*275*
CAT 11		2006	1.5	381963	4899840	*212*
CAT 12		2006	1.5	381896	4899805	***327***
CAT 13		2006	1.5	381921	4899782	*240*
CAT 14		2006	1.5	381967	4899779	*232*
CAT 15		2006	1.5	381879	4899743	***315***

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
CAT 16		2006	1.5	381928	4899734	*252*
CAT 17		2006	1.5	381868	4899964	*211*
CAT 18		2006	1.5	382074	4900453	*155*
CAT 19		2006	1.5	382211	4900465	*133*
CAT 20		2006	1.5	382346	4900382	*151*
CAT 21		2006	1.5	381856	4900386	*259*
CAT 22		2006	1.5	382074	4900657	***343***
CAT 24		2006	1.5	381744	4901241	*262*
CAT 26		2006	1.5	381816	4900433	*286*
CAT 27		2006	0-10	381896	4900503	***458***
CAT 28		2006	11-25	381896	4900503	***506***
CAT 29		2006	26-33	381896	4900503	***549***
CAT 32		2006	0-10	381882	4900406	*260*
CAT 32		2006	11-25	381882	4900406	*251*
CAT 32		2006	26-46	381882	4900406	*189*
10. ESG, 2007-2009						
07-29644	T7	2007	2.5	382276	4900493	*132*
07-29646	T8	2007	2.5	382092	4900523	*126*
07-29647	T6	2007	2.5	382205	4900143	*190*
07-29648	T9	2007	2.5	382360	4900282	*159*
07-29649	T5	2007	2.5	382375	4900031	*170*
08-29891	T15	2008	2.5	382358	4900314	*151*
08-29892	T14	2008	2.5	382282	4900498	119
08-29893	T13	2008	2.5	382040	4900546	*155*
08-29895	T16	2008	2.5	382172	4900375	*124*
08-29898	T17	2008	2.5	382138	4900158	*189*
08-29900	T18	2008	2.5	381902	4899869	***380***
08-42000	T7	2008	2.5	382274	4900493	*125*
08-42004	T8	2008	2.5	382128	4900541	*134*
08-42012	Station BIV5	2008	2.5	382111	4900630	*161*
08-42041	Station BC1	2008	2.5	381914	4899874	*178*
08-42046	Station BC2	2008	2.5	382055	4900058	*161*
08-42051	Station BC3	2008	2.5	381980	4900226	*185*
08-42064	Cat4	2008	2.5	382313	4900651	53
08-42068	Cat3	2008	2.5	382073	4900663	*152*
08-42076	Cat1	2008	2.5	381816	4900557	***429***
08-42104	C1 15-20	2008	17.5	382026	4900462	*125*
08-42116	C4 15-20	2008	22.5	381920	4900136	*186*
08-42140	SSM9	2008	5.0	382090	4900492	*143*
08-42141	SSM1	2008	5.0	381924	4900549	***342***
08-42143	SSM3	2008	5.0	382175	4900605	*154*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
08-42146	SSM6	2008	5.0	382244	4900435	116
08-42147	SSM7	2009	5.0	382019	4900387	*170*
09-25600		2009	5.0	382040	4900391	*160*
09-25601		2009	5.0	381978	4900229	*168*
09-25602		2009	5.0	381927	4900085	*131*
09-25605		2009	5.0	382055	4900042	*167*
09-25606		2009	5.0	382037	4899905	116
09-25610		2009	5.0	381912	4900512	***356***
09-25611		2009	5.0	382195	4900591	*128*
09-25612		2009	5.0	382010	4900575	*197*
09-25613		2009	5.0	382089	4900518	*137*
09-25614		2009	5.0	382168	4900369	**122**
09-25706	C20	2009	5.0	381961	4900471	***317***
09-25705	C8	2009	5.0	381970	4900509	*284*
11. MOE, Scheider Memo 2009						
KING1		2009	5.0	381914	4899303	*260*
KING2		2009	5.0	381823	4899679	***330***
KING3		2009	5.0	381874	4899847	***470***
KING4		2009	5.0	381871	4899925	*180*
KING5		2009	5.0	381950	4900487	*310*
12. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	*290*
Station 2		2010	5.0	382076	4899080	*140*
Station 3		2010	5.0	381912	4899352	***340***
Station 4		2010	5.0	382111	4899341	*160*
Station 5		2010	5.0	381822	4899620	***330***
Station 6		2010	5.0	382119	4899617	*190*
Station 7		2010	5.0	381996	4899810	*190*
Station 8		2010	5.0	382484	4900015	*130*
13. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	***460***
2011-B		2011	5.0	382021	4899133	*230*
2011-C		2011	5.0	382022	4899322	*190*
2011-D		2011	5.0	382241	4899116	*160*
2011-E		2011	5.0	382240	4899285	*160*
2011-F		2011	5.0	381891	4899510	*230*
2011-G		2011	5.0	382097	4899514	*180*
2011-H		2011	5.0	381966	4899697	*220*
2011-I		2011	5.0	382175	4899790	*160*
2011-J		2011	5.0	382024	4900152	*190*
2011-K		2011	5.0	382278	4900213	*150*

Table D-II-5: Zinc Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		Zn
			[cm]	**Easting**	**Northing**	[ppm]
2011-L		2011	5.0	382027	4900320	*170*
14. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	*162*
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	107
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	70
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	47
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	*127*
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	118
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	118
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	*137*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cu
				Easting	Northing	
			[cm]			[ppm]
CCME ISQG						*35.7*
CCME PEL						***197***
Ontario SQG - LEL						**16**
1. Jaagumagi, 1991						
AQ1		1990	2.5	381842	4899073	*130*
AQ2		1990	2.5	381921	4899102	*110*
AQ3		1990	2.5	381866	4899143	*95*
2. Totten Sims Hubicki Associates, 1992						
T10		1985	0.0	381866	4900031	*38*
T11		1985	0.0	382152	4899924	*60*
T12		1985	0.0	382473	4899823	*42*
T13		1985	0.0	382791	4899729	**35**
T14		1985	0.0	381752	4899657	***220***
T15		1985	0.0	381850	4899465	*64*
T16		1985	0.0	382053	4899419	*50*
T17		1985	0.0	382258	4899365	*44*
T18		1985	0.0	382462	4899315	*37*
T19		1985	0.0	381856	4899139	*87*
T6		1985	0.0	381911	4900575	*88*
T7		1985	0.0	382261	4900493	*46*
T8		1985	0.0	382801	4900362	**29**
T9		1985	0.0	383089	4900296	**33**
3. Brooks et al, 1998						
E3		1998	0.0	381871	4901152	*38*
G1		1998	0.0	382387	4899355	*39*
G3		1998	0.0	382417	4899805	*36*
G4		1998	0.0	382131	4899813	*68*
G5		1998	0.0	383058	4900393	**27**
K10		1998	0.0	382363	4900631	*54*
K11		1998	0.0	382175	4900657	*44*
K12		1998	0.0	381902	4900584	*43*
K13		1998	0.0	381806	4900526	*119*
4. Derry et al, 2003						
31	SE-1	2001	0.5	381868	4899833	*120*
37	SE-7	2001	0.5	381859	4900242	*36*
38	SE-8	2001	0.5	382580	4899260	**34**
39	SE-9	2001	0.5	382998	4899601	*40*
40	SE-10	2001	0.5	383168	4900213	*53*
47	SE-17	2001	0.5	382118	4900643	*39*
54	SE-24	2001	0.5	381848	4899058	*98*
56	SE-26	2001	0.5	381841	4900318	*53*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
63	Duplicate of 31	2001	0.5	381868	4899833	*150*
A3		2001	2.5	382503	4899989	*36*
A4		2001	2.5	382427	4900147	*39*
A5		2001	2.5	382307	4900281	*42*
A6		2001	2.5	382086	4900398	*38*
A7		2001	2.5	381985	4900357	*48*
G3		2001	2.5	382401	4899801	*39*
G4		2001	2.5	382122	4899844	*93*
K10		2001	2.5	382086	4900398	*37*
K11		2001	2.5	382180	4900652	*36*
K12		2001	2.5	381908	4900590	*68*
K12		2001	2.5	381908	4900590	*110*
K13		2001	2.5	381811	4900538	*110*
S10		2001	2.5	382221	4900609	*44*
S11		2001	2.5	381928	4900203	*44*
S12		2001	2.5	382142	4900256	**27**
S13		2001	2.5	382336	4900489	**35**
S14		2001	2.5	381921	4900144	*47*
S15		2001	2.5	382195	4900079	*40*
S16		2001	2.5	382294	4900071	**32**
S7		2001	2.5	381809	4900491	*78*
S8		2001	2.5	381882	4900449	*41*
S9		2001	2.5	382034	4900580	*36*
5. ESG , 2002						
FF6		2002	2.5	382136	4900380	*53*
6. MOE Benoit, 2006						
06 15 083		2003	5.0	381836	4900494	*110*
06 15 085		2003	5.0	381726	4901247	*53*
06 15 0182		2003	5.0	382072	4900635	*39*
06 15 0183		2003	5.0	381867	4899898	*55*
06 15 0184		2003	5.0	381882	4899764	*76*
L10A		2003	5.0	381845	4899956	*42*
L10B		2003	15	381845	4899956	*43*
L11A		2003	5.0	381848	4899944	*71*
L11B		2003	15	381848	4899944	*69*
L12A		2003	5.0	381850	4899911	*82*
L12B		2003	15	381850	4899911	*94*
L13A		2003	5.0	381848	4899883	*59*
L13B		2003	15	381848	4899883	**30**
L14A		2003	5.0	381854	4899838	***337***
L14B		2003	15	381854	4899838	*40*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
L7A		2003	5.0	381848	4900062	*49*
L8A		2003	5.0	381849	4900031	**32**
L9A		2003	5.0	381857	4899996	*123*
L9B		2003	15	381857	4899996	*39*
RC-1		2003	1.0	381866	4899998	*46*
RC-10		2003	1.0	381916	4899802	*56*
RC-11		2003	1.0	381957	4899802	*55*
RC-12		2003	1.0	381884	4899736	*88*
RC-13		2003	1.0	381924	4899736	*62*
RC-14		2003	1.0	381965	4899736	*59*
RC-15		2003	1.0	381914	4899964	*90*
RC-16		2003	1.0	381866	4899931	*66*
RC-17		2003	1.0	381914	4899899	*60*
RC-18		2003	1.0	381867	4899934	*58*
RC-2		2003	1.0	381914	4899998	*49*
RC-2		2003	5.0	381914	4899998	*48*
RC-2		2003	15	381914	4899998	*48*
RC-2		2003	25	381914	4899998	*54*
RC-3		2003	1.0	381867	4899934	*56*
RC-4		2003	1.0	381912	4899934	*47*
RC-4		2003	5.0	381912	4899934	*49*
RC-4		2003	15	381912	4899934	*46*
RC-4		2003	25	381912	4899934	*47*
RC-5		2003	1.0	381961	4899934	*49*
RC-6		2003	1.0	381867	4899867	*55*
RC-7		2003	1.0	381914	4899867	*50*
RC-7		2003	5.0	381914	4899867	*43*
RC-7		2003	15	381914	4899867	*39*
RC-8		2003	1.0	381961	4899867	*52*
RC-9		2003	1.0	381875	4899802	*144*
7. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	**34**
04-24249	ERA2	2004	2.5	382567	4899317	*40*
04-24254	ERA3	2004	2.5	382622	4899477	*37*
04-24259	ERA4	2004	2.5	382388	4899535	*39*
04-24264	ERA5	2004	2.5	382133	4900254	*49*
04-24269	ERA6	2004	2.5	383123	4900238	*39*
04-24283	ERA8	2004	2.5	382851	4901111	**30**
04-24284	ERA8	2004	2.5	382851	4901111	**28**
04-24295	SED11	2004	2.5	382753	4899612	**32**
04-24296	SED12	2004	2.5	382914	4899802	**35**

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
04-24297	SED13	2004	2.5	383025	4899970	**33**
04-24301	SED16	2004	2.5	382979	4900418	**32**
04-24302	SED17	2004	2.5	382862	4899987	*37*
04-24303	SED18	2004	2.5	382609	4900093	**35**
04-24304	SED19	2004	2.5	382538	4899915	**35**
04-24305	SED20	2004	2.5	382645	4899810	**30**
04-24306	SED21	2004	2.5	382368	4899708	*37*
04-24307	SED22	2004	2.5	382329	4899541	*41*
04-24308	SED23	2004	2.5	382298	4899304	*38*
04-24309	SED24	2004	2.5	382505	4899251	*40*
05-17280	Core3	2005	2.5	381932	4899911	*38*
05-17281	Core3	2005	7.5	381932	4899911	*40*
05-17282	Core3	2005	12.5	381932	4899911	*61*
05-17283	Core3	2005	17.5	381932	4899911	*53*
05-17284	Core3	2005	22.5	381932	4899911	*50*
05-17285	Core3	2005	27.5	381932	4899911	*52*
05-17286	Core3	2005	32	381932	4899911	*49*
05-17287	Core4	2005	2.5	381921	4900336	*40*
05-17288	Core4	2005	7.5	381921	4900336	*48*
05-17289	Core4	2005	12.5	381921	4900336	*50*
05-17290	Core4	2005	17.5	381921	4900336	*45*
05-17291	Core4	2005	22.5	381921	4900336	*60*
05-17292	Core4	2005	27.5	381921	4900336	*68*
05-17293	Core4	2005	31.5	381921	4900336	*52*
05-17294	Core5	2005	2.5	382215	4899499	*41*
05-17295	Core5	2005	7.5	382215	4899499	*47*
05-17296	Core5	2005	12.5	382215	4899499	*39*
05-17297	Core5	2005	17.5	382215	4899499	*42*
05-17298	Core5	2005	37.5	382215	4899499	*46*
05-17299	Core6	2005	2.5	382246	4899945	*39*
05-17300	Core6	2005	7.5	382246	4899945	*47*
05-17301	Core6	2005	12.5	382246	4899945	*43*
05-17302	Core6	2005	17.5	382246	4899945	*40*
05-17303	Core6	2005	22.5	382246	4899945	*50*
05-17304	Core6	2005	27.5	382246	4899945	*56*
05-17305	Core6	2005	32.5	382246	4899945	*41*
05-17306	Core6	2005	36.5	382246	4899945	*41*
05-17311	Core1	2005	2.5	382506	4899126	*38*
05-17312	Core1	2005	7.5	382506	4899126	*39*
05-17313	Core1	2005	12.5	382506	4899126	*39*
05-17314	Core1	2005	17.5	382506	4899126	*40*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
				Easting	**Northing**	
			[cm]			**[ppm]**
05-17315	Core1	2005	22.5	382506	4899126	*50*
05-17316	Core1	2005	27.5	382506	4899126	*84*
05-17317	Core1	2005	32.5	382506	4899126	*49*
05-17351	SED37	2005	2.5	382689	4900329	**30**
05-17352	SED38	2005	2.5	382424	4900259	*42*
05-17353	Core7	2005	2.5	383047	4900149	*39*
05-17354	Core7	2005	7.5	383047	4900149	**33**
05-17355	Core7	2005	12.5	383047	4900149	**31**
05-17356	Core7	2005	17.5	383047	4900149	**34**
05-17357	Core7	2005	22.5	383047	4900149	**34**
05-17358	Core7	2005	27.5	383047	4900149	**33**
05-17388	Core8	2005	2.5	382424	4900227	*42*
05-17389	Core8	2005	7.5	382424	4900227	*45*
05-17390	Core8	2005	12.5	382424	4900227	*41*
05-17391	Core8	2005	17.5	382424	4900227	*41*
05-17392	Core8	2005	22.5	382424	4900227	*44*
05-17393	Core8	2005	26	382424	4900227	*36*
05-17421	SED39	2005	2.5	382026	4899286	*54*
05-17422	SED40	2005	2.5	382175	4899130	*44*
05-17436	Core2	2005	2.5	382592	4899410	**34**
05-17437	Core2	2005	7.5	382592	4899410	*37*
05-17438	Core2	2005	12.5	382592	4899410	*38*
05-17439	Core2	2005	17.5	382592	4899410	*39*
05-17440	Core2	2005	22.5	382592	4899410	*39*
05-17441	Core2	2005	27.5	382592	4899410	**25**
05-17442	Core2	2005	31.5	382592	4899410	**35**
05-30029	ERA11	2005	2.5	382036	4900455	*50*
05-30056	SED28	2005	2.5	382187	4899646	*53*
05-30058	SED26	2005	2.5	382357	4899119	*39*
8. ESG, 2006						
06-17060	C1 percussion	2006	2.5	382507	4899119	**29**
06-17061	C1 percussion	2006	7.5	382507	4899119	<40
06-17062	C1 percussion	2006	12.5	382507	4899119	**22**
06-17063	C1 percussion	2006	17.5	382507	4899119	**31**
06-17064	C1 percussion	2006	22.5	382507	4899119	*37*
06-17065	C1 percussion	2006	27.5	382507	4899119	**29**
06-17066	C1 percussion	2006	32.5	382507	4899119	**31**
06-17067	C1 percussion	2006	37.5	382507	4899119	*50*
06-17068	C1 percussion	2006	42.5	382507	4899119	**21**
06-17069	C1 percussion	2006	47.5	382507	4899119	*37*
06-17070	C1 percussion	2006	52.5	382507	4899119	**34**

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cu
			[cm]	Easting	Northing	[ppm]
06-17071	C1 percussion	2006	57.5	382507	4899119	**34**
06-17072	C1 percussion	2006	62.5	382507	4899119	**28**
06-17073	C1 percussion	2006	67.5	382507	4899119	**33**
06-17074	C1 percussion	2006	72.5	382507	4899119	**29**
06-17075	C1 percussion	2006	77.5	382507	4899119	*36*
06-17076	C1 percussion	2006	82.5	382507	4899119	*39*
06-17077	C1 percussion	2006	87.5	382507	4899119	**23**
06-17078	C1 percussion	2006	92.5	382507	4899119	**29**
06-17079	C1 percussion	2006	97.5	382507	4899119	**24**
06-17080	C1 percussion	2006	102.5	382507	4899119	*39*
06-17081	C1KLB	2006	2.5	382507	4899119	**29**
06-17081d	C1KLB	2006	2.5	382507	4899119	**32**
06-17081d2	C1KLB	2006	2.5	382507	4899119	*37*
06-17082	C1KLB	2006	7.5	382507	4899119	**35**
06-17083	C1KLB	2006	12.5	382507	4899119	<40
06-17083b	C1KLB	2006	12.5	382507	4899119	**25**
06-17084	C1KLB	2006	17.5	382507	4899119	*39*
06-17084d	C1KLB	2006	17.5	382507	4899119	**28**
06-17085	C1KLB	2006	22.5	382507	4899119	*44*
06-17085d	C1KLB	2006	22.5	382507	4899119	**32**
06-17086	C1KLB	2006	27.5	382507	4899119	**29**
06-17086d	C1KLB	2006	27.5	382507	4899119	**31**
06-17086d2	C1KLB	2006	22.5	382507	4899119	**35**
06-17087	C7 KLB	2006	2.5	382123	4900523	**22**
06-17088	C7 KLB	2006	7.5	382123	4900523	<40
06-17088b	C7 KLB	2006	12.5	382123	4900523	*37*
06-17089	C7 KLB	2006	17.5	382123	4900523	**21**
06-17089	C7 KLB	2006	22.5	382123	4900523	<40
06-17090	C7 KLB	2006	27.5	382123	4900523	**26**
06-17091	C7 KLB	2006	32.5	382123	4900523	*37*
06-17091d	C7 KLB	2006	32.5	382123	4900523	**33**
06-17093	C7 KLB	2006	2.5	382123	4900523	*45*
06-17094	C7 KLB	2006	7.5	382123	4900523	*43*
06-17095	C7 KLB	2006	12.5	382123	4900523	**35**
06-17096	C7 KLB	2006	17.5	382123	4900523	*49*
06-17097	C7 KLB	2006	22.5	382123	4900523	*43*
06-17098	C7 KLB	2006	27.5	382123	4900523	*60*
06-17099	C7 KLB	2006	32.5	382123	4900523	**27**
06-17100	C3 Percussion	2006	2.5	382237	4899987	**34**
06-17101	C3 Percussion	2006	7.5	382237	4899987	*43*
06-17102	C3 Percussion	2006	12.5	382237	4899987	*40*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
06-17102d	C3 Percussion	2006	12.5	382237	4899987	**28**
06-17103	C3 Percussion	2006	17.5	382237	4899987	**31**
06-17104	C3 Percussion	2006	22.5	382237	4899987	**26**
06-17105	C3 Percussion	2006	27.5	382237	4899987	**31**
06-17106	C3 Percussion	2006	32.5	382237	4899987	**22**
06-17107	C3 Percussion	2006	37.5	382237	4899987	**30**
06-17108	C3 Percussion	2006	42.5	382237	4899987	**20**
06-17109	C3 Percussion	2006	47.5	382237	4899987	<40
06-17110	C4 percussion	2006	2.5	381902	4900326	**30**
06-17111	C4 percussion	2006	7.5	381902	4900326	*44*
06-17112	C4 percussion	2006	12.5	381902	4900326	*39*
06-17113	C4 percussion	2006	17.5	381902	4900326	*44*
06-17114	C4 percussion	2006	22.5	381902	4900326	*43*
06-17115	C4 percussion	2006	27.5	381902	4900326	*45*
06-17116	C4 percussion	2006	32.5	381902	4900326	*54*
06-17116d	C4 percussion	2006	32.5	381902	4900326	*45*
06-17117	C4 percussion	2006	37.5	381902	4900326	**27**
06-17120	C4 percussion	2006	52.5	381902	4900326	<40
06-17121	C4 percussion	2006	57.5	381902	4900326	<40
06-17122	C4 percussion	2006	62.5	381902	4900326	<40
06-17123	C4 KLB	2006	2.5	381902	4900326	*37*
06-17124	C4 KLB	2006	7.5	381902	4900326	*48*
06-17124d	C4 KLB	2006	7.5	381902	4900326	*40*
06-17125	C4 KLB	2006	12.5	381902	4900326	*53*
06-17126	C4 KLB	2006	17.5	381902	4900326	*36*
06-17127	C4 KLB	2006	22.5	381902	4900326	**18**
06-17128	C5 KLB	2006	2.5	382113	4900266	**31**
06-17129	C5 KLB	2006	7.5	382113	4900266	*46*
06-17130	C5 KLB	2006	12.5	382113	4900266	*47*
06-17131	C5 KLB	2006	17.5	382113	4900266	*42*
06-17132	C5 KLB	2006	22.5	382113	4900266	*51*
06-17133	C5 KLB	2006	27.5	382113	4900266	*74*
06-17137	C5 Percussion	2006	17.5	382113	4900266	*52*
06-17138	C5 Percussion	2006	22.5	382113	4900266	*55*
06-17139	C5 Percussion	2006	27.5	382113	4900266	*57*
06-17140	C5 Percussion	2006	32.5	382113	4900266	*44*
06-17141	C5 Percussion	2006	37.5	382113	4900266	**27**
06-17141b	C5 Percussion	2006	37.5	382113	4900266	**28**
06-17141c	C5 Percussion	2006	37.5	382113	4900266	*37*
06-17142	C5 Percussion	2006	42.5	382113	4900266	**25**
06-17143	C5 Percussion	2006	47.5	382113	4900266	**20**

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cu
			[cm]	Easting	Northing	[ppm]
06-17144	C5 Percussion	2006	52.5	382113	4900266	**26**
06-17145	C5 Percussion	2006	57.5	382113	4900266	**24**
06-17146	C6 Percussion	2006	2.5	382444	4900245	**27**
06-17148	C6 Percussion	2006	12.5	382444	4900245	**34**
06-17149	C6 Percussion	2006	17.5	382444	4900245	*39*
06-17149b	C6 Percussion	2006	17.5	382444	4900245	*38*
06-17149c	C6 Percussion	2006	17.5	382444	4900245	*44*
06-17150	C6 Percussion	2006	22.5	382444	4900245	*40*
06-17150b	C6 Percussion	2006	22.5	382444	4900245	**31**
06-17151	C6 Percussion	2006	27.5	382444	4900245	**23**
06-17152	C6 Percussion	2006	32.5	382444	4900245	**19**
06-17153	C6 KLB	2006	2.5	382444	4900245	**24**
06-17154	C6 KLB	2006	7.5	382444	4900245	*39*
06-17155	C6 KLB	2006	12.5	382444	4900245	**34**
06-17156	C6 KLB	2006	17.5	382444	4900245	*41*
06-17157	C6 KLB	2006	22.5	382444	4900245	**33**
06-17158	C6 KLB	2006	27.5	382444	4900245	*40*
06-17160	C2 Percussion	2006	2.5	382569	4899352	**21**
06-17161	C2 Percussion	2006	7.5	382569	4899352	**32**
06-17162	C2 Percussion	2006	12.5	382569	4899352	**30**
06-17163	C2 Percussion	2006	17.5	382569	4899352	**28**
06-17164	C2 Percussion	2006	22.5	382569	4899352	**24**
06-17165	C2 Percussion	2006	27.5	382569	4899352	**18**
06-17166	C2 Percussion	2006	32.5	382569	4899352	**27**
06-17166d	C2 Percussion	2006	32.5	382569	4899352	**33**
06-17167	C2 Percussion	2006	37.5	382569	4899352	*36*
06-17167d	C2 Percussion	2006	37.5	382569	4899352	*36*
06-17168	C2 Percussion	2006	42.5	382569	4899352	**28**
06-17169	C2 Percussion	2006	47.5	382569	4899352	**31**
06-17170	C2 Percussion	2006	52.5	382569	4899352	**34**
06-17171	C2 Percussion	2006	57.5	382569	4899352	**32**
06-17172	C2 Percussion	2006	62.5	382569	4899352	**31**
06-17180	C2 Percussion	2006	2.5	382569	4899352	<40
06-17181	C2 Percussion	2006	7.5	382569	4899352	**24**
06-17182	C2 Percussion	2006	12.5	382569	4899352	**27**
06-17183	C2 Percussion	2006	17.5	382569	4899352	**30**
06-17184	C2 Percussion	2006	22.5	382569	4899352	**35**
06-17185	C2 Percussion	2006	27.5	382569	4899352	**28**
06-17186	C8 KLB	2006	2.5	381971	4900510	*46*
06-17187	C8 KLB	2006	7.5	381971	4900510	*46*
06-17188	C8 KLB	2006	12.5	381971	4900510	*48*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
06-17189	C8 KLB	2006	17.5	381971	4900510	*81*
06-17190	C7 Percussion	2006	2.5	382123	4900523	**35**
06-17190d	C7 Percussion	2006	2.5	382123	4900523	**34**
06-17191	C7 Percussion	2006	7.5	382123	4900523	*38*
06-17192	C7 Percussion	2006	12.5	382123	4900523	**35**
06-17193	C7 Percussion	2006	17.5	382123	4900523	*42*
06-17193d	C7 Percussion	2006	17.5	382123	4900523	*38*
06-17194	C7 Percussion	2006	22.5	382123	4900523	**31**
06-17195	C7 Percussion	2006	27.5	382123	4900523	**33**
06-17196	C7 Percussion	2006	32.5	382123	4900523	**31**
06-17197	C7 Percussion	2006	37.5	382123	4900523	**19**
06-17198	C7 Percussion	2006	42.5	382123	4900523	<40
06-17199	C7 Percussion	2006	47.5	382123	4900523	<40
06-17200	C7 Percussion	2006	52.5	382123	4900523	<40
06-17201	C7 Percussion	2006	57.5	382123	4900523	<40
06-17202	C7 Percussion	2006	62.5	382123	4900523	<40
06-17203	C7 Percussion	2006	67.5	382123	4900523	<40
06-17204	C7 Percussion	2006	72.5	382123	4900523	<40
06-17205	C8 Percussion	2006	2.5	381971	4900510	*39*
06-17206	C8 Percussion	2006	7.5	381971	4900510	*54*
06-17207	C8 Percussion	2006	12.5	381971	4900510	*58*
06-17208	C8 Percussion	2006	17.5	381971	4900510	*50*
06-17209	C8 Percussion	2006	22.5	381971	4900510	*57*
06-17210	C8 Percussion	2006	27.5	381971	4900510	*49*
06-17211	C8 Percussion	2006	32.5	381971	4900510	*51*
06-17212	C8 Percussion	2006	37.5	381971	4900510	*76*
06-17213	C8 Percussion	2006	42.5	381971	4900510	*88*
06-17214	C8 Percussion	2006	47.5	381971	4900510	*84*
06-17215	C8 Percussion	2006	52.5	381971	4900510	*54*
06-17216	C8 Percussion	2006	57.5	381971	4900510	14
06-17217	C8 Percussion	2006	62.5	381971	4900510	11
06-17218	C8 Percussion	2006	67.5	381971	4900510	<40
06-17219	C8 Percussion	2006	72.5	381971	4900510	<40
06-17220	C8 Percussion	2006	77.5	381971	4900510	<40
06-17221	C8 Percussion	2006	82.5	381971	4900510	<40
06-17222	C8 Percussion	2006	87.5	381971	4900510	<40
06-17265	T3	2006	2.5	382057	4900047	*46*
06-17267	T4	2006	2.5	381977	4900232	*47*
9. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	*46*
CAT 3		2006	1.5	381918	4899966	*49*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cu
			[cm]	Easting	Northing	[ppm]
CAT 4		2006	1.5	381917	4899936	*36*
CAT 5		2006	1.5	381971	4899936	*46*
CAT 6		2006	1.5	381962	4899897	*47*
CAT 7		2006	1.5	381914	4899897	*43*
CAT 8		2006	1.5	381863	4899902	*70*
CAT 9		2006	1.5	381872	4899839	*118*
CAT 10		2006	1.5	381915	4899835	*60*
CAT 11		2006	1.5	381963	4899840	*54*
CAT 12		2006	1.5	381896	4899805	*95*
CAT 13		2006	1.5	381921	4899782	*55*
CAT 14		2006	1.5	381967	4899779	*75*
CAT 15		2006	1.5	381879	4899743	*103*
CAT 16		2006	1.5	381928	4899734	*74*
CAT 17		2006	1.5	381868	4899964	*60*
CAT 18		2006	1.5	382074	4900453	*48*
CAT 19		2006	1.5	382211	4900465	*40*
CAT 20		2006	1.5	382346	4900382	*40*
CAT 21		2006	1.5	381856	4900386	*60*
CAT 22		2006	1.5	382074	4900657	*73*
CAT 24		2006	1.5	381744	4901241	*62*
CAT 26		2006	1.5	381816	4900433	*75*
CAT 27 (CAT 29)0-10cnm		2006	0-10	381896	4900503	*113*
CAT 28 (CAT 29) 11-25 cm		2006	11-25	381896	4900503	*105*
CAT 29 26-33CM		2006	26-33	381896	4900503	*132*
CAT 32 0-10CM		2006	0-10	381882	4900406	*73*
CAT 32 11-25CM		2006	11-25	381882	4900406	*70*
CAT 32 26-46 cm		2006	26-46	381882	4900406	*46*
10. ESG, 2007-2009						
07-29644	T7	2007	2.5	382276	4900493	*38*
07-29646	T8	2007	2.5	382092	4900523	*38*
07-29647	T6	2007	2.5	382205	4900143	*47*
07-29648	T9	2007	2.5	382360	4900282	*42*
07-29649	T5	2007	2.5	382375	4900031	*43*
08-29891	T15	2008	2.5	382358	4900314	*40*
08-29892	T14	2008	2.5	382282	4900498	**32**
08-29893	T13	2008	2.5	382040	4900546	*43*
08-29895	T16	2008	2.5	382172	4900375	**35**
08-29898	T17	2008	2.5	382138	4900158	*46*
08-29900	T18	2008	2.5	381902	4899869	*55*
08-42000	T7	2008	2.5	382274	4900493	**34**
08-42004	T8	2008	2.5	382128	4900541	*39*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Cu
			[cm]	Easting	Northing	[ppm]
08-42012	Station BIV5	2008	2.5	382111	4900630	*44*
08-42041	Station BC1	2008	2.5	381914	4899874	*45*
08-42046	Station BC2	2008	2.5	382055	4900058	*41*
08-42051	Station BC3	2008	2.5	381980	4900226	*47*
08-42064	Cat4	2008	2.5	382313	4900651	**20**
08-42068	Cat3	2008	2.5	382073	4900663	*62*
08-42076	Cat1	2008	2.5	381816	4900557	*105*
08-42104	C1 15-20	2008	17.5	382026	4900462	*42*
08-42116	C4 15-20	2008	22.5	381920	4900136	*45*
08-42140	SSM9	2008	5.0	382090	4900492	*40*
08-42141	SSM1	2008	5.0	381924	4900549	*82*
08-42143	SSM3	2008	5.0	382175	4900605	*41*
08-42146	SSM6	2008	5.0	382244	4900435	**32**
08-42147	SSM7	2009	5.0	382019	4900387	*44*
09-25600		2009	5.0	382040	4900391	*41*
09-25601		2009	5.0	381978	4900229	*41*
09-25602		2009	5.0	381927	4900085	**28**
09-25605		2009	5.0	382055	4900042	*43*
09-25606		2009	5.0	382037	4899905	**32**
09-25610		2009	5.0	381912	4900512	*81*
09-25611		2009	5.0	382195	4900591	**35**
09-25612		2009	5.0	382010	4900575	*48*
09-25613		2009	5.0	382089	4900518	*37*
09-25614		2009	5.0	382168	4900369	**34**
09-25706	C20	2009	5.0	381961	4900471	*68*
09-25705	C8	2009	5.0	381970	4900509	*64*
11. MOE, Scheider Memo 2009						
KING1		2009	5.0	381914	4899303	*74*
KING2		2009	5.0	381823	4899679	*84*
KING3		2009	5.0	381874	4899847	*100*
KING4		2009	5.0	381871	4899925	*49*
KING5		2009	5.0	381950	4900487	*60*
12. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	*120*
Station 2		2010	5.0	382076	4899080	*83*
Station 3		2010	5.0	381912	4899352	*67*
Station 4		2010	5.0	382111	4899341	*43*
Station 5		2010	5.0	381822	4899620	*98*
Station 6		2010	5.0	382119	4899617	*49*
Station 7		2010	5.0	381996	4899810	*55*
Station 8		2010	5.0	382484	4900015	*36*

Table D-II-6: Copper Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Cu**
			[cm]	**Easting**	**Northing**	**[ppm]**
13. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	***780***
2011-B		2011	5.0	382021	4899133	*120*
2011-C		2011	5.0	382022	4899322	*65*
2011-D		2011	5.0	382241	4899116	*43*
2011-E		2011	5.0	382240	4899285	*44*
2011-F		2011	5.0	381891	4899510	*61*
2011-G		2011	5.0	382097	4899514	*51*
2011-H		2011	5.0	381966	4899697	*57*
2011-I		2011	5.0	382175	4899790	*48*
2011-J		2011	5.0	382024	4900152	*47*
2011-K		2011	5.0	382278	4900213	*40*
2011-L		2011	5.0	382027	4900320	*45*
14.. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	*61*
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	**34**
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	**27**
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	**18**
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	*65*
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	*36*
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	*36*
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	*39*

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Report Locator	Sampling Date	Depth [cm]	UTM, NAD 84 Easting	UTM, NAD 84 Northing	As [ppm]
CCME ISQG						*5.9*
CCME PEL						***17***
Ontario SQG - LEL						**6.0**
1. Jaagumagi, 1991						
AQ1		1990	2.5	381842	4899073	**8.2**
AQ2		1990	2.5	381921	4899102	*5.9*
AQ3		1990	2.5	381866	4899143	**8.0**
2. Totten Sims Hubicki Associates, 1992						
T10		1985	0.0	381866	4900031	**11**
T11		1985	0.0	382152	4899924	**9.1**
T12		1985	0.0	382473	4899823	**6.0**
T13		1985	0.0	382791	4899729	3.0
T14		1985	0.0	381752	4899657	4.7
T15		1985	0.0	381850	4899465	**13**
T16		1985	0.0	382053	4899419	**8.4**
T17		1985	0.0	382258	4899365	5.4
T18		1985	0.0	382462	4899315	3.2
T19		1985	0.0	381856	4899139	**8.6**
T6		1985	0.0	381911	4900575	**15**
T7		1985	0.0	382261	4900493	5.3
T8		1985	0.0	382801	4900362	4.3
T9		1985	0.0	383089	4900296	2.8
3. ESG , 2002						
FF6		2002	2.5	382136	4900380	3.7
4. MOE Benoit, 2006						
L10A		2003	5.0	381845	4899956	***84***
L10B		2003	15	381845	4899956	***87***
L11A		2003	5.0	381848	4899944	***97***
L11B		2003	15	381848	4899944	***134***
L12A		2003	5.0	381850	4899911	***285***
L12B		2003	15	381850	4899911	***367***
L13A		2003	5.0	381848	4899883	***129***
L13B		2003	15	381848	4899883	***30***
L14A		2003	5.0	381854	4899838	***52***
L14B		2003	15	381854	4899838	***28***
L7A		2003	5.0	381848	4900062	***51***
L8A		2003	5.0	381849	4900031	***17***
L9A		2003	5.0	381857	4899996	***477***
L9B		2003	15	381857	4899996	***119***
RC-1		2003	1.0	381866	4899998	***71***
RC-10		2003	1.0	381916	4899802	**13**

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**As**
				Easting	**Northing**	
			[cm]			**[ppm]**
RC-11		2003	1.0	381957	4899802	**7.0**
RC-12		2003	1.0	381884	4899736	***58***
RC-13		2003	1.0	381924	4899736	***19***
RC-14		2003	1.0	381965	4899736	**10**
RC-15		2003	1.0	381914	4899964	***49***
RC-16		2003	1.0	381866	4899931	**16**
RC-17		2003	1.0	381914	4899899	***19***
RC-18		2003	1.0	381867	4899934	***56***
RC-2		2003	1.0	381914	4899998	**13**
RC-2		2003	5.0	381914	4899998	**9.0**
RC-2		2003	15	381914	4899998	**11**
RC-2		2003	25	381914	4899998	**15**
RC-3		2003	1.0	381867	4899934	***56***
RC-4		2003	1.0	381912	4899934	**12**
RC-4		2003	5.0	381912	4899934	**8.0**
RC-4		2003	15	381912	4899934	**6.0**
RC-4		2003	25	381912	4899934	**9.0**
RC-5		2003	1.0	381961	4899934	**9.0**
RC-6		2003	1.0	381867	4899867	***201***
RC-7		2003	1.0	381914	4899867	***17***
RC-7		2003	5.0	381914	4899867	**10**
RC-7		2003	15	381914	4899867	**11**
RC-8		2003	1.0	381961	4899867	**8.0**
RC-9		2003	1.0	381875	4899802	***81***
5. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	3.0
04-24249	ERA2	2004	2.5	382567	4899317	3.4
04-24254	ERA3	2004	2.5	382622	4899477	4.3
04-24259	ERA4	2004	2.5	382388	4899535	2.6
04-24264	ERA5	2004	2.5	382133	4900254	3.2
04-24269	ERA6	2004	2.5	383123	4900238	2.1
04-24283	ERA8	2004	2.5	382851	4901111	1.9
04-24284	ERA8	2004	2.5	382851	4901111	1.9
04-24295	SED11	2004	2.5	382753	4899612	3.4
04-24296	SED12	2004	2.5	382914	4899802	2.8
04-24297	SED13	2004	2.5	383025	4899970	3.7
04-24301	SED16	2004	2.5	382979	4900418	3.0
04-24302	SED17	2004	2.5	382862	4899987	3.0
04-24303	SED18	2004	2.5	382609	4900093	4.8
04-24304	SED19	2004	2.5	382538	4899915	3.4
04-24305	SED20	2004	2.5	382645	4899810	1.8

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**As**
			[cm]	**Easting**	**Northing**	**[ppm]**
04-24306	SED21	2004	2.5	382368	4899708	3.0
04-24307	SED22	2004	2.5	382329	4899541	3.8
04-24308	SED23	2004	2.5	382298	4899304	3.9
04-24309	SED24	2004	2.5	382505	4899251	3.3
05-17351	SED37	2005	2.5	382689	4900329	3.1
05-17352	SED38	2005	2.5	382424	4900259	5.4
05-17421	SED39	2005	2.5	382026	4899286	**9.7**
05-17422	SED40	2005	2.5	382175	4899130	3.6
05-30029	ERA11	2005	2.5	382036	4900455	4.6
05-30056	SED28	2005	2.5	382187	4899646	**6.1**
05-30058	SED26	2005	2.5	382357	4899119	3.3
6. ESG, 2006						
06-17116	C4 percussion	2006	32.5	381902	4900326	***17***
06-17150	C6 Percussion	2006	22.5	382444	4900245	**13**
06-17154	C6 KLB	2006	7.5	382444	4900245	3.5
06-17158	C6 KLB	2006	27.5	382444	4900245	***27***
06-17186	C8 KLB	2006	2.5	381971	4900510	<3.0
06-17189	C8 KLB	2006	17.5	381971	4900510	<1.0
06-17193	C7 Percussion	2006	17.5	382123	4900523	5.2
06-17206	C8 Percussion	2006	7.5	381971	4900510	**9.6**
06-17210	C8 Percussion	2006	27.5	381971	4900510	**8.4**
06-17212	C8 Percussion	2006	37.5	381971	4900510	<3.0
06-17215	C8 Percussion	2006	52.5	381971	4900510	<1.0
06-17217	C8 Percussion	2006	62.5	381971	4900510	1.7
06-17265	T3	2006	2.5	382057	4900047	5.6
06-17267	T4	2006	2.5	381977	4900232	**6.8**
7. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	***86***
CAT 3		2006	1.5	381918	4899966	***22***
CAT 4		2006	1.5	381917	4899936	**13**
CAT 5		2006	1.5	381971	4899936	**13**
CAT 6		2006	1.5	381962	4899897	**11**
CAT 7		2006	1.5	381914	4899897	***17***
CAT 8		2006	1.5	381863	4899902	***742***
CAT 9		2006	1.5	381872	4899839	***109***
CAT 10		2006	1.5	381915	4899835	***32***
CAT 11		2006	1.5	381963	4899840	**14**
CAT 12		2006	1.5	381896	4899805	***72***
CAT 13		2006	1.5	381921	4899782	***24***
CAT 14		2006	1.5	381967	4899779	***20***
CAT 15		2006	1.5	381879	4899743	***63***

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**As**
			[cm]	**Easting**	**Northing**	**[ppm]**
CAT 16		2006	1.5	381928	4899734	***34***
CAT 17		2006	1.5	381868	4899964	***70***
CAT 18		2006	1.5	382074	4900453	**8.0**
CAT 19		2006	1.5	382211	4900465	**6.0**
CAT 20		2006	1.5	382346	4900382	**7.0**
CAT 21		2006	1.5	381856	4900386	**10**
CAT 22		2006	1.5	382074	4900657	**12**
CAT 24		2006	1.5	381744	4901241	3.0
CAT 26		2006	1.5	381816	4900433	**9.0**
CAT 27		2006	0-10	381896	4900503	**13**
CAT 28		2006	11-25	381896	4900503	**15**
CAT 29		2006	26-33	381896	4900503	***38***
CAT 32		2006	0-10	381882	4900406	**11**
CAT 32		2006	11-25	381882	4900406	**13**
CAT 32		2006	26-46	381882	4900406	***24***
8. ESG, 2007-2009						
07-29644	T7	2007	2.5	382276	4900493	3.6
07-29646	T8	2007	2.5	382092	4900523	5.0
07-29647	T6	2007	2.5	382205	4900143	**6.5**
07-29648	T9	2007	2.5	382360	4900282	4.8
07-29649	T5	2007	2.5	382375	4900031	5.2
08-29891	T15	2008	2.5	382358	4900314	4.3
08-29892	T14	2008	2.5	382282	4900498	3.8
08-29893	T13	2008	2.5	382040	4900546	4.8
08-29895	T16	2008	2.5	382172	4900375	3.9
08-29898	T17	2008	2.5	382138	4900158	5.5
08-29900	T18	2008	2.5	381902	4899869	***32***
08-42000	T7	2008	2.5	382274	4900493	4.1
08-42004	T8	2008	2.5	382128	4900541	5.0
08-42012	Station BIV5	2008	2.5	382111	4900630	4.3
08-42041	Station BC1	2008	2.5	381914	4899874	***17***
08-42046	Station BC2	2008	2.5	382055	4900058	4.8
08-42051	Station BC3	2008	2.5	381980	4900226	**7.4**
08-42064	Cat4	2008	2.5	382313	4900651	1.9
08-42068	Cat3	2008	2.5	382073	4900663	4.6
08-42076	Cat1	2008	2.5	381816	4900557	**9.1**
08-42104	C1 15-20	2008	17.5	382026	4900462	3.1
08-42116	C4 15-20	2008	22.5	381920	4900136	**9.9**
08-42140	SSM9	2008	5.0	382090	4900492	4.4
08-42141	SSM1	2008	5.0	381924	4900549	**13**
08-42143	SSM3	2008	5.0	382175	4900605	5.5

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**As**
			[cm]	**Easting**	**Northing**	**[ppm]**
08-42146	SSM6	2008	5.0	382244	4900435	5.0
08-42147	SSM7	2009	5.0	382019	4900387	**6.9**
09-25600		2009	5.0	382040	4900391	**6.3**
09-25601		2009	5.0	381978	4900229	**6.4**
09-25602		2009	5.0	381927	4900085	5.7
09-25605		2009	5.0	382055	4900042	5.5
09-25606		2009	5.0	382037	4899905	3.4
09-25610		2009	5.0	381912	4900512	**8.8**
09-25611		2009	5.0	382195	4900591	3.1
09-25612		2009	5.0	382010	4900575	4.8
09-25613		2009	5.0	382089	4900518	4.1
09-25614		2009	5.0	382168	4900369	3.4
09-25706	C20	2009	5.0	381961	4900471	**13**
09-25705	C8	2009	5.0	381970	4900509	**10**
9. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	5.0
Station 2		2010	5.0	382076	4899080	4.0
Station 3		2010	5.0	381912	4899352	***22***
Station 4		2010	5.0	382111	4899341	**7.0**
Station 5		2010	5.0	381822	4899620	**11**
Station 6		2010	5.0	382119	4899617	**7.0**
Station 7		2010	5.0	381996	4899810	**9.0**
Station 8		2010	5.0	382484	4900015	4.0
10. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	**7.0**
2011-B		2011	5.0	382021	4899133	**7.0**
2011-C		2011	5.0	382022	4899322	**7.0**
2011-D		2011	5.0	382241	4899116	4.0
2011-E		2011	5.0	382240	4899285	5.0
2011-F		2011	5.0	381891	4899510	**10**
2011-G		2011	5.0	382097	4899514	**6.0**
2011-H		2011	5.0	381966	4899697	**11**
2011-I		2011	5.0	382175	4899790	5.0
2011-J		2011	5.0	382024	4900152	**7.0**
2011-K		2011	5.0	382278	4900213	5.0
2011-L		2011	5.0	382027	4900320	**6.0**
11. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	3.9
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	2.7
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	2.2
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	2.1

Table D-II-7: Arsenic Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth [cm]	UTM, NAD 84 Easting	UTM, NAD 84 Northing	As [ppm]
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	2.7
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	4.8
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	4.8
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	4.4

Table D-II-8: Antimony Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Sb
			[cm]	Easting	Northing	[ppm]
No sediment guidelines available						n/a
*OMOE SCS (soil within 30m of water body)**						**1.0**
CCME Soil Quality Guideline						***20***
1. ESG , 2002						
FF6		2002	2.5	382136	4900380	<10
2. MOE Benoit, 2006						
L10A		2003	5.0	381845	4899956	**7.0**
L10B		2003	15	381845	4899956	**6.0**
L11A		2003	5.0	381848	4899944	**11**
L11B		2003	15	381848	4899944	**14**
L12A		2003	5.0	381850	4899911	**14**
L12B		2003	15	381850	4899911	**16**
L13A		2003	5.0	381848	4899883	**7.0**
L13B		2003	15	381848	4899883	**3.0**
L14A		2003	5.0	381854	4899838	**10**
L14B		2003	15	381854	4899838	**2.0**
L7A		2003	5.0	381848	4900062	**14**
L8A		2003	5.0	381849	4900031	**4.0**
L9A		2003	5.0	381857	4899996	***22***
L9B		2003	15	381857	4899996	**7.0**
RC-1		2003	1.0	381866	4899998	<5.0
RC-10		2003	1.0	381916	4899802	<5.0
RC-11		2003	1.0	381957	4899802	<5.0
RC-12		2003	1.0	381884	4899736	<5.0
RC-13		2003	1.0	381924	4899736	<5.0
RC-14		2003	1.0	381965	4899736	<5.0
RC-15		2003	1.0	381914	4899964	<5.0
RC-16		2003	1.0	381866	4899931	<5.0
RC-17		2003	1.0	381914	4899899	<5.0
RC-18		2003	1.0	381867	4899934	<5.0
RC-2		2003	1.0	381914	4899998	<5.0
RC-2		2003	5.0	381914	4899998	<5.0
RC-2		2003	15	381914	4899998	<5.0
RC-2		2003	25	381914	4899998	<5.0
RC-3		2003	1.0	381867	4899934	<5.0
RC-4		2003	1.0	381912	4899934	<5.0
RC-4		2003	5.0	381912	4899934	<5.0
RC-4		2003	15	381912	4899934	<5.0
RC-4		2003	25	381912	4899934	<5.0
RC-5		2003	1.0	381961	4899934	<5.0
RC-6		2003	1.0	381867	4899867	**7.0**

Table D-II-8: Antimony Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Sb**
			[cm]	**Easting**	**Northing**	**[ppm]**
RC-7		2003	1.0	381914	4899867	<5.0
RC-7		2003	5.0	381914	4899867	<5.0
RC-7		2003	15	381914	4899867	<5.0
RC-8		2003	1.0	381961	4899867	<5.0
RC-9		2003	1.0	381875	4899802	**5.0**
3. Tinney, 2006						
04-24244	ERA1	2004	2.5	382500	4899082	<10
04-24249	ERA2	2004	2.5	382567	4899317	<10
04-24254	ERA3	2004	2.5	382622	4899477	<10
04-24259	ERA4	2004	2.5	382388	4899535	<10
04-24264	ERA5	2004	2.5	382133	4900254	***22***
04-24269	ERA6	2004	2.5	383123	4900238	<10
04-24283	ERA8	2004	2.5	382851	4901111	<10
04-24284	ERA8	2004	2.5	382851	4901111	<10
04-24295	SED11	2004	2.5	382753	4899612	<10
04-24296	SED12	2004	2.5	382914	4899802	<10
04-24297	SED13	2004	2.5	383025	4899970	<10
04-24301	SED16	2004	2.5	382979	4900418	<10
04-24302	SED17	2004	2.5	382862	4899987	<10
04-24303	SED18	2004	2.5	382609	4900093	<10
04-24304	SED19	2004	2.5	382538	4899915	<10
04-24305	SED20	2004	2.5	382645	4899810	<10
04-24306	SED21	2004	2.5	382368	4899708	<10
04-24307	SED22	2004	2.5	382329	4899541	<10
04-24308	SED23	2004	2.5	382298	4899304	<10
04-24309	SED24	2004	2.5	382505	4899251	<10
05-30029	ERA11	2005	2.5	382036	4900455	**17**
05-30056	SED28	2005	2.5	382187	4899646	**17**
05-30058	SED26	2005	2.5	382357	4899119	<10
4. ESG, 2006						
06-17116	C4 percussion	2006	32.5	381902	4900326	***81***
06-17150	C6 Percussion	2006	22.5	382444	4900245	***30***
06-17154	C6 KLB	2006	7.5	382444	4900245	**15**
06-17158	C6 KLB	2006	27.5	382444	4900245	***30***
06-17189	C8 KLB	2006	17.5	381971	4900510	***249***
06-17193	C7 Percussion	2006	17.5	382123	4900523	<10
06-17215	C8 Percussion	2006	52.5	381971	4900510	***894***
06-17217	C8 Percussion	2006	62.5	381971	4900510	<10
5. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	**2.0**
CAT 3		2006	1.5	381918	4899966	0.7

Table D-II-8: Antimony Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Report Locator	Sampling Date	Depth [cm]	UTM, NAD 84 Easting	UTM, NAD 84 Northing	Sb [ppm]
CAT 4		2006	1.5	381917	4899936	0.4
CAT 5		2006	1.5	381971	4899936	0.3
CAT 6		2006	1.5	381962	4899897	0.6
CAT 7		2006	1.5	381914	4899897	0.8
CAT 8		2006	1.5	381863	4899902	***23***
CAT 9		2006	1.5	381872	4899839	**2.5**
CAT 10		2006	1.5	381915	4899835	0.9
CAT 11		2006	1.5	381963	4899840	0.1
CAT 12		2006	1.5	381896	4899805	0.7
CAT 13		2006	1.5	381921	4899782	0.2
CAT 14		2006	1.5	381967	4899779	0.2
CAT 15		2006	1.5	381879	4899743	0.5
CAT 16		2006	1.5	381928	4899734	0.1
CAT 17		2006	1.5	381868	4899964	**2.4**
CAT 18		2006	1.5	382074	4900453	0.5
CAT 19		2006	1.5	382211	4900465	0.3
CAT 20		2006	1.5	382346	4900382	0.5
CAT 21		2006	1.5	381856	4900386	**1.7**
CAT 22		2006	1.5	382074	4900657	**3.2**
CAT 24		2006	1.5	381744	4901241	**1.0**
CAT 26		2006	1.5	381816	4900433	**2.3**
CAT 27 (CAT 29)0-10cnm		2006	0-10	381896	4900503	**7.6**
CAT 28 (CAT 29) 11-25 cm		2006	11-25	381896	4900503	**8.9**
CAT 29 26-33CM		2006	26-33	381896	4900503	***84***
CAT 32 0-10CM		2006	0-10	381882	4900406	**2.1**
CAT 32 11-25CM		2006	11-25	381882	4900406	**2.0**
CAT 32 26-46 cm		2006	26-46	381882	4900406	**4.4**
6. ESG, 2007						
07-29644	T7	2007	2.5	382276	4900493	***22***
07-29646	T8	2007	2.5	382092	4900523	**11**
7. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	0.8
Station 2		2010	5.0	382076	4899080	0.3
Station 3		2010	5.0	381912	4899352	**1.3**
Station 4		2010	5.0	382111	4899341	0.7
Station 5		2010	5.0	381822	4899620	**1.2**
Station 6		2010	5.0	382119	4899617	0.7
Station 7		2010	5.0	381996	4899810	0.8
Station 8		2010	5.0	382484	4900015	0.3
8. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	**1.8**

Table D-II-8: Antimony Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Report Locator**	**Sampling Date**	**Depth**	**UTM, NAD 84**		**Sb**
			[cm]	**Easting**	**Northing**	**[ppm]**
2011-B		2011	5.0	382021	4899133	0.9
2011-C		2011	5.0	382022	4899322	0.6
2011-D		2011	5.0	382241	4899116	0.4
2011-E		2011	5.0	382240	4899285	0.5
2011-F		2011	5.0	381891	4899510	**1.0**
2011-G		2011	5.0	382097	4899514	0.6
2011-H		2011	5.0	381966	4899697	**1.0**
2011-I		2011	5.0	382175	4899790	0.5
2011-J		2011	5.0	382024	4900152	**1.0**
2011-K		2011	5.0	382278	4900213	0.5
2011-L		2011	5.0	382027	4900320	0.9
9. ESG Anglin Bay, 2012						
12-01609	ABA-1 (AB-02)	2012	5.0	381951	4899103	<10
12-01614	ABA-2 (AB-03)	2012	5.0	381989	4899102	<10
12-01618	ABA-3 (AB-04)	2012	5.0	382017	4899099	<10
12-01622	ABA-4 (AB-05)	2012	5.0	382044	4899096	<10
12-01626	ABA-7 (AB-06)	2012	5.0	382058	4899077	<10
12-01630	ABA-8 (AB-07)	2012	5.0	382059	4899051	<10
12-01635	ABA-5 (AB-08)	2012	5.0	382054	4899097	<10
12-01636	ABA-5 (AB-08)	2012	5.0	382054	4899097	<10

* OMOE Site Condition Standard for Use within 30m of a Water Body (Agricultural Use)

Table D-II-9: Mercury Concentrations in Sediment Samples Collected in the Kingston Inner Harb APEC

Sample #	Report Locator	Sampling Date	Depth [cm]	UTM, NAD 84 Easting	UTM, NAD 84 Northing	Hg [ppm]
CCME ISQG						*0.17*
CCME PEL						***0.49***
Ontario SQG - LEL						**0.2**
1. Jaagumagi, 1991						
AQ1		1990	2.5	381842	4899073	***0.51***
AQ2		1990	2.5	381921	4899102	***0.5***
AQ3		1990	2.5	381866	4899143	**0.41**
2. Totten Sims Hubicki Associates, 1992						
T10		1985	0.0	381866	4900031	**0.21**
T11		1985	0.0	382152	4899924	**0.41**
T12		1985	0.0	382473	4899823	*0.17*
T13		1985	0.0	382791	4899729	0.09
T14		1985	0.0	381752	4899657	***4.9***
T15		1985	0.0	381850	4899465	***0.64***
T16		1985	0.0	382053	4899419	**0.48**
T17		1985	0.0	382258	4899365	**0.38**
T18		1985	0.0	382462	4899315	0.12
T19		1985	0.0	381856	4899139	***0.5***
T6		1985	0.0	381911	4900575	***0.58***
T7		1985	0.0	382261	4900493	0.09
T8		1985	0.0	382801	4900362	0.01
T9		1985	0.0	383089	4900296	0.07
3. MOE Benoit, 2006						
L10A		2003	5	381845	4899956	***1.7***
L10B		2003	15	381845	4899956	***1.0***
L11A		2003	5	381848	4899944	***2.7***
L11B		2003	15	381848	4899944	***3.0***
L12A		2003	5	381850	4899911	***4.6***
L12B		2003	15	381850	4899911	***6.7***
L13A		2003	5	381848	4899883	***4.3***
L13B		2003	15	381848	4899883	***0.7***
L14A		2003	5	381854	4899838	***8.5***
L14B		2003	15	381854	4899838	**0.3**
L7A		2003	5	381848	4900062	***1.8***
L8A		2003	5	381849	4900031	***0.5***
L9A		2003	5	381857	4899996	***3.0***
L9B		2003	15	381857	4899996	***1.7***
RC-1		2003	1	381866	4899998	***1.02***
RC-10		2003	1	381916	4899802	***0.8***
RC-11		2003	1	381957	4899802	***0.6***
RC-12		2003	1	381884	4899736	***2.6***

Table D-II-9: Mercury Concentrations in Sediment Samples Collected in the Kingston Inner Harbour Al
(cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Hg
			[cm]	Easting	Northing	[ppm]
RC-13		2003	1	381924	4899736	***1.0***
RC-14		2003	1	381965	4899736	***0.8***
RC-15		2003	1	381914	4899964	***1.3***
RC-16		2003	1	381866	4899931	***0.9***
RC-17		2003	1	381914	4899899	***0.9***
RC-18		2003	1	381867	4899934	***2.0***
RC-2		2003	1	381914	4899998	***0.6***
RC-2		2003	5	381914	4899998	***0.5***
RC-2		2003	15	381914	4899998	***0.5***
RC-2		2003	25	381914	4899998	***0.8***
RC-3		2003	1	381867	4899934	***1.5***
RC-4		2003	1	381912	4899934	***0.6***
RC-4		2003	5	381912	4899934	**0.4**
RC-4		2003	15	381912	4899934	**0.4**
RC-4		2003	25	381912	4899934	***0.6***
RC-5		2003	1	381961	4899934	**0.3**
RC-6		2003	1	381867	4899867	***1.2***
RC-7		2003	1	381914	4899867	***0.5***
RC-7		2003	5	381914	4899867	***0.5***
RC-7		2003	15	381914	4899867	***0.5***
RC-8		2003	1	381961	4899867	**0.4**
RC-9		2003	1	381875	4899802	***3.03***
4. ESG, 2006						
06-17042	s9	2006	2.5	381867	4900472	***0.51***
06-17044	S8	2006	2.5	381882	4900335	**0.48**
06-17086	C1KLB	2006	27.5	382507	4899119	**0.25**
06-17205	C8 Percussion	2006	2.5	381971	4900510	**0.45**
5. Manion, 2007						
C1-: 12-13		2006	12.5	381959	4899314	***2.8***
C1: 14-15		2006	14.5	381959	4899314	***2.7***
C2: 15-16		2006	15.5	382329	4900552	0.13
C2: 9-10		2006	9.5	382329	4900552	0.15
C3: 14-15		2006	14.5	381879	4900523	***0.6***
C3: 15-16		2006	15.5	381879	4900523	***0.72***
C4: 15-16		2006	15.5	381903	4900331	***0.53***
C5: 14-15		2006	14.5	381872	4899911	***1.8***
C6: 17-18		2006	17.5	381872	4899853	***10***
C13: 11-12		2007	11.5	381832	4899682	***2.0***
C13: 20-21		2007	20.5	381832	4899682	***1.8***
C14: 37-38		2007	37.5	381822	4899686	***0.76***
C6: 16-17		2007	16.5	381872	4899853	***11***

Table D-II-9: Mercury Concentrations in Sediment Samples Collected in the Kingston Inner Harbour Al
(cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Hg
			[cm]	Easting	Northing	[ppm]
C7: 11-12		2007	11.5	381869	4899093	**0.31**
C7: 25-26		2007	25.5	381869	4899093	***0.89***
C8: 16-17		2007	16.5	382059	4899186	**0.25**
C8:27-28		2007	27.5	382059	4899186	**0.28**
C9: 12-13		2007	12.5	381910	4899302	***1.9***
C9: 23-24		2007	23.5	381910	4899302	***2.3***
C9: 26-27		2007	26.5	381910	4899302	***5.9***
RC1: 35-40		2007	37.5	382507	4899119	**0.36**
RC3: 35-40		2007	37.5	382237	4899987	0.004
RC4: 15-20		2007	17.5	381902	4900326	**0.48**
RC4: 30-35		2007	32.5	381902	4900326	***1.0***
RC5: 45-50		2007	47.5	382113	4900266	**0.24**
RC5: 50-55		2007	52.5	382113	4900266	*0.17*
RC7: 40-45		2007	42.5	382123	4900523	0.05
RC8: 85-90		2007	87.5	381971	4900510	0.03
6. MOE, Benoit et al, 2010						
CAT 2		2006	1.5	381867	4899939	***1.8***
CAT 3		2006	1.5	381918	4899966	***0.6***
CAT 4		2006	1.5	381917	4899936	**0.35**
CAT 5		2006	1.5	381971	4899936	**0.47**
CAT 6		2006	1.5	381962	4899897	**0.42**
CAT 7		2006	1.5	381914	4899897	***0.61***
CAT 8		2006	1.5	381863	4899902	***6.1***
CAT 9		2006	1.5	381872	4899839	***3.9***
CAT 10		2006	1.5	381915	4899835	***0.89***
CAT 11		2006	1.5	381963	4899840	***0.66***
CAT 12		2006	1.5	381896	4899805	***2.8***
CAT 13		2006	1.5	381921	4899782	***1.1***
CAT 14		2006	1.5	381967	4899779	***0.72***
CAT 15		2006	1.5	381879	4899743	***1.6***
CAT 16		2006	1.5	381928	4899734	***1.4***
CAT 17		2006	1.5	381868	4899964	***1.5***
CAT 18		2006	1.5	382074	4900453	**0.27**
CAT 19		2006	1.5	382211	4900465	**0.2**
CAT 20		2006	1.5	382346	4900382	**0.26**
CAT 21		2006	1.5	381856	4900386	**0.4**
CAT 22		2006	1.5	382074	4900657	***0.68***
CAT 24		2006	1.5	381744	4901241	0.05
CAT 26		2006	1.5	381816	4900433	**0.31**
CAT 27		2006	0-10	381896	4900503	***0.62***
CAT 28		2006	11-25	381896	4900503	***0.75***

Table D-II-9: Mercury Concentrations in Sediment Samples Collected in the Kingston Inner Harbour Al
(cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Hg
			[cm]	Easting	Northing	[ppm]
CAT 29		2006	26-33	381896	4900503	***1.7***
CAT 32		2006	0-10	381882	4900406	**0.34**
CAT 32		2006	11-25	381882	4900406	**0.43**
CAT 32		2006	26-46	381882	4900406	***0.65***
7. ESG, 2007-2010						
08-42113	C4 0-5	2008	7.5	381920	4900136	**0.29**
10-20498	sed15	2010	5.0	381935	4899383	***0.98***
10-20501	sed16	2010	5.0	381818	4899680	***1.9***
10-20502	sed17	2010	5.0	381935	4899591	***1.9***
10-20503	sed18	2010	5.0	382082	4899651	***0.93***
10-20492	sed20	2010	5.0	382053	4900034	**0.22**
8. MOE Hg 2009						
KING1		2009	5.0	381914	4899303	***0.67***
KING2		2009	5.0	381823	4899679	***0.97***
KING3		2009	5.0	381874	4899847	***2.3***
KING4		2009	5.0	381871	4899925	***1.9***
KING5		2009	5.0	381950	4900487	**0.35**
9. Golder, PQRA 2011						
Station 1		2010	5.0	381891	4899105	**0.28**
Station 2		2010	5.0	382076	4899080	*0.17*
Station 3		2010	5.0	381912	4899352	***1.6***
Station 4		2010	5.0	382111	4899341	**0.37**
Station 5		2010	5.0	381822	4899620	***1.9***
Station 6		2010	5.0	382119	4899617	**0.46**
Station 7		2010	5.0	381996	4899810	***0.51***
Station 8		2010	5.0	382484	4900015	0.15
10. Golder, DQA 2012						
2011-A		2011	5.0	381820	4899198	**0.3**
2011-B		2011	5.0	382021	4899133	**0.39**
2011-C		2011	5.0	382022	4899322	**0.36**
2011-D		2011	5.0	382241	4899116	*0.19*
2011-E		2011	5.0	382240	4899285	*0.17*
2011-F		2011	5.0	381891	4899510	***0.66***
2011-G		2011	5.0	382097	4899514	**0.33**
2011-H		2011	5.0	381966	4899697	***0.65***
2011-I		2011	5.0	382175	4899790	**0.26**
2011-J		2011	5.0	382024	4900152	**0.36**
2011-K		2011	5.0	382278	4900213	**0.24**
2011-L		2011	5.0	382027	4900320	**0.23**
11. ESG Anglin Bay, 2012						
12-01610	ABA-1 (AB-02)	2012	5.0	381951	4899103	**0.3**

Table D-II-9: Mercury Concentrations in Sediment Samples Collected in the Kingston Inner Harbour Al
(cont'd)

Sample #	Report Locator	Sampling Date	Depth	UTM, NAD 84		Hg
			[cm]	Easting	Northing	[ppm]
12-01615	ABA-2 (AB-03)	2012	5.0	381989	4899102	<0.1
12-01619	ABA-3 (AB-04)	2012	5.0	382017	4899099	<0.1
12-01623	ABA-4 (AB-05)	2012	5.0	382044	4899096	**0.2**
12-01627	ABA-7 (AB-06)	2012	5.0	382058	4899077	<0.1
12-01631	ABA-8 (AB-07)	2012	5.0	382059	4899051	<0.1
12-01634	ABA-5 (AB-08)	2012	5.0	382054	4899097	**0.2**

Table D-II-10: Concentrations of Aroclors and Total PCBs in Sediment Samples Collected in the Kingston

Sample #	Location	UTM, NAD 84		Sampling Date	Depth	Aroclor 1242	Aroclor 1254	Aroclor 1260	Total PCBs	Total Aroclor Sum 1262, 1016, 1221, 1232, 1248, 1254, 1260, 1268	SUM PCB Congeners
		Easting	Northing		[cm]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
CCME ISQG									*34*	*34*	*34*
CCME PEL									***277***	***277***	***277***
Ontario SQG - LEL									**70**	**70**	**70**
1. Totten Sims Hubicki Associates, 1992											
T10		381866	4900031	1992	0				***330***		
T11		382152	4899924	1992	0				***920***		
T12		382473	4899823	1992	0				***420***		
T13		382791	4899729	1992	0				*50*		
T14		381752	4899657	1992	0				***685***		
T15		381850	4899465	1992	0				***1185***		
T16		382053	4899419	1992	0				***1160***		
T17		382258	4899365	1992	0				***465***		
T18		382462	4899315	1992	0				**175**		
T19		381856	4899139	1992	0				***835***		
T6		381911	4900575	1992	0				***3655***		
T7		382261	4900493	1992	0				***550***		
T8		382801	4900362	1992	0				20		
T9		383089	4900296	1992	0				*50*		
2. Brooks et al, 1998											
A5		382296	4900300	1998	0	7.2	89	170			***279***
A6		382103	4900377	1998	0	18	180	310			***531***
A7		381967	4900347	1998	0	16	240	410			***686***
E3		381871	4901152	1998	0	<9	27	62	**89**		
E5		382219	4700888	1998	0	<120	120	60	**180**		
G1		382387	4899355	1998	0	5.7	89	130	**225**		
G3		382417	4899805	1998	0	<21	240	430	***670***		
G4		382131	4899813	1998	0	26	510	850	***1386***		
K10		382363	4900631	1998	0	69	370	660			***1160***
K11		382175	4900657	1998	0	100	1500	6500	***8100***		
K12		381902	4900584	1998	0	26	180	340			***583***
K13		381806	4900526	1998	0	140	1500	3100			***4959***
3. Cross, 1999											
AA3		382519	4899983	1999	5.0	<22	160	225	***385***		***354***
EE3		381871	4901152	1999	5.0						**85**
EE5		382219	4900888	1999	5.0						**182**
GG1		382387	4899355	1999	5.0						**203**
GG3		382417	4899805	1999	5.0						***617***
GG4		382131	4899813	1999	5.0						***1302***
KK11		382175	4900657	1999	5.0						***6742***
4. MOE, Derry et al, 2003											
31	SE-1	381868	4899833	2001	0.5		180	100		***280***	
37	SE-7	381859	4900242	2001	0.5		230	290		***520***	
38	SE-8	382580	4899260	2001	0.5		330	250		***580***	
39	SE-9	382998	4899601	2001	0.5		200	100		***300***	
40	SE-10	383168	4900213	2001	0.5		72	47		**120**	
47	SE-17	382118	4900643	2001	0.5		580	1300		***1900***	
A3		382503	4899989	2001	2.5					***530***	
A4		382427	4900147	2001	2.5					***1000***	
A5		382307	4900281	2001	2.5					***850***	
A6		382086	4900398	2001	2.5					***360***	
A7		381985	4900357	2001	2.5					***930***	
G3		382401	4899801	2001	2.5					***1100***	
G4		382122	4899844	2001	2.5					***1300***	
K10		382086	4900398	2001	2.5					***1500***	
K11		382180	4900652	2001	2.5					***320***	
K12		381908	4900590	2001	2.5					***3000***	
K12		381908	4900590	2001	2.5					***2900***	
K13		381811	4900538	2001	2.5					***1200***	
S10		382221	4900609	2001	2.5					***700***	
S11		381928	4900203	2001	2.5					***1100***	
S12		382142	4900256	2001	2.5					***1400***	
S13		382336	4900489	2001	2.5					***440***	
S14		381921	4900144	2001	2.5					***490***	
S15		382195	4900079	2001	2.5					***1700***	
S16		382294	4900071	2001	2.5					**270**	
S17		382549	4900247	2001	2.5					***980***	
S7		381809	4900491	2001	2.5					***360***	
S8		381882	4900449	2001	2.5					***1800***	
S9		382034	4900580	2001	2.5					***880***	

Table D-II-10: Concentrations of Aroclors and Total PCBs in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Location**	**UTM, NAD 84**		**Sampling Date**	**Depth**	**Aroclor 1242**	**Aroclor 1254**	**Aroclor 1260**	**Total PCBs**	**Total Aroclor Sum 1262, 1016, 1221, 1232, 1248, 1254, 1260, 1268**	**SUM PCB Congeners**
		Easting	**Northing**		**[cm]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**
5. ESG, 2002											
FF6		382136	4900380	2002	5.0	130	270	400	***800***		
6. MOE, Benoit, 2006											
06 15 083		381836	4900494	2003	5.0						***510***
06 15 085		381726	4901247	2003	5.0						*47*
06 15 0182		382072	4900635	2003	5.0						***710***
06 15 0183		381867	4899898	2003	5.0						**210**
06 15 0184		381882	4899764	2003	5.0						***490***
L10A		381845	4899956	2003	5.0		3600	900		***4400***	
L10B		381845	4899956	2003	15					***490***	
L11A		381848	4899944	2003	5.0		9600	2300		***12000***	
L11B		381848	4899944	2003	15					***1800***	
L12A		381850	4899911	2003	5.0		420	180		***600***	
L12B		381850	4899911	2003	15					ND	
L13A		381848	4899883	2003	5.0		10	ND		10	
L13B		381848	4899883	2003	15					ND	
L14A		381854	4899838	2003	5.0		20	20		*40*	
L14B		381854	4899838	2003	15					ND	
L7A		381848	4900062	2003	5.0		180	290		***470***	
L8A		381849	4900031	2003	5.0		830	320		***1200***	
L9A		381857	4899996	2003	5.0		50	30		**80**	
L9B		381857	4899996	2003	15					***740***	
RC-1		381866	4899998	2003	1.0					***350***	
RC-10		381916	4899802	2003	1.0					***440***	
RC-11		381957	4899802	2003	1.0					***550***	
RC-12		381884	4899736	2003	1.0					***580***	
RC-13		381924	4899736	2003	1.0					***1200***	
RC-14		381965	4899736	2003	1.0					***650***	
RC-15		381914	4899964	2003	1.0					***580***	
RC-16		381866	4899931	2003	1.0					***430***	
RC-17		381914	4899899	2003	1.0					***610***	
RC-18		381867	4899934	2003	1.0					***1500***	
RC-2		381914	4899998	2003	1.0					***380***	
RC-2		381914	4899998	2003	5.0					***490***	
RC-2		381914	4899998	2003	15					***530***	
RC-2		381914	4899998	2003	25					***3900***	
RC-3		381867	4899934	2003	1.0					***2000***	
RC-4		381912	4899934	2003	1.0					***340***	
RC-4		381912	4899934	2003	5.0					***450***	
RC-4		381912	4899934	2003	15					***440***	
RC-4		381912	4899934	2003	25					***700***	
RC-5		381961	4899934	2003	1.0					***460***	
RC-6		381867	4899867	2003	1.0					***360***	
RC-7		381914	4899867	2003	1.0					***460***	
RC-7		381914	4899867	2003	5.0					***510***	
RC-7		381914	4899867	2003	15					***1100***	
RC-8		381961	4899867	2003	1.0					***500***	
RC-9		381875	4899802	2003	1.0					**250**	
7. Tinney, 2006											
04-24244	ERA1	382500	4899082	2004	2.5		30	50	**80**		
04-24249	ERA2	382567	4899317	2004	2.5		49	89	**138**		
04-24254	ERA3	382622	4899477	2004	2.5		59	68	**127**		
04-24259	ERA4	382388	4899535	2004	2.5		25	64	**90**		
04-24264	ERA5	382133	4900254	2004	2.5		62	380	***442***		
04-24269	ERA6	383123	4900238	2004	2.5		14	31	*45*		
04-24283	ERA8	382851	4901111	2004	2.5		<10	<10	<20		
04-24284	ERA8	382851	4901111	2004	2.5		<10	25	25		
04-24295	SED11	382753	4899612	2004	2.5		47	89	**136**		
04-24296	SED12	382914	4899802	2004	2.5		11	48	*59*		
04-24297	SED13	383025	4899970	2004	2.5		20	21	*41*		
04-24301	SED16	382979	4900418	2004	2.5		<10	20	20		
04-24302	SED17	382862	4899987	2004	2.5		16	35	*51*		
04-24303	SED18	382609	4900093	2004	2.5		44	83	**127**		
04-24304	SED19	382538	4899915	2004	2.5		32	88	**120**		
04-24305	SED20	382645	4899810	2004	2.5		16	41	*57*		
04-24306	SED21	382368	4899708	2004	2.5		34	82	**116**		
04-24307	SED22	382329	4899541	2004	2.5		42	110	**152**		
04-24308	SED23	382298	4899304	2004	2.5		46	100	**146**		
04-24309	SED24	382505	4899251	2004	2.5		31	47	**78**		
05-17351	SED37	382689	4900329	2005	2.5		<3.0	34.5	*35*		
05-17352	SED38	382424	4900259	2005	2.5		<3.0	235	**235**		

Table D-II-10: Concentrations of Aroclors and Total PCBs in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Location**	**UTM, NAD 84**		**Sampling Date**	**Depth**	**Aroclor 1242**	**Aroclor 1254**	**Aroclor 1260**	**Total PCBs**	**Total Aroclor Sum 1262, 1016, 1221, 1232, 1248, 1254, 1260, 1268**	**SUM PCB Congeners**
		Easting	**Northing**		**[cm]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**
05-17421	SED39	382026	4899286	2005	2.5		2110	390	***2500***		
05-17422	SED40	382175	4899130	2005	2.5		<3.0	340	***340***		
05-30029	ERA11	382036	4900455	2005	2.5		<10	30	30		
05-30049	ERA12	381971	4900066	2005	2.5		<10	34	*34*		
05-30056	SED28	382187	4899646	2005	2.5		<10	120	**120**		
05-30057	SED27	382185	4899191	2005	2.5		<10	13	13		
05-30058	SED26	382357	4899119	2005	2.5		<10	12	12		
8. ESG, 2006											
06-17100	C3 Percussion	382237	4899987	2006	2.5	< 3.0	< 3.0	<3.0	<3.0		
06-17123	C4 KLB	381902	4900326	2006	2.5	12	62	410	***484***		
06-17205	C8 Percussion	381971	4900510	2006	2.5	4.6	9.9	14	29		
06-17207	C8 Percussion	381971	4900510	2006	12.5	< 3.0	< 3.0	4.4	4.4		
06-17209	C8 Percussion	381971	4900510	2006	22.5	< 3.0	4.2	7.0	11		
06-17211	C8 Percussion	381971	4900510	2006	32.5	< 3.0	4.6	20	25		
06-17213	C8 Percussion	381971	4900510	2006	42.5	< 3.0	5.5	25	31		
06-17214	C8 Percussion	381971	4900510	2006	47.5	< 3.0	5.0	25	30		
06-17216	C8 Percussion	381971	4900510	2006	57.5	< 3.0	47	170	**217**		
06-17220	C8 Percussion	381971	4900510	2006	77.5		5.8	<3.0	5.8		
06-17267	T4	381977	4900232	2006	2.5	< 3.0	< 3.0	< 3.0	<3.0		
9. MOE, Benoit et al, 2010											
CAT 2		381867	4899939	2006	1.5						***443***
CAT 3		381918	4899966	2006	1.5						**236**
CAT 4		381917	4899936	2006	1.5						**227**
CAT 5		381971	4899936	2006	1.5						**183**
CAT 6		381962	4899897	2006	1.5						**210**
CAT 7		381914	4899897	2006	1.5						**231**
CAT 8		381863	4899902	2006	1.5						**226**
CAT 9		381872	4899839	2006	1.5						***295***
CAT 10		381915	4899835	2006	1.5						**231**
CAT 11		381963	4899840	2006	1.5						***910***
CAT 12		381896	4899805	2006	1.5						***628***
CAT 13		381921	4899782	2006	1.5						**272**
CAT 14		381967	4899779	2006	1.5						***318***
CAT 15		381879	4899743	2006	1.5						***374***
CAT 16		381928	4899734	2006	1.5						***473***
CAT 17		381868	4899964	2006	1.5						***620***
CAT 18		382074	4900453	2006	1.5						**263**
CAT 19		382211	4900465	2006	1.5						**172**
CAT 20		382346	4900382	2006	1.5						***313***
CAT 21		381856	4900386	2006	1.5						***441***
CAT 22		382074	4900657	2006	1.5						***2560***
CAT 24		381744	4901241	2006	1.5						31
CAT 25		381796	4900464	2006	1.5						***549***
CAT 26		381816	4900433	2006	1.5						***533***
CAT 27		381896	4900503	2006	0-10						***1080***
CAT 28		381896	4900503	2006	11-25						***2310***
CAT 29		381896	4900503	2006	26-33						***851***
CAT 32		381882	4900406	2006	0-10						***437***
CAT 32		381882	4900406	2006	11-25						***606***
CAT 32		381882	4900406	2006	26-46						***861***
10. ESG 2007 - 2010											
07-29647	T6	382205	4900143	2007	2.5		28	30	*58*		
08-29910	S2-2008	382052	4899289	2008	2.5	5.4	15	<3.0	20		
08-29911	S1-2008	382070	4899514	2008	2.5	<3.0	11	13	24		
08-42000	T7	382274	4900493	2008	2.5	< 3.0	< 3.0	< 3.0	<3.0		
08-42004	T8	382128	4900541	2008	2.5	< 3.0	< 3.0	< 3.0	<3.0		
08-42063	SS8	381911	4900545	2008	2.5	< 3.0	5.1	7.9	13		
08-42068	Cat3	382073	4900663	2008	2.5	<3.0	51	130	**181**		
08-42076	Cat1	381816	4900557	2008	2.5	<3.0	44	54	**98**		
10-20405	C10	382149	4900448	2010	2.5		13	101	**114**		
10-20422	C9	382109	4900648	2010	2.5		11	228	**239**		
10-20424	C9	382109	4900648	2010	12.5		33	59	**92**		
10-20424d1	C9	382109	4900648	2010	12.5		41	69	**110**		
10-20426	C9	382109	4900648	2010	22.5		40	400	***440***		
10-20429	C9	382109	4900648	2010	37.5		<3.0	77.4	**77**		
10-20431	C9	382109	4900648	2010	47.5		4.1	17	21		
10-20400	C11	382170	4900255	2010	22.5		151	127	***278***		
10-20403	C11	382170	4900255	2010	37.5		<3.0	<3.0	<3.0		
10-20476	C11	382170	4900255	2010	2.5		3.0	93	**96**		
10-20478	C11	382170	4900255	2010	12.5		<3.0	249	**249**		

Table D-II-10: Concentrations of Aroclors and Total PCBs in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Location	UTM, NAD 84		Sampling Date	Depth	Aroclor 1242	Aroclor 1254	Aroclor 1260	Total PCBs	Total Aroclor Sum 1262, 1016, 1221, 1232, 1248, 1254, 1260, 1268	SUM PCB Congeners
		Easting	Northing		[cm]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
10-20470	C12	382195	4900076	2010	2.5		35	295	***330***		
10-20470d1	C12	382195	4900076	2010	2.5		39	328	***367***		
10-20470d2	C12	382195	4900076	2010	2.5		31	262	***293***		
10-20472	C12	382195	4900076	2010	12.5		83	55	**138**		
10-20475	C12	382195	4900076	2010	27.5		<3.0	<3.0	<3.0		
10-20495	sed1	382040	4899246	2010			<3	34	*36*		
10-20494	sed2	382169	4899375	2010			3.6	53	*57*		
10-20499	sed5	381869	4899333	2010			300	154	***454***		
10-20504	sed6	381976	4899568	2010			164	302	***466***		
10-20504d1	sed6	381976	4899568	2010			173	288	***461***		
10-20488	sed7	382122	4899844	2010			54	110	**164**		
10-20489	sed8	382277	4899824	2010			314	26	***330***		
10-20491	sed9	382406	4899933	2010			79	94	**172**		
10-20482	sed11	381912	4900427	2010			30	130	**160**		
10-20480	sed12	381908	4900588	2010			69	146	**215**		
10-20483	sed13	382277	4900533	2010			14	120	**134**		
10-20486	sed22	381964	4900183	2010			14	169	**183**		
11. Golder & Assoc PQRA 2011											
Station 1		381891	4899105	2010	5.0	<50	140	110	**275**		
Station 2		382076	4899080	2010	5.0	<40	120	50	**190**		
Station 3		381912	4899352	2010	5.0	70	880	420	***1370***		
Station 4		382111	4899341	2010	5.0	<50	480	260	***765***		
Station 5		381822	4899620	2010	5.0	<50	220	140	***385***		
Station 6		382119	4899617	2010	5.0	<60	510	670	***1210***		
Station 7		381996	4899810	2010	5.0	<50	530	490	***1045***		
Station 8		382484	4900015	2010	5.0	<70	170	180	***385***		
12. Golder & Assoc DQA 2012											
2011-A		381820	4899198	2011	5.0				**200**		
2011-B		382021	4899133	2011	5.0				***600***		
2011-C		382022	4899322	2011	5.0				***1100***		
2011-D		382241	4899116	2011	5.0				**140**		
2011-E		382240	4899285	2011	5.0				**180**		
2011-F		381891	4899510	2011	5.0				***900***		
2011-G		382097	4899514	2011	5.0				***400***		
2011-H		381966	4899697	2011	5.0				**180**		
2011-I		382175	4899790	2011	5.0				***600***		
2011-J		382024	4900152	2011	5.0				***380***		
2011-K		382278	4900213	2011	5.0				***400***		
2011-L		382027	4900320	2011	5.0				***400***		
13. ESG, Anglin Bay, 2012											
12-01607	ABA-1 (AB-02)	381951	4899103	2012	5.0		<100	<100	<100		
12-01608	ABA-1 (AB-02)	381951	4899103	2012	5.0		<100	<100	<100		
12-01613	ABA-2 (AB-03)	381989	4899102	2012	5.0		<100	<100	<100		
12-01617	ABA-3 (AB-04)	382017	4899099	2012	5.0		<100	<100	<100		
12-01621	ABA-4 (AB-05)	382044	4899096	2012	5.0		<100	<100	<100		
12-01625	ABA-7 (AB-06)	382058	4899077	2012	5.0		<100	<100	<100		
12-01629	ABA-8 (AB-07)	382059	4899051	2012	5.0		<100	<100	<100		
12-01633	ABA-5 (AB-08)	382054	4899097	2012	5.0		<100	<100	<100		

Table D-II-11: PAH Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Depth [cm]	Easting	Northing	Sampling Date	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene	Benzo(a)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
					[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
CCME ISQG					*34.6*	*59*	*67*	*21.2*	*41.9*	*46.9*	*111*	*53*	*31.7*	*57.1*			*31.9*		*6.2*				
CCME PEL					***391***	***128***	***88.9***	***144***	***515***	***245***	***2355***	***875***	***385***	***862***			***782***		***135***				
Ontario SQG - LEL								**190**	**560**	**220**	**750**	**490**	**320**	**340**			**370**		**60**	**200**	**170**	**240**	**4000**
1. CH2M Hill, 1991																							
D1	30	381839	4899068	1989	<12000	***7700***	***7400***	<4800	<1600	<2400	***20450***	***34450***	<17000	***17750***	29200		***22300***		<9500	**21350**	**14300**		**174900**
S1	102	381867	4899159	1989	***7500***	***10200***	***11200***	**5850**	**38750**	***15550***	***25800***	***39350***	***45800***	***121000***	17550		***33850***			**17550**	**12700**	**19550**	**422200**
S11	102	381847	4899087	1989	***3780***	***3105***	***10950***	**2180**	**19550**	***3515***	***15050***	***15400***	***9450***	***7050***	18850		***8750***			**4050**	**5250**	**2025**	**128955**
S12	102	381985	4899101	1989	<1200	***750***	<480	<480	**1540**	<240	***2850***	***3965***	<1300	<1510	3800		***1175***		<950	<680	**1070**	<1100	**18640**
S13	102	382089	4899023	1989	<1200	***8950***	***3390***	**1600**	**13900**	***6750***	***23800***	***31550***	***25900***	***19600***	38700		***24900***		***3175***	**11450**	**14250**	**6400**	**234315**
S2	102	381839	4899068	1989	***131000***	***26950***	***76000***	**38300**	**187500**	***57500***	***77000***	***114500***	***136000***	***432500***	41300		***79000***			**40350**	**28200**	<1100	**1466100**
S3	110	381876	4899082	1989	***13200***	***6550***	***5200***	**3845**	**22000**	***7850***	***14900***	***22200***	***24145***	***76500***	11800		***19800***			**10850**	**8550**	<1100	**247390**
S4	102	381917	4899099	1989	***2535***	***6050***	***2610***	**1965**	**11050**	***5100***	***9400***	***16800***	***18150***	***57500***	8750		***16750***			**9000**	**6300**	**9550**	**181510**
S5	102	381859	4899076	1989	***3780***	***7950***	***6150***	**3755**	**27950**	***9000***	***18900***	***27750***	***30000***	***86500***	12600		***23600***			**13200**	**10600**	**12700**	**294435**
S6	103	381857	4899082	1989	***2540***	***3520***	***1980***	**2130**	**15100**	***4825***	***11750***	***15400***	***15250***	***53500***	7750		***13600***			**7600**	**6100**	**8000**	**169045**
S7	103	381850	4899080	1989	***3195000***	<4800	***1215000***	**665000**	**2685000**	***740000***	***675000***	***940000***	***1060000***	<1510	433000		***4400000***		<9500	**3210000**	**1070000**	**317000**	**20605000**
S8	102	381902	4899101	1989	***28200***	<4800	***20000***	**9250**	**157500**	***70000***	***166000***	***270500***	***64500***	***74500***	32700		***32050***		<9500	**32650**	<9500	**45550**	**1003400**
S9	80	381958	4899169	1989	***16150***	***19450***	***65500***	**22400**	**111000**	<2400	***67500***	***127000***	***43000***	***46800***	60000		***48950***		<9500	**27550**	<9500	<1100	**655300**
2. R.Jaagumagi, 1991																							
AQ1	2.5	381842	4899073	1990	***2200***	***2100***	***1700***	**1700**	**8600**	***3300***	***11500***	***15700***	***9400***	***9400***	12500		***13900***		***2170***	**9240**	**9730**	**5100**	**118240**
AQ2	2.5	381921	4899102	1990	***460***	***700***	***500***	**500**	**3120**	***1130***	***4280***	***5940***	***3350***	***3620***	4190		***4380***		***560***	**2010**	**2230**	**1630**	**38600**
AQ3	2.5	381866	4899143	1990	***430***	***630***	***450***	**410**	**2040**	***970***	***3320***	***5390***	***3120***	***3260***	3970		***4240***		***530***	**2000**	**2040**	**1500**	**34300**
3. Brooks et al, 1998																							
A6	0	382103	4900377	1998	*98*	38	54	*75*	*420*	*170*	**790**	***1300***	***790***	***930***	1200	620	***990***	290	***140***	**530**	**490**		**8925**
G4	0	382131	4899813	1998	*280*	***130***	62	*94*	*420*	*120*	**980**	***1700***	ndr	***1000***	1400	1100	***1200***	ndr	ndr	**230**	**320**		**9036**
K11	0	382175	4900657	1998	***950***	***810***	***550***	**460**	**4700**	***1400***	**6000**	***10000***	***4700***	***5100***	5800	3900	***5900***	970	***1100***	**860**	**1200**		**54400**
K12	0	381902	4900584	1998	***600***	*100*	***160***	**330**	**1300**	***340***	**1800**	***2300***	***1200***	***1300***	1500	700	***1300***	280	***180***	**680**	**630**		**14700**
4. ESG 2002																							
FF6	0	382136	4900380	2002	***450***	***360***	50	<50	*220*	**220**	*600*	***1100***	***540***	**630**	540		***810***		**100**	**560**	**550**	**540**	**7270**
4. MOE Benoit et al, 2006																							
06 15 083	5.0	381836	4900494	2003	*300*	***1100***	***400***	**460**	**2800**	***700***	**5800**	***7800***	***4900***	***5500***	5300		***4300***		***800***	**3200**	**2900**	**1800**	**48060**
06 15 085	5.0	381726	4901247	2003	*120*	*100*	***340***	**780**	**1700**	***420***	**3300**	***2700***	***800***	***1100***	1300		***840***		***200***	**800**	**720**	**440**	**15660**
06 15 0182	5.0	382072	4900635	2003	*140*	***340***	40	*40*	**620**	220	**1600**	***2400***	***1200***	***1300***	1600		***1800***		***320***	**1000**	**1000**	**600**	**14260**
06 15 0183	5.0	381867	4899898	2003	***1200***	***180***	***860***	**1200**	**1000**	***1900***	**1400**	***1200***	***5100***	***5100***	5900		***4800***		***840***	**3100**	**2800**	**2300**	**38880**
06 15 0184	5.0	381882	4899764	2003	*180*	***140***	60	*80*	**1100**	*200*	**2300**	***2300***	***1100***	***1300***	1600		***1200***		***200***	**880**	**840**	**600**	**14080**
L14A	5.0	381854	4899838	2003	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000			<1000		<1000	<1000	<1000	<1000	<1000
L14B	15	381854	4899838	2003	<1000	<1000	<1000	<1000	**1000**	<1000	**1000**	***1000***	<1000	<1000	<1000		<1000		<1000	<1000	<1000	<1000	3000

Table D-II-11: PAH Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Depth [cm]	Easting	Northing	Sampling Date	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene	Benzo(a)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
					[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
RC-1	1.0	381866	4899998	2003																			2197
RC-10	1.0	381916	4899802	2003																			2052
RC-11	1.0	381957	4899802	2003																			2054
RC-12	1.0	381884	4899736	2003																			**10219**
RC-13	1.0	381924	4899736	2003																			2567
RC-14	1.0	381965	4899736	2003																			2135
RC-15	1.0	381914	4899964	2003																			**18035**
RC-16	1.0	381866	4899931	2003																			1878
RC-17	1.0	381914	4899899	2003																			849
RC-18	1.0	381867	4899934	2003																			2904
RC-2	1.0	381914	4899998	2003																			1600
RC-2	5.0	381914	4899998	2003																			1618
RC-2	15	381914	4899998	2003																			3340
RC-2	25	381914	4899998	2003																			**8715**
RC-3	1.0	381867	4899934	2003																			**4609**
RC-4	1.0	381912	4899934	2003																			2409
RC-4	5.0	381912	4899934	2003																			1532
RC-4	15	381912	4899934	2003																			2187
RC-4	25	381912	4899934	2003																			3882
RC-5	1.0	381961	4899934	2003																			1226
RC-6	1.0	381867	4899867	2003																			3603
RC-7	1.0	381914	4899867	2003																			1679
RC-7	5.0	381914	4899867	2003																			2977
RC-7	15	381914	4899867	2003																			2143
RC-8	1.0	381961	4899867	2003																			2034
RC-9	1.0	381875	4899802	2003																			**36550**
5. Tinney, 2006																							
04-24244	2.5	382500	4899082	2004	*90*	***140***	<50	<50	*380*	**220**	**1100**	***1500***	***700***	**780**	600		***970***		***140***	**610**	**540**	**560**	**8400**
04-24249	2.5	382567	4899317	2004	*70*	*80*	<50	<50	*160*	*80*	*430*	**580**	*250*	*300*	300		**410**		**70**	**290**	**250**	220	3500
04-24254	2.5	382622	4899477	2004	*80*	*80*	<50	<50	*170*	*100*	*500*	**700**	*310*	**370**	300		**460**		**80**	**330**	**290**	**290**	**4100**
04-24259	2.5	382388	4899535	2004	*200*	*70*	<50	<50	*130*	*50*	*290*	*390*	*190*	*210*	240		*350*		**80**	**290**	**280**	190	3000
04-24264	2.5	382133	4900254	2004	*120*	***160***	<50	<50	*190*	*90*	*430*	**660**	**320**	**370**	470		**680**		**120**	**570**	**510**	**310**	**5100**
04-24269	2.5	383123	4900238	2004	*60*	<50	<50	<50	*90*	<50	*180*	*160*	*60*	*80*	100		*100*		<50	<100	<100	<50	1100
04-24283	2.5	382851	4901111	2004	<60	<50	<50	<50	<50	<50	70	*60*	<50	<50	<50		<100		<50	<100	<100	<50	130
04-24284	2.5	382851	4901111	2004	*60*	<50	<50	<50	<50	<50	60	50	<50	<50	<50		<100		<50	<100	<100	<50	170
04-24295	2.5	382753	4899612	2004	*90*	*60*	<50	<50	*120*	*60*	*340*	*440*	*190*	*240*	230		*310*		**80**	**250**	**240**	160	2800
04-24296	2.5	382914	4899802	2004	*70*	50	<50	<50	*120*	<50	*390*	*430*	*200*	*220*	210		*290*		*50*	**220**	**190**	130	2600

Table D-II-11: PAH Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Depth [cm]	Easting	Northing	Sampling Date	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene	Benzo(a)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
					[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
04-24297	2.5	383025	4899970	2004	60	<50	<50	<50	60	<50	160	160	50	80	80		<100		<50	100	<100	60	800
04-24301	2.5	382979	4900418	2004	60	<50	<50	<50	<50	<50	120	130	60	80	80		100		<50	<100	<100	60	690
04-24302	2.5	382862	4899987	2004	60	<50	<50	<50	70	<50	180	190	90	110	120		160		<50	130	120	90	1400
04-24303	2.5	382609	4900093	2004	70	70	<50	<50	130	50	370	470	190	230	230		330		60	250	230	170	2800
04-24304	2.5	382538	4899915	2004	<60	<50	<50	<50	80	<50	210	270	130	140	140		220		<50	170	150	120	1800
04-24305	2.5	382645	4899810	2004	<60	<50	<50	<50	60	<50	140	150	60	80	100		110		<50	100	<100	70	1100
04-24306	2.5	382368	4899708	2004	70	60	<50	<50	110	50	270	380	170	200	190		300		50	230	210	160	2500
04-24307	2.5	382329	4899541	2004	80	100	<50	<50	170	90	410	600	310	320	280		540		80	380	340	180	3900
04-24308	2.5	382298	4899304	2004	100	280	90	80	490	300	1100	1700	880	860	740		1600		230	1100	900	250	11000
04-24309	2.5	382505	4899251	2004	70	50	<50	<50	110	60	290	370	160	200	250		300		50	230	200	130	2500
05-17351	2.5	382689	4900329	2005	<60	<50	<50	<50	<50	<50	50	90	<50	50	<50		<100		60	<100	100	<50	350
05-17352	2.5	382424	4900259	2005	60	<50	<50	<50	60	<50	70	110	60	80	50		<100		90	100	130	60	870
05-17421	2.5	382026	4899286	2005	320	180	130	80	500	260	890	1500	760	920	570		1400		280	1000	1100	790	10680
05-17422	2.5	382175	4899130	2005	90	<50	<50	<50	60	<50	60	90	<50	<50	<50		<100		<50	<100	<100	<50	300
05-30029	2.5	382036	4900455	2005	46	150	30	26	140	82	380	600	300	370	260		590		98	330	270	170	3842
05-30049	2.5	381971	4900066	2005	36	26	11	<20	74	27	<20	180	110	130	82		180		<5	100	86	35	1077
05-30056	2.5	382187	4899646	2005	170	180	68	54	270	130	500	830	450	500	340		740		110	410	340	220	5312
05-30057	2.5	382185	4899191	2005	150	130	95	81	390	270	850	1200	630	720	420		810		120	430	340	240	6876
05-30058	2.5	382357	4899119	2005	120	26	16	36	140	46	300	350	130	190	110		180		27	96	78	70	1915
6. ESG, 2008																							
08-29911	2.5	382070	4899514	2008	120	50	<50	<50	130	<50	250	300	230	220	250		300		<50	270	230	80	2500
08-42046	2.5	382055	4900058	2008	90	<50	<50	<50	50	<50	50	70	<50	<50	60		<100		<50	<100	<100	<50	<1000
7. MOE Benoit, 2010																							
CAT 2	1.5	381867	4899939	2006	95.3	50.8	46.4	41.5	310	88.8	565	659	312	416	731		115		87.9	288	297		3415
CAT 3	1.5	381918	4899966	2006	95.8	84.6	36.3	30	201	74.8	404	509	246	346	703		422		76	315	344		2870
CAT 4	1.5	381917	4899936	2006	67.8	93.1	34.5	20.8	154	66.1	343	507	259	305	586		400		70	253	271		2591
CAT 5	1.5	381971	4899936	2006	87.8	80.2	27.9	28.1	179	72	374	482	245	347	722		448		84.6	325	359		2815
CAT 6	1.5	381962	4899897	2006	116	88.4	49.1	45.9	325	115	509	608	341	418	823		537		98.4	350	365		3616
CAT 7	1.5	381914	4899897	2006	130	101	43.2	35.5	300	88.2	550	665	341	443	855		545		95.7	358	380		3718
CAT 8	1.5	381863	4899902	2006	285	175	130	159	1560	399	2610	2620	1310	1540	2570		1580		229	950	922		13519
CAT 9	1.5	381872	4899839	2006	867	128	294	363	3530	817	5680	5410	2950	3270	5620		3220		549	2050	1790		28868
CAT 10	1.5	381915	4899835	2006	140	143	43.3	38.5	314	107	601	717	372	491	988		612		106	428	444		4129
CAT 11	1.5	381963	4899840	2006	194	128	50.2	50.6	320	120	627	864	473	586	1220		820		141	545	583		4957
CAT 12	1.5	381896	4899805	2006	613	198	177	169	1540	383	2480	2730	1370	1730	2980		1830		309	1210	1160		14689
CAT 13	1.5	381921	4899782	2006	178	161	59.1	54	418	142	816	970	490	658	1270		792		160	546	539		5437
CAT 14	1.5	381967	4899779	2006	176	116	47.9	47.4	329	106	667	864	445	569	1200		777		149	529	552		4845
CAT 15	1.5	381879	4899743	2006	992	221	483	512	5040	976	6730	6130	2940	3650	5920		3380		561	2250	2110		33725

Table D-II-11: PAH Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	Depth [cm]	Easting	Northing	Sampling Date	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene	Benzo(a)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
					[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
CAT 16	1.5	381928	4899734	2006	220	161	65.3	80.2	581	180	1120	1290	661	884	1740		1040		56.4	719	763		7102
CAT 17	1.5	381868	4899964	2006	190	303	100	113	839	310	1680	2240	1120	1260	2400		1650		224	965	983		11012
CAT 18	1.5	382074	4900453	2006	117	156	42.7	41.4	256	128	600	933	524	704	1290		933		146	557	620		5201
CAT 19	1.5	382211	4900465	2006	97.6	146	37.6	38.3	245	125	609	953	542	672	1250		939		156	536	576		5137
CAT 20	1.5	382346	4900382	2006	169	356	58.6	52.4	332	244	780	1250	859	1050	1840		1540		223	831	915		7829
CAT 21	1.5	381856	4900386	2006	262	177	111	83.2	528	163	1200	1690	682	1070	1950		1150		194	792	868		8178
CAT 22	1.5	382074	4900657	2006	926	2450	669	591	4220	2190	7330	9790	6690	7990	13100		11400		1810	6170	6550		62606
CAT 24	1.5	381744	4901241	2006	73.9	46.8	42.3	64	541	109	1140	1080	469	716	1220		608		113	505	541		5544
CAT 26	1.5	381816	4900433	2006	202	267	142	104	704	206	1520	2260	867	1510	2490		1380		239	1000	1060		10461
CAT 27	0-10	381896	4900503	2006	632	1290	465	284	2080	795	3530	5650	2620	3380	6030		4730		612	2740	3000		29068
CAT 28	11-25	381896	4900503	2006	978	2180	945	534	2800	1300	4590	8510	4080	4850	8590		7700		899	3930	4440		43806
CAT 29	26-33	381896	4900503	2006	1660	648	1880	780	3940	1120	2750	4240	1850	2370	2980		2380		292	1260	1310		25220
CAT 32	0-10	381882	4900406	2006	169	215	94.9	68.9	519	164	1100	1630	658	1110	2060		1110		196	842	910		7945
CAT 32	11-25	381882	4900406	2006	222	280	116	83.5	587	224	1190	1730	779	1140	2080		1290		217	840	884		8743
CAT 32	26-46	381882	4900406	2006	438	575	209	88.5	563	293	1070	1900	913	1110	1910		1560		215	810	902		9837
8. Golder PQRA 2011																							
Station 1	5.0	381891	4899105	2010	110	59	83	74	530	180	1000	1200	520	710	540		700	120	110	440	520	400	7780
Station 2	5.0	382076	4899080	2010	80	98	65	53	270	220	680	990	510	540	380		700	150	87	350	380	290	6220
Station 3	5.0	381912	4899352	2010	170	250	150	110	750	300	1600	2100	1100	1300	1000		1600	300	220	870	880	690	14310
Station 4	5.0	382111	4899341	2010	290	740	210	190	870	840	2400	3600	2400	2600	2700		3800	610	490	1800	2000	1300	28620
Station 5	5.0	381822	4899620	2010	50	39	75	83	900	160	1900	1600	640	1000	1100		750	110	130	550	600	590	10800
Station 6	5.0	382119	4899617	2010	83	140	66	68	330	180	670	1100	540	590	510		850	160	120	470	480	320	7180
Station 7	5.0	381996	4899810	2010	59	95	32	36	210	120	460	690	330	390	310		500	110	83	340	360	220	4650
Station 8	5.0	382484	4900015	2010	<5	35	<5	<5	130	62	320	380	150	190	140		190	99	25	120	120	98	2190
9. Golder, DQA 2012																							
2011-A	5.0	381820	4899198	2011	91	100	110	88	690	220	1400	1600	850	1100	660		930	180	110	430	630	370	10150
2011-B	5.0	382021	4899133	2011	55	63	47	46	370	270	930	1100	550	700	390		560	140	83	270	380	240	6500
2011-C	5.0	382022	4899322	2011	66	240	130	130	620	400	1400	2100	1200	1300	680		1300	230	180	550	740	410	12220
2011-D	5.0	382241	4899116	2011	36	76	90	46	340	370	1200	1500	760	860	370		670	170	79	240	330	230	7690
2011-E	5.0	382240	4899285	2011	41	80	<5.0	27	270	400	1300	1900	1000	1100	330		700	180	63	250	360	240	8590
2011-F	5.0	381891	4899510	2011	46	87	50	33	260	150	680	870	440	500	390		570	130	93	300	420	220	5540
2011-G	5.0	382097	4899514	2011	30	65	31	22	190	160	570	770	380	450	250		400	110	50	180	250	160	4310
2011-H	5.0	381966	4899697	2011	26	39	16	12	170	90	460	540	250	320	220		310	72	43	160	220	130	3270
2011-I	5.0	382175	4899790	2011	33	79	18	18	150	120	470	670	340	410	220		380	96	52	170	240	150	3830
2011-J	5.0	382024	4900152	2011	39	68	14	7	130	81	360	500	250	340	230		330	75	54	180	250	130	3230
2011-K	5.0	382278	4900213	2011	26	69	21	17	130	98	380	560	300	370	230		350	93	52	170	240	130	3440
2011-L	5.0	382027	4900320	2011	35	56	5	18	140	85	390	540	260	360	250		340	81	47	190	270	140	3410

Table D-II-11: PAH Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Depth [cm]**	**Easting**	**Northing**	**Sampling Date**	**Naphthalene**	**Acenaphthylene**	**Acenaphthene**	**Fluorene**	**Phenanthrene**	**Anthracene**	**Fluoranthene**	**Pyrene**	**Benzo(a)anthracene**	**Chrysene**	**Benzo(b)fluoranthene**	**Benzo(k)pyrene**	**Benzo(a)pyrene**	**Perylene**	**Dibenz(a,h)anthracene**	**Indeno(1,2,3-cd)pyrene**	**Benzo(ghi)perylene**	**Benzo(k)fluoranthene**	**Total PAH**
					[ppb]	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**	**[ppb]**
10. ESG, Anglin Bay 2012																							
12-01607	5.0	381951	4899103	2012	*60*	<5.0	<5.0	<20	<40	<40	<50	<50	<30	<50	<50		<30		<5.0	<100	<30	<50	<250
12-01608	5.0	381989	4899102	2012	<30	<5.0	<5.0	<20	<40	<40	<50	<50	<30	<50	<50		<30		<5.0	<100	<30	<50	<250
12-01613	5.0	382017	4899099	2012	***800***	<5.0	<5.0	<20	<40	<40	*600*	**600**	<30	<50	<50		<30		<5.0	<100	<30	<50	3000
12-01617	5.0	382044	4899096	2012	*70*	<5.0	<5.0	<20	*190*	*50*	*170*	*130*	<30	<50	<50		<30		<5.0	<100	<30	<50	610
12-01621	5.0	382058	4899077	2012	*70*	***130***	20	*30*	*120*	*90*	**950**	***1800***	***950***	***1000***	750		***1000***		**80**	**280**	**380**	**350**	**8000**
12-01625	5.0	382059	4899051	2012	<30	*60*	<5.0	<20	*100*	***440***	*440*	**650**	*280*	*310*	180		*290*		*20*	<100	80	90	3000
12-01629	5.0	382054	4899097	2012	30	30	10	20	*130*	40	*240*	*220*	*100*	*160*	130		*150*		*20*	<100	70	70	1500
12-01633	5.0	382054	4899097	2012	*40*	<5.0	<5.0	<20	<40	<40	<50	<50	<30	<50	<50		<30		<5.0	<100	<30	<50	<250

Table D-II-12: DDT and Chlordane Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC

Sample #	Depth [cm]	UTM, NAD 84		Date	DDT	Chlordane sum
		Easting	Northing		[ppb]	[ppb]
CCME ISQG					1.19	*4.5*
CCME PEL					***4.77***	***8.87***
Ontario SQG - LEL					**7.0**	**7.0**
1. Brooks et al, 1998						
A6	0.0	382103	4900377	1998	**44**	
AA3	5.0	382519	4899983	1999	**11**	<1.6
EE3	5.0	381871	4901152	1999	**29**	1.1
EE5	5.0	382219	4900888	1999	**9.8**	<2.2
GG3	5.0	382417	4899805	1999	**14**	3.5
GG4	5.0	382131	4899813	1999	**13**	3.9
KK11	5.0	382175	4900657	1999	**145**	***41***
2. MOE, Derry et al 2003						
31	0.5	381868	4899833	2001	<15	<5.0
37	0.5	381859	4900242	2001	<20	<5.0
38	0.5	382580	4899260	2001	<6.0	<6.0
39	0.5	382998	4899601	2001	<10	<5.0
40	0.5	383168	4900213	2001	<7.0	<6.0
47	0.5	382118	4900643	2001	<20	***12***
54	0.5	381848	4899058	2001	<20	<2.0
56	0.5	381841	4900318	2001	<30	*6.0*
3. MOE, Benoit 2010						
CAT 2	1.5	381867	4899939	2006	**9.2**	0.9
CAT 3	1.5	381918	4899966	2006	**8.5**	0.7
CAT 4	1.5	381917	4899936	2006	***6.1***	0.6
CAT 5	1.5	381971	4899936	2006	**7.6**	0.5
CAT 6	1.5	381962	4899897	2006	**7.1**	0.5
CAT 7	1.5	381914	4899897	2006	**8.3**	0.7
CAT 8	1.5	381863	4899902	2006	**11**	0.7
CAT 9	1.5	381872	4899839	2006	**16**	1.3
CAT 10	1.5	381915	4899835	2006	**8.0**	0.7
CAT 11	1.5	381963	4899840	2006	**19**	*6.6*
CAT 12	1.5	381896	4899805	2006	***6.5***	2.0
CAT 13	1.5	381921	4899782	2006	**11**	0.9
CAT 14	1.5	381967	4899779	2006	**12**	0.7
CAT 15	1.5	381879	4899743	2006	**22**	1.5
CAT 16	1.5	381928	4899734	2006	***6.5***	1.5
CAT 17	1.5	381868	4899964	2006	***6.3***	1.6
CAT 18	1.5	382074	4900453	2006	*3.6*	1.0
CAT 19	1.5	382211	4900465	2006	*2.8*	0.7
CAT 20	1.5	382346	4900382	2006	***5.3***	1.0
CAT 21	1.5	381856	4900386	2006	**8.2**	*5.0*
CAT 22	1.5	382074	4900657	2006	**27**	***11***

Table D-II-12: DDT and Chlordane Concentrations in Sediment Samples Collected in the Kingston Inner Harbour APEC (cont'd)

Sample #	**Depth [cm]**	**UTM, NAD 84**		**Date**	**DDT**	**Chlordane sum**
		Easting	**Northing**		**[ppb]**	**[ppb]**
CAT 24	1.5	381744	4901241	2006	*2.2*	0.7
CAT 25	1.5	381796	4900464	2006	**37**	**7.4**
CAT 26	1.5	381816	4900433	2006	**12**	**8.8**
CAT 27 (CAT 29)	0-10	381896	4900503	2006	**20**	***15***
CAT 28 (CAT 29)	11-25	381896	4900503	2006	**37**	***25***
CAT 29	26-33	381896	4900503	2006	**8.8**	*4.6*
CAT 32	0-10	381882	4900406	2006	**8.9**	*5.3*
CAT 32	11-25	381882	4900406	2006	**9.8**	*5.0*
CAT 32	26-46	381882	4900406	2006	**11**	3.0
4. ESG 2008						
08-42062	2.5	382087	4900597	2008	<10	
5. Golder PQRA 2011						
Station 1	5.0	381891	4899105	2010	<50	<50
Station 2	5.0	382076	4899080	2010	<40	<40
Station 3	5.0	381912	4899352	2010	<100	<40
Station 5	5.0	381822	4899620	2010	<40	<40
Station 6	5.0	382119	4899617	2010		<40
Station 7	5.0	381996	4899810	2010	<50	<40

Table D-II-13: Concentrations of Inorganic Elements and PCBs in Kingston Inner Harbour Sediments at Reference Locations

Year	Sample ID	Depth	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb	Hg	PCBs
		[cm]	Easting	Northing	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppb]
CCME ISQG					*36*	*35*	*123*	*37.3*	*5.9*		*0.17*	*34*
CCME PEL					***197***	***91***	***315***	***90***	***17***	*n/a*	***0.49***	***277***
Ontario SQG - LEL					**16**	**31**	**120**	**26**	**6.0**	*n/a*	**0.2**	**70**
CCME Sediment Quality Guideline										*20*		
*OMOE SCS (soil within 30m of water body)**										**1.0**		
1. Totten Sims Hubicki Associates, 1992												
1992	T1	0.0	381910	4901298	**33**	***290***	***370***	**35**	4.3			*55*
1992	T2	0.0	382317	4901332	*37*	*82*	*160*	*57*	4.4			**125**
1992	T3	0.0	382729	4901345	**34**	30	92	*50*	3.1			**105**
1992	T4	0.0	382465	4900871	*49*	*58*	*130*	***110***	3.4			**110**
1992	T5	0.0	382914	4900914	**32**	*35*	88	*58*	2.4			*55*
2. Brooks et al, 1998, Katherine Cross (PCBs) 1999												
1998	E4	0	382168	4901275	*47*	***192***	*281*					**100**
1998	G6	0	382714	4901513	**28**	*42*	98					
1998	G7	0	382613	4901555	**28**	*37*	108					*45*
1998	G8	0	382381	4901573	**30**	*55*	*123*					
1998	K8	0	382878	4900723		29	71					
1998	S31	0	383053	4902374	**26**	**31**	100					
1998	S31a	0	383053	4902374	**29**		112					
1998	S31b	0	383053	4902374	**23**		89					
3. MOE, Derry et al, 2003												
2001	42	0.5	382768	4901315	**24**	21	76	**37**				27
2001	48	0.5	382396	4900750	*58*	***110***	***2200***	***110***				***580***
4. ESG 2002												
2002	FF4	5.0	382230	4901590	**27**	*59*	109	**34**	3.7	<10		4.0
5. Tinney, 2006												
2004	04-24276	2.5	383091	4900458	**31**	*42*	**122**	*77*	2.7	<10		*35*
2004	04-24289	2.5	383017	4901912	**27**	21	87	**36**	1.8	<10		<20
2004	04-24294	2.5	382154	4901536	**30**	*36*	104	**35**	2.6	<10		15
2004	04-24298	2.5	383107	4900677	**27**	**31**	111	*62*	2.3	<10		18
2004	04-24299	2.5	382967	4900671	**31**	*56*	*141*	*89*	2.9	<10		29
2004	04-24300	2.5	382967	4900671	**33**	*52*	*139*	*89*	3.0	<10		*47*
2005	05-17349	2.5	382298	4900940	**29**	*42*	111	*84*	4.0			24
2005	05-17350	2.5	382818	4900529	**29**	*43*	111	***136***	2.5			*44*
2005	05-30034	2.5	383328	4902972	**23**	25	63	*<20*	1.8	<10		<10
2005	05-30050	2.5	383127	4902654	**30**	**32**	95	**35**	2.3	<10		12
2005	05-30051	2.5	382919	4902296	**30**	**32**	97	**34**	2.3	<10		<10
2005	05-30052	2.5	383260	4902377	**26**	25	82	**32**	3.1	<10		<10
2005	05-30053	3	382256	4901063	**29**	*70*	*133*	*47*	2.9	<10		<10
2005	05-30054	2.5	382600	4901063	**34**	*44*	**120**	*86*	2.8	<10		<10
2005	05-30055	3	382875	4900606	**27**	27	79	*80*	2.5	<10		13
6. ESG 2006 - 2007												
2006	06-17261	2.5	382107	4901525	**30**	*62*	*130*	*47*	<1.0			
2007	07-29645	2.5	382702	4901241	**29**	**32**	104	*50*	1.9			
2007	07-29645d	2.5	382702	4901241	<40	**32**	77	*<53*	<16			
7. Manion, 2007												
2007	C11: 23-24	23.5	382833	4900773							0.15	
2007	C11: 31-32	31.5	382833	4900773							*0.18*	

Table D-II-13: Concentrations of Inorganic Elements and PCBs in Kingston Inner Harbour Sediments at Reference Locations (cont'd)

Year	Sample ID	Depth	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb	Hg	PCBs
		[cm]	Easting	Northing	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppb]
2007	C12: 17-18	17.5	383430	4903072							0.069	
2007	C12: 5-6	5.5	383430	4903072							0.095	
8. ESG, 2008 - 2009												
2008	08-29902	2.5	382198	4901650	**29**	*52*	120	**37**	1.8			
2008	08-42008	2.5	382199	4901539	**24**	*43*	99	*37*	1.8			
2008	08-42020	2.5	382156	4901549	**32**	*66*	*123*	*45*	3.9			
2008	08-42036	2.5	382224	4901586	**27**	*48*	110	*42*	1.9			
2008	08-42080	2.5	382243	4902687	**21**	*51*	98	*<20*	4.7			<3.0
2008	08-42119	2.5	382151	4901507	**32**	*72*	*138*	***182***	2.9			
2009	09-25603	5.0	382466	4901662	**27**	*36*	115	*38*	1.2			
2009	09-25604	5.0	382500	4901517	**23**	30	87	*40*	1.2			
2009	09-25704	5.0	382974	4902026	**21**	21	73	**30**	1.1			
9. MOE MeHg Memo 2009												
2009	KING6	5.0	383748	4903525	**17**	13	53	*23*			0.04	
10. Golder etc, 2012												
2011	2011-M	5.0	382845	4900811	*36*	*58*	*130*	***240***	3.0	*0.4*	0.11	<100
2011	2011-N	5.0	382347	4901493	**33**	*46*	110	*58*	2.0	*0.2*	0.1	<50

* OMOE Site Condition Standard for Use within 30m of a Water Body (Agricultural Use)

Table D-II-14: PAH Concentrations in Kingston Inner Harbour Sediment Samples at Reference Stations

Sample	Report Locator	Depth (cm)	Easting	Northing	Date	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene	Benzo(a)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
						[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
CCME ISQG						34.6	59	67	21.2	41.9	46.9	111	53	31.7	57.1			31.9		6.2				
CCME PEL						**391**	**128**	**88.9**	**144**	**515**	**245**	**2355**	**875**	**385**	**862**			**782**		**135**				
Ontario SQG - LEL									**190**	**560**	**220**	**750**	**490**	**320**	**340**			**370**		**60**	**200**	**170**	**240**	**4000**
1. Brooks, et al, 1998																								
E4		0	382168	4901275	1998	76	8.8	23	45	140	30	300	250	100	170	350	170	150	ndr*	ndr*	ndr*	ndr*		1813
2. ESG 2002																								
FF4		5.0	382230	4901590	2002	250	<50	<50	<50	90	<50	190	160	70	100	80		50		<50	<100	<100	50	1040
3. Tinney, 2006																								
04-24276	ERA7	2.5	383091	4900458	2004	60	<50	<50	<50	80	<50	300	270	180	170	210		240		<50	190	140	120	2100
04-24289	ERA9	2.5	383017	4901912	2004	<60	<50	<50	<50	<50	<50	80	70	<50	<50	<50		<100		<50	<100	<100	<50	150
04-24294	ERA10	2.5	382154	4901536	2004	80	<50	<50	<50	70	<50	180	140	60	70	120		100		**60**	100	<100	90	1200
04-24298	SED14	2.5	383107	4900677	2004	<60	<50	<50	<50	110	70	340	330	160	210	220		260		**60**	**240**	**200**	160	2400
04-24299	SED15	2.5	382967	4900671	2004	70	<50	<50	<50	50	<50	120	120	<50	50	60		<100		<50	<100	<100	<50	470
04-24300	SED15	2.5	382967	4900671	2004	70	<50	<50	<50	70	<50	160	170	80	100	100		130		<50	110	110	80	1300
05-17349	SED35	2.5	382298	4900940	2005	100	<50	<50	<50	<50	<50	130	230	160	190	110		<100		<50	<100	110	130	1200
05-17350	SED36	2.5	382818	4900529	2005	60	<50	<50	<50	80	<50	240	440	290	**340**	170		330		**220**	**290**	**270**	**240**	3000
05-30034	ERA13	2.5	383328	4902972	2005	51	<5	7.0	38	110	<20	110	79	21	41	23		24		11	21	<20	<20	536
05-30050	SED32	2.5	383127	4902654	2005	59	9.0	5.0	31	95	<20	160	110	41	56	39		55		11	41	30	21	763
05-30051	SED33	2.5	382919	4902296	2005	52	63	9.0	41	500	180	**1300**	**1000**	**480**	**460**	320		**570**		**97**	**380**	**260**	150	**5862**
05-30052	SED34	2.5	383260	4902377	2005	39	9	<5	<20	94	35	400	330	210	210	150		230		37	140	77	80	2041
05-30053	SED31	2.5	382256	4901063	2005	47	26	6	23	80	30	230	290	83	120	<20		130		21	62	57	53	1258
05-30054	SED30	2.5	382600	4901063	2005	46	10	10	31	92	<20	130	110	30	52	40		42		10	36	31	<20	670
05-30055	SED29	2.5	382875	4900606	2005	53	38	17	38	220	63	420	410	200	240	140		230		41	140	110	56	2416
4. Golder Assoc, 2012 DQA																								
2011-M		5.0	382845	4900811	2011	20	25	6.0	27	64	68	210	260	110	180	73		99	53	<5.0	38	69	41	1400
2011-N		5.0	382347	4901493	2011	20	5.0	7.0	6.0	67	27	180	140	49	93	38		39	43	6.0	22	29	33	860

* ndr indicates peak detected but results did not meet laboratory quanification criteria

Table D-II-15: DDT and Chlordane Concentrations in Kingston Inner Harbour Sediment Sample Reference Stations

Sample #	Depth [cm]	UTM, NAD 84		Date	DDT	Chlordane
		Easting	Northing		[ppb]	[ppb]
CCME ISQG					*1.19*	*4.5*
CCME PEL					***4.77***	***8.87***
Ontario SQG - LEL					**7.0**	**7.0**
1. Cross, 1999						
AA4	5.0	382168	4901275	1999	**12**	<2.8
GG7	5.0	382613	4901555	1999	**8.5**	<1.3
2. MOE, Derry et al 2003						
42	0.5	382768	4901315	2001	***6.0***	<2.0
48	0.5	382396	4900750	2001	**36**	<4.0

Table D-III-1: Inorganic Elements in Kingston Inner Harbour Macrophytes and Associated Sediments

Sample #	Location On Site	Matrix	Easting	Northing	Cu [ppm] dry weight	Ni [ppm] dw	Co [ppm] dw	Cd [ppm] dw	Pb [ppm] dw	Zn [ppm] dw	Cr [ppm] dw	As [ppm] dw	Sb [ppm] dw	Cu wet weight*	Ni [ppm] ww	Co [ppm] ww	Cd [ppm] ww	Pb [ppm] ww	Zn [ppm] ww	Cr [ppm] ww	As [ppm] ww	Sb [ppm] ww
1. ESG 2008														*1. ESG, 2008*								
08-42141	SSM1	sediment	381924	4900549	82	23	11	1.1	380	340	5500	13		16	4.6	2.2	0.22	76	68	1100	2.6	
08-42224	SSM1	macrophytes, roots	381924	4900549	5.8	3.7	1.8	<1.0	23	46	210	8.4		0.8	0.48	0.23	<0.13	3.0	5.9	27	1.1	
08-42231	SSM1	macrophytes, stem	381924	4900549	5.8	4.6	1.4	<1.0	7.3	54	22	1.9		0.8	0.6	0.18	<0.13	0.95	7.0	2.9	0.25	
08-42143	SSM3	sediment	382175	4900605	41	25	14	<1.0	100	150	1300	5.5		8.2	5.0	2.8	<0.13	20	30	260	1.1	
08-42220	SSM3	macrophytes, roots	382175	4900605	7.0	8.2	3.0	<1.0	11	29	45	4.5		0.91	1.1	0.39	<0.13	1.4	3.8	5.9	0.58	
08-42233	SSM3	macrophytes, stem	382175	4900605	3.8	3.5	<1.0	<1.0	3.2	19	12	1.2		0.5	0.45	<0.13	<0.13	0.41	2.5	1.6	0.15	
08-42146	SSM6	sediment	382244	4900435	32	23	13	<1.0	71	120	790	5.0		6.4	4.6	2.7	<0.13	14	24	158	1.0	
08-42225	SSM6	macrophytes, roots	382244	4900435	<2.0	<2.0	<1.0	<1.0	<2.0	7.9	<2.0	<1.0		<0.3	<0.3	<0.13	<0.13	<0.3	1.0	<0.3	<0.13	
08-42236a/b/c	SSM6	macrophytes, stem	382244	4900435	5.6	4.4	<1.0	<1.0	2.3	16	8	1.2		0.72	0.57	<0.13	<0.13	0.29	2.1	1.1	0.16	
08-42147	SSM7	sediment	382019	4900387	44	28	16	<1.0	110	170	960	6.9		8.9	5.6	3.2	<0.13	22	34	192	1.4	
08-42237	SSM7	macrophytes, stem	382019	4900387	4.0	3.5	1.0	<1.0	6.4	21	13	1.4		0.51	0.45	<0.13	<0.13	0.83	2.7	1.8	0.18	
08-42140	SSM9	sediment	382090	4900492	40	30	16	<1.0	80	140	740	4.4		8.1	5.9	3.2	<0.13	16	28	148	0.88	
08-42226	SSM9	macrophytes, roots	382090	4900492	3.3	13	1.2	<1.0	7.1	40	13	1.3		0.43	1.7	0.16	<0.13	0.92	5.3	1.7	0.17	
08-42238	SSM9	macrophytes, stem	382090	4900492	4.1	3.8	1.0	<1.0	6.0	31	16	1.5		0.54	0.49	0.14	<0.13	0.78	4.0	2.0	0.19	
08-42119/b/c	SSM10	sediment	382151	4901507	32	24	13	1.1	72	140	180	2.9		6.4	4.7	2.6	0.23	14	28	36	0.59	
08-42216	SSM10	macrophytes, roots	382151	4901507	5.8	5.7	2.0	<1.0	8.9	73	4.2	1.2		0.76	0.74	0.26	<0.13	1.2	9.5	0.55	0.16	
08-42239	SSM10	macrophytes, stem	382151	4901507	3.3	3.4	<1.0	<1.0	2.8	25	2.5	<1.0		0.43	0.45	<0.13	<0.13	0.36	3.3	0.33	<0.13	
2. Tinney, 2006														*2. Tinney, 2006*								
04-24321	ERA4	M spicatum	382388	4899535	5.4	2.7	1.4	0.08	4.3	61	10	1.5	<0.05	0.7	0.35	0.18	0.01	0.56	7.9	1.3	0.2	<0.0065
05-30060	ERA4	P crispus	382388	4899535	7.4	2.5	0.4	0.06	0.5	20	<0.5	<0.5	<0.05	0.96	0.33	0.047	0.0078	0.07	2.6	<0.1	<0.1	<0.0065
04-24259	ERA4	sediment	382388	4899535	39	29	15	<0.6	57	140	189	2.6	<10	5.0	3.8	1.9	<0.078	7.4	18	25	0.34	<1.3
04-24314	ERA5	M spicatum	382133	4900254	4.8	6.8	1.4	0.08	12	21	49	1.7	<0.05	0.62	0.88	0.18	0.01	1.6	2.7	6.4	0.22	<0.0065
04-24264	ERA5	sediment	382133	4900254	49	33	18	<0.6	144	195	1480	3.2	22	6.4	4.3	2.4	<0.078	19	25	192	0.42	2.9
05-30070	ERA5	M spicatum	382133	4900254	21	1.1	0.3	<1.0	2.8	24	4.1	<0.5	0.4	2.7	0.14	0.043	<0.13	0.36	3.1	0.53	<0.1	0.056
05-30061	ERA11	P crispus	382036	4900455	8.5	2.2	0.8	0.055	2.0	20	5.7	<0.5	<0.05	1.1	0.29	0.098	0.0072	0.26	2.6	0.74	<0.1	<0.0065
05-30029	ERA11	sediment	382036	4900455	50	33	19	<1.0	86	157	763	4.6	17	6.5	4.3	2.5	<0.13	11	20	99	0.6	2.2
05-30062	ERA12	P crispus	381971	4900066	7.7	1.6	0.8	0.055	3.2	29	10	1.9	<0.05	1.0	0.21	0.1	0.0072	0.42	3.8	1.3	0.25	<0.0065
05-60063	ERA12	M spicatum	381971	4900066	5.0	1.8	1.2	0.11	6.5	45	19	2.7	0.1	0.65	0.23	0.16	0.014	0.85	5.9	2.5	0.35	0.0078

* Assumed 87% moisture content for the aquatic macrophytes to calculate wet weight concentrations. 80 percent moisture assumed for sediment.

Table D-III-2: Inorganic Elements and PCBs in Kingston Inner Harbour and Reference Cattails and Associated Sediments

Sample #	Location On Site	Matrix	Easting	Northing	Cu [ppm] dw	Ni [ppm] dw	Co [ppm] dw	Cd [ppm] dw	Pb [ppm] dw	Zn [ppm] dw	Cr [ppm] dw	As [ppm] dw	Aroclor 1242 [ppb]	Aroclor 1254 [ppb]	Aroclor 1260 [ppb]	Total PCB [ppb]
ESG 2008																
08-42064	Cat4	sediment	382313	4900651	20	8.4	<5.0	<1.0	22	53	74	1.9				
08-42065	Cat4	root	382313	4900651	4.8	2.5	<1.0	<1.0	4.0	18	5.1	2.4				
08-42066	Cat4	shoot	382313	4900651	4.3	<2.0	<1.0	<1.0	<2.0	16	<2.0	<1.0				
08-42068	Cat3	sediment	382073	4900663	62	11	5.9	<1.0	77	150	1600	4.6	< 3.0	51	130	180
08-42069/b/c/d	Cat3	root	382073	4900663	2.4	7.4	1.6	<1.0	5.6	20	50	4.1	<3.0	7.5	28	35
08-42070/b/c/d	Cat3	shoot	382073	4900663	<2.0	3.1	<1.0	<1.0	<2.0	11	7.3	<1.0	<3.0	<3.0	7.4	7.4
08-42076	Cat1	sediment	381816	4900557	110	26	9.9	1.6	430	430	3600	9.1	< 3.0	44	54	98
08-42077	Cat1	root	381816	4900557	4.2	4.0	<1.0	<1.0	15	25	42	2.1	<3.0	6.3	9.6	16
08-42078	Cat1	shoot	381816	4900557	2.2	22	<1.0	<1.0	<2.0	10	3.8	<1.0	<3.0	<3.0	6.4	6.4
08-42080	Cat Reference	sediment	382243	4902687	21	9.3	<5.0	<1.0	51	98	<20	4.7	< 3.0	<3.0	<3.0	<3.0
08-42081/b/c	Cat Reference	root	382243	4902687	<2.0	<2.0	<1.0	<1.0	<2.0	22	<2.0	<1.0	<3.0	3.4	<3.0	3.4
08-42082	Cat Reference	shoot	382243	4902687	<2.0	<2.0	<1.0	<1.0	<2.0	8.4	<2.0	1.5	< 3.0	<3.0	<3.0	<3.0

Table D-III-3: Chromium in Kingston Inner Harbour Invertebrates and Associated Sediments

Sample #	Report Locator	Sample type	Easting	Northing	Cr [ppm]
ESG 2008					
08-42012	BIV5	sediment	382111	4900630	1400
08-42013	BIV5	Crustaceans	382111	4900630	260
08-42015	BIV5	Oligochaetes	382111	4900630	180
08-42016	BIV2	sediment	382292	4900471	630
08-42019	BIV2	Insects and Molluscs	382292	4900471	130
08-42020	BIV6	sediment	382156	4901549	45
08-42023	BIV6	Insects and Oligochaetes	382156	4901549	1.7
08-42024/b/c	BIV3	sediment	382063	4900539	960
08-42026	BIV3	Crustaceans	382063	4900539	69
08-42027	BIV3	Insects and Molluscs	382063	4900539	120

Table D-III-4: Chromium in *Hyalella azteca* Following 28 Day Lab Bioassays with Kingston Inner Harbour Sediments

Location On Site	Replicate #	Sediment - Cr [ppm]	*Hyalella* Tissue - Cr [ppm]
T1	1	47	0.20
T1	2	47	0.50
T1	3	47	0.20
T1	4	47	0.40
T1	5	47	0.70
T1	6	47	4.8
T1	**Replicate Avg**	**-**	**1.1**
T2	1	50	0.30
T2	2	50	0.30
T2	3	50	0.50
T2	4	50	0.20
T2	5	50	0.12
T2	6	50	0.40
T2	**Replicate Avg**	**-**	**0.30**
T3	1	1000	2.4
T3	2	1000	1.2
T3	3	1000	0.70
T3	4	1000	1.2
T3	5	1000	1.8
T3	6	1000	2.6
T3	**Replicate Avg**	**-**	**1.7**
T4	1	1000	1.1
T4	2	1000	8.7
T4	3	1000	4.7
T4	4	1000	2.0
T4	5	1000	3.9
T4	6	1000	5.4
T4	**Replicate Avg**	**-**	**4.3**
T5	1	780	2.4
T5	2	780	2.2
T5	3	780	3.5
T5	4	780	2.5
T5	5	780	4.1
T5	6	780	6.9
T5	**Replicate Avg**	**-**	**3.6**
T6	1	1200	6.5
T6	2	1200	12
T6	3	1200	7.8
T6	4	1200	7.4
T6	5	1200	3.5
T6	6	1200	13
T6	**Replicate Avg**	**-**	**8.3**
T7a	1	850	3.2
T7a	2	850	3.9
T7a	3	850	12
T7a	4	850	4.6
T7a	5	850	2.3
T7a	6	850	4.7
T7a	**Replicate Avg**	**-**	**5.1**
T7b	1	1000	2.0
T7b	2	1000	2.4
T7b	3	1000	1.6
T7b	4	1000	6.3
T7b	5	1000	3.0
T7b	6	1000	6.8
T7b	**Replicate Avg**	**-**	**3.7**
T8a	1	610	3.2
T8a	2	610	2.3
T8a	3	610	4.1
T8a	4	610	4.3
T8a	5	610	8.9
T8a	6	610	5.6
T8a	**Replicate Avg**	**-**	**4.7**

Table D-III-4: Chromium in *Hyalella azteca F* ollowing 28 Day Lab Bioassays with Kingston Inner Harbour Sediments, Cont'd

Location On Site	**Replicate #**	**Sediment - Cr [ppm]**	***Hyalella* Tissue - Cr [ppm]**
T8b	1	820	1.4
T8b	2	820	1.6
T8b	3	820	1.2
T8b	4	820	4.8
T8b	5	820	5.2
T8b	6	820	2.6
T8b	**Replicate Avg**	**-**	**2.8**
T19	1	37	0.60
T19	2	37	0.30
T19	3	37	0.30
T19	4	37	0.50
T19	5	37	0.15
T19	6	37	0.70
T19	**Replicate Avg**	**-**	**0.43**
T20	1	38	0.80
T20	2	38	1.0
T20	3	38	0.20
T20	4	38	0.20
T20	5	38	0.70
T20	6	38	0.20
T20	**Replicate Avg**	**-**	**0.52**
T21	1	990	3.3
T21	2	990	3.1
T21	3	990	2.1
T21	4	990	3.1
T21	5	990	6.7
T21	6	990	7.8
T21	**Replicate Avg**	**-**	**4.4**
T22	1	840	2.1
T22	2	840	8.8
T22	3	840	2.1
T22	4	840	13
T22	5	840	6.6
T22	6	840	4.4
T22	**Replicate Avg**	**-**	**6.2**
T23	1	7500	21
T23	2	7500	14
T23	3	7500	140
T23	4	7500	49
T23	5	7500	
T23	6	7500	20
T23	**Replicate Avg**	**-**	**48**
T24	1	430	45
T24	2	430	3.6
T24	3	430	
T24	4	430	6.4
T24	5	430	6.8
T24	6	430	22
T24	**Replicate Avg**	**-**	**17**

Table D-III-5: Inorganic Elements and PCBs in Kingston Inner Harbour Fish Collected at Reference Stations (wet weight)

Year	Sampler	Sample number (ESG)	Fish Type	Part Analyzed	Total Length [mm]	Total Body [g]	Lipid [%]	Moisture [%]	Cu [ppm]	Ni [ppm]	Cd [ppm]	Pb [ppm]	Zn [ppm]	Cr [ppm]	As [ppm]	Hg [ppm]	PCBs [ppm]	pp-DDE [ppm]
1997	MOE		Perch	fillet	150	45										0.07		
1997	MOE		Perch	fillet	160	58										0.05		
1997	MOE		Perch	fillet	170	58										0.08		
1997	MOE		Perch	fillet	170	67										0.05		
1997	MOE		Perch	fillet	170	67										0.07		
1997	MOE		Perch	fillet	180	64										0.08		
1997	MOE		Perch	fillet	180	65										0.06		
1997	MOE		Perch	fillet	180	72										0.08		
1997	MOE		Perch	fillet	190	93										0.07		
1997	MOE		Perch	fillet	200	110										0.07		
1997	MOE		Perch	fillet	220	140										0.11		
1997	MOE		Perch	fillet	230	160										0.13		
2008	MOE - MeHg report	00FF2991	Perch	unknown	60		2.0									0.03	0.12	0.00
2008	MOE - MeHg report	00FF2992	Perch	unknown	60		2.0									0.03	0.07	0.00
2008	MOE - MeHg report	00FF2993	Perch	unknown	62		2.0									0.04	0.03	0.00
2008	MOE - MeHg report	00FF2994	Perch	unknown	60		6.0									0.04	0.05	0.00
2008	MOE - MeHg report	00FF2995	Perch	unknown	59		2.0									0.03	0.06	0.00
2009	ESG	09-07700	Perch	whole	210	140	5.0	72	0.8	<0.28	<0.14	<0.14	17	0.3	<0.28		0.04	
2009	ESG	09-07778	Perch	whole	150	40	0.8	74	0.6	<0.26	<0.13	<0.13	25	0.3	<0.26		0.05	
2009	ESG	09-07784	Perch	whole	150	48	2.0	72	0.5	0.4	<0.14	<0.14	24	0.4	<0.28		0.02	
1997	MOE		Brown Bullhead	fillet	200	120	0.4		0.06	nd	nd	0.8	14			0.04*	nd	
1997	MOE		Brown Bullhead	fillet	300	450	0.6		0.05	0.05*	nd	1.0	6.7			0.20	nd	
2009	ESG	09-07676	Brown Bullhead	whole	250	220	2.5	70	1.80	<0.3	<0.15	<0.15	15	0.3	<0.30		<0.007	
2009	ESG	09-07685	Brown Bullhead	whole	260	300	15.4	73	0.73	<0.27	<0.13	<0.13	14	0.3	<0.27		<0.007	
2009	ESG	09-07739	Brown Bullhead	whole	260	230	8.8	78	1.20	<0.23	<0.11	<0.11	12	<0.23	<0.23		<0.006	
2009	ESG	09-07667	Northern Pike	fillet	680	1725	2.9	73	0.62	<0.54	<0.13	<0.14	21	<0.27	<0.27		0.15	
2009	ESG	09-07670	Northern Pike	fillet	469	585	17.4	75	0.36	0.58	<0.13	<0.13	33	<0.25	<0.25		0.06	
2009	ESG	09-07831	Northern Pike	whole	390	350	1.3	75	0.69	<0.25	<0.13	<0.13	35	<0.25	<0.25		0.03	
1997	MOE		Carp	fillet	570	2600	4.4		0.46	0.05*	nd	1.4	8.0			0.05	nd	
1997	MOE		Carp	fillet	580	2900	4.2		0.30	nd	nd	0.8	11			0.05	nd	
1997	MOE		Carp	fillet	600	3100	2.2		0.18	0.41	0.0	0.3	8.3			0.06	nd	
1997	MOE		Carp	fillet	670	4200	6.8		0.80	0.14	nd	0.2	14			0.09	0.04	
1997	MOE		Carp	fillet	690	4100	3.7		0.76	0.05*	nd	0.5	19			0.10	nd	
1997	MOE		Carp	fillet	700	5500	4.1		0.55	nd	nd	0.7	10			0.16	0.06	
1997	MOE		Carp	fillet	720	6300	7.2		0.05	0.26	nd	0.9	15			0.02*	0.04	
1997	MOE		Carp	fillet	730	6500	7.1		0.06	nd	nd	1.5	10			0.10	0.04	
1997	MOE		Carp	fillet	760	6500	2.7		0.06	0.19	nd	0.7	8.3			0.10	nd	
1997	MOE		Carp	fillet	770	7500	6.4		0.30	nd	nd	0.9	18			0.05	0.04	
1997	MOE		Large-mouth Bass	fillet	220	150	0.6		0.15	nd	nd	0.45	7			0.09	nd	
1997	MOE		Large-mouth Bass	fillet	270	290	0.3		nd	0.15	nd	1.1	6.6			0.1	nd	

Table D-III-5: Inorganic Elements and PCBs in Kingston Inner Harbour Fish Collected at Reference Stations (wet weight) (cont'd)

Year	Sampler	Sample number (ESG)	Fish Type	Part Analyzed	Total Length	Total Body	Lipid	Moisture	Cu	Ni	Cd	Pb	Zn	Cr	As	Hg	PCBs	pp-DDE
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
1997	MOE		Large-mouth Bass	fillet	270	290	0.5		0.05	0.15	nd	1.0	6.4			0.11	nd	
1997	MOE		Large-mouth Bass	fillet	280	330	0.5		0.06	nd	nd	1.2	4.8			0.11	nd	
1997	MOE		Large-mouth Bass	fillet	340	700	0.4		0.05	nd	nd	1.2	6.3			0.12	nd	
1997	MOE		Black Crappie	fillet	180	89										0.05	nd	
1997	MOE		Black Crappie	fillet	210	150										0.06	nd	
1997	MOE		Black Crappie	fillet	230	170										0.10	nd	
1997	MOE		Bluegill	fillet	120	38										0.04*		
1997	MOE		Bluegill	fillet	140	46										0.05		
1997	MOE		Bluegill	fillet	140	54										0.03*		
1997	MOE		Bluegill	fillet	150	68										0.03*		
1997	MOE		Bluegill	fillet	150	65										0.05		
1997	MOE		Bluegill	fillet	150	69										0.05		
1997	MOE		Bluegill	fillet	150	78										0.03*		
1997	MOE		Bluegill	fillet	150	79										0.03*		
1997	MOE		Bluegill	fillet	160	93										0.04*		
1997	MOE		Bluegill	fillet	180	120										0.06		
1997	MOE		Bluegill	fillet	180	110										0.06		
1997	MOE		Bluegill	fillet	180	120										0.05		
1997	MOE		Pumpkin Seed	fillet	130	49										0.03*		
1997	MOE		Pumpkin Seed	fillet	140	67										0.05		
1997	MOE		Pumpkin Seed	fillet	150	77										0.04*		
1997	MOE		Pumpkin Seed	fillet	150	72										0.04*		
1997	MOE		Pumpkin Seed	fillet	160	91										0.06		
1997	MOE		Pumpkin Seed	fillet	160	89										0.09		
1997	MOE		Pumpkin Seed	fillet	170	100										0.07		
1997	MOE		Pumpkin Seed	fillet	170	110										0.08		
1997	MOE		Pumpkin Seed	fillet	170	100										0.07		
1997	MOE		Pumpkin Seed	fillet	180	120										0.09		

* a measurable trace amount
nd - no measurable response; non-detect
1997 MOE - samples from Colonel By Lake, ref MeHg memo 2009, from Wolfgang Scheider
Golder samples (Golder 2011) are not included because the fish were collected N of Belle Island, not the same background location that we used.

Table D-III-6: Inorganic Elements and PCBs in Kingston Inner Harbour Fish Collected at Stations within the APEC (wet weight)

Year	Sampler	Sample number (ESG)	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Cu	Ni	Cd	Pb	Zn	Cr	As	Hg	PCBs	pp-DDE
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
2002	MOE		Perch	fillet	150	38	1.3									0.09	0.06	
2002	MOE		Perch	fillet	160	53	1.1									0.10	0.14	
2002	MOE		Perch	fillet	170	57	1.9									0.06	0.06	
2002	MOE		Perch	fillet	170	59	1.4									0.16	0.04	
2002	MOE		Perch	fillet	180	72	0.6									0.09	0.06	
2002	MOE		Perch	fillet	180	84	0.3									0.06	0.06	
2002	MOE		Perch	fillet	190	75	0.8									0.09	0.06	
1999	MOE		Perch	fillet	160	40	0.4									0.14	0.30	
1999	MOE		Perch	fillet	170	40	0.5									0.00	0.10	
1999	MOE		Perch	fillet	170	57	1.4									0.08	0.10	
1999	MOE		Perch	fillet	170	58	0.6									0.07	0.12	
1999	MOE		Perch	fillet	180	61	0.5									0.08	0.10	
1999	MOE		Perch	fillet	190	81	0.5									0.08	0.08	
2008	MOE - MeHg memo	00FF2996	Perch	unknown	59		2.2									0.02	0.36	0.003
2008	MOE - MeHg memo	00FF2997	Perch	unknown	57		2.0									0.03	0.34	0.003
2008	MOE - MeHg memo	00FF2998	Perch	unknown	57		2.0									0.03	0.34	0.003
2008	MOE - MeHg memo	00FF2999	Perch	unknown	57		2.0									0.02	0.33	0.003
2008	MOE - MeHg memo	00FF3000	Perch	unknown	56		2.0									0.03	0.43	0.003
2008	MOE - MeHg memo	00FF3001	Perch	unknown	57		2.0									0.06	0.43	0.003
2008	MOE - MeHg memo	00FF3002	Perch	unknown	57		2.0									0.17	0.33	0.002
2008	MOE - MeHg memo	00FF3003	Perch	unknown	55		2.0									0.05	0.25	0.002
2008	MOE - MeHg memo	00FF3004	Perch	unknown	57		2.0									0.07	0.46	0.003
2008	MOE - MeHg memo	00FF3005	Perch	unknown	58		2.0									0.05	0.39	0.004
2008	MOE - MeHg memo	00FF3006	Perch	unknown	57		2.0									0.02	0.17	0.002
2008	MOE - MeHg memo	00FF3007	Perch	unknown	57		2.0									0.03	0.20	0.002
2008	MOE - MeHg memo	00FF3008	Perch	unknown	59		2.0									0.03	0.18	0.002
2008	MOE - MeHg memo	00FF3009	Perch	unknown	60		2.0									0.03	0.24	nd
2008	MOE - MeHg memo	00FF3010	Perch	unknown	60		2.0									0.03	2.70	0.002
2009	ESG	09-07646	Perch	whole	190	77	9.6	71	0.73	0.34	<0.14	<0.14	23	0.41	<0.29		0.39	
2009	ESG	09-07649	Perch	whole	130	27	1.9	67	0.75	<0.3	<0.16	<0.16	39	0.61	<0.33		0.62	
2009	ESG	09-07652	Perch	whole	160	43	9.1	67	1.1	<0.3	<0.17	<0.17	25	0.47	<0.33		0.27	
2009	ESG	09-07826	Perch	whole	130	27	5.0	74	0.4	<1.3	<0.13	<0.13	25	<1.6	<0.26		0.02	
2009	ESG	09-07879	Perch	whole	150	36	1.6	73	0.46	<0.27	<0.14	<0.14	21	0.84	<0.27		0.27	
2002	MOE		Brown	fillet	200	100	2.5		0.29	nd	nd	nd	5.5		0.06*	0.03*	0.18	
2002	MOE		Brown	fillet	230	150	3.5		0.4	nd	nd	nd	6.4		nd	0.03*	0.12	
2002	MOE		Brown	fillet	240	170	3.0		0.40	nd	nd	0.49	7.4		nd	0.02*	0.08	
2002	MOE		Brown	fillet	260	210	3.6		0.3	0.10	nd	nd	5.0		nd	0.04*	0.16	
2002	MOE		Brown	fillet	260	220	3.8		0.3	nd	nd	nd	6.3		nd	0.03*	0.16	
2002	MOE		Brown	fillet	260	230	1.8		0.4	nd	nd	nd	6.9		nd	0.05	0.24	
2002	MOE		Brown	fillet	270	240	0.9		0.4	nd	nd	nd	6.2		nd	0.04*	0.10	
2002	MOE		Brown	fillet	270	240	0.6		0.4	nd	nd	nd	6.9		nd	0.04*	0.54	
2002	MOE		Brown	fillet	280	300	0.1		0.4	nd	nd	nd	4.9		nd	0.03*	0.04	
2002	MOE		Brown	fillet	280	260	1.5		0.2	nd	nd	nd	4.4		nd	0.03*	0.16	
2002	MOE		Brown	fillet	310	420	1.9		0.3	nd	nd	nd	5.3		nd	0.03*	0.26	
1999	MOE		Brown	fillet	210	120	1.0									0.03*	0.14	
1999	MOE		Brown	fillet	220	130	1.5									0.02*	0.14	
1999	MOE		Brown	fillet	240	200	3.9									0.03*	0.28	
1999	MOE		Brown	fillet	240	170	2.2									0.02*	0.36	
1999	MOE		Brown	fillet	250	170	1.7									0.03*	0.24	
1999	MOE		Brown	fillet	250	200	1.0									0.04*	0.08	
1999	MOE		Brown	fillet	250	210	1.5									0.04*	0.22	

Table D-III-6: Inorganic Elements and PCBs in Kingston Inner Harbour Fish Collected at Stations within the APEC (wet weight) (cont'd)

Year	Sampler	Sample number (ESG)	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Cu	Ni	Cd	Pb	Zn	Cr	As	Hg	PCBs	pp-DDE
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
1999	MOE		Brown	fillet	260	220	0.9									nd	0.14	
1999	MOE		Brown	fillet	260	200	0.8									0.03*	0.22	
1999	MOE		Brown	fillet	260	230	1.6									0.03*	0.26	
2009	ESG	09-07703	Brown	whole	240	210	11	72	0.67	<0.56	<0.14	<0.01	18	1.10	<0.28		0.78	
2009	ESG	09-07721	Brown	whole	320	420	3.7	75	1.2	<0.24	<0.12	1.3	13	0.54	<0.25		0.18	
2009	ESG	09-07736	Brown	whole	230	160	6.0	72	1.2	<0.254	<0.13	<0.13	14	1.21	<0.25		0.28	
2009	ESG	09-07793	Brown	whole	230	140	14	70	1.1	<0.298	<0.15	<0.15	21	0.40	<0.3		0.57	
2009	ESG	09-07796	Brown	whole	330	440	14	73	1.3	<0.271	<0.14	<0.14	14	0.48	<0.27		0.35	
2002	MOE		Pike	fillet	300	170	0.1		0.21	nd	nd	nd	3.8		nd	0.11	0.06	
2002	MOE		Pike	fillet	340	200	0.4		0.21	0.10	nd	nd	3.8		nd	0.09	0.10	
2002	MOE		Pike	fillet	380	260	0.2		0.20	nd	nd	nd	4.8		nd	0.09	0.12	
2002	MOE		Pike	fillet	510	530	0.4		0.20	0.20	nd	0.20	5.7		nd	0.40	1.40	
2002	MOE		Pike	fillet	560	650	0.3		0.20	nd	nd	0.41	6.4		nd	0.50	0.54	
1999	MOE		Pike	fillet	330	200	0.3									0.09	0.16	
1999	MOE		Pike	fillet	360	240	0.2									0.09	0.12	
1999	MOE		Pike	fillet	380	300	0.2									0.08	0.12	
1999	MOE		Pike	fillet	380	350	0.3									0.08	0.12	
1999	MOE		Pike	fillet	410	450	0.7									0.13	0.10	
1999	MOE		Pike	fillet	430	390	0.6									0.14	0.06	
1999	MOE		Pike	fillet	480	660	0.7									0.12	0.14	
1999	MOE		Pike	fillet	570	1100	0.4									0.29	0.28	
1999	MOE		Pike	fillet	570	1100	0.3									0.23	0.18	
1999	MOE		Pike	fillet	710	2200	0.2									0.31	0.14	
2009	ESG	09-07802	Pike	whole	450	500	0.1	76	0.42	<0.24	<0.12	<0.12	22	0.36	<0.24		0.23	
2009	ESG	09-07805	Pike	whole	400	390	0.8	75	0.64	<0.25	<0.13	<0.13	33	<0.25	<0.35		0.36	
2009	ESG	09-07811	Pike	whole	460	590	0.1	74	0.65	<0.26	<0.13	<0.13	24	<0.26	<0.26		<0.006	
2009	ESG	09-07787	Pike	whole	640	170	5.6	72	0.50	<0.28	<0.14	<0.14	34	0.35	<0.28		0.64	
2009	ESG	09-07873	Pike	whole	420	410	2.7	74	0.58	<0.26	<0.13	<0.13	24	<0.26	<0.26		0.36	
2002	MOE		Carp	fillet	410	1200	1.4		0.29	nd	nd	0.29	5.5		0.16*	0.02*	0.04	
2002	MOE		Carp	fillet	490	1700	0.7		0.36	nd	nd	0.30	6.2		0.15*	0.03*	0.04	
2002	MOE		Carp	fillet	580	3400	2.7		0.39	0.20	nd	0.10	8.8		0.13*	0.06	0.06	
2002	MOE		Carp	fillet	590	3000	3.4		0.40	0.10	nd	0.90	6.3		0.10*	0.05	0.14	
2002	MOE		Carp	fillet	710	5000	5.6		0.20	nd	nd	0.50	9.8		0.11*	0.13	0.26	
2002	MOE		Carp	fillet	730	6900	3.3		0.31	0.20	nd	0.31	6.4		nd	0.11	0.32	
2002	MOE		Carp	fillet	730	5300	5.1		0.40	nd	0.04	nd	4.9		nd	0.23	1.50	
2002	MOE		Carp	fillet	840	9200	5.9		0.41	0.10	0.017*	0.51	6.2		0.20*	0.16	0.90	
1999	MOE		Carp	fillet	250	300	0.4									0.04*	0.08	
1999	MOE		Carp	fillet	590	3300	3.0									0.07	0.30	
1999	MOE		Carp	fillet	620	3700	2.9									0.12	0.46	
1999	MOE		Carp	fillet	640	5100	5.0									0.13	0.28	
1999	MOE		Carp	fillet	670	4200	3.5									0.11	0.48	
1999	MOE		Carp	fillet	670	5200	7.4									0.07	0.52	
1999	MOE		Carp	fillet	710	4000	7.5									0.11	1.90	

Table D-III-6: Inorganic Elements and PCBs in Kingston Inner Harbour Fish Collected at Stations within the APEC (wet weight) (cont'd)

Year	Sampler	Sample number (ESG)	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Cu	Ni	Cd	Pb	Zn	Cr	As	Hg	PCBs	pp-DDE
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
1999	MOE		Carp	fillet	740	6900	2.7									0.08	0.56	
1999	MOE		Carp	fillet	740	6600	7.0									0.20	1.60	
1999	MOE		Carp	fillet	760	7500	9.0									0.22	0.86	
2002	MOE		Bluegill	fillet	160	78	1.2									0.12	0.10	
2002	MOE		Bluegill	fillet	160	88	1.0									0.05	0.06	
2002	MOE		Bluegill	fillet	160	91	1.5									0.03*	0.04	
2002	MOE		Bluegill	fillet	170	99	0.9									0.03*	0.04	
2002	MOE		Bluegill	fillet	170	97	1.6									0.04*	0.04	
2002	MOE		Largemouth	fillet	180	91	0.3									0.08	0.08	
2002	MOE		Largemouth	fillet	210	140	0.3									0.08	0.08	
2002	MOE		Largemouth	fillet	230	180	0.2									0.10	0.06	
2002	MOE		Largemouth	fillet	350	720	0.2									0.12	0.08	
1999	MOE		Largemouth	fillet	210	150	0.5									0.03*	0.06	
1999	MOE		Largemouth	fillet	220	180	0.4									0.04*	0.04	
1999	MOE		Largemouth	fillet	270	350	0.4									0.07	0.08	
1999	MOE		Largemouth	fillet	390	1000	0.5									0.21	0.14	
1999	MOE		Largemouth	fillet	400	1200	5.8									0.22	0.12	
2010	Golder	MF1-Fish 1	Pike	fillet	500-550	1000-1250	0.5	79								0.24	<0.03	
2010	Golder	MF1-Fish 2	Pike	fillet	500-550	1000-1250	0.3	78								0.11	<0.03	
2010	Golder	NF2-Fish 1	Perch	fillet	195-240	150-250	0.3									0.19	0.08	
2010	Golder	NF2-Fish 2	Perch	fillet	195-240	150-250	0.4									0.06	<0.03	
2010	Golder	NF2-Fish 3	Perch	fillet	195-240	150-250	1.4									0.16	0.08	
2010	Golder	FF1-Fish 1	Perch	fillet	200-220	175-200	0.4									0.07	<0.03	
2010	Golder	FF1-Fish 2	Perch	fillet	200-220	175-200	1.2									0.06	<0.03	
2010	Golder	FF1-Fish 3	Perch	fillet	200	200	0.8									0.05	<0.03	
2010	Golder	MF1-Fish 1	Pike	whole	500-550	1000-1250	0.5	78									0.04	
2010	Golder	MF1-Fish 2	Pike	whole	500-550	1000-1250	0.4	78									0.04	
2010	Golder	NF2-Fish 1	Perch	whole	195-240	150-250	0.5										0.13	
2010	Golder	NF2-Fish 2	Perch	whole	195-240	150-250	0.5										0.08	
2010	Golder	NF2-Fish 3	Perch	whole	195-240	150-250	1.2										0.13	
2010	Golder	FF1-Fish 1	Perch	whole	200-220	175-200	0.6										0.04	
2010	Golder	FF1-Fish 2	Perch	whole	200-220	175-200	1.1										0.05	
2010	Golder	FF1-Fish 3	Perch	whole	200	200	0.9										0.04	
2010	Golder	FF1-J	Juvenile	whole	51	2												
2010	Golder	MF1-J	Juvenile	whole	40-50	1-2.5										0.02		
2010	Golder	NF2-J	Juvenile	whole	44-50	1.4-1.7	3.0									0.02	0.10	
2010	Golder	NF2-extra	additional	whole	44-50	1.4-1.7										0.04		

* a measurable trace amount

nd - no measurable response; non-detect

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples

Location	Laboratory	Replicate	Control	Reference	Sediment Cr	*Chironomus tentans* Survival	*Chironomus tentans* Growth	*Hyalella azteca* Survival	*Hyalella azteca* Growth	*Chironomus riparius* Survival	*Chironomus riparius* Growth	*Hexagenia* Survival	*Hexagenia* Growth	*Tubifex* Survival	*Tubifex*	*Tubifex* Hatch	*Tubifex*
					[ppm]	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(# cocoons /adult)	(%)	(# young /adult)
C1	CANTEST Ltd	1		T1		100	1.3	100	0.13								
C1	CANTEST Ltd	2		T1		50	1.8	80	0.13								
C1	CANTEST Ltd	3		T1		70	1.8	70	0.11								
C1	CANTEST Ltd	4		T1		50	1.3	100	0.11								
C1	CANTEST Ltd	5		T1		30	2.3	90	0.10								
C1	CANTEST Ltd	6		T1		50	1.9	100	0.10								
T1	CANTEST Ltd	1	C1		47	40	2.0	90	0.36								
T1	CANTEST Ltd	2	C1		47	70	1.5	100	0.33								
T1	CANTEST Ltd	3	C1		47	0	0.0	100	0.34								
T1	CANTEST Ltd	4	C1		47	40	1.2	80	0.37								
T1	CANTEST Ltd	5	C1		47	60	1.8	100	0.33								
T1	CANTEST Ltd	6	C1		47			100	0.33								
T3	CANTEST Ltd	1	C1	T1	1000	50	0.9	80	0.53								
T3	CANTEST Ltd	2	C1	T1	1000	30	1.6	100	0.37								
T3	CANTEST Ltd	3	C1	T1	1000	0	0.0	50	0.69								
T3	CANTEST Ltd	4	C1	T1	1000	20	1.0	90	0.50								
T3	CANTEST Ltd	5	C1	T1	1000	0	0.0	80	0.51								
T3	CANTEST Ltd	6	C1	T1	1000	10	3.8	70	0.50								
T4	CANTEST Ltd	1	C1	T1	1000	40	1.0	60	0.51								
T4	CANTEST Ltd	2	C1	T1	1000	10	1.8	60	0.65								
T4	CANTEST Ltd	3	C1	T1	1000	10	1.3	100	0.44								
T4	CANTEST Ltd	4	C1	T1	1000	40	1.7	80	0.49								
T4	CANTEST Ltd	5	C1	T1	1000	40	1.2	60	0.61								
T4	CANTEST Ltd	6	C1	T1	1000	30	1.4	10	1.0								
C2	CANTEST Ltd	1		T2		50	0.9	90	0.48								
C2	CANTEST Ltd	2		T2		30	1.6	90	0.42								
C2	CANTEST Ltd	3		T2		90	0.9	100	0.44								
C2	CANTEST Ltd	4		T2		100	0.8	100	0.41								
C2	CANTEST Ltd	5		T2		70	0.8	100	0.45								
C2	CANTEST Ltd	6		T2		80	1.2	80	0.42								
T2	CANTEST Ltd	1	C2		50	70	1.3	100	0.45								
T2	CANTEST Ltd	2	C2		50	100	0.71	100	0.45								
T2	CANTEST Ltd	3	C2		50	90	1.2	100	0.45								
T2	CANTEST Ltd	4	C2		50	100	1.4	100	0.39								
T2	CANTEST Ltd	5	C2		50	100	1.0	90	0.50								
T2	CANTEST Ltd	6	C2		50	100	1.1	80	0.47								
T5	CANTEST Ltd	1	C2	T2	780	70	1.4	100	0.45								
T5	CANTEST Ltd	2	C2	T2	780	90	0.87	90	0.49								
T5	CANTEST Ltd	3	C2	T2	780	70	1.4	90	0.45								
T5	CANTEST Ltd	4	C2	T2	780	70	1.5	90	0.42								
T5	CANTEST Ltd	5	C2	T2	780	70	1.5	90	0.36								
T5	CANTEST Ltd	6	C2	T2	780	100	0.74	100	0.41								

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples (cont'd)

Location	**Laboratory**	**Replicate**	**Control**	**Reference**	**Sediment Cr**	***Chironomus tentans* Survival**	***Chironomus tentans* Growth**	***Hyalella azteca* Survival**	***Hyalella azteca* Growth**	***Chironomus riparius* Survival**	***Chironomus riparius* Growth**	***Hexagenia* Survival**	***Hexagenia* Growth**	***Tubifex* Survival**	***Tubifex***	***Tubifex* Hatch**	***Tubifex***
					[ppm]	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(# cocoons /adult)**	**(%)**	**(# young /adult)**
T6	CANTEST Ltd	1	C2	T2	1200	50	0.76	90	0.47								
T6	CANTEST Ltd	2	C2	T2	1200	70	1.0	80	0.52								
T6	CANTEST Ltd	3	C2	T2	1200	50	1.2	90	0.48								
T6	CANTEST Ltd	4	C2	T2	1200	80	1.0	100	0.39								
T6	CANTEST Ltd	5	C2	T2	1200	60	1.2	100	0.42								
T6	CANTEST Ltd	6	C2	T2	1200	70	1.2	100	0.42								
T7a	CANTEST Ltd	1	C2	T2	850	80	0.77										
T7a	CANTEST Ltd	2	C2	T2	850	80	0.51										
T7a	CANTEST Ltd	3	C2	T2	850	50	0.76										
T7a	CANTEST Ltd	4	C2	T2	850	60	0.66										
T7a	CANTEST Ltd	5	C2	T2	850	90	0.33										
T7a	CANTEST Ltd	6	C2	T2	850	70	0.48										
T8a	CANTEST Ltd	1	C2	T2	610	70	0.49										
T8a	CANTEST Ltd	2	C2	T2	610	50	0.25										
T8a	CANTEST Ltd	3	C2	T2	610	30	0.80										
T8a	CANTEST Ltd	4	C2	T2	610	10	0.45										
T8a	CANTEST Ltd	5	C2	T2	610	60	0.63										
T8a	CANTEST Ltd	6	C2	T2	610	30	0.87										
C3	CANTEST Ltd	1		T19				100	0.26								
C3	CANTEST Ltd	2		T19				100	0.24								
C3	CANTEST Ltd	3		T19				100	0.24								
C3	CANTEST Ltd	4		T19				90	0.27								
C3	CANTEST Ltd	5		T19				90	0.24								
C3	CANTEST Ltd	6		T19				80	0.20								
T19	CANTEST Ltd	1	C3		37			100	0.30								
T19	CANTEST Ltd	2	C3		37			100	0.37								
T19	CANTEST Ltd	3	C3		37			90	0.35								
T19	CANTEST Ltd	4	C3		37			90	0.32								
T19	CANTEST Ltd	5	C3		37			100	0.33								
T19	CANTEST Ltd	6	C3		37			100	0.32								
T7b	CANTEST Ltd	1	C3	T19	1000			90	0.45								
T7b	CANTEST Ltd	2	C3	T19	1000			100	0.49								
T7b	CANTEST Ltd	3	C3	T19	1000			90	0.50								
T7b	CANTEST Ltd	4	C3	T19	1000			90	0.30								
T7b	CANTEST Ltd	5	C3	T19	1000			80	0.40								
T7b	CANTEST Ltd	6	C3	T19	1000			80	0.40								
T8b	CANTEST Ltd	1	C3	T19	820			60	0.87								
T8b	CANTEST Ltd	2	C3	T19	820			80	0.60								
T8b	CANTEST Ltd	3	C3	T19	820			60	0.36								
T8b	CANTEST Ltd	4	C3	T19	820			50	0.42								
T8b	CANTEST Ltd	5	C3	T19	820			50	0.36								
T8b	CANTEST Ltd	6	C3	T19	820			90	0.38								

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples (cont'd)

Location	Laboratory	Replicate	Control	Reference	Sediment Cr	*Chironomus tentans* Survival	*Chironomus tentans* Growth	*Hyalella azteca* Survival	*Hyalella azteca* Growth	*Chironomus riparius* Survival	*Chironomus riparius* Growth	*Hexagenia* Survival	*Hexagenia* Growth	*Tubifex* Survival	*Tubifex*	*Tubifex* Hatch	*Tubifex*
					[ppm]	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(# cocoons /adult)	(%)	(# young /adult)
C4	Env Canada	1		T11				93	0.41	93	0.78	100	3.6	100	12	59	35
C4	Env Canada	2		T11				87	0.43	67	0.69	100	3.4	100	12	54	34
C4	Env Canada	3		T11				27	0.34	87	1.1	100	3.9	100	12	65	34
C4	Env Canada	4		T11				100	0.65	40	1.2	100	3.7	100	12	56	39
C4	Env Canada	5		T11				100	0.51	80	0.74	100	3.8	100	12	51	36
T11	Env Canada	1	C4		37			53	0.20	100	0.64	100	3.0	100	10	48	27
T11	Env Canada	2	C4		37			27	0.18	93	0.53	100	3.6	100	10	59	28
T11	Env Canada	3	C4		37			20	0.18	93	0.82	100	2.9	100	11	52	23
T11	Env Canada	4	C4		37			80	0.65	100	0.56	100	3.3	100	11	50	28
T15	Env Canada	1	C4	T11	1100			93	0.74	87	0.80	100	4.2	100	12	46	27
T15	Env Canada	2	C4	T11	1100			93	0.79	100	0.42	100	3.6	100	12	52	34
T15	Env Canada	3	C4	T11	1100			93	0.64	100	0.79	100	4.2	100	10	51	29
T15	Env Canada	4	C4	T11	1100			73	0.61	93	0.41	100	3.3	100	12	52	25
T16	Env Canada	1	C4	T11	660			80	0.52			100	3.4	100	9.5	55	28
T16	Env Canada	2	C4	T11	660			73	0.54			100	3.7	100	12	63	30
T16	Env Canada	3	C4	T11	660			93	0.59			100	3.9	100	10	54	31
T16	Env Canada	4	C4	T11	660			100	0.54			100	3.9	100	11	57	24
T17	Env Canada	1	C4	T11	1100			80	0.17	93	0.59	100	3.9	100	13	62	31
T17	Env Canada	2	C4	T11	1100			87	0.69	100	0.40	100	3.7	100	8.0	50	19
T17	Env Canada	3	C4	T11	1100			80	0.46	93	0.73	100	4.0	100	12	59	26
T17	Env Canada	4	C4	T11	1100			87	0.44	87	0.73	100	4.2	100	12	61	29
T18	Env Canada	1	C4	T11	760			67	0.42	100	0.62	100	3.8	100	13	46	18
T18	Env Canada	2	C4	T11	760			100	0.56	73	0.79	100	5.1	100	13	29	11
T18	Env Canada	3	C4	T11	760			73	0.34	87	0.85	100	4.3	100	12	60	28
T18	Env Canada	4	C4	T11	760			60	0.74	100	0.82	100	4.5	100	12	59	28
C5	CANTEST Ltd	1		T20		60	1.5	100	0.27								
C5	CANTEST Ltd	2		T20		70	1.6	100	0.25								
C5	CANTEST Ltd	3		T20		80	1.1	90	0.34								
C5	CANTEST Ltd	4		T20		60	1.5	90	0.31								
C5	CANTEST Ltd	5		T20		80	1.3	100	0.30								
C5	CANTEST Ltd	6		T20		70	1.6	90	0.29								
T20	CANTEST Ltd	1	C5		38	90	1.9	100	0.27								
T20	CANTEST Ltd	2	C5		38	60	2.5	100	0.25								
T20	CANTEST Ltd	3	C5		38	40	2.3	90	0.34								
T20	CANTEST Ltd	4	C5		38	70	2.5	100	0.31								
T20	CANTEST Ltd	5	C5		38	70	2.3	100	0.30								
T20	CANTEST Ltd	6	C5		38	100	1.8	100	0.29								
T21	CANTEST Ltd	1	C5	T20	990	70	2.5	90	0.33								
T21	CANTEST Ltd	2	C5	T20	990	60	2.4	100	0.24								
T21	CANTEST Ltd	3	C5	T20	990	60	2.2	100	0.28								
T21	CANTEST Ltd	4	C5	T20	990	50	2.9	90	0.20								
T21	CANTEST Ltd	5	C5	T20	990	70	2.6	100	0.22								
T21	CANTEST Ltd	6	C5	T20	990	90	2.1	100	0.24								

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples (cont'd)

Location	Laboratory	Replicate	Control	Reference	Sediment Cr	*Chironomus tentans* Survival	*Chironomus tentans* Growth	*Hyalella azteca* Survival	*Hyalella azteca* Growth	*Chironomus riparius* Survival	*Chironomus riparius* Growth	*Hexagenia* Survival	*Hexagenia* Growth	*Tubifex* Survival	*Tubifex*	*Tubifex* Hatch	*Tubifex*
					[ppm]	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(# cocoons /adult)	(%)	(# young /adult)
T22	CANTEST Ltd	1	C5	T20	840	70	2.4	90	0.28								
T22	CANTEST Ltd	2	C5	T20	840	90	1.8	90	0.36								
T22	CANTEST Ltd	3	C5	T20	840	70	2.8	90	0.27								
T22	CANTEST Ltd	4	C5	T20	840	70	2.5	90	0.34								
T22	CANTEST Ltd	5	C5	T20	840	90	1.8	100	0.25								
T22	CANTEST Ltd	6	C5	T20	840	60	3.3	80	0.28								
T23	CANTEST Ltd	1	C5	T20	7500	40	1.9	100	0.27								
T23	CANTEST Ltd	2	C5	T20	7500	40	3.4	80	0.32								
T23	CANTEST Ltd	3	C5	T20	7500	50	2.9	100	0.27								
T23	CANTEST Ltd	4	C5	T20	7500	90	1.9	80	0.28								
T23	CANTEST Ltd	5	C5	T20	7500	70	2.3	90	0.36								
T23	CANTEST Ltd	6	C5	T20	7500	40	2.4	100	0.31								
T24	CANTEST Ltd	1	C5	T20	430	100	1.3	90	0.30								
T24	CANTEST Ltd	2	C5	T20	430	85	1.6	90	0.34								
T24	CANTEST Ltd	3	C5	T20	430	70	2.1	90	0.33								
T24	CANTEST Ltd	4	C5	T20	430			100	0.39								
T24	CANTEST Ltd	5	C5	T20	430			100	0.31								
T24	CANTEST Ltd	6	C5	T20	430												
C7a	Env Canada	1		T27				100	0.41	87	0.35	100	5.3	100	11	58	31
C7a	Env Canada	2		T27				100	0.28	93	0.26	100	5.1	100	11	64	39
C7a	Env Canada	3		T27				100	0.69	73	0.39	100	5.4	100	11	60	39
C7a	Env Canada	4		T27				93	0.51	11	0.44	100	5.4	100	11	59	35
C7a	Env Canada	5		T27				87	0.40	100	0.32	100	5.2	100	12	57	35
T27	Env Canada	1	C7a		40			93	0.50	87	0.35	100	5.6	100	11	50	21
T27	Env Canada	2	C7a		40			100	0.53	100	0.27	100	6.9	100	12	35	17
T27	Env Canada	3	C7a		40			100	0.33	100	0.28	100	6.5	100	12	40	18
T27	Env Canada	4	C7a		40			100	0.76	87		100	7.1	100	13	46	21
T25	Env Canada	1	C7a	T27	2300			100	0.65	93	0.30	100	6.8	100	12	45	31
T25	Env Canada	2	C7a	T27	2300			93	0.81	93	0.34	100	7.1	100	12	53	32
T25	Env Canada	3	C7a	T27	2300			100	0.57	100	0.32	100	6.5	100	11	42	30
T25	Env Canada	4	C7a	T27	2300			100	0.67	93	0.31	100	5.5	100	12	55	39
T26	Env Canada	1	C7a	T27	560			100	0.53	87	0.29	100	5.6	100	11	57	24
T26	Env Canada	2	C7a	T27	560			93	0.58	93	0.29	100	5.8	100	11	60	31
T26	Env Canada	3	C7a	T27	560			100	0.60	67	0.36	100	5.8	100	12	54	31
T26	Env Canada	4	C7a	T27	560			73.3	0.16	80		100	6.3	100	12	57	29
T28	Env Canada	1	C7a	T27	930			100	0.50	93	0.26	100	5.3	100	9.0	50	30
T28	Env Canada	2	C7a	T27	930			93	0.42	100	0.26	100	5.5	100	11	58	25
T28	Env Canada	3	C7a	T27	930			100	0.61	93	0.28	100	5.3	100	12	58	28
T28	Env Canada	4	C7a	T27	930			93	0.35	100	0.26	100	6.2	100	11	58	28

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples (cont'd)

Location	**Laboratory**	**Replicate**	**Control**	**Reference**	**Sediment Cr**	***Chironomus tentans* Survival**	***Chironomus tentans* Growth**	***Hyalella azteca* Survival**	***Hyalella azteca* Growth**	***Chironomus riparius* Survival**	***Chironomus riparius* Growth**	***Hexagenia* Survival**	***Hexagenia* Growth**	***Tubifex* Survival**	***Tubifex***	***Tubifex* Hatch**	***Tubifex***
					[ppm]	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(mg/ind)**	**(%)**	**(# cocoons /adult)**	**(%)**	**(# young /adult)**
C7b	Env Canada	1		T27				100	0.28	80	0.42			100	11	56	41
C7b	Env Canada	2		T27				93	0.46	53	0.56			100	14	55	38
C7b	Env Canada	3		T27				100	0.19	93	0.38			100	13	60	43
C7b	Env Canada	4		T27				93	0.33	80	0.48			100	13	62	40
C7b	Env Canada	5		T27				100	0.41	87	0.38			100	12	60	42
T27	Env Canada	1	C7b	C7a, C7b	40			93	0.50	87	0.35	100	5.6	100	11	50	21
T27	Env Canada	2	C7b	C7a, C7b	40			100	0.53	100	0.27	100	6.9	100	12	35	17
T27	Env Canada	3	C7b	C7a, C7b	40			100	0.33	100	0.28	100	6.5	100	12	40	18
T27	Env Canada	4	C7b	C7a, C7b	40			100	0.76	87		100	7.1	100	13	46	21
T29	Env Canada	1	C7b	T27	990			100	0.51	73	0.40			100	12	53	25
T29	Env Canada	2	C7b	T27	990			93	0.47	80	0.34			100	12	51	31
T29	Env Canada	3	C7b	T27	990			87	0.44	93	0.36			100	12	53	34
T29	Env Canada	4	C7b	T27	990			100	0.47	87	0.39			100	12	56	35
T30	Env Canada	1	C7b	T27	720			100	0.69	93	0.21			100	11	58	28
T30	Env Canada	2	C7b	T27	720			93	0.57	93	0.29			100	13	62	42
T30	Env Canada	3	C7b	T27	720			100	0.59	80	0.22			100	12	56	36
T30	Env Canada	4	C7b	T27	720			100	0.64	87	0.38			100	12	57	36
T31	Env Canada	1	C7b	T27	860			100	0.43	93	0.24			100	12	32	17
T31	Env Canada	2	C7b	T27	860			33	0.12	80	0.37			100	13	41	16
T31	Env Canada	3	C7b	T27	860			100	0.42	100	0.24			100	10	39	18
T31	Env Canada	4	C7b	T27	860			100	0.41	67	0.25			100	12	35	12
C7c	Env Canada	1		T27								100	5.5				
C7c	Env Canada	2		T27								100	5.0				
C7c	Env Canada	3		T27								100	5.0				
C7c	Env Canada	4		T27								100	6.0				
C7c	Env Canada	5		T27								100	5.5				
T27	Env Canada	1	C7c	C7c	40							100	5.6				
T27	Env Canada	2	C7c	C7c	40							100	6.9				
T27	Env Canada	3	C7c	C7c	40							100	6.5				
T27	Env Canada	4	C7c	C7c	40							100	7.1				
T29	Env Canada	1	C7c	T27	990							100	5.4				
T29	Env Canada	2	C7c	T27	990							100	5.5				
T29	Env Canada	3	C7c	T27	990							100	5.6				
T29	Env Canada	4	C7c	T27	990							100	6.5				
T30	Env Canada	1	C7c	T27	720							100	6.5				
T30	Env Canada	2	C7c	T27	720							100	6.2				
T30	Env Canada	3	C7c	T27	720							100	5.7				
T30	Env Canada	4	C7c	T27	720							100	6.0				
T31	Env Canada	1	C7c	T27	860							100	4.7				
T31	Env Canada	2	C7c	T27	860							100	5.2				
T31	Env Canada	3	C7c	T27	860							100	2.9				
T31	Env Canada	4	C7c	T27	860							100	5.3				

Table D-III-7: Benthic Invertebrate Toxicity Test Results for Kingston Inner Harbour Sediment Samples (cont'd)

Location	Laboratory	Replicate	Control	Reference	Sediment Cr	*Chironomus tentans* Survival	*Chironomus tentans* Growth	*Hyalella azteca* Survival	*Hyalella azteca* Growth	*Chironomus riparius* Survival	*Chironomus riparius* Growth	*Hexagenia* Survival	*Hexagenia* Growth	*Tubifex* Survival	*Tubifex*	*Tubifex* Hatch	*Tubifex*
					[ppm]	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(mg/ind)	(%)	(# cocoons /adult)	(%)	(# young /adult)
C8	CANTEST Ltd	1	C8	PC-12		70	2.2										
C8	CANTEST Ltd	2	C8	PC-12		70	2.4										
C8	CANTEST Ltd	3	C8	PC-12		50	2.9										
C8	CANTEST Ltd	4	C8	PC-12		30	2.2										
C8	CANTEST Ltd	5	C8	PC-12		60	2.3										
C8	CANTEST Ltd	6	C8	PC-12		70	2.4										
C8	CANTEST Ltd	7	C8	PC-12		40	2.9										
C8	CANTEST Ltd	8	C8	PC-12		50	2.3										
C8	CANTEST Ltd	9	C8	PC-12		40	2.9										
C8	CANTEST Ltd	10	C8	PC-12		50	2.3										
C8	CANTEST Ltd	11	C8	PC-12		60	2.7										
C8	CANTEST Ltd	12	C8	PC-12		50	2.6										
PC-12	CANTEST Ltd	1	C8		30	60	2.9										
PC-12	CANTEST Ltd	2	C8		30	60	2.7										
PC-12	CANTEST Ltd	3	C8		30	40	2.5										
PC-12	CANTEST Ltd	4	C8		30	40	2.8										
PC-12	CANTEST Ltd	5	C8		30	80	2.6										
PC-12	CANTEST Ltd	6	C8		30	90	2.3										
PC-12	CANTEST Ltd	7	C8		30	90	2.1										
PC-12	CANTEST Ltd	8	C8		30	100	1.8										
PC-12	CANTEST Ltd	9	C8		30	100	2.0										
PC-12	CANTEST Ltd	10	C8		30	40	2.9										
PC-12	CANTEST Ltd	11	C8		30	100	2.3										
PC-12	CANTEST Ltd	12	C8		30	70	2.4										
PC-13	CANTEST Ltd	1	C8	PC-12	5700	100	1.8										
PC-13	CANTEST Ltd	2	C8	PC-12	5700	100	1.8										
PC-13	CANTEST Ltd	3	C8	PC-12	5700	80	2.4										
PC-13	CANTEST Ltd	4	C8	PC-12	5700	100	1.9										
PC-13	CANTEST Ltd	5	C8	PC-12	5700	80	2.3										
PC-13	CANTEST Ltd	6	C8	PC-12	5700	100	2.2										
PC-13	CANTEST Ltd	7	C8	PC-12	5700	90	1.7										
PC-13	CANTEST Ltd	8	C8	PC-12	5700	100	1.9										
PC-13	CANTEST Ltd	9	C8	PC-12	5700	70	2.5										
PC-13	CANTEST Ltd	10	C8	PC-12	5700	100	1.8										
PC-13	CANTEST Ltd	11	C8	PC-12	5700	90	2.0										
PC-13	CANTEST Ltd	12	C8	PC-12	5700	90	1.9										
PC-14	CANTEST Ltd	1	C8	PC-12	11000	80	2.2										
PC-14	CANTEST Ltd	2	C8	PC-12	11000	100	2.2										
PC-14	CANTEST Ltd	3	C8	PC-12	11000	80	2.3										
PC-14	CANTEST Ltd	4	C8	PC-12	11000	70	2.8										
PC-14	CANTEST Ltd	5	C8	PC-12	11000	90	2.2										
PC-14	CANTEST Ltd	6	C8	PC-12	11000	80	2.2										
PC-14	CANTEST Ltd	7	C8	PC-12	11000	80	2.5										
PC-14	CANTEST Ltd	8	C8	PC-12	11000	70	2.7										
PC-14	CANTEST Ltd	9	C8	PC-12	11000	100	2.3										
PC-14	CANTEST Ltd	10	C8	PC-12	11000	80	2.4										
PC-14	CANTEST Ltd	11	C8	PC-12	11000	90	2.3										
PC-14	CANTEST Ltd	12	C8	PC-12	11000	100	1.9										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples

TAXA	BC1					BC2				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	34	30	35			25	25	59		
P. Cnidaria										
Cl. Hydrozoa										
O. Hydroida										
F. Hydridae										
Hydra sp.						0	0	6.7	6.7	0.54
P. Annelida										
Cl. Clitellata										
O. Haplotaxida										
F. Enchytraeidae										
Enchytraeus sp.						0	0	3.3	3.3	0.27
F. Naidinae										
Sf. Naidinae										
Nais simplex										
Nais sp.										
Nais simplex										
Nais variablis	0	3.3	2.8	6.1	0.22	0	8.0	0	8.0	0.65
N immatures without cheatal hairs	0	3.3	2.8	6.1	0.22	0	0	1.6	1.6	0.13
SF: Pristinae										
Pristina leidyi						4.0	0	0	4.0	0.33
Stylaria lacustris						0	8.0	3.3	11	0.92
SF: Chaetogastrinae										
Dero sp.										
Dero digitata										
Dero nivea										
Slavina appendiculata										
Sf. Tubificinae										
Aulodrilus pigueti						12	12	0	24	2.0
Aulodrilus pluriseta										
Quistradrilus multisetosus	5.8	0	2.8	8.6	0.31	0	0	1.6	1.6	0.13
Sf. Limnodriloidinae										
Limnodrilus hoffmeisteri									0	0
O. Rhynchobdellida										
F. Glossiphoniidae										
Alboglossiphonia heteroclita	0	3.3	0	3.3	0.12	0	4.0	1.6	5.6	0.46
P. Mollusca										
Cl. Bivalvia										
O. Veneroida										
F. Dreissenidae										
Dreissena sp.										
Dreissena polymorpha	5.8	3.3	2.8	12	0.43					
F. Sphaeriidae										
Pisidium casertanum	2.9	0	2.8	5.7	0.20	12	0	1.6	14	1.1
Cl. Gastropoda										
O. Bosommatophora										
F: Ancylidae										
Ferressia rivularis										
F. Physidae										
Physa sp.										
unknown specimen										
Sf. Planorbinae										
Gyraulus sp.	12	0	0	12	0.42	0	4.0	5.0	9.0	0.73
Gyraulus deflectus	0	0	0	0	0	4.0	0	0	4.0	0.33
Sf. Bulininae										
Menetus dialatatus										
Promenetus exacuous	0	3.3	2.8	6.1	0.22					
O: Neotaenioglossa										
F: Hydrobiidae										
Sf. Amnicolinae										
Amnicola limosus	0	13	0	13	0.48					
Pyrgulopsis lacustrica										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC3					BC4				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
P. Cnidaria										
Cl. Hydrozoa										
O. Hydroida										
F. Hydridae										
Hydra sp.						0	0	4.0	4.0	1.1
P. Annelida										
Cl. Clitellata										
O. Haplotaxida										
F. Enchytraeidae										
Enchytraeus sp.										
F. Naidinae										
Sf. Naidinae										
Nais simplex	0	4.0	0	4.0	1.4					
Nais sp.										
Nais simplex										
Nais variablis										
N immatures without cheatal hairs						0	0	4.0	4.0	1.1
SF: Pristinae										
Pristina leidyi										
Stylaria lacustris										
SF: Chaetogastrinae										
Dero sp.										
Dero digitata										
Dero nivea						0	4.0	0	4.0	1.1
Slavina appendiculata										
Sf. Tubificinae										
Aulodrilus pigueti										
Aulodrilus pluriseta										
Quistradrilus multisetosus										
Sf. Limnodriloidinae										
Limnodrilus hoffmeisteri										
O. Rhynchobdellida										
F. Glossiphoniidae										
Alboglossiphonia heteroclita	0	0	4.0	4.0	1.4					
P. Mollusca										
Cl. Bivalvia										
O. Veneroida										
F. Dreissenidae										
Dreissena sp.										
Dreissena polymorpha										
F. Sphaeriidae										
Pisidium casertanum										
Cl. Gastropoda										
O. Bosommatophora										
F: Ancylidae										
Ferressia rivularis										
F. Physidae										
Physa sp.	4.0	0	0	4.0	1.4	0	4.0	0	4.0	1.1
unknown specimen	0	12	0	12	4.3					
Sf. Planorbinae										
Gyraulus sp.										
Gyraulus deflectus										
Sf. Bulininae										
Menetus dialatatus										
Promenetus exacuous										
O: Neotaenioglossa										
F: Hydrobiidae										
Sf. Amnicolinae										
Amnicola limosus										
Pyrgulopsis lacustrica	4.0	0	4.0	8.0	2.9	0	8.0	0	8.0	2.3

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC5					BC6				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			39	25	25		
P. Cnidaria										
Cl. Hydrozoa										
O. Hydroida										
F. Hydridae										
Hydra sp.						0	0	4.0	4.0	0.36
P. Annelida										
Cl. Clitellata										
O. Haplotaxida										
F. Enchytraeidae										
Enchytraeus sp.						2.5	0	0	2.5	0.23
F. Naidinae										
Sf. Naidinae										
Nais simplex						18	0	0	18	1.6
Nais sp.										
Nais simplex	4.0	0	0	4.0	0.86					
Nais variablis	8.0	0	0	8.0	1.7	0	4.0	0	4.0	0.36
N immatures without cheatal hairs						13	0	4.0	17	1.5
SF: Pristinae										
Pristina leidyi										
Stylaria lacustris										
SF: Chaetogastrinae										
Dero sp.	0	0	20	20	4.3	0	0	4.0	4.0	0.36
Dero digitata	8.0	16	0	24	5.2					
Dero nivea										
Slavina appendiculata						5.1	0	0	5.1	0.46
Sf. Tubificinae										
Aulodrilus pigueti	4.0	0	0	4.0	0.86					
Aulodrilus pluriseta	4.0	0	0	4.0	0.86					
Quistradrilus multisetosus										
Sf. Limnodriloidinae										
Limnodrilus hoffmeisteri						2.5	0	0	2.5	0.23
O. Rhynchobdellida										
F. Glossiphoniidae										
Alboglossiphonia heteroclita										
P. Mollusca										
Cl. Bivalvia										
O. Veneroida										
F. Dreissenidae										
Dreissena sp.										
Dreissena polymorpha										
F. Sphaeriidae										
Pisidium casertanum	4.0	0	0	4.0	0.86					
Cl. Gastropoda										
O. Bosommatophora										
F: Ancylidae										
Ferressia rivularis										
F. Physidae										
Physa sp.						5.1	0	0	5.1	0.46
unknown specimen						13	0	0	13	1.2
Sf. Planorbinae										
Gyraulus sp.										
Gyraulus deflectus										
Sf. Bulininae										
Menetus dialatatus										
Promenetus exacuous										
O: Neotaenioglossa										
F: Hydrobiidae										
Sf. Amnicolinae										
Amnicola limosus										
Pyrgulopsis lacustrica						7.6	0	8.0	16	1.4

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC7					BC8				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
P. Cnidaria										
Cl. Hydrozoa										
O. Hydroida										
F. Hydridae										
Hydra sp.										
P. Annelida										
Cl. Clitellata										
O. Haplotaxida										
F. Enchytraeidae										
Enchytraeus sp.										
F. Naidinae										
Sf. Naidinae										
Nais simplex										
Nais sp.										
Nais simplex										
Nais variablis										
N immatures without cheatal hairs	4.0	20	16	40	12					
SF: Pristinae										
Pristina leidyi										
Stylaria lacustris										
SF: Chaetogastrinae										
Dero sp.										
Dero digitata										
Dero nivea										
Slavina appendiculata										
Sf. Tubificinae										
Aulodrilus pigueti	0	0	4.0	4.0	1.2					
Aulodrilus pluriseta										
Quistradrilus multisetosus										
Sf. Limnodriloidinae										
Limnodrilus hoffmeisteri										
O. Rhynchobdellida										
F. Glossiphoniidae										
Alboglossiphonia heteroclita										
P. Mollusca										
Cl. Bivalvia										
O. Veneroida										
F. Dreissenidae										
Dreissena sp.						0	4.0	0	4.0	1.3
Dreissena polymorpha										
F. Sphaeriidae										
Pisidium casertanum										
Cl. Gastropoda										
O. Bosommatophora										
F: Ancylidae										
Ferressia rivularis										
F. Physidae										
Physa sp.										
unknown specimen										
Sf. Planorbinae										
Gyraulus sp.										
Gyraulus deflectus										
Sf. Bulininae										
Menetus dialatatus										
Promenetus exacuous										
O: Neotaenioglossa										
F: Hydrobiidae										
Sf. Amnicolinae										
Amnicola limosus										
Pyrgulopsis lacustrica	4.0	0	0	4.0	1.2					

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC9				
Replicate #	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25		
P. Cnidaria					
Cl. Hydrozoa					
O. Hydroida					
F. Hydridae					
Hydra sp.					
P. Annelida					
Cl. Clitellata					
O. Haplotaxida					
F. Enchytraeidae					
Enchytraeus sp.					
F. Naidinae					
Sf. Naidinae					
Nais simplex					
Nais sp.		0	4.0	4.0	0.93
Nais simplex					
Nais variablis					
N immatures without cheatal hairs		0	4.0	4.0	0.93
SF: Pristinae					
Pristina leidyi					
Stylaria lacustris					
SF: Chaetogastrinae					
Dero sp.					
Dero digitata					
Dero nivea					
Slavina appendiculata					
Sf. Tubificinae					
Aulodrilus pigueti		8.0	8.0	16	3.7
Aulodrilus pluriseta					
Quistradrilus multisetosus	4.0	0	8.0	12	2.8
Sf. Limnodriloidinae					
Limnodrilus hoffmeisteri					
O. Rhynchobdellida					
F. Glossiphoniidae					
Alboglossiphonia heteroclita					
P. Mollusca					
Cl. Bivalvia					
O. Veneroida					
F. Dreissenidae					
Dreissena sp.					
Dreissena polymorpha		0	4.0	4.0	0.93
F. Sphaeriidae					
Pisidium casertanum	20	4.0	0	24	5.6
Cl. Gastropoda					
O. Bosommatophora					
F: Ancylidae					
Ferressia rivularis		0	4.0	4.0	0.93
F. Physidae					
Physa sp.					
unknown specimen					
Sf. Planorbinae					
Gyraulus sp.	4.0	0	0	4.0	0.93
Gyraulus deflectus	4.0	0	0	4.0	0.93
Sf. Bulininae					
Menetus dialatatus	4.0	0	0	4.0	0.93
Promenetus exacuous					
O: Neotaenioglossa					
F: Hydrobiidae					
Sf. Amnicolinae					
Amnicola limosus					
Pyrgulopsis lacustrica					

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC1					BC2				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	34	30	35			25	25	59		
Sf. Nymphophilinae										
Pyrgulopsis lacustrica	2.9	0	8.5	11	0.41	12	8.0	10	30	2.4
unknown specimen				0	0				0	0
O: Heterostropha										
Sf. Valvatoidae										
Valvata tricarinata	5.8	17	2.8	25	0.91	4.0	8.0	6.7	19	1.5
Cl: Insecta										
O: Ephemeroptera										
Sf. Caenidae										
Caenis sp.	2.9	0	0	2.9	0.10	4.0	0	1.6	5.6	0.46
Caenis amica										
Caenis punctata										
unknown specimens	0	10	0	10	0.36					
O. Odonata										
F. Coenagroenidae										
Ischnura sp.						0	4.0	0	4.0	0.33
unknown specimen	2.9	0	2.9	5.8	0.21					
O. Trichoptera										
F. Hydroptilidae										
Sf. Hydroptilinae										
Oxyethira sp.	5.8	17	5.7	28	1.0	4.0	0	0	4.0	0.33
SF: Ochrotrichiini										
Othrotrichia sp.	0	6.7	5.7	12	0.44	0	0	3.3	3.3	0.27
F. Leptoceridae										
SF: Leptocerinae										
Leptocerus americanus	59	20	11	90	3.2	0	12	17	29	2.3
Oecetis (Pl.) *cinerascens*						0	0	6.7	6.7	0.54
Mystacides sepulchralis	0	0	2.8	2.8	0.10					
Triaenodes tardus										
O.Coleoptera										
F. Dytiscidae										
Sf. Hydroporinae										
Liodessus flavicollis										
F. Elmidae										
Sf. Elminae										
Dubiraphia bivittata										
O. Diptera										
F. Ceratopgonidae										
Sf. Ceratopgoninae										
Bezzia/Palpomyia sp.	2.9	0	0	2.9	0.10					
Ceratopogon sp.										
Culicoides sp.	2.9	0	0	2.9	0.10					
Probezzia sp.						4.0	8.0	0	12	0.98
Serromyia sp.									0	0
unknown specimen	12	30	11	53	1.9	8.0	0	8.4	16	1.3
Sf. Tanypodinae										
Ablabesmyia(Karelia) sp.	0	20	5.7	26	0.92	4.0	0	3.3	7.3	0.59
Sf.Chironominae										
Chironomus sp.										
Chironomus riparius										
Cladotanytarsus sp.										
Cladopelma sp.						0	0	6.7	6.7	0.54
Cryptochironomus sp.						4.0	0	5.0	9.0	0.73
Cryptotendipe s sp.										
Dicrotendipes sp.	18	23	34	75	2.7	8.0	16	6.7	31	2.5

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC3					BC4				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Sf. Nymphophilinae										
Pyrgulopsis lacustrica										
unknown specimen										
O: Heterostropha										
Sf. Valvatoidae										
Valvata tricarinata										
Cl: Insecta										
O: Ephemeroptera										
Sf. Caenidae										
Caenis sp.										
Caenis amica						0	0	4.0	4.0	1.1
Caenis punctata										
unknown specimens						0	8.0	0	8.0	2.3
O. Odonata										
F. Coenagroenidae										
Ischnura sp.										
unknown specimen										
O. Trichoptera										
F. Hydroptilidae										
Sf. Hydroptilinae										
Oxyethira sp.						4.0	12	0	16	4.6
SF: Ochrotrichiini										
Othrotrichia sp.						0	0	4.0	4.0	1.1
F. Leptoceridae										
SF: Leptocerinae										
Leptocerus americanus	8.0	4.0	0	12	4.3	4.0	36	12	52	15
Oecetis (Pl.) *cinerascens*						0	0	4.0	4.0	1.1
Mystacides sepulchralis										
Triaenodes tardus										
O.Coleoptera										
F. Dytiscidae										
Sf. Hydroporinae										
Liodessus flavicollis										
F. Elmidae										
Sf. Elminae										
Dubiraphia bivittata										
O. Diptera										
F. Ceratopgonidae										
Sf. Ceratopgoninae										
Bezzia/Palpomyia sp.										
Ceratopogon sp.	4.0	0	0	4.0	1.4					
Culicoides sp.						0	0	4.0	4.0	1.1
Probezzia sp.										
Serromyia sp.						0	0	4.0	4.0	1.1
unknown specimen						0	0	4.0	4.0	1.1
Sf. Tanypodinae										
Ablabesmyia(Karelia) sp.	4.0	0	4.0	8.0	2.9	0	32	4.0	36	10
Sf.Chironominae										
Chironomus sp.						0	4.0	0	4.0	1.1
Chironomus riparius	0	0	4.0	4.0	1.4	4.0	4.0	0	8.0	2.3
Cladotanytarsus sp.										
Cladopelma sp.										
Cryptochironomus sp.										
*Cryptotendipe*s sp.	0	8.0	0	8.0	2.9					
Dicrotendipes sp.	4.0	4.0	8.0	16	5.8	0	8.0	12	20	5.7

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC5**					**BC6**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			39	25	25		
Sf. Nymphophilinae										
Pyrgulopsis lacustrica	4.0	0	0	4.0	0.86					
unknown specimen						5.1	0	0	5.1	0.46
O: Heterostropha										
Sf. Valvatoidae										
Valvata tricarinata	0	8.0	8.0	16	3.4					
Cl: Insecta										
O: Ephemeroptera										
Sf. Caenidae										
Caenis sp.	0	4.0	4.0	8.0	1.7					
Caenis amica										
Caenis punctata						0	4.0	0	4.0	0.36
unknown specimens						2.5	0	0	2.5	0.23
O. Odonata										
F. Coenagroenidae										
Ischnura sp.										
unknown specimen										
O. Trichoptera										
F. Hydroptilidae										
Sf. Hydroptilinae										
Oxyethira sp.	4.0	0	4.0	8.0	1.7					
SF: Ochrotrichiini										
Othrotrichia sp.	0	0	4.0	4.0	0.86	0	0	4.0	4.0	0.36
F. Leptoceridae										
SF: Leptocerinae										
Leptocerus americanus	0	0	4.0	4.0	0.86	300	8.0	120	430	39
Oecetis (Pl.) *cinerascens*						18	4.0	0	22	2.0
Mystacides sepulchralis										
Triaenodes tardus						10	0	8.0	18	1.7
O.Coleoptera										
F. Dytiscidae										
Sf. Hydroporinae										
Liodessus flavicollis						2.5	0	0	2.5	0.23
F. Elmidae										
Sf. Elminae										
Dubiraphia bivittata										
O. Diptera										
F. Ceratopgonidae										
Sf. Ceratopgoninae										
Bezzia/Palpomyia sp.						5.1	0	4.0	9.1	0.83
Ceratopogon sp.										
Culicoides sp.						2.5	0	0	2.5	0.23
Probezzia sp.	4.0	0	0	4.0	0.86					
Serromyia sp.										
unknown specimen	4.0	8.0	0	12	2.6	10	0	4.0	14	1.3
Sf. Tanypodinae										
Ablabesmyia(Karelia) sp.	4.0	4.0	0	8.0	1.7	18	0	0	18	1.6
Sf.Chironominae										
Chironomus sp.	4.0	4.0	4.0	12	2.6	0	4.0	4.0	8.0	0.73
Chironomus riparius				0	0					
Cladotanytarsus sp.	4.0	0	0	4.0	0.86					
Cladopelma sp.	0	0	0	0	0					
Cryptochironomus sp.	0	0	0	0	0	2.5	0	0	2.5	0.23
Cryptotendipe s sp.	4.0	12	4.0	20	4.3					
Dicrotendipes sp.	16	12	12	40	8.6	26	4.0	4.0	34	3.1

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC7**					**BC8**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Sf. Nymphophilinae										
Pyrgulopsis lacustrica										
unknown specimen										
O: Heterostropha										
Sf. Valvatoidae										
Valvata tricarinata										
Cl: Insecta										
O: Ephemeroptera										
Sf. Caenidae										
Caenis sp.										
Caenis amica										
Caenis punctata										
unknown specimens	0	0	4.0	4.0	1.2					
O. Odonata										
F. Coenagroenidae										
Ischnura sp.										
unknown specimen										
O. Trichoptera										
F. Hydroptilidae										
Sf. Hydroptilinae										
Oxyethira sp.	0	4.0	0	4.0	1.2	4.0	0	0	4.0	1.3
SF: Ochrotrichiini										
Othrotrichia sp.										
F. Leptoceridae										
SF: Leptocerinae										
Leptocerus americanus	72	60	12	140	44	8.0	0	0	8.0	2.7
Oecetis (Pl.) *cinerascens*										
Mystacides sepulchralis										
Triaenodes tardus										
O.Coleoptera										
F. Dytiscidae										
Sf. Hydroporinae										
Liodessus flavicollis										
F. Elmidae										
Sf. Elminae										
Dubiraphia bivittata	0	0	4.0	4.0	1.2					
O. Diptera										
F. Ceratopgonidae										
Sf. Ceratopgoninae										
Bezzia/Palpomyia sp.										
Ceratopogon sp.										
Culicoides sp.										
Probezzia sp.	4.0	0	0	4.0	1.2					
Serromyia sp.										
unknown specimen	0	8.0	4.0	12	3.7					
Sf. Tanypodinae										
Ablabesmyia(Karelia) sp.						28	0	0	28	9.3
Sf.Chironominae										
Chironomus sp.	4.0	0	0	4.0	1.2					
Chironomus riparius	0	16	12	28	8.5					
Cladotanytarsus sp.										
Cladopelma sp.										
Cryptochironomus sp.										
Cryptotendipe s sp.										
Dicrotendipes sp.	0	0	4.0	4.0	1.2					

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC9**				
Replicate #	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25		
Sf. Nymphophilinae					
Pyrgulopsis lacustrica		8.0	12	20	4.6
unknown specimen					
O: Heterostropha					
Sf. Valvatoidae					
Valvata tricarinata	8.0	8.0	4.0	20	4.6
Cl: Insecta					
O: Ephemeroptera					
Sf. Caenidae					
Caenis sp.		4.0	0	4.0	0.93
Caenis amica					
Caenis punctata					
unknown specimens					
O. Odonata					
F. Coenagroenidae					
Ischnura sp.					
unknown specimen					
O. Trichoptera					
F. Hydroptilidae					
Sf. Hydroptilinae					
Oxyethira sp.		0	4.0	4.0	0.93
SF: Ochrotrichiini					
Othrotrichia sp.		4.0	0	4.0	0.93
F. Leptoceridae					
SF: Leptocerinae					
Leptocerus americanus	8.0	0	4.0	12	2.8
Oecetis (Pl.) *cinerascens*					
Mystacides sepulchralis					
Triaenodes tardus					
O.Coleoptera					
F. Dytiscidae					
Sf. Hydroporinae					
Liodessus flavicollis					
F. Elmidae					
Sf. Elminae					
Dubiraphia bivittata					
O. Diptera					
F. Ceratopgonidae					
Sf. Ceratopgoninae					
Bezzia/Palpomyia sp.					
Ceratopogon sp.					
Culicoides sp.					
Probezzia sp.					
Serromyia sp.					
unknown specimen					
Sf. Tanypodinae					
Ablabesmyia(Karelia) sp.		4.0	4.0	8.0	1.9
Sf.Chironominae					
Chironomus sp.					
Chironomus riparius					
Cladotanytarsus sp.	4.0	0	8.0	12	2.8
Cladopelma sp.					
Cryptochironomus sp.					
*Cryptotendipe*s sp.		12	12	24	5.6
Dicrotendipes sp.	8.0	12	8.0	28	6.5

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC1					BC2				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	34	30	35			25	25	59		
Glyptotendipes sp.	12	6.7	8.5	27	0.96	100	120	76	290	24
Labrundina neopilosella	2.9	0	2.8	5.7	0.20					
Micropsectra sp.	0	0	2.8	2.8	0.10					
Parachironomus sp.	8.8	3.3	0	12	0.43	20	0	3.3	23	1.9
Phaenopsectra sp.	8.8	0	0	8.8	0.32					
Polypedilum sp.	2.9	10	0	13	0.46					
Polypedilum bergi										
Polypedilum halteral e group	0	13	11	25	0.89	0	0	24	24	1.9
Polypedilum scalaenum group						16	4.0	0	20	1.6
Polypedilum tritum	2.9	3.3	0	6.2	0.22	8.0	0	15	23	1.9
Saetheria tylus	0	6.7	2.8	9.5	0.34	0	0	1.6	1.6	0.13
Tanytarsus sp.	130	120	100	360	13	4.0	4.0	5.0	13	1.1
Tribelo s sp.						4.0	4.0	0	8.0	0.65
Xenochironomus xenolabis										
Zavreliella marmorata	0	6.7	0	6.7	0.24	4.0	4.0	1.6	9.6	0.78
SF Orthocladiinae										
Orthocladius sp.	260	300	320	890	32	4.0	0	8.4	12	1.0
Orthocladius(S.) annectens						0	0	0	0	0
Cricotopus sp.	12	50	34	96	3.4	20	8.0	20	48	3.9
Cricotopus(I) intersectus										
Corynoneura sp.	0	3.3	8.5	12	0.42	0	0	6.7	6.7	0.54
Nanocladius sp.	24	10	14	48	1.7	8.0	16	17	41	3.3
Nanocladius(N) alternantherae										
Parakiefferiella sp.	8.8	10	26	45	1.6	0	0	32	32	2.6
Paralauterborniella nigrohalterale	0	0	0	0	0					
Psectrocladius sp.	8.8	13	14	36	1.3	4.0	0	0	4.0	0.33
Psectrocladius(Ps) sordidellus group	0	0	23	23	0.82	24	20	42	86	7.0
Psectrocladius(Ps) vernalis	91	100	43	230	8.4	20	32	46	98	7.9
Pseudochironomus sp.										
Rheocricotopus sp.	0	3.3	0	3.3	0.12					
Thienemanniella sp.	26	57	66	150	5.3	12	28	22	62	5.0
Sf. Tanypodinae										
Paramerina sp.										
Paratanytarsus sp.	44	50	46	140	5.0	16	12	56	84	6.8
Procladius sp.	5.8	6.7	8.5	21	0.75	8.0	0	3.3	11	0.92
Potthastia longimana	0	0	2.8	2.8	0.10					
Rheotanytarsus sp.										
Thienemannimyia group	8.8	0	8.5	17	0.62	4.0	0	3.3	7.3	0.59
Tanypus sp.	8.8	3.3	0	12	0.43	0	0	3.3	3.3	0.27
F. Muscidae										
unknown specimen										
Cl. Malacostraca										
O. Amphipoda										
F. Hyalellidae										
Hyalella sp.	32	27	26	85	3.0	4.0	8.0	8.4	20	1.7
F. Gammaridae										
Gammarus sp.										
O. Isopoda										
F. Asellidae										
Caecidotea sp.	5.8	3.3	5.7	15	0.53	0	4.0	1.6	5.6	0.46
P. Chelicerata										
Cl. Arachnida										
O. Prostigmata										
F. Aturidae										
SF. Aturinae										
Aturus sp.										
Sf. Axonopsinae										
Albaxona sp.										
F. Arrenuridae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC3**					**BC4**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Glyptotendipes sp.										
Labrundina neopilosella										
Micropsectra sp.										
Parachironomus sp.									0	0
Phaenopsectra sp.						0	4.0	0	4.0	1.1
Polypedilum sp.										
Polypedilum bergi										
Polypedilum halteral e group										
Polypedilum scalaenum group										
Polypedilum tritum										
Saetheria tylus										
Tanytarsus sp.	0	8.0	0	8.0	2.9	0	8.0	0	8.0	2.3
Tribelo s sp.										
Xenochironomus xenolabis	0	4.0	0	4.0	1.4					
Zavreliella marmorata										
SF Orthocladiinae										
Orthocladius sp.										
Orthocladius(S.) annectens										
Cricotopus sp.										
Cricotopus(I) intersectus						0	8.0	0	8.0	2.3
Corynoneura sp.										
Nanocladius sp.										
Nanocladius(N) alternantherae						0	12	0	12	3.4
Parakiefferiella sp.										
Paralauterborniella nigrohalterale										
Psectrocladius sp.						0	0	4.0	4.0	1.1
Psectrocladius(Ps) sordidellus group	0	60	0	60	22	0	12	0	12	3.4
Psectrocladius(Ps) vernalis	12	0	0	12	4.3	8.0	0	0	8.0	2.3
Pseudochironomus sp.						0	8.0	8.0	16	4.6
Rheocricotopus sp.										
Thienemanniella sp.	4.0	0	0	4.0	1.4	0	8.0	4.0	12	3.4
Sf. Tanypodinae										
Paramerina sp.										
Paratanytarsus sp.	52	24	0	76	28	0	4.0	16	20	5.7
Procladius sp.	0	4.0	0	4.0	1.4	4.0	0	0	4.0	1.1
Potthastia longimana										
Rheotanytarsus sp.	4.0	0	0	4.0	1.4					
Thienemannimyia group										
Tanypus sp.										
F. Muscidae										
unknown specimen	0	4.0	0	4.0	1.4					
Cl. Malacostraca										
O. Amphipoda										
F. Hyalellidae										
Hyalella sp.	0	8.0	0	8.0	2.9	8.0	24	4.0	36	10
F. Gammaridae										
Gammarus sp.										
O. Isopoda										
F. Asellidae										
Caecidotea sp.										
P. Chelicerata										
Cl. Arachnida										
O. Prostigmata										
F. Aturidae										
SF. Aturinae										
Aturus sp.										
Sf. Axonopsinae										
Albaxona sp.										
F. Arrenuridae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC5					BC6				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			39	25	25		
Glyptotendipes sp.	12	8.0	4.0	24	5.2	10	0	0	10	0.93
Labrundina neopilosella										
Micropsectra sp.										
Parachironomus sp.	20	8.0	8.0	36	7.8					
Phaenopsectra sp.										
Polypedilum sp.										
Polypedilum bergi	8.0	0	0	8.0	1.7					
Polypedilum halteral e group						2.5	0	0	2.5	0.23
Polypedilum scalaenum group	4.0	4.0	8.0	16	3.4					
Polypedilum tritum										
Saetheria tylus										
Tanytarsus sp.	8.0	4.0	0	12	2.6	7.6	0	4.0	12	1.1
Tribelo s sp.										
Xenochironomus xenolabis						21	0	0	21	1.9
Zavreliella marmorata	0	4.0	0	4.0	0.86					
SF Orthocladiinae										
Orthocladius sp.	4.0	0	4.0	8.0	1.7	64	12	24	100	9.1
Orthocladius(S.) annectens										
Cricotopus sp.	4.0	0	0	4.0	0.86	0	0	4.0	4.0	0.36
Cricotopus(I) intersectus						13	0	0	13	1.2
Corynoneura sp.										
Nanocladius sp.						23	0	0	23	2.1
Nanocladius(N) alternantherae										
Parakiefferiella sp.						10	4.0	0	14	1.3
Paralauterborniella nigrohalterale										
Psectrocladius sp.										
Psectrocladius(Ps) sordidellus group	0	4.0	0	4.0	0.86	5.1	0	0	5.1	0.46
Psectrocladius(Ps) vernalis						0	0	4.0	4.0	0.36
Pseudochironomus sp.										
Rheocricotopus sp.										
Thienemanniella sp.	12	0	0	12	2.6	33	0	24	57	5.2
Sf. Tanypodinae										
Paramerina sp.	12	0	0	12	2.6					
Paratanytarsus sp.	8.0	4.0	4.0	16	3.4	49	0	4.0	53	4.8
Procladius sp.	4.0	8.0	4.0	16	3.4					
Potthastia longimana	0	0	0	0	0					
Rheotanytarsus sp.										
Thienemannimyia group						10	4.0	0	14	1.3
Tanypus sp.	0	4.0	12	16	3.4					
F. Muscidae										
unknown specimen										
Cl. Malacostraca										
O. Amphipoda										
F. Hyalellidae										
Hyalella sp.	16	16	20	52	11	36	8.0	12	56	5.1
F. Gammaridae										
Gammarus sp.										
O. Isopoda										
F. Asellidae										
Caecidotea sp.	0	4.0	0	4.0	0.86					
P. Chelicerata										
Cl. Arachnida										
O. Prostigmata										
F. Aturidae										
SF. Aturinae										
Aturus sp.										
Sf. Axonopsinae										
Albaxona sp.						2.5	0	0	2.5	0.23
F. Arrenuridae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC7**					**BC8**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Glyptotendipes sp.										
Labrundina neopilosella										
Micropsectra sp.										
Parachironomus sp.										
Phaenopsectra sp.										
Polypedilum sp.	0	4.0	0	4.0	1.2					
Polypedilum bergi										
Polypedilum halteral e group	0	0	4.0	4.0	1.2	32	0	0	32	11
Polypedilum scalaenum group										
Polypedilum tritum										
Saetheria tylus										
Tanytarsus sp.										
Tribelo s sp.										
Xenochironomus xenolabis										
Zavreliella marmorata						0	4.0	0	4.0	1.3
SF Orthocladiinae										
Orthocladius sp.						0	0	0	0	0
Orthocladius(S.) annectens										
Cricotopus sp.						16	0	0	16	5.3
Cricotopus(I) intersectus										
Corynoneura sp.										
Nanocladius sp.	0	4.0	0	4.0	1.2					
Nanocladius(N) alternantherae										
Parakiefferiella sp.										
Paralauterborniella nigrohalterale										
Psectrocladius sp.	8.0	0	0	8.0	2.4	4.0	0	0	4.0	1.3
Psectrocladius(Ps) sordidellus group										
Psectrocladius(Ps) vernalis						52	0	0	52	17
Pseudochironomus sp.	0	0	4.0	4.0	1.2					
Rheocricotopus sp.										
Thienemanniella sp.						4.0	0	0	4.0	1.3
Sf. Tanypodinae										
Paramerina sp.										
Paratanytarsus sp.	0	16	0	16	4.9	100	4.0	0	110	36
Procladius sp.	4.0	0	0	4.0	1.2					
Potthastia longimana										
Rheotanytarsus sp.	4.0	0	0	4.0	1.2					
Thienemannimyia group	0	4.0	0	4.0	1.2	4.0	0	0	4.0	1.3
Tanypus sp.										
F. Muscidae										
unknown specimen										
Cl. Malacostraca										
O. Amphipoda										
F. Hyalellidae										
Hyalella sp.						16	4.0	8.0	28	9.3
F. Gammaridae										
Gammarus sp.										
O. Isopoda										
F. Asellidae										
Caecidotea sp.										
P. Chelicerata										
Cl. Arachnida										
O. Prostigmata										
F. Aturidae										
SF. Aturinae										
Aturus sp.										
Sf. Axonopsinae										
Albaxona sp.										
F. Arrenuridae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC9**				
Replicate #	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25		
Glyptotendipes sp.					
Labrundina neopilosella					
Micropsectra sp.					
Parachironomus sp.		4.0	0	4.0	0.93
Phaenopsectra sp.					
Polypedilum sp.					
Polypedilum bergi					
Polypedilum halteral e group	4.0	4.0	12	20	4.6
Polypedilum scalaenum group					
Polypedilum tritum					
Saetheria tylus		4.0	0	4.0	0.93
Tanytarsus sp.	8.0	4.0	0	12	2.8
Tribelo s sp.					
Xenochironomus xenolabis					
Zavreliella marmorata	4.0	0	0	4.0	0.93
SF Orthocladiinae					
Orthocladius sp.		0	4.0	4.0	0.93
Orthocladius(S.) annectens	4.0	0	8.0	12	2.8
Cricotopus sp.					
Cricotopus(I) intersectus					
Corynoneura sp.	4.0	0	0	4.0	0.93
Nanocladius sp.					
Nanocladius(N) alternantherae					
Parakiefferiella sp.	12	0	0	12	2.8
Paralauterborniella nigrohalterale		4.0	0	4.0	0.93
Psectrocladius sp.		4.0	0	4.0	0.93
Psectrocladius(Ps) sordidellus group					
Psectrocladius(Ps) vernalis	4.0	0	12	16	3.7
Pseudochironomus sp.					
Rheocricotopus sp.					
Thienemanniella sp.	8.0	12	4.0	24	5.6
Sf. Tanypodinae					
Paramerina sp.					
Paratanytarsus sp.	4.0	4.0	0	8.0	1.9
Procladius sp.	4.0	12	4.0	20	4.6
Potthastia longimana					
Rheotanytarsus sp.					
Thienemannimyia group	4.0	0	0	4.0	0.93
Tanypus sp.					
F. Muscidae					
unknown specimen					
Cl. Malacostraca					
O. Amphipoda					
F. Hyalellidae					
Hyalella sp.	4.0	0	4.0	8.0	1.9
F. Gammaridae					
Gammarus sp.	4.0	12	8.0	24	5.6
O. Isopoda					
F. Asellidae					
Caecidotea sp.	8.0	4.0	4.0	16	3.7
P. Chelicerata					
Cl. Arachnida					
O. Prostigmata					
F. Aturidae					
SF. Aturinae					
Aturus sp.					
Sf. Axonopsinae					
Albaxona sp.					
F. Arrenuridae					

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC1					BC2				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	34	30	35			25	25	59		
Arrenurus sp.	5.8	0	2.8	8.6	0.31					
F. Hygrobatidae										
Hygrobate s sp.	2.9	0	0	2.9	0.10					
F. Hydrodromidae										
Hydrodroma sp.										
F. Pionidae										
Sf. Tiphysinae										
Neotiphys sp.	15	13	11	39	1.4					
F. Limnesiidae										
Sf. Limnesiinae										
Limnesia sp.						0	0	3.3	3.3	0.27
F. Mideopsidae										
Sf. Mideopsinae										
Mideopsis sp.	0	3.3	0	3.3	0.12	0	0	1.6	1.6	0.13
F. Oxidae										
Sf. Oxinae										
Frontipoda sp.	2.9	6.7	0	9.6	0.34	4.0	0	6.7	11	0.87
Oxus sp.	2.9	0	0	2.9	0.10	0	0	0	0	0
F. Unionicolidae										
Sf. Unionicolinae										
Uninonicola sp.	2.9	0	0	2.9	0.10					
unknown specimen										
O.Oribati										
F. Hydrozetidae										
Hydrozetes sp.	2.9	0	0	2.9	0.10	0	0	1.6	1.6	0.13
P. Porifera										
Cl. Demospongiliidae										
O. Haplosclerida										
F. Spongillidae	40000	17000	20000			8400	12000	15000		
P. Plathelmynthes										
C. Turbellaria										
O. Tricladida										
F. Dugesiidae										
unknown specimen	8.8	6.7	0			0	0	1.6		
F. Planaridae										
unknown specimen										
O. Prolecithophora										
F. Plagiostomidae										
Hydrolimax sp.	8.8	0	2.8							
P. Arthropoda										
Cl. Brachiopoda										
O. Cladocera										
F. Chydoridae	15	6.7	31			0	4.0	14		
F: Cyclopidae	2.9	6.7	2.8			0	4.0	3.3		
O: Harpacticoida	79	73	34			12	0	1.6		
Cl: OSTRACODA										
O: Podocopa	400	470	490			260	170	290		
F. Bosminidae	5.8	0	0	2800	100	0	0	0	1200	100
F. Daphnidae	0	3.3	0			0	0	1.6		
F. Macrothricidae	18	17	8.5			0	0	1.6		

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC3**					**BC4**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Arrenurus sp.						0	0	4.0	4.0	1.1
F. Hygrobatidae										
Hygrobate s sp.										
F. Hydrodromidae										
Hydrodroma sp.						0	4.0	0	4.0	1.1
F. Pionidae										
Sf. Tiphysinae										
Neotiphys sp.										
F. Limnesiidae										
Sf. Limnesiinae										
Limnesia sp.										
F. Mideopsidae										
Sf. Mideopsinae										
Mideopsis sp.										
F. Oxidae										
Sf. Oxinae										
Frontipoda sp.										
Oxus sp.										
F. Unionicolidae										
Sf. Unionicolinae										
Uninonicola sp.										
unknown specimen	4.0	0	0	4.0	1.4					
O.Oribati										
F. Hydrozetidae										
Hydrozetes sp.	4.0	0	0	4.0	1.4	0	4.0	0	4.0	1.1
P. Porifera										
Cl. Demospongiliidae										
O. Haplosclerida										
F. Spongillidae	3500	5800	4100			10000	11000	3800		
P. Plathelmynthes										
C. Turbellaria										
O. Tricladida										
F. Dugesiidae										
unknown specimen										
F. Planaridae										
unknown specimen	4.0	8.0	0			0	16	0		
O. Prolecithophora										
F. Plagiostomidae										
Hydrolimax sp.										
P. Arthropoda										
Cl. Brachiopoda										
O. Cladocera										
F. Chydoridae	0	4.0	0			0	8.0	0		
F: Cyclopidae	4.0	4.0	0			0	0	4.0		
O: Harpacticoida	12	16	0			12	16	68		
Cl: OSTRACODA										
O: Podocopa	110	130	12			12	160	84		
F. Bosminidae				280	100				350	100
F. Daphnidae										
F. Macrothricidae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC5**					**BC6**				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			39	25	25		
Arrenurus sp.	0	4.0	0	4.0	0.86	2.5	0	0	2.5	0.23
F. Hygrobatidae										
Hygrobate s sp.						5.1	0	0	5.1	0.46
F. Hydrodromidae										
Hydrodroma sp.						2.5	0	0	2.5	0.23
F. Pionidae										
Sf. Tiphysinae										
Neotiphys sp.						7.6	0	0	7.6	0.69
F. Limnesiidae										
Sf. Limnesiinae										
Limnesia sp.										
F. Mideopsidae										
Sf. Mideopsinae										
Mideopsis sp.										
F. Oxidae										
Sf. Oxinae										
Frontipoda sp.										
Oxus sp.										
F. Unionicolidae										
Sf. Unionicolinae										
Uninonicola sp.	0	4.0	0	4.0	0.86					
unknown specimen										
O.Oribati										
F. Hydrozetidae										
Hydrozetes sp.						13	0	8.0	21	1.9
P. Porifera										
Cl. Demospongiliidae										
O. Haplosclerida										
F. Spongillidae	4600	4700	8500			15000	6500	13000		
P. Plathelmynthes										
C. Turbellaria										
O. Tricladida										
F. Dugesiidae										
unknown specimen	4.0	0	8.0							
F. Planaridae										
unknown specimen	0	0	0			5.1	0	0		
O. Prolecithophora										
F. Plagiostomidae										
Hydrolimax sp.	0	0	0							
P. Arthropoda										
Cl. Brachiopoda										
O. Cladocera										
F. Chydoridae	4.0	0	8.0			0	4.0	4.0		
F: Cyclopidae	4.0	0	8.0			0	0	8.0		
O: Harpacticoida	0	0	12			87	56	32		
Cl: OSTRACODA										
O: Podocopa	360	480	520			400	100	150		
F. Bosminidae	0	0	0	460	100				1100	100
F. Daphnidae	0	0	0							
F. Macrothricidae	4.0	0	4.0							

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	BC7					BC8				
Replicate #	1	2	3	Total	rel. abund. (%)	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25			25	25	25		
Arrenurus sp.	0	4.0	0	4.0	1.2	4.0	0	0	4.0	1.3
F. Hygrobatidae										
Hygrobate s sp.										
F. Hydrodromidae										
Hydrodroma sp.										
F. Pionidae										
Sf. Tiphysinae										
Neotiphys sp.	0	4.0	0	4.0	1.2					
F. Limnesiidae										
Sf. Limnesiinae										
Limnesia sp.										
F. Mideopsidae										
Sf. Mideopsinae										
Mideopsis sp.										
F. Oxidae										
Sf. Oxinae										
Frontipoda sp.										
Oxus sp.										
F. Unionicolidae										
Sf. Unionicolinae										
Uninonicola sp.										
unknown specimen										
O.Oribati										
F. Hydrozetidae										
Hydrozetes sp.	8.0	0	4.0	12	3.7					
P. Porifera										
Cl. Demospongiliidae										
O. Haplosclerida										
F. Spongillidae	23000	34000	13000			42000	50000	46000	140000	
P. Plathelmynthes										
C. Turbellaria										
O. Tricladida										
F. Dugesiidae										
unknown specimen	4.0	0	0							
F. Planaridae										
unknown specimen										
O. Prolecithophora										
F. Plagiostomidae										
Hydrolimax sp.										
P. Arthropoda										
Cl. Brachiopoda										
O. Cladocera										
F. Chydoridae						12	0	0	12	
F: Cyclopidae	0	4.0	0							
O: Harpacticoida	28	36	280							
Cl: OSTRACODA										
O: Podocopa	16	28	20			24	8.0	0	32	
F. Bosminidae				330	100					
F. Daphnidae										
F. Macrothricidae										

Table D-III-8: Benthic Invertebrate Species in Kingston Inner Harbour Sediment Samples (cont'd)

TAXA	**BC9**				
Replicate #	1	2	3	Total	rel. abund. (%)
# of cells sorted	25	25	25		
Arrenurus sp.		4.0	0	4.0	0.93
F. Hygrobatidae					
Hygrobate s sp.					
F. Hydrodromidae					
Hydrodroma sp.					
F. Pionidae					
Sf. Tiphysinae					
Neotiphys sp.		0	4.0	4.0	0.93
F. Limnesiidae					
Sf. Limnesiinae					
Limnesia sp.					
F. Mideopsidae					
Sf. Mideopsinae					
Mideopsis sp.					
F. Oxidae					
Sf. Oxinae					
Frontipoda sp.		4.0	0	4.0	0.93
Oxus sp.					
F. Unionicolidae					
Sf. Unionicolinae					
Uninonicola sp.					
unknown specimen					
O.Oribati					
F. Hydrozetidae					
Hydrozetes sp.					
P. Porifera					
Cl. Demospongiliidae					
O. Haplosclerida					
F. Spongillidae	34000	39000	39000		
P. Plathelmynthes					
C. Turbellaria					
O. Tricladida					
F. Dugesiidae					
unknown specimen		0	0		
F. Planaridae					
unknown specimen		0	0		
O. Prolecithophora					
F. Plagiostomidae					
Hydrolimax sp.		0	0		
P. Arthropoda					
Cl. Brachiopoda					
O. Cladocera					
F. Chydoridae	8.0	0	0		
F: Cyclopidae		0	4.0		
O: Harpacticoida		4.0	0		
Cl: OSTRACODA					
O: Podocopa	260	170	200		
F. Bosminidae		4.0	0	430	100
F. Daphnidae		0	0		
F. Macrothricidae		0	0		

Table D-IV-1: Concentrations of Inorganic Elements and PCBs in Kingston Inner Harbour Water Samples at Reference Stations

Year	Sample ID	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb	PCB Total
		Easting	Northing	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppb]
1. ESG, 2002										
2002	FF4	382230	4901590	0.005	<0.01	0.02	<0.005	<0.003	<0.01	<0.02
2. Tinney, 2006										
2004	04-24273	383091	4900458	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
2004	04-24275	383091	4900458							<0.02
2004	04-24287	383017	4901912							<0.02
2004	04-24288	383017	4901912	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
2004	04-24292	382154	4901536							<0.02
2004	04-24293	382154	4901536	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
2005	05-30030	383328	4902972							<0.02
2005	05-30033	383328	4902972	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
3. ESG 2009										
2009	09-25659	382008	4901789	<0.005	<0.01	<0.01	<0.005	<0.003		
2009	09-25660	382008	4901789	<0.005	<0.01	<0.01	<0.005	<0.003		

Table D-IV-2: PAH Concentrations in Kingston Inner Harbour Water Samples at Reference Stations

Date	Sample ID	Easting	Northing	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(a)pyrene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene	Total PAH
				[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
1. ESG, 2002																				
2002	FF4	382230	4901590	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
2. Tinney, 2006																				
2004	04-24274	383091	4900458	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	<2.0
2004	04-24285	383017	4901912	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	<2.0
2004	04-24291	382154	4901536	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	<2.0
2005	05-30032	383328	4902972	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	<10

Table D-IV-3: Concentrations of Inorganic Elements (Total and Dissolved) in Kingston Inner Harbour Water Samples at APEC Stations

Year	Sample ID	Report Locator	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb
			Easting	Northing	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Total Elements										
1 ESG 2002										
2002	FF6				<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2. Tinney, 2006										
2004	04-24243	ERA1	382500	4899082	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24248	ERA2	382567	4899317	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24251	ERA3	382622	4899477	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24257	ERA4	382388	4899535	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24261	ERA5	382133	4900254	0.005	<0.01	<0.01	0.008	<0.003	<0.01
2004	04-24267	ERA6	383123	4900238	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24280	ERA8	382851	4901111	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2004	04-24281	ERA8	382851	4901111	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
2005	05-30027	ERA11	382036	4900455	<0.005	<0.01	<0.01	0.006	<0.003	<0.01
2005	05-30048	ERA12	381971	4900066	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01
3. MOE Benoit, 2010										
2006	GL063054	ref CAT 24	381744	4901241	0.01	0.061	0.083	0.004		
2006	GL063067	ref CAT-24	381744	4901241	0.0023	0.00092	0.0065	0.002		
2006	GL063056	ref CAT-22	382074	4900657	0.0006	0.00082	0.0021	0.002		
2006	GL063069	ref CAT-22	382074	4900657	0.0007	0.00076	0.0028	0.002		
2006	GL063052	ref CAT-2	381867	4899939	0.002	0.00027	0.0011	0.001		
2006	GL063065	ref CAT-2	381867	4899939	0.0007	0.00051	0.002	0.001		
2006	GL063057	ref 06 15 083	381836	4900494	0.0038	0.0035	0.0067	0.004		
2006	GL063070	ref 06 15 083	381836	4900494	0.0042	0.0099	0.021	0.012		
2006	GL063058	ref CAT-25	381796	4900464	0.0044	0.0006	0.018	0.003		
2006	GL063071	ref CAT-25	381796	4900464	0.003	0.036	0.49	0.032		
2006	GL063059	ref CAT-15	381879	4899743	0.0054	0.00085	0.0056	0.001		
2006	GL063072	ref CAT-15	381879	4899743	0.0006	0.00024	0.0016	0.001		
4. ESG 2009										
2009	09-25656	location 1	381866	4900259	0.035	0.0103	0.064	0.061	<0.003	
2009	09-25657	location 1	381866	4900259	0.027	0.019	0.18	0.012	<0.003	
2009	09-25681	location 2	381849	4900525	0.1	0.3	0.31	4.2	<0.003	
2009	09-25682	location 2	381849	4900525	0.21	1.1	0.61	22	<0.003	
2009	09-25684	location 3	381848	4900481	0.052	0.14	0.18	1.6	<0.003	
2009	09-25685	location 3	381848	4900481	0.041	0.23	5.3	0.83	<0.003	
2009	09-25687	location 4&5	381828	4900388	0.0051	<0.010	0.019	0.04	<0.003	
2009	09-25688	location 4&5	381828	4900388	0.014	0.0203	0.036	0.17	<0.003	
Dissolved Elements										
4. ESG 2009										
2009	09-25656	location 1	381866	4900259	<0.005	<0.010	0.012	<0.005	<0.003	
2009	09-25657	location 1	381866	4900259	0.0064	<0.010	0.052	<0.005	<0.003	
2009	09-25681	location 2	381849	4900525	<0.005	<0.010	0.016	<0.005	<0.003	
2009	09-25682	location 2	381849	4900525	<0.005	<0.010	0.027	<0.005	<0.003	
2009	09-25684	location 3	381848	4900481	<0.005	<0.010	0.14	<0.005	<0.003	
2009	09-25685	location 3	381848	4900481	<0.005	<0.010	1.9	<0.005	<0.003	
2009	09-25687	location 4&5	381828	4900388	<0.005	<0.010	<0.010	<0.005	<0.003	
2009	09-25688	location 4&5	381828	4900388	<0.005	<0.010	0.0146	<0.005	<0.003	

Table D-IV-4: PCB Concentrations in Kingston Inner Harbour Water Samples at APEC Stations

Year	Sample ID	Report Locator	UTM, NAD 84		Arocolor 1254	Aroclor 1260	PCB Total RMC Lab (Aroclor 1254+1260 plus 1242 where reported	SUM PCB Congeners
			Easting	Northing	µg/L [ppb]	µg/L [ppb]	µg/L [ppb]	µg/L [ppb]
1 ESG 2002								
2002	FF6		382136	4900380	<0.02	<0.02	<0.02	
2. Tinney, 2006								
2004	04-24240	ERA1	382500	4899082	<0.02	<0.02	<0.02	
2004	04-24245	ERA2	382567	4899317	<0.02	<0.02	<0.02	
2004	04-24252	ERA3	382622	4899477	<0.02	<0.02	<0.02	
2004	04-24258	ERA4	382388	4899535	<0.02	<0.02	<0.02	
2004	04-24262	ERA5	382133	4900254	<0.02	<0.02	<0.02	
2004	04-24265	ERA6	383123	4900238	<0.02	<0.02	<0.02	
2004	04-24278	ERA8	382851	4901111	<0.02	<0.02	<0.02	
2004	04-24282	ERA8	382851	4901111	<0.02	<0.02	<0.02	
2005	05-30025	ERA11	382036	4900455	<0.02	<0.02	<0.02	
2005	05-30045	ERA12	381971	4900066	<0.02	<0.02	<0.02	
3. MOE Benoit, 2010								
2006	GL063054	ref CAT 24	381744	4901241				0.010
2006	GL063067	ref CAT-24	381744	4901241				0.001
2006	GL063056	ref CAT-22	382074	4900657				0.014
2006	GL063069	ref CAT-22	382074	4900657				0.040
2006	GL063052	ref CAT-2	381867	4899939				0.003
2006	GL063065	ref CAT-2	381867	4899939				0.004
2006	GL063057	ref 06 15 083	381836	4900494				0.010
2006	GL063070	ref 06 15 083	381836	4900494				0.030
2006	GL063058	ref CAT-25	381796	4900464				0.010
2006	GL063071	ref CAT-25	381796	4900464				0.090
2006	GL063059	ref CAT-15	381879	4899743				0.010
2006	GL063072	ref CAT-15	381879	4899743				0.002

Table D-IV-5: PAH Concentrations in Kingston Inner Harbour
Water Samples at APEC Stations

Date	Sample ID	Easting	Northing	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(a)pyrene	Benzo(e)pyrene	Perylene	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	7,12-dimethylbenz(a)anthracene	Benzo(k)fluoranthene	Total PAH
				[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
1. ESG, 2002																							
2002	FF6	382136	4900380	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0			<1.0	<1.0	<1.0		<1.0	<1.0
2. Tinney, 2006																							
2004	04-24241	382500	4899082	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24246	382567	4899317	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24253	382622	4899477	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24256	382388	4899535	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24263	382133	4900254	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24266	383123	4900238	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2004	04-24277	382851	4901111	< 2.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<2.0
2005	05-30028	382036	4900455	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<10
2005	05-30047	381971	4900066	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0			< 1.0	< 1.0	< 1.0		< 1.0	<10
3. MOE, Benoit et al 2010																							
2006	GL063054	381744	4901241					0.056	<0.01	0.1	0.1	0.034	0.052	0.048	<0.001	0.031	<0.01	<0.02	<0.02	<0.02	<0.01	0.036	0.51
2006	GL063067	381744	4901241					0.024	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.15
2006	GL063056	382074	4900657					0.018	<0.01	0.015	0.02	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.16
2006	GL063069	382074	4900657					0.1	<0.01	0.038	0.034	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.28
2006	GL063052	381867	4899939					<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.14
2006	GL063065	381867	4899939					0.032	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.16
2006	GL063057	381836	4900494					0.039	<0.01	0.046	0.067	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.26
2006	GL063070	381836	4900494					0.065	<0.01	0.052	0.064	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.29
2006	GL063058	381796	4900464					<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.14
2006	GL063071	381796	4900464					0.14	<0.01	0.081	0.078	0.022	0.031	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.43
2006	GL063059	381879	4899743					<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.14
2006	GL063072	381879	4899743					0.037	<0.01	0.011	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	0.17

Table D-IV-6: Concentrations of Inorganic Elements in Kingston Inner Harbour Sediments in the Special Management Area: Rowing Club/Emma Martin Park

Year	Location on site	Depth	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb	Hg
		[cm]	Easting	Northing	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
CCME ISQG					*36*	*35*	*123*	*37.3*	*5.9*		*0.17*
CCME PEL					***197***	***91***	***315***	***90***	***17***	*n/a*	***0.49***
Ontario SQG - LEL					**16**	**31**	**120**	**26**	**6.0**	*n/a*	**0.2**
CCME Sediment Quality Guideline										*20*	
*OMOE SCS (soil within 30m of water body)**										**1.0**	
1. Totten Sims Hubicki Associates, 1992											
1992	T10	0.0	381866	4900031	38	***85***	140	800	11		**0.21**
2. MOE Benoit, 2006											
2003	L10A	5.0	381845	4899956	*42*	***94***		***260***	***84***	**7.0**	***1.7***
2003	L10B	15	381845	4899956	*43*	*58*		***150***	***87***	**6.0**	***1.0***
2003	L11A	5.0	381848	4899944	*71*	***330***		***750***	***97***	**11**	***2.7***
2003	L11B	15	381848	4899944	*69*	***250***		***1000***	***130***	**14**	***3.0***
2003	L12A	5.0	381850	4899911	*82*	***230***		***640***	***290***	**14**	***4.6***
2003	L12B	15	381850	4899911	*94*	***310***		***550***	***370***	**16**	***6.7***
2003	L13A	5.0	381848	4899883	*59*	***160***		*83*	***130***	**7.0**	***4.3***
2003	L13B	15	381848	4899883	**30**	*39*		*73*	***30***	**3.0**	***0.7***
2003	L14A	5.0	381854	4899838	***340***	***730***		*65*	***52***	**10**	***8.5***
2003	L14B	15	381854	4899838	*40*	***110***		**31**	***28***	**2.0**	**0.3**
2003	L7A	5.0	381848	4900062	*49*	***190***		***1100***	***51***	**14**	***1.8***
2003	L8A	5.0	381849	4900031	**32**	*55*		***270***	***17***	**4.0**	***0.5***
2003	L9A	5.0	381857	4899996	*120*	***370***		***150***	***480***	*22*	***3.0***
2003	L9B	15	381857	4899996	*39*	***110***		***260***	***120***	**7.0**	***1.7***
2003	RC-1	1.0	381866	4899998	*46*	***120***	**120**	***350***	***71***	*<5.0*	***1.0***
2003	RC-10	1.0	381916	4899802	*56*	***150***	*190*	***850***	**13**	*<5.0*	***0.76***
2003	RC-12	1.0	381884	4899736	*88*	***280***	***330***	***990***	***58***	*<5.0*	***2.6***
2003	RC-13	1.0	381924	4899736	*62*	***190***	*230*	***1100***	***19***	*<5.0*	***1.0***
2003	RC-15	1.0	381914	4899964	*90*	***230***	***400***	***530***	***49***	*<5.0*	***1.3***
2003	RC-16	1.0	381866	4899931	*66*	***180***	*240*	***710***	**16**	*<5.0*	***0.9***
2003	RC-17	1.0	381914	4899899	*60*	***180***	*220*	***1000***	***19***	*<5.0*	***0.9***
2003	RC-18	1.0	381867	4899934	*58*	***190***	*200*	***640***	***56***	*<5.0*	***2.0***
2003	RC-2	1.0	381914	4899998	*49*	***130***	*160*	***770***	**13**	*<5.0*	***0.56***
2003	RC-2	5.0	381914	4899998	*48*	***140***	*160*	***900***	**9.0**	*<5.0*	**0.46**
2003	RC-2	15	381914	4899998	*48*	***160***	*160*	***1300***	**11**	*<5.0*	**0.48**
2003	RC-2	25	381914	4899998	*54*	***240***	*220*	***2600***	**15**	*<5.0*	***0.75***
2003	RC-3	1.0	381867	4899934	*56*	***190***	*200*	***620***	***56***	*<5.0*	***1.5***
2003	RC-4	1.0	381912	4899934	*47*	***130***	*160*	***740***	**12**	*<5.0*	***0.65***
2003	RC-4	5.0	381912	4899934	*49*	***140***	*160*	***930***	**8.0**	*<5.0*	**0.41**
2003	RC-4	15	381912	4899934	*46*	***150***	*150*	***1100***	**6.0**	*<5.0*	**0.37**
2003	RC-4	25	381912	4899934	*47*	***180***	*170*	***1800***	**9.0**	*<5.0*	***0.61***
2003	RC-6	1.0	381867	4899867	*55*	***150***	*200*	***500***	***200***	**7.0**	***1.2***
2003	RC-7	1.0	381914	4899867	*50*	***140***	*170*	***850***	***17***	*<5.0*	***0.5***
2003	RC-7	5.0	381914	4899867	*43*	***140***	*150*	***1000***	**10**	*<5.0*	***0.52***
2003	RC-7	15	381914	4899867	*39*	***110***	**120**	***1000***	**11**	*<5.0*	**0.46**
2003	RC-9	1.0	381875	4899802	*140*	***490***	***430***	***400***	***81***	**5.0**	***3.0***
2003	06 15 0183	5.0	381867	4899898	*55*	***150***	*230*	***670***			
2003	06 15 0184	5.0	381882	4899764	*76*	***250***	*310*	***1000***			
3. Tinney, 2006											
2005	05-17284	22.5	381932	4899911	*50*	***130***	*170*	***1000***			
2005	05-17285	27.5	381932	4899911	*52*	***150***	*190*	***1200***			
2005	05-17286	32.0	381932	4899911	*49*	***160***	*200*	***1300***			

Table D-IV-6: Concentrations of Inorganic Elements in Kingston Inner Harbour Sediments in the Special Management Area: Rowing Club/Emma Martin Park (cont'd)

Year	Location on site	Depth	UTM, NAD 84		Cu	Pb	Zn	Cr	As	Sb	Hg
		[cm]			[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
4. MOE Benoit et al, 2010											
2006	CAT 2	1.5	381867	4899939	*46*	***110***	*180*	***430***	***86***	**2.0**	***1.8***
2006	CAT 3	1.5	381918	4899966	*49*	***110***	*190*	***680***	***22***	*0.7*	***0.6***
2006	CAT 4	1.5	381917	4899936	*36*	*73*	*140*	***500***	**13**	*0.4*	**0.35**
2006	CAT 7	1.5	381914	4899897	*43*	***110***	*190*	***750***	***17***	*0.8*	***0.61***
2006	CAT 8	1.5	381863	4899902	*70*	***220***	*240*	***390***	***740***	*23*	***6.1***
2006	CAT 9	1.5	381872	4899839	*120*	***450***	***440***	***400***	***110***	**2.5**	***3.9***
2006	CAT 10	1.5	381915	4899835	*60*	***170***	*280*	***870***	***32***	*0.9*	***0.89***
2006	CAT 12	1.5	381896	4899805	*95*	***320***	***330***	***1100***	***72***	*0.7*	***2.8***
2006	CAT 13	1.5	381921	4899782	*55*	***170***	*240*	***930***	***24***	*0.2*	***1.1***
2006	CAT 15	1.5	381879	4899743	*100*	***240***	***320***	***500***	***63***	*0.5*	***1.6***
2006	CAT 16	1.5	381928	4899734	*74*	***210***	*250*	***900***	***34***	*0.1*	***1.4***
2006	CAT 17	1.5	381868	4899964	*60*	***190***	*210*	***1100***	***70***	**2.4**	***1.5***
5. Manion, 2007											
2006	C5: 14-15	14.5	381872	4899911							***1.8***
2007	C13: 11-12	11.5	381832	4899682							***2.0***
2007	C13: 20-21	20.5	381832	4899682							***1.8***
2007	C7: 11-12	11.5	381869	4899093							**0.3**
2007	C7: 25-26	25.5	381869	4899093							***0.89***
2007	C8: 16-17	16.5	382059	4899186							**0.25**
2007	C8:27-28	27.5	382059	4899186							**0.28**
2007	C9: 12-13	12.5	381910	4899302							***1.9***
2007	C9: 23-24	23.5	381910	4899302							***2.3***
2007	C9: 26-27	26.5	381910	4899302							***5.9***
2007	RC1: 35-40	37.5	382507	4899119							**0.4**
2007	RC3: 35-40	37.5	382237	4899987							0.004
2007	RC4: 15-20	17.5	381902	4900326							**0.48**
2007	RC4: 30-35	32.5	381902	4900326							***1.0***
2007	RC7: 40-45	42.5	382123	4900523							0.05
2007	C6: 16-17	16.5	381872	4899853							***11***
2006	C6: 17-18	17.5	381872	4899853							***10***
6. ESG, 2008											
2008	08-29900	2.5	381902	4899869	*55*	***280***	***380***	***760***	***32***		
2008	08-42041	2.5	381914	4899874	*45*	***120***	*180*	***650***	***17***		
7. MOE MeHg Scheider Memo 2009											
2009	KING3		381874	4899847	*100*	***510***	***470***	***700***			***2.3***
2009	KING4		381871	4899925	*49*	***120***	*180*	***360***			***1.9***

* OMOE Site Condition Standard for Use within 30m of a Water Body (Agricultural Use)

Table D-IV-7: Mercury (Hg) and PCB Concentrations in Filets of Kingston Inner Harbour Fish Collected from Reference Areas (for HHRA) (wet weight)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Hg [ppm]	PCBs [ppm]
1997	MOE		Perch	fillet	150	45		0.07	
1997	MOE		Perch	fillet	160	58		0.05	
1997	MOE		Perch	fillet	170	58		0.08	
1997	MOE		Perch	fillet	170	67		0.05	
1997	MOE		Perch	fillet	170	67		0.07	
1997	MOE		Perch	fillet	180	64		0.08	
1997	MOE		Perch	fillet	180	65		0.06	
1997	MOE		Perch	fillet	180	72		0.08	
1997	MOE		Perch	fillet	190	93		0.07	
1997	MOE		Perch	fillet	200	110		0.07	
1997	MOE		Perch	fillet	220	140		0.11	
1997	MOE		Perch	fillet	230	160		0.13	
2008	MOE - MeHg report	00FF2991	Perch	unknown	60		2.0	0.03	0.12
2008	MOE - MeHg report	00FF2992	Perch	unknown	60		2.0	0.03	0.07
2008	MOE - MeHg report	00FF2993	Perch	unknown	62		2.0	0.04	0.03
2008	MOE - MeHg report	00FF2994	Perch	unknown	60		6.0	0.04	0.05
2008	MOE - MeHg report	00FF2995	Perch	unknown	59		2.0	0.03	0.06
1997	MOE		Brown Bullhead	fillet	200	120	0.40	0.04	nd
1997	MOE		Brown Bullhead	fillet	300	450	0.60	0.20	nd
1997	MOE		Carp	fillet	570	2600	4.4	0.05	nd
1997	MOE		Carp	fillet	580	2900	4.2	0.05	nd
1997	MOE		Carp	fillet	600	3100	2.2	0.06	nd
1997	MOE		Carp	fillet	670	4200	6.8	0.09	0.040
1997	MOE		Carp	fillet	690	4100	3.7	0.10	nd
1997	MOE		Carp	fillet	700	5500	4.1	0.16	0.060
1997	MOE		Carp	fillet	720	6300	7.2	0.02	0.040
1997	MOE		Carp	fillet	730	6500	7.1	0.10	0.040
1997	MOE		Carp	fillet	760	6500	2.7	0.10	nd
1997	MOE		Carp	fillet	770	7500	6.4	0.05	0.040
1997	MOE		Large-mouth Bass	fillet	220	150	0.60	0.09	nd
1997	MOE		Large-mouth Bass	fillet	270	290	0.30	0.10	nd
1997	MOE		Large-mouth Bass	fillet	270	290	0.50	0.11	nd
1997	MOE		Large-mouth Bass	fillet	280	330	0.50	0.11	nd
1997	MOE		Large-mouth Bass	fillet	340	700	0.40	0.12	nd
1997	MOE		Crappie	fillet	180	89		0.05	nd
1997	MOE		Crappie	fillet	210	150		0.06	nd
1997	MOE		Crappie	fillet	230	170		0.10	nd
1997	MOE		Bluegill	fillet	120	38		0.04	

Table D-IV-7: Mercury (Hg) and PCB Concentrations in Filets of Kingston Inner Harbour Fish Collected from Reference Areas (for HHRA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Hg [ppm]	PCBs [ppm]
1997	MOE		Bluegill	fillet	140	46		0.05	
1997	MOE		Bluegill	fillet	140	54		0.03	
1997	MOE		Bluegill	fillet	150	68		0.03	
1997	MOE		Bluegill	fillet	150	65		0.05	
1997	MOE		Bluegill	fillet	150	69		0.05	
1997	MOE		Bluegill	fillet	150	78		0.03	
1997	MOE		Bluegill	fillet	150	79		0.03	
1997	MOE		Bluegill	fillet	160	93		0.04	
1997	MOE		Bluegill	fillet	180	120		0.06	
1997	MOE		Bluegill	fillet	180	110		0.06	
1997	MOE		Bluegill	fillet	180	120		0.05	
1997	MOE		Seed	fillet	130	49		0.03	
1997	MOE		Seed	fillet	140	67		0.05	
1997	MOE		Seed	fillet	150	77		0.04	
1997	MOE		Seed	fillet	150	72		0.04	
1997	MOE		Seed	fillet	160	91		0.06	
1997	MOE		Seed	fillet	160	89		0.09	
1997	MOE		Seed	fillet	170	100		0.07	
1997	MOE		Seed	fillet	170	110		0.08	
1997	MOE		Seed	fillet	170	100		0.07	
1997	MOE		Seed	fillet	180	120		0.09	

* a measurable trace amount

nd - no measurable response; non-detect

1997 MOE - samples from Colonel By Lake, ref MeHg memo 2009, from Wolfgang Scheider

Table D-IV-8: Mercury (Hg) and PCB Concentrations in Filets of Kingston Inner Harbour Fish Collected from the APEC (for HHRA) (wet weight)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Hg	PCBs
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]
2002	MOE		Perch	fillet	150	38	1.3		0.09	0.06
2002	MOE		Perch	fillet	160	53	1.1		0.10	0.14
2002	MOE		Perch	fillet	170	57	1.9		0.06	0.06
2002	MOE		Perch	fillet	170	59	1.4		0.16	0.04
2002	MOE		Perch	fillet	180	72	0.6		0.09	0.06
2002	MOE		Perch	fillet	180	84	0.3		0.06	0.06
2002	MOE		Perch	fillet	190	75	0.8		0.09	0.06
1999	MOE		Perch	fillet	160	40	0.4		0.14	0.30
1999	MOE		Perch	fillet	170	40	0.5		0.00	0.10
1999	MOE		Perch	fillet	170	57	1.4		0.08	0.10
1999	MOE		Perch	fillet	170	58	0.6		0.07	0.12
1999	MOE		Perch	fillet	180	61	0.5		0.08	0.10
1999	MOE		Perch	fillet	190	81	0.5		0.08	0.08
2008	MOE - MeHg report	00FF2996	Perch	unknown	59		2.2		0.02	0.36
2008	MOE - MeHg report	00FF2997	Perch	unknown	57		2.0		0.03	0.34
2008	MOE - MeHg report	00FF2998	Perch	unknown	57		2.0		0.03	0.34
2008	MOE - MeHg report	00FF2999	Perch	unknown	57		2.0		0.02	0.33
2008	MOE - MeHg report	00FF3000	Perch	unknown	56		2.0		0.03	0.43
2008	MOE - MeHg report	00FF3001	Perch	unknown	57		2.0		0.06	0.43
2008	MOE - MeHg report	00FF3002	Perch	unknown	57		2.0		0.17	0.33
2008	MOE - MeHg report	00FF3003	Perch	unknown	55		2.0		0.05	0.25
2008	MOE - MeHg report	00FF3004	Perch	unknown	57		2.0		0.07	0.46
2008	MOE - MeHg report	00FF3005	Perch	unknown	58		2.0		0.05	0.39
2008	MOE - MeHg report	00FF3006	Perch	unknown	57		2.0		0.02	0.17
2008	MOE - MeHg report	00FF3007	Perch	unknown	57		2.0		0.03	0.20
2008	MOE - MeHg report	00FF3008	Perch	unknown	59		2.0		0.03	0.18
2008	MOE - MeHg report	00FF3009	Perch	unknown	60		2.0		0.03	0.24
2008	MOE - MeHg report	00FF3010	Perch	unknown	60		2.0		0.03	2.7
2002	MOE		Brown Bullhead	fillet	200	100	2.5		0.03*	0.18
2002	MOE		Brown Bullhead	fillet	230	150	3.5		0.03*	0.12
2002	MOE		Brown Bullhead	fillet	240	170	3.0		0.02*	0.08
2002	MOE		Brown Bullhead	fillet	260	210	3.6		0.04*	0.16
2002	MOE		Brown Bullhead	fillet	260	220	3.8		0.03*	0.16
2002	MOE		Brown Bullhead	fillet	260	230	1.8		0.05	0.24
2002	MOE		Brown Bullhead	fillet	270	240	0.9		0.04*	0.10
2002	MOE		Brown Bullhead	fillet	270	240	0.6		0.04*	0.54

Table D-IV-8: Mercury (Hg) and PCB Concentrations in Filets of Kingston Inner Harbour Fish Collected from the APEC (for HHRA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Hg	PCBs
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]
2002	MOE		Brown Bullhead	fillet	280	300	0.1		0.03*	0.04
2002	MOE		Brown Bullhead	fillet	280	260	1.5		0.03*	0.16
2002	MOE		Brown Bullhead	fillet	310	420	1.9		0.03*	0.26
1999	MOE		Brown Bullhead	fillet	210	120	1.0		0.03*	0.14
1999	MOE		Brown Bullhead	fillet	220	130	1.5		0.02*	0.14
1999	MOE		Brown Bullhead	fillet	240	200	3.9		0.03*	0.28
1999	MOE		Brown Bullhead	fillet	240	170	2.2		0.02*	0.36
1999	MOE		Brown Bullhead	fillet	250	170	1.7		0.03*	0.24
1999	MOE		Brown Bullhead	fillet	250	200	1.0		0.04*	0.08
1999	MOE		Brown Bullhead	fillet	250	210	1.5		0.04*	0.22
1999	MOE		Brown Bullhead	fillet	260	220	0.9		nd	0.14
1999	MOE		Brown Bullhead	fillet	260	200	0.8		0.03*	0.22
1999	MOE		Brown Bullhead	fillet	260	230	1.6		0.03*	0.26
2002	MOE		Pike	fillet	300	170	0.1		0.11	0.06
2002	MOE		Pike	fillet	340	200	0.4		0.09	0.10
2002	MOE		Pike	fillet	380	260	0.2		0.09	0.12
2002	MOE		Pike	fillet	510	530	0.4		0.40	1.40
2002	MOE		Pike	fillet	560	650	0.3		0.50	0.54
1999	MOE		Pike	fillet	330	200	0.3		0.09	0.16
1999	MOE		Pike	fillet	360	240	0.2		0.09	0.12
1999	MOE		Pike	fillet	380	300	0.2		0.08	0.12
1999	MOE		Pike	fillet	380	350	0.3		0.08	0.12
1999	MOE		Pike	fillet	410	450	0.7		0.13	0.10
1999	MOE		Pike	fillet	430	390	0.6		0.14	0.06
1999	MOE		Pike	fillet	480	660	0.7		0.12	0.14
1999	MOE		Pike	fillet	570	1100	0.4		0.29	0.28
1999	MOE		Pike	fillet	570	1100	0.3		0.23	0.18
1999	MOE		Pike	fillet	710	2200	0.2		0.31	0.14
2002	MOE		Carp	fillet	410	1200	1.4		0.02*	0.04
2002	MOE		Carp	fillet	490	1700	0.7		0.03*	0.04
2002	MOE		Carp	fillet	580	3400	2.7		0.06	0.06
2002	MOE		Carp	fillet	590	3000	3.4		0.05	0.14
2002	MOE		Carp	fillet	710	5000	5.6		0.13	0.26

Table D-IV-8: Mercury (Hg) and PCB Concentrations in Filets of Kingston Inner Harbour Fish Collected from the APEC (for HHRA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Hg	PCBs
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]
2002	MOE		Carp	fillet	730	6900	3.3		0.11	0.32
2002	MOE		Carp	fillet	730	5300	5.1		0.23	1.50
2002	MOE		Carp	fillet	840	9200	5.9		0.16	0.90
1999	MOE		Carp	fillet	250	300	0.4		0.04*	0.08
1999	MOE		Carp	fillet	590	3300	3.0		0.07	0.30
1999	MOE		Carp	fillet	620	3700	2.9		0.12	0.46
1999	MOE		Carp	fillet	640	5100	5.0		0.13	0.28
1999	MOE		Carp	fillet	670	4200	3.5		0.11	0.48
1999	MOE		Carp	fillet	670	5200	7.4		0.07	0.52
1999	MOE		Carp	fillet	710	4000	7.5		0.11	1.90
1999	MOE		Carp	fillet	740	6900	2.7		0.08	0.56
1999	MOE		Carp	fillet	740	6600	7.0		0.20	1.60
1999	MOE		Carp	fillet	760	7500	9.0		0.22	0.86
2002	MOE		Bluegill	fillet	160	78	1.2		0.12	0.10
2002	MOE		Bluegill	fillet	160	88	1.0		0.05	0.06
2002	MOE		Bluegill	fillet	160	91	1.5		0.03*	0.04
2002	MOE		Bluegill	fillet	170	99	0.9		0.03*	0.04
2002	MOE		Bluegill	fillet	170	97	1.6		0.04*	0.04
2002	MOE		Largemouth Bass	fillet	180	91	0.3		0.08	0.08
2002	MOE		Largemouth Bass	fillet	210	140	0.3		0.08	0.08
2002	MOE		Largemouth Bass	fillet	230	180	0.2		0.10	0.06
2002	MOE		Largemouth Bass	fillet	350	720	0.2		0.12	0.08
1999	MOE		Largemouth Bass	fillet	210	150	0.5		0.03*	0.06
1999	MOE		Largemouth Bass	fillet	220	180	0.4		0.04*	0.04
1999	MOE		Largemouth Bass	fillet	270	350	0.4		0.07	0.08
1999	MOE		Largemouth Bass	fillet	390	1000	0.5		0.21	0.14
1999	MOE		Largemouth Bass	fillet	400	1200	5.8		0.22	0.12
2010	Golder	MF1-Fish 1	Pike	fillet			0.5	79	0.24	<0.03
2010	Golder	MF1-Fish 2	Pike	fillet			0.3	78	0.11	<0.03
2010	Golder	NF2-Fish 1	Perch	fillet			0.3		0.19	0.080
2010	Golder	NF2-Fish 2	Perch	fillet			0.4		0.06	<0.03
2010	Golder	NF2-Fish 3	Perch	fillet			1.4		0.16	0.080
2010	Golder	FF1-Fish 1	Perch	fillet			0.4		0.07	<0.03
2010	Golder	FF1-Fish 2	Perch	fillet			1.2		0.06	<0.03
2010	Golder	FF1-Fish 3	Perch	fillet			0.8		0.05	<0.03

* a measurable trace amount
nd - no measurable response; non-detect
No conversions from whole body to fillet were attempted.

Table D-IV-9: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from Reference Areas (for ERA) (wet weight)

Year	Sampler	Sample ID	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Hg	PCBs	Hg	PCBs
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	ppm	ppm
											Whole Body Concentrations	
1997	MOE		Perch	fillet	150	45			0.07		**0.049**	
1997	MOE		Perch	fillet	160	58			0.05		**0.036**	
1997	MOE		Perch	fillet	170	58			0.08		**0.055**	
1997	MOE		Perch	fillet	170	67			0.05		**0.036**	
1997	MOE		Perch	fillet	170	67			0.07		**0.049**	
1997	MOE		Perch	fillet	180	64			0.08		**0.055**	
1997	MOE		Perch	fillet	180	65			0.06		**0.043**	
1997	MOE		Perch	fillet	180	72			0.08		**0.055**	
1997	MOE		Perch	fillet	190	93			0.07		**0.049**	
1997	MOE		Perch	fillet	200	110			0.07		**0.049**	
1997	MOE		Perch	fillet	220	140			0.11		**0.073**	
1997	MOE		Perch	fillet	230	160			0.13		**0.085**	
2008	MOE - MeHg report	00FF2991	Perch	unknown	60		2.0		0.03	0.12	**0.03**	**0.12**
2008	MOE - MeHg report	00FF2992	Perch	unknown	60		2.0		0.03	0.073	**0.03**	**0.073**
2008	MOE - MeHg report	00FF2993	Perch	unknown	62		2.0		0.04	0.031	**0.04**	**0.031**
2008	MOE - MeHg report	00FF2994	Perch	unknown	60		6.0		0.04	0.054	**0.04**	**0.054**
2008	MOE - MeHg report	00FF2995	Perch	unknown	59		2.0		0.03	0.064	**0.03**	**0.064**
2009	ESG	09-07700	Perch	whole	210	140	5.0	72		0.037		**0.037**
2009	ESG	09-07778	Perch	whole	150	40	0.8	74		0.045		**0.045**
2009	ESG	09-07784	Perch	whole	150	48	2.0	42		0.017		**0.017**
1997	MOE		Brown Bullhead	fillet	200	120	0.4		0.04*	nd	**0.03**	**0.022**
1997	MOE		Brown Bullhead	fillet	300	450	0.6		0.2	nd	**0.13**	**0.022**
2009	ESG	09-07676	Brown Bullhead	whole	250	220	2.5	70.1		<0.007		**<0.007**
2009	ESG	09-07685	Brown Bullhead	whole	260	300	15	73.1		<0.007		**<0.007**

Table D-IV-9: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from Reference Areas (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample ID	Fish Type	Part Analyzed	Total Length	Total Body Weight	Lipid	Moisture	Hg	PCBs	Hg	PCBs
					[mm]	[g]	[%]	[%]	[ppm]	[ppm]	ppm	ppm
2009	ESG	09-07739	Brown Bullhead	whole	260	230	8.8	77.5		<0.006		**<0.006**
2009	ESG	09-07667	Northern Pike	fillet	680	1725	2.9	73		0.15		**0.15**
2009	ESG	09-07670	Northern Pike	fillet	469	585	17	75		0.06		**0.06**
2009	ESG	09-07831	Northern Pike	whole	390	350	1.3	74.6		0.028		**0.028**
1997	MOE		Carp	fillet	570	2600	4.4		0.05	nd	**0.036**	**0.016**
1997	MOE		Carp	fillet	580	2900	4.2		0.05	nd	**0.036**	**0.016**
1997	MOE		Carp	fillet	600	3100	2.2		0.06	nd	**0.043**	**0.016**
1997	MOE		Carp	fillet	670	4200	6.8		0.09	0.04	**0.061**	**0.064**
1997	MOE		Carp	fillet	690	4100	3.7		0.1	nd	**0.067**	**0.016**
1997	MOE		Carp	fillet	700	5500	4.1		0.16	0.06	**0.10**	**0.097**
1997	MOE		Carp	fillet	720	6300	7.2		0.02*	0.04	**0.016**	**0.064**
1997	MOE		Carp	fillet	730	6500	7.1		0.1	0.04	**0.067**	**0.064**
1997	MOE		Carp	fillet	760	6500	2.7		0.1	nd	**0.067**	**0.016**
1997	MOE		Carp	fillet	770	7500	6.4		0.05	0.04	**0.036**	**0.064**
1997	MOE		Large-mouth Bass	fillet	220	150	0.6		0.09	nd	**0.061**	**0.01**
1997	MOE		Large-mouth Bass	fillet	270	290	0.3		0.1	nd	**0.067**	**0.01**
1997	MOE		Large-mouth Bass	fillet	270	290	0.5		0.11	nd	**0.073**	**0.01**
1997	MOE		Large-mouth Bass	fillet	280	330	0.5		0.11	nd	**0.073**	**0.01**

Table D-IV-9: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from Reference Areas (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample ID	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
1997	MOE		Large-mouth Bass	fillet	340	700	0.4		0.12	nd	**0.079**	**0.01**
1997	MOE		Black Crappie	fillet	180	89			0.05	nd	**0.036**	**0.01**
1997	MOE		Black Crappie	fillet	210	150			0.06	nd	**0.043**	**0.01**
1997	MOE		Black Crappie	fillet	230	170			0.1	nd	**0.067**	**0.01**
1997	MOE		Bluegill	fillet	120	38			0.04*		**0.03**	
1997	MOE		Bluegill	fillet	140	46			0.05		**0.036**	
1997	MOE		Bluegill	fillet	140	54			0.03*		**0.02**	
1997	MOE		Bluegill	fillet	150	68			0.03*		**0.02**	
1997	MOE		Bluegill	fillet	150	65			0.05		**0.04**	
1997	MOE		Bluegill	fillet	150	69			0.05		**0.04**	
1997	MOE		Bluegill	fillet	150	78			0.03*		**0.02**	
1997	MOE		Bluegill	fillet	150	79			0.03*		**0.023**	
1997	MOE		Bluegill	fillet	160	93			0.04*		**0.03**	
1997	MOE		Bluegill	fillet	180	120			0.06		**0.043**	
1997	MOE		Bluegill	fillet	180	110			0.06		**0.043**	
1997	MOE		Bluegill	fillet	180	120			0.05		**0.036**	
1997	MOE		Pumpkin Seed	fillet	130	49			0.03*		**0.023**	
1997	MOE		Pumpkin Seed	fillet	140	67			0.05		**0.036**	
1997	MOE		Pumpkin Seed	fillet	150	77			0.04*		**0.03**	
1997	MOE		Pumpkin Seed	fillet	150	72			0.04*		**0.03**	
1997	MOE		Pumpkin Seed	fillet	160	91			0.06		**0.043**	

Table D-IV-9: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from Reference Areas (for ERA) (wet weight) (cont'd)

Year	**Sampler**	**Sample ID**	**Fish Type**	**Part Analyzed**	**Total Length [mm]**	**Total Body Weight [g]**	**Lipid [%]**	**Moisture [%]**	**Hg [ppm]**	**PCBs [ppm]**	**Hg ppm**	**PCBs ppm**
1997	MOE		Pumpkin Seed	fillet	160	89			0.09		**0.061**	
1997	MOE		Pumpkin Seed	fillet	170	100			0.07		**0.049**	
1997	MOE		Pumpkin Seed	fillet	170	110			0.08		**0.055**	
1997	MOE		Pumpkin Seed	fillet	170	100			0.07		**0.049**	
1997	MOE		Pumpkin Seed	fillet	180	120			0.09		**0.061**	

1. * a measurable trace amount

2. nd - no measurable response; non-detect

3. Blue highlighted cells indicate values that were used in the comparison to fish tissue residue toxicity thresholds, but not in estimated daily intake (EDI) exposure dose calculations for higher trophic level ecological receptors in the ERA

4. 1997 MOE - samples from Colonel By Lake, ref MeHg memo 2009, from Wolfgang Scheider

5. Golder samples (Golder 2011) are not included because the fish were collected N of Belle Island, not the same background location that we used.

6. For conversion and stats, assumed a detection limit of 0.01, based on what appeared to be detectable.

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
											Whole Body Concentrations	
2002	MOE		Perch	fillet	150	38	1.3		0.09	0.06	**0.061**	**0.33**
2002	MOE		Perch	fillet	160	53	1.1		0.1	0.14	**0.067**	**0.77**
2002	MOE		Perch	fillet	170	57	1.9		0.06	0.06	**0.043**	**0.33**
2002	MOE		Perch	fillet	170	59	1.4		0.16	0.04	**0.1**	**0.22**
2002	MOE		Perch	fillet	180	72	0.6		0.09	0.06	**0.061**	**0.33**
2002	MOE		Perch	fillet	180	84	0.3		0.06	0.06	**0.043**	**0.33**
2002	MOE		Perch	fillet	190	75	0.8		0.09	0.06	**0.061**	**0.33**
1999	MOE		Perch	fillet	160	40	0.4		0.14	0.3	**0.091**	**1.65**
1999	MOE		Perch	fillet	170	40	0.5		0	0.1	**0.0085**	**0.55**
1999	MOE		Perch	fillet	170	57	1.4		0.08	0.1	**0.055**	**0.55**
1999	MOE		Perch	fillet	170	58	0.6		0.07	0.12	**0.049**	**0.66**
1999	MOE		Perch	fillet	180	61	0.5		0.08	0.1	**0.055**	**0.55**
1999	MOE		Perch	fillet	190	81	0.5		0.08	0.08	**0.055**	**0.44**
2008	MOE - MeHg report	00FF2996	Perch	unknown	59		2.2		0.02	0.36	**0.02**	**0.36**
2008	MOE - MeHg report	00FF2997	Perch	unknown	57		2.0		0.03	0.34	**0.03**	**0.34**
2008	MOE - MeHg report	00FF2998	Perch	unknown	57		2.0		0.03	0.34	**0.03**	**0.34**
2008	MOE - MeHg report	00FF2999	Perch	unknown	57		2.0		0.02	0.33	**0.02**	**0.33**
2008	MOE - MeHg report	00FF3000	Perch	unknown	56		2.0		0.03	0.43	**0.03**	**0.43**
2008	MOE - MeHg report	00FF3001	Perch	unknown	57		2.0		0.06	0.43	**0.06**	**0.43**
2008	MOE - MeHg report	00FF3002	Perch	unknown	57		2.0		0.17	0.33	**0.17**	**0.33**
2008	MOE - MeHg report	00FF3003	Perch	unknown	55		2.0		0.05	0.25	**0.05**	**0.25**
2008	MOE - MeHg report	00FF3004	Perch	unknown	57		2.0		0.07	0.46	**0.07**	**0.46**
2008	MOE - MeHg report	00FF3005	Perch	unknown	58		2.0		0.05	0.39	**0.05**	**0.39**
2008	MOE - MeHg report	00FF3006	Perch	unknown	57		2.0		0.02	0.17	**0.02**	**0.17**
2008	MOE - MeHg report	00FF3007	Perch	unknown	57		2.0		0.03	0.2	**0.03**	**0.2**
2008	MOE - MeHg report	00FF3008	Perch	unknown	59		2.0		0.03	0.18	**0.03**	**0.18**
2008	MOE - MeHg report	00FF3009	Perch	unknown	60		2.0		0.03	0.24	**0.03**	**0.24**
2008	MOE - MeHg report	00FF3010	Perch	unknown	60		2.0		0.03	2.7	**0.03**	**2.7**

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
2009	ESG	09-07646	Perch	whole	190	77	9.6	71		0.39		**0.39**
2009	ESG	09-07649	Perch	whole	130	27	1.9	67		0.62		**0.62**
2009	ESG	09-07652	Perch	whole	160	43	9.1	67		0.27		**0.27**
2009	ESG	09-07826	Perch	whole	130	27	5.0	74		0.02		**0.02**
2009	ESG	09-07879	Perch	whole	150	36	1.6	73		0.27		**0.27**
2002	MOE		Brown Bullhead	fillet	200	100	2.5		0.03*	0.18	**0.023**	**0.4**
2002	MOE		Brown Bullhead	fillet	230	150	3.5		0.03*	0.12	**0.023**	**0.26**
2002	MOE		Brown Bullhead	fillet	240	170	3		0.02*	0.08	**0.016**	**0.18**
2002	MOE		Brown Bullhead	fillet	260	210	3.6		0.040*	0.16	**0.03**	**0.35**
2002	MOE		Brown Bullhead	fillet	260	220	3.8		0.03*	0.16	**0.023**	**0.35**
2002	MOE		Brown Bullhead	fillet	260	230	1.8		0.05	0.24	**0.036**	**0.53**
2002	MOE		Brown Bullhead	fillet	270	240	0.9		0.040*	0.1	**0.03**	**0.22**
2002	MOE		Brown Bullhead	fillet	270	240	0.6		0.040*	0.54	**0.03**	**1.2**
2002	MOE		Brown Bullhead	fillet	280	300	0.1		0.03*	0.04	**0.023**	**0.088**
2002	MOE		Brown Bullhead	fillet	280	260	1.5		0.03*	0.16	**0.023**	**0.35**
2002	MOE		Brown Bullhead	fillet	310	420	1.9		0.03*	0.26	**0.023**	**0.57**
1999	MOE		Brown Bullhead	fillet	210	120	1.0		0.03*	0.14	**0.023**	**0.31**
1999	MOE		Brown Bullhead	fillet	220	130	1.5		0.02*	0.14	**0.016**	**0.31**
1999	MOE		Brown Bullhead	fillet	240	200	3.9		0.03*	0.28	**0.023**	**0.62**

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
1999	MOE		Brown Bullhead	fillet	240	170	2.2		0.02*	0.36	**0.016**	**0.79**
1999	MOE		Brown Bullhead	fillet	250	170	1.7		0.03*	0.24	**0.023**	**0.53**
1999	MOE		Brown Bullhead	fillet	250	200	1.0		0.04*	0.08	**0.03**	**0.18**
1999	MOE		Brown Bullhead	fillet	250	210	1.5		0.04*	0.22	**0.03**	**0.48**
1999	MOE		Brown Bullhead	fillet	260	220	0.9		nd	0.14	**0.01**	**0.31**
1999	MOE		Brown Bullhead	fillet	260	200	0.8		0.03*	0.22	**0.02**	**0.48**
1999	MOE		Brown Bullhead	fillet	260	230	1.6		0.03*	0.26	**0.02**	**0.57**
2009	ESG	09-07703	Brown Bullhead	whole	240	210	11	72		0.78		**0.78**
2009	ESG	09-07721	Brown Bullhead	whole	320	420	3.7	75		0.18		**0.18**
2009	ESG	09-07736	Brown Bullhead	whole	230	160	6	75		0.28		**0.28**
2009	ESG	09-07793	Brown Bullhead	whole	230	140	14	70		0.57		**0.57**
2009	ESG	09-07796	Brown Bullhead	whole	330	440	14	73		0.35		**0.35**
2002	MOE		Pike	fillet	300	170	0.1		0.11	0.06	**0.073**	**0.25**
2002	MOE		Pike	fillet	340	200	0.4		0.09	0.1	**0.061**	**0.41**
2002	MOE		Pike	fillet	380	260	0.2		0.09	0.12	**0.061**	**0.49**
2002	MOE		Pike	fillet	510	530	0.4		0.4	1.4	**0.23**	**5.7**
2002	MOE		Pike	fillet	560	650	0.3		0.5	0.54	**0.29**	**2.2**
1999	MOE		Pike	fillet	330	200	0.3		0.09	0.16	**0.061**	**0.66**
1999	MOE		Pike	fillet	360	240	0.2		0.09	0.12	**0.061**	**0.49**
1999	MOE		Pike	fillet	380	300	0.2		0.08	0.12	**0.055**	**0.49**
1999	MOE		Pike	fillet	380	350	0.3		0.08	0.12	**0.055**	**0.49**

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
1999	MOE		Pike	fillet	410	450	0.7		0.13	0.1	**0.085**	**0.41**
1999	MOE		Pike	fillet	430	390	0.6		0.14	0.06	**0.091**	**0.25**
1999	MOE		Pike	fillet	480	660	0.7		0.12	0.14	**0.079**	**0.57**
1999	MOE		Pike	fillet	570	1100	0.4		0.29	0.28	**0.18**	**1.1**
1999	MOE		Pike	fillet	570	1100	0.3		0.23	0.18	**0.14**	**0.74**
1999	MOE		Pike	fillet	710	2200	0.2		0.31	0.14	**0.19**	**0.57**
2009	ESG	09-07802	Pike	whole	450	500	0.12	76		0.23		**0.23**
2009	ESG	09-07805	Pike	whole	400	390	0.8	75		0.36		**0.36**
2009	ESG	09-07811	Pike	whole	460	590	0.12	74		<0.006		**<0.006**
2009	ESG	09-07787	Pike	whole	640	170	5.6	72		0.64		**0.64**
2009	ESG	09-07873	Pike	whole	420	410	2.7	74		0.36		**0.36**
2002	MOE		Carp	fillet	410	1200	1.4		0.02*	0.04	**0.016**	**0.032**
2002	MOE		Carp	fillet	490	1700	0.7		0.03*	0.04	**0.023**	**0.048**
2002	MOE		Carp	fillet	580	3400	2.7		0.06	0.06	**0.043**	**0.097**
2002	MOE		Carp	fillet	590	3000	3.4		0.05	0.14	**0.036**	**0.081**
2002	MOE		Carp	fillet	710	5000	5.6		0.13	0.26	**0.085**	**0.21**
2002	MOE		Carp	fillet	730	6900	3.3		0.11	0.32	**0.073**	**0.18**
2002	MOE		Carp	fillet	730	5300	5.1		0.23	1.5	**0.14**	**0.37**
2002	MOE		Carp	fillet	840	9200	5.9		0.16	0.9	**0.1**	**0.26**
1999	MOE		Carp	fillet	250	300	0.4		0.04*	0.08	**0.03**	**0.064**
1999	MOE		Carp	fillet	590	3300	3.0		0.07	0.3	**0.045**	**0.11**
1999	MOE		Carp	fillet	620	3700	2.9		0.12	0.46	**0.079**	**0.19**
1999	MOE		Carp	fillet	640	5100	5.0		0.13	0.28	**0.085**	**0.21**
1999	MOE		Carp	fillet	670	4200	3.5		0.11	0.48	**0.073**	**0.18**
1999	MOE		Carp	fillet	670	5200	7.4		0.07	0.52	**0.049**	**0.11**
1999	MOE		Carp	fillet	710	4000	7.5		0.11	1.9	**0.073**	**0.18**
1999	MOE		Carp	fillet	740	6900	2.7		0.08	0.56	**0.055**	**0.13**
1999	MOE		Carp	fillet	740	6600	7.0		0.2	1.6	**0.13**	**0.32**
1999	MOE		Carp	fillet	760	7500	9.0		0.22	0.86	**0.14**	**0.35**
2002	MOE		Bluegill	fillet	160	78	1.2		0.12	0.1	**0.079**	**0.1**

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
2002	MOE		Bluegill	fillet	160	88	1.0		0.05	0.06	**0.036**	**0.06**
2002	MOE		Bluegill	fillet	160	91	1.5		0.03*	0.04	**0.023**	**0.04**
2002	MOE		Bluegill	fillet	170	99	0.9		0.03*	0.04	**0.023**	**0.04**
2002	MOE		Bluegill	fillet	170	97	1.6		0.04*	0.04	**0.03**	**0.04**
2002	MOE		Largemouth Bass	fillet	180	91	0.3		0.08	0.08	**0.055**	**0.08**
2002	MOE		Largemouth Bass	fillet	210	140	0.3		0.08	0.08	**0.055**	**0.08**
2002	MOE		Largemouth Bass	fillet	230	180	0.2		0.1	0.06	**0.067**	**0.06**
2002	MOE		Largemouth Bass	fillet	350	720	0.2		0.12	0.08	**0.079**	**0.08**
1999	MOE		Largemouth Bass	fillet	210	150	0.5		0.03*	0.06	**0.023**	**0.06**
1999	MOE		Largemouth Bass	fillet	220	180	0.4		0.04*	0.04	**0.03**	**0.04**
1999	MOE		Largemouth Bass	fillet	270	350	0.4		0.07	0.08	**0.049**	**0.08**
1999	MOE		Largemouth Bass	fillet	390	1000	0.5		0.21	0.14	**0.13**	**0.14**
1999	MOE		Largemouth Bass	fillet	400	1200	5.8		0.22	0.12	**0.14**	**0.12**
2010	Golder	MF1-Fish 1	Pike	fillet	500-550	1000-1250	0.5	79	0.24	<0.03	**0.15**	**0.123**
2010	Golder	MF1-Fish 2	Pike	fillet	500-550	1000-1250	0.3	78	0.11	<0.03	**0.073**	**0.12**
2010	Golder	NF2-Fish 1	Perch	fillet	195-240	150-250	0.3		0.19	0.08	**0.12**	**0.33**
2010	Golder	NF2-Fish 2	Perch	fillet	195-240	150-250	0.4		0.059	<0.03	**0.042**	**0.12**
2010	Golder	NF2-Fish 3	Perch	fillet	195-240	150-250	1.4		0.16	0.08	**0.1**	**0.33**
2010	Golder	FF1-Fish 1	Perch	fillet	200-220	175-200	0.4		0.066	<0.03	**0.046**	**0.12**
2010	Golder	FF1-Fish 2	Perch	fillet	200-220	175-200	1.2		0.057	<0.03	**0.041**	**0.12**
2010	Golder	FF1-Fish 3	Perch	fillet	200	200	0.8		0.045	<0.03	**0.033**	**0.12**
2010	Golder	MF1-Fish 1	Pike	whole (reconstituted)	500-550	1000-1250	0.53	78		0.04		**0.04**

Table D-IV-10: Mercury (Hg) and PCB Concentrations in Whole Body Kingston Inner Harbour Fish Collected from the APEC (for ERA) (wet weight) (cont'd)

Year	Sampler	Sample number	Fish Type	Part Analyzed	Total Length [mm]	Total Body Weight [g]	Lipid [%]	Moisture [%]	Hg [ppm]	PCBs [ppm]	Hg ppm	PCBs ppm
2010	Golder	MF1-Fish 2	Pike	whole (reconstituted)	500-550	1000-1250	0.39	78		0.04		**0.04**
2010	Golder	NF2-Fish 1	Perch	whole (reconstituted)	195-240	150-250	0.45			0.13		**0.13**
2010	Golder	NF2-Fish 2	Perch	whole (reconstituted)	195-240	150-250	0.52			0.08		**0.08**
2010	Golder	NF2-Fish 3	Perch	whole (reconstituted)	195-240	150-250	1.22			0.13		**0.13**
2010	Golder	FF1-Fish 1	Perch	whole (reconstituted)	200-220	175-200	0.58			0.04		**0.04**
2010	Golder	FF1-Fish 2	Perch	whole (reconstituted)	200-220	175-200	1.14			0.05		**0.05**
2010	Golder	FF1-Fish 3	Perch	whole (reconstituted)	200	200	0.86			0.04		**0.04**
2010	Golder	FF1-J	Juvenile sunfish	whole	51	2.0						
2010	Golder	MF1-J	Juvenile sunfish	whole	40-50	1-2.5			0.018		**0.018**	
2010	Golder	NF2-J	Juvenile sunfish	whole	44-50	1.4-1.7	3.0		0.024	0.1	**0.024**	**0.1**
2010	Golder	NF2-extra	additional	whole	44-50	1.4-1.7			0.042		**0.042**	

1.* a measurable trace amount

2. nd - no measurable response; non-detect

3. Blue highlighted cells indicate values that were used in the comparison to fish tissue residue toxicity thresholds, but not in estimated daily intake (EDI) exposure dose calculations for higher trophic level ecological receptors in the ERA

Table D-IV-11: Concentrations of Inorganic Elements in Macrophytes Collected from the Kingston Inner Harbour

Sample #	Location On Site	Matrix	Easting	Northing	Cu	Ni	Co	Cd	Pb	Zn	Cr	As	Sb
					dw	dw	dw	dw	dw	dw	dw	dw	dw
1. ESG 2008													
08-42231	SSM1	macrophytes, stem	381924	4900549	5.8	4.6	1.4	<1.0	7.3	54	22	1.9	
08-42233	SSM3	macrophytes, stem	382175	4900605	3.8	3.5	<1.0	<1.0	3.2	19	12	1.2	
08-42236a/b/c	SSM6	macrophytes, stem	382244	4900435	5.6	4.4	<1.0	<1.0	2.3	16	8.2	1.2	
08-42237	SSM7	macrophytes, stem	382019	4900387	4.0	3.5	1.0	<1.0	6.4	21	13	1.4	
08-42238	SSM9	macrophytes, stem	382090	4900492	4.1	3.8	1.0	<1.0	6.0	31	16	1.5	
08-42239	SSM10	macrophytes, stem	382151	4901507	3.3	3.4	<1.0	<1.0	2.8	25	2.5	<1.0	
08-42066	Cat4	cattail shoot	382313	4900651	4.3	<2.0	<1.0	<1.0	1.0	16	1.0	<1.0	
08-42070/b/c/d	Cat3	cattail shoot	382073	4900663	<2.0	3.1	<1.0	<1.0	1.0	11	7.3	<1.0	
08-42078	Cat1	cattail shoot	381816	4900557	2.2	22	<1.0	<1.0	1.0	10	3.8	<1.0	
2. Tinney, 2006													
04-24321	ERA4	M spicatum	382388	4899535	5.4	2.7	1.4	0.08	4.3	61	9.7	1.5	<0.05
04-24314	ERA5	M spicatum	382133	4900254	4.8	6.8	1.4	0.08	12	21	49	1.7	<0.05
05-30060	ERA4	P crispus	382388	4899535	7.4	2.5	0.36	0.06	0.51	20	<0.5	<0.5	<0.05
05-30070	ERA5	M spicatum	382133	4900254	21	1.1	0.33	<0.05	2.8	24	4.1	<0.5	0.43
05-30061	ERA11	P crispus	382036	4900455	8.5	2.2	0.75	0.055	2.0	20	5.7	<0.5	<0.05
05-30062	ERA12	P crispus	381971	4900066	7.7	1.6	0.78	0.055	3.2	29	9.8	1.9	<0.05
05-60063	ERA12	M spicatum	381971	4900066	5.0	1.8	1.2	0.11	6.5	45	19	2.7	0.06

Table D-IV-12: PAH Concentrations in Macrophytes Collected from the Kingston Inner Harbour APEC

Sample ID	Report Locator	Area	Macrophyte Species	Naphthalene [ppm]	Acenaphthylene [ppm]	Acenaphthene [ppm]	Fluorene [ppm]	Phenanthrene [ppm]	Anthracene [ppm]	Fluoranthene [ppm]	Pyrene [ppm]	Benzo(a)anthracene [ppm]	Chrysene [ppm]	Benzo(b)fluoranthene [ppm]	Benzo(k)fluoranthene [ppm]	Benzo(a)pyrene [ppm]	Indeno(1,2,3-cd)pyrene [ppm]	Dibenz(a,h)anthracene [ppm]	Benzo(ghi)perylene [ppm]	Sum PAHs [ppm]
1. ESG, 2002																				
03-21323	FF1	Outer KH	*unknown species*	2.2	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.2	1.3	0.67	0.26	< 0.20	< 0.20	< 0.20	< 0.20	4.9
03-21327	FF1	Outer KH	*unknown species*	0.39	< 0.10	< 0.10	< 0.10	0.13	< 0.10	0.27	0.14	0.32	0.65	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 2.5
03-21340	FF2	Outer KH	*unknown species*	0.62	< 0.10	< 0.10	< 0.10	0.1	< 0.10	0.215	< 0.10	0.715	2.05	0.69	0.245	< 0.20	< 0.20	< 0.20	< 0.20	4.6
2. Tinney, 2006																				
04-24311	ERA4	KIH	*M. spicatum*	0.041	<0.005	<0.005	<0.02	<0.02	<0.02	0.021	0.029	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	<0.02	0.091
04-24314	ERA5	KIH	*M. spicatum*	0.022	<0.005	<0.005	<0.02	<0.02	<0.02	0.023	0.038	<0.02	0.028	0.02	<0.02	<0.02	<0.02	<0.005	<0.02	0.13
05-30070	ERA5	KIH	*M. spicatum*	<0.02	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	<0.02	<0.02
05-30061	ERA11	KIH	*P. Crispus*	0.034	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	0.035	<0.02	0.022	<0.02	<0.02	<0.02	<0.02	<0.005	<0.02	0.091
05-30062	ERA12	KIH	*P. Crispus*	0.03	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	0.021	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	<0.02	0.051
05-30063	ERA12	KIH	*M. spicatum*	<0.02	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.005	<0.02	<0.02

D-IV-13: Concentrations of Inorganic Elements and PCBs in Water Samples from Orchard Street Marsh

Year	TN (Tg Number)	Report Locator	Easting	Northing	(ppm)	(ppm)	(ppm)	Cr (ppm)	As (ppm)	Sb	PCBs
					[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppb]
1. MOE Benoit et al, 2010											
2006	GL063055	ref CAT 23	381606	4900478	0.002	0.00024	0.004	0.0029			0.00085
2006	GL063068	ref CAT 23	381606	4900478	0.0023	0.00024	0.0061	0.0024			0.00076
2. ESG, 2009											
2009	09-25481		381569	4900402	<0.005	<0.01	<0.01	0.0081	<0.003	<0.01	
2009	09-25482		381719	4900362	<0.005	0.05	0.095	0.20	<0.003	<0.01	
2009	09-25483		381684	4900355	0.011	0.015	0.05	0.13	<0.003	<0.01	
2009	09-25487		381793	4900387	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
2009	09-25481		381569	4900402	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	
2009	09-25482		381719	4900362	<0.005	<0.01	0.022	<0.005	<0.003	<0.01	
2009	09-25483		381684	4900355	<0.005	<0.01	<0.01	0.0094	<0.003	<0.01	
2009	09-25487		381793	4900387	<0.005	<0.01	<0.01	<0.005	<0.003	<0.01	

All samples are total (not filtered)

Table D-IV-14: PAH Concentrations in Water Samples from Orchard Street Marsh

Year	TN (Tg Number)	Report Locator	Easting	Northing	PAH Total [ppb]	Phenanthrene [ppb]	Anthracene [ppb]	Fluoranthene [ppb]	Pyrene [ppb]	Benzo(a)anthracene [ppb]	Chrysene [ppb]	Benzo(b)fluoranthene [ppb]	Benzo(a)pyrene [ppb]	Perylene [ppb]	Dibenz(a,h)anthracene [ppb]	Indeno(1,2,3-cd)pyrene [ppb]	Benzo(ghi)perylene [ppb]	7,12-dimethylbenz(a)anthracene [ppb]	Benzo(k)fluoranthene [ppb]
1. MOE, Benoit et al, 2010																			
2006	GL063055	CAT 23	381606	4900478	<0.02	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01
2006	GL063068	CAT 23	381606	4900478	<0.05	<0.05	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.001	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01

All samples are total (not filtered)

Table D-IV-15: Concentrations of Inorganic Elements and PCBs in Sediments from Orchard Street Marsh

Year	Sample ID	Report Locator	Easting	Northing	Depth	Cu	Pb	Zn	Cr	As	Sb	Hg	PCB Total RMC Lab (Aroclor 1254+1260 plus 1242 where reported)	Total Aroclor Sum 1262, 1016, 1221, 1232, 1248, 1254, 1260, 1268	SUM PCB Congeners
					(cm)	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppb]	[ppb]	[ppb]
CCME ISQG						*36*	*35*	*123*	*37*	*5.9*		*0.17*	*34*	*34*	*34*
CCME PEL						***197***	*91*	***315***	***90***	***17***	*n/a*	***0.49***	***277***	***277***	***277***
Ontario SQG - LEL						**16**	**31**	**120**	**26**	**6.0**	*n/a*	**0.2**	**70**	**70**	**70**
CCME Sediment Quality Guideline											*20*				
*OMOE SCS (soil within 30m of water body)**											**1.0**				
1. Brooks et al, 1998															
1998	K14		381578	4900386	0	*50*	***405***	***421***					**260**		**207**
1998	K15		381499	4900384	0	*66*	***403***	***412***					*49*		**155**
2. MOE Derry et al, 2003															
2001	32	SE-2	381584	4900467	0.5	*81*	*51*	*140*	*41*					***520***	
2001	33	SE-3	381596	4900465	0.5	*130*	***2900***	***630***	***22000***					***5300***	
2001	34	SE-4	381613	4900456	0.5	*99*	***130***	*260*	***1200***					***370***	
2001	36	SE-6	381637	4900460	0.5	*120*	***170***	*300*	***2800***					***510***	
2001	50	SE-20	381701	4900520	0.5	*180*	***390***	***720***	***3900***					***3000***	
2001	51	SE-21	381645	4900489	0.5	*84*	***180***	*300*	***470***						
2001	52	SE-22	381615	4900477	0.5	*110*	***130***	***380***	***98***						
2001	55	SE-25	381804	4900446	0.5	*37*	***180***	*150*	***1900***						
2001	59	SE-27	381826	4900317	0.5	*37*	*61*	**120**	***780***						
3. MOE Benoit 2006															
2002	OMOE81		381583	4900482	0-5	*89*	***100***	*260*	*66*						**78**
2002	OMOE82		381817	4900441	0-5	**34**	***150***	*140*	***1600***						**240**
2002	OMOE84		381589	4900398	0-5	*56*	***190***	***520***	***9100***						25
4. CRA report 2006															
2006	SED1				0-30	*123*	***1190***	***879***	***4070***	***25***		***1.1***			
2006	SED2				0-30	*62*	***2480***	***516***	***3110***	***27***		**0.32**			
2006	SED3				0-30	*48*	***308***	***370***	***8750***	***30***		**0.22**			
2006	SED4				0-30	*169*	***683***	***420***	***104000***	***42***		**0.39**			
2006	SED5				0-30	*191*	***550***	***437***	***63600***	***23***		***1.2***			
2006	SED6				0-30	**35**	***276***	*188*	***8050***	**11**					
2006	SED7				0-30	**24**	*57*		*64*						
5. MOE, Benoit, 2010															
2006	CAT 23		381606	4900478	1.5	**30**	19	76	**37**	1.0		0.034			**116**
6. ESG 2007-2009															
2007	07-23560	C1	381802	4900446	0-10	**28**	***99***	110	***1100***	2.7	**5.2**				
2007	07-23562	C1	381802	4900446	20-30	**26**	***170***	110	***1800***	5.3	**9.2**				
2007	07-23563	C1	381802	4900446	30-40	<40	**34**	<30	***220***						
2007	07-23565	C1	381802	4900446	0-10	**30**	***210***	*140*	***2200***	5.6	**10**				
2007	07-23567	C2	381790	4900445	20-30	**26**	***120***	*130*	***1400***	3.8	**6.4**				
2007	07-23568	C2	381790	4900445	30-40	**32**	***190***	*170*	***3400***	**9.1**	**18**				
2007	07-23569	C2	381790	4900445	40-50	**23**	***210***	**120**	***2900***	**7.9**	**16**				
2007	07-23571	C2	381777	4900438	0-10	*37*	***350***	*200*	***4100***	**6.6**	*22*				
2007	07-23572	C2	381777	4900438	10-20	*38*	***360***	*200*	***4200***	**6.8**	*23*				
2007	07-23574	C3	381777	4900438	30-40	<40	<30	<30	*<60*						
2007	07-23577	C4	381811	4900361	0-10	**28**	***93***	110	***1800***	**8.5**	**6.2**				
2007	07-23578	C4	381811	4900361	10-20	**17**	26	100	***660***	<3.0	**2.6**				
2007	07-23579	C4	381811	4900361	20-30	<40	<30	<30	***128***						
2007	07-23581		381583	4900473	0-8	<40	<30	<30	*<200*						
2007	07-23582		381589	4900471	0-10	<40	<30	39	*<200*						
2007	07-23585		381619	4900482	0-10	*47*	*38*	100	*49*	<1.0					
2008	08-42130	SC 0-5	381667	4900485	2.5	4.5	10	23	*16*	<3.0					
2008	08-42131	SC 5-10	381667	4900485	7.5	**20**	*35*	37	*14*	<3.0					
2008	08-42132	SC 10-15	381667	4900485	12.5	12	5.0	25	*23*	<3.0					
2008	08-42133	SC 15-20	381667	4900485	17.5	3.8	6.6	34	**29**	<3.0					
2008	08-42134	SC 20-25	381667	4900485	22.5	**29**	*82*	98	***5920***	**8.8**					
2008	08-42135	SC 25-30	381667	4900485	27.5	*43*	***430***	**120**	***83000***	<3.0					
2008	08-42136	SC 30-35	381667	4900485	32.5	*40*	***210***	*130*	***19000***	<3.0		0.5			
2008	08-42137	SC 35-40	381667	4900485	37.5	*51*	***200***	*150*	***6400***	***19***					
2008	08-42138	SC 40-45	381667	4900485	42.5	*44*	***144***	110	***6500***	**11**					
2008	08-42139	SC 45-50	381667	4900485	47.5	**22**	*48*	57	***2300***	**10**					
2009	09-25576					**28**	***270***	*170*	***16000***	**7.3**					
2009	09-25716					*73*	***230***	*210*	***41000***	**12**					
2009	09-25717					13	**33**	94	***1400***	<1.0					
2009	09-25718					**30**	***250***	*150*	***8900***	4.3					
2009	09-25719					**28**	***270***	*180*	***13000***	*5.9*					

* OMOE Site Condition Standard for Use within 30m of a Water Body (Agricultural Use)

Table D-IV-16: Concentations of Pesticides in Sediments from Orchard Street Marsh

Year	Sample ID	Report Locator	Easting	Northing	DDT [ppb]	Chlordane [ppb]
CCME ISQG					*1.19*	*4.5*
CCME PEL					***4.77***	***8.87***
Ontario SQG - LEL					**7.0**	**7.0**
1. Cross, 1999						
1999	KK14		381578	4900386	**28**	***20***
2. MOE Derry et al, 2003						
2001	32	SE-2	381584	4900467	<25	3.5
2001	33	SE-3	381596	4900465	**340**	***260***
2001	34	SE-4	381613	4900456	<20	***10***
2001	36	SE-6	381637	4900460	**52**	***18***
2001	50	SE-20	381701	4900520	**205**	***43***
2001	51	SE-21	381645	4900489	**33**	**7.0**
2001	52	SE-22	381615	4900477	**15**	*4.5*
2001	55	SE-25	381804	4900446	**39**	***9.0***
2001	59	SE-27	381826	4900317	<8.0	2.0
3. MOE Benoit et al, 2010						
2006	CAT 23		381606	4900478	*2.3*	1.6

Table D-IV-17: PAH Concentrations in Sediments from Orchard Street Marsh (calculated as dry weight*)

Year	Sanple ID	Easting	Northing	Depth	PAH Total	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)pyrene (ppb)	Benzo(a)pyrene	Perylene (ppb)	Dibenz(a,h)anthracene	Indeno(1,2,3-cd)pyrene	Benzo(ghi)perylene	Benzo(k)fluoranthene
				(cm)	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]	[ppb]
CCME ISQG						*34.6*	*59*	*67*	*21.2*	*41.9*	*46.9*	*111*	*53*	*31.7*	*57.1*			*31.9*		*6.2*			
CCME PEL						***391***	***128***	***88.9***	***144***	***515***	***245***	***2355***	***875***	***385***	***862***			***782***		***135***			
Ontario SQG - LEL					**4000**				**190**	**560**	**220**	**750**	**490**	**320**	**340**			**370**		**60**	**200**	**170**	**240**
1. Brooks et al, 1998																							
1998	K14	381578	4900386	0.0	**16640**	***1400***	***1300***	***3000***	**750**	**780**	*190*	**2200**	***3400***	*200*	**810**	1100		***960***		**100**	**200**	**200**	
2. Cross, 1999																							
1999	KK14	381578	4900386	5.0	**15567**	***1200***	*79*	***3800***	**1900**	**900**	***850***	**1900**	***2600***	***440***	**680**			*340*		**87**	**350**	**360**	
3. MOE Benoit et al, 2003																							
2002	OMOE81	381583	4900482	0-5	**26400**	*60*	20	*80*	*120*	**1900**	***260***	***5000***	***4200***	***2000***	***2900***	3200		***1800***		***360***	**1800**	**1500**	**1200**
2002	OMOE82	381817	4900441	0-5	**5440**	*80*	***160***	20	*40*	*280*	*80*	*640*	**780**	***440***	**520**	660		**560**		**120**	**440**	**400**	220
2002	OMOE84	381589	4900398	0-5	2560	*200*	40	*80*	*40*	*160*	40	*320*	*380*	*160*	*220*	280		*200*		*40*	160	160	80
4. MOE Benoit et al, 2010																							
2006	CAT 23	381606	4900478	1.5	**18250**	*72*	13	***298***	**327**	**3170**	***635***	***4390***	***3470***	***1310***	***1770***	2880		***1510***		***235***	**1090**	**1050**	

*corrected to dry weight using 80% moisture = wet/dry = 1/(1-0.8) = 5

APPENDIX E: QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

TABLE OF CONTENTS

TABLE OF CONTENTS, CONT'D

TABLE OF CONTENTS, CONT'D

I. CHAPTER II: QUALITY ASSURANCE/QUALITY CONTROL: 2006–2009 ESG DATA

ESG follows an internal quality assurance/quality control (QA/QC) program that was implemented to allow data quality to be monitored on an ongoing basis. This program is completely described in the Quality Assurance Project Plan (QAPP) (ESG, 2009). The points relevant to the discussion of QA/QC sample collection and analysis from Kingston Inner Harbour and Cataraqui River in 2006, 2007, 2008 and 2009 are summarized here for completeness.

All samples are given sequential numerical codes before submission to the analytical firms; these codes mask any information concerning site location, sample type or possible concentration of the sample.

Accuracy is measured and controlled by instrument calibration, the use of control standards and control spikes and the collection and analysis of analytical blanks.

Control standards and control spikes are reference materials with known concentrations. After analysis of a control standard or spike, the instrument's calibration is evaluated by comparing the results with the known concentration.

Analytical blanks are processed through extraction/digestion and analysis procedures. These blanks give a measure of the quantity of any contaminant (analyte) that may be added to the overall result during the analysis.

Precision is measured and controlled by the analysis of analytical duplicates. Analytical duplicates are replicate preparations and analyses of the same sample. Comparisons of the average relative standard deviations (RSD%), also known as coefficients of variation, which are calculated as the standard deviation divided by the mean, are used to evaluate laboratory precision. Acceptable limits are generally considered to be less than 40 percent RSD for inorganics and 30 percent for other analyses, with 20 percent or less considered good agreement.

The results of the QA/QC program for the 2006-2009 sampling program in Kingston Inner Harbour and Cataraqui River are discussed below in order of analysis type. The laboratory associated with each analysis type is listed.

A. Inorganic Elements in 2006 Sediment Samples Analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP) — Analytical Services Unit (ASU), Queen's University

Selected sediment samples taken in 2006 were analyzed by ICP for a suite of 30 inorganic elements; QA/QC results are listed in Tables E-II-1 to E-II-3.

1. Accuracy

Accuracy was monitored internally by ASU with the analysis of Standard Reference materials, specifically NRC Canada Marine Sediment Reference MESS-3, contaminated soil reference material SS-2 (E-II-1 and E-II-2). The results for several elements were consistently lower than the certified value for MESS-3. This discrepancy is attributed to differences between the digestion methods used at ASU and those used to obtain the certified values. The reference values are established by a variety of techniques that analyze the total metal content of the standard substrate. By contrast, *aqua regia* digestion, the method used in most laboratories, including the ASU lab, extracts only the available metals in the sample substrate. This is because metals present within minerals forming part of the soil matrix are not released in the extraction process. As these metals form part of the soil matrix, they are also biologically unavailable. Because these elements are not extractable under the strongly oxidizing acid digestion procedure, they will not usually be mobilized by normal weathering and are therefore not environmentally significant. The fact that numerical environmental criteria for metals are designed to be compared with potentially biologically available metal concentrations means that the level of accuracy reported above is acceptable. ASU has developed a set of warning and control limits for MESS-3 sediment analyzed using *aqua regia* digestion, and results must be within these limits. The limits were created by compiling data from each MESS-3 sample over the last several years and checking for trends such as moving averages. The data compiled takes into account day to day variations in such factors as the weighing, acid digestion procedures and instrumentation. For the current MESS-3 limits, more than 600 data points for the Arctic suite elements (Cu, Ni, Co, Cd, Pb, Zn, Cr, As) were used in the development of the control limits. Control limits of elements analyzed less frequently were prepared using over 60 data points. All results determined for inorganic elements in MESS-3 in soils analyzed by ICP were within control limits (Table E-II-1).

Soil reference material SS-2 was also used to monitor accuracy, and determined results were again within control limits. Certified values provided in Table E-II-2 reflect results obtained by the supplier for total digest analysis, which are similar to MESS-3 certified values. While the supplier also lists EPA-3050 acid digestion values, the procedure is different from that used at ASU and digestion times are not provided by the supplier. Typically, digestion efficiencies for partial digestion methods have to be established by individual labs. As is also the case for MESS-3, the control limits established for SS-2 analysis at ASU are based on hundreds of digestions performed over several years, and the tolerance intervals are much smaller than those listed by the SS-2 supplier for acid digestion.

One analytical blank sample was run with the 2006 sediment samples. The results are presented in Table E-II-3, and all elements in the analytical blank were below detection limits.

2. Precision/Repeatability

Internal precision was monitored by ASU with the analysis of one analytical duplicate (Table E-II-3). The average RSDs for all detectable elements were below 12 percent, indicating good precision between analytical duplicates for these elements.

B. Inorganic Elements in 2006–2008 Sediment Samples — ASU, Queen's University

1. Accuracy

Accuracy was monitored internally by ASU with the analysis of Standard Reference Materials MESS-3 and SS-2 (Table E-II-4). Average determined results were within ASU control limits.

Soil reference material SS-2 was also used to monitor accuracy and average determined results were again within control limits (Table E-II-4).

Analytical blank samples were run with the sediment batches (Table E-II-5). All elements in the analytical blanks were below detection limits.

2. Precision/Repeatability

Internal precision was monitored by ASU through the use of analytical duplicates. Seven sediment samples were analyzed in duplicate for inorganic elements (Table E-2-6). The average RSDs for copper (9.1 percent), nickel (4.8 percent), cobalt (5.5 percent), cadmium (3.1 percent) and zinc (10 percent) in the soil replicates were below 10 percent, indicating very good precision between analytical duplicates for these elements (Table E-II-6). Average RSDs for lead (16 percent), chromium (18 percent) and arsenic (13 percent) average RSDs were higher but still below 20 percent, indicating good agreement.

Occasionally, duplicate results straddled the criteria for that element. In those cases, if RSDs were acceptable and if other elements were over criteria in the duplicate sample, no further action was taken.

Some individual RSDs were greater than 40 percent. If duplicate results were in agreement with respect to criteria used, or if another element in the sample was over the criteria indicating cleanup, no further action was taken. Where duplicate results straddle the criteria, other elements were reviewed to determine if they were over criteria. In those cases, reanalysis was not required.

In some cases where one duplicate result was above the detection limit while the other was below, if results were in agreement with respect to criteria, reanalysis was not required. For these duplicates, we have not calculated RSDs. Previously in such cases, ESG calculated the relative standard deviation by a conventional method that takes the lower of the duplicate results as half of the detection limit. This method invariably leads to artificially inflated RSDs, even when the concentration in the higher result is close to the detection limit. In our experience, in such cases the two results generally are, in fact, very close and do represent good precision. For these reasons, these duplicate calculations are no longer included in the QA/QC analysis.

C. Inorganic Elements in 2008 Sediment Samples — Analytical Sciences Division (ASD), Royal Military College of Canada (RMC), Kingston, ON

Sediment samples from 2006 and 2008 were analyzed at ASD for 10 inorganic elements, using inductively coupled plasma optical emission spectroscopy (ICP-OES) analysis.

1. Accuracy

Sample batches were analyzed along with MESS-3 standard reference material, and results showed copper, nickel and zinc averages to be lower than the ASU control limits (Table E-II-7). Three analytical blanks were analyzed with the sediment samples, and all results were below detection (Table E-II-8).

2. Precision

Precision was monitored with the analysis of two duplicates and results are listed in Table E-II-9. Four of the 10 elements showed detectable levels, and all resulting average RSDs were below 15 percent, with most below 10 percent, indicating very good agreement between duplicates (Table E-II-9).

D. Mercury in 2006 and 2008 Sediment Samples — Analytical Sciences Group (ASG), RMC

1. Accuracy

Sediment samples were analyzed for mercury along with one control spiked sample, and the resulting recovery was 73 percent (Table E-II-10). One blank sample was analyzed for mercury, and results were below detection (also listed in Table E-II-10).

2. Precision

One sediment analytical duplicate was analyzed for mercury, and the resulting RSD was 7.2 percent (Table E-II-10).

E. Polychlorinated Biphenyls (PCBs) in 2006 and 2008 Sediment Samples — ASG, RMC

The QA/QC protocol for PCBs calls for analyses to be carried out in batches of no more than 30 samples. Each batch must include one analytical duplicate, a procedural blank and a spiked control sample. Each batch is treated as a separate unit: samples within the same batch must be worked up and analyzed continuously, and the QA/QC data must be considered with respect to each batch.

1. Accuracy

Internally, all samples were spiked with an aliquot of the surrogate standard decachlorobiphenyl (DCBP) prior to analysis by gas chromatography (GC) with electron capture detection (ECD), in order to measure recovery of PCBs. Sample results were corrected for this recovery. The method was calibrated using known standards of Aroclor 1254 and 1260. A calibration check standard was run with each batch to verify the calibration. Duplicates, blanks, the spiked control sample, DCBP recovery and the calibration check were all required to be within predetermined control limits.

Spiked control samples (3) were run with the sediment PCB analyses; the average recovery was 100 percent for Aroclor 1260 (Table E-II-11). Laboratory control limits allow for a 30 percent variation in spike recovery.

Each batch was monitored internally by analyzing blank samples for PCBs. All results were below detection limits for analytical blanks (Table E-II-11).

2. Precision/Repeatability

Precision was monitored internally by ASG using sediment analytical replicates (Table E-II-11). Three soil analytical duplicates were run and those with detectable PCBs reported RSDs ranging from 0 percent to 19 percent, indicating good agreement between replicates (Table E-II-11).

F. DDT Pesticide Analysis of 2008 Sediment Sample — ASG, RMC

1. Accuracy

One sediment sample was analyzed for DDT pesticides, and results for the control spikes are listed in Table E-II-12. Average recoveries for 4,4-DDE, 4,4-DDD and 4,4-DDT were 160 percent, 150 percent and 160 percent respectively. Laboratory control limits allow for a 30 percent variation in spike recovery. The presence of PCBs in the sample may have interfered with the DDT analysis.

The analytical blank sample run with the sediment reported results below detection for all (Table E-II-12).

2. Precision

The sediment sample was analyzed in duplicate for DDT pesticides and results are listed in Table E-II-12. Detection limits were raised for this sample due interference from the presence of PCBs in the sediment. Results for DDT pesticides were below detection in the sample.

G. Polycyclic Aromatic Hydrocarbon (PAH) Analysis of 2008 Sediment Samples — ASG, RMC

Selected sediment samples from Kingston Inner Harbour were analyzed for PAHs, and QA/QC results are listed in Table E-II-13.

1. Accuracy and Precision

Control spike recoveries were 82 percent for total PAHs, and all individual recoveries were within acceptable limits of 30% (Table E-II-13).

PAH results were below detection in the analytical blank (Table E-II-13). Results for PAHs in the analytical duplicate yielded RSDs ranging from 2.8 percent to 21 percent, indicating good agreement between replicates.

H. Volatile Organic Compounds (VOC) Analysis of 2008 Sediment Samples — ASG, RMC

A calibration standard of known concentration containing 60 known volatile organic components was run daily. The standard was spiked into organic-free deionized water. The sample results were calculated using the calibration standard and corrected for surrogate recovery. Blanks (organic-free deionized water), control samples, and duplicates were run at a frequency of 10%.

1. Accuracy

One control spiked sample was run, and results are listed in Table E-II-14. The average recovery of VOCs in soil was 98% ± 7.3, indicating good accuracy for the method.

Results were below detection in the analytical blank (Table E-II-14).

2. Precision

One duplicate sample was analyzed for VOCs, and RSD results for detectable compounds ranged from zero percent to 38 percent. One compound showed an RSD outside of the 30 percent acceptable level (Table E-II-14).

I. Nitrate/Nitrite (as N), Total Phosphorus and Total Kjeldahl Nitrogen (TKN) in 2007 and 2008 Water Samples — ASU, Queen's University, and ASG, RMC

1. Accuracy and Precision — 2007 Water Samples

Water samples taken in 2007 were analyzed for nitrate/nitrite (as N), total phosphorus (P), and TKN at ASU, and QA/QC results are listed in Table E-II-15. Control spike recoveries ranged from 102 percent to 106 percent. Blank results were below detection for all.

Two analytical duplicates were analyzed in 2007 to monitor precision. One sample pair reported nitrate samples above detection; the resulting RSD was 0 percent. TKN results produced an RSD of 1.4 percent in one sample pair, indicating very good precision between replicates (Table E-II-15).

2. Accuracy and Precision — 2008 Water Samples

Water samples from 2008 were also analyzed for nitrate and nitrite at ASU. Control spike recoveries averaged 83 percent and 80 percent respectively (Table E-II-16). Results were below detection in the analytical blanks.

In 2008, water samples were analyzed for phosphorus at ASG, RMC. Control spike recovery was 85 percent. Results were below detection in both the analytical blank and the analytical duplicate (Table E-II-17).

J. Alkalinity Analysis of 2007 Water Samples — ASG, RMC

1. Accuracy and Precision

One control spike was analyzed for alkalinity, and the resulting recovery was 98 percent (Table E-II-18). One water sample was analyzed in duplicate, and the results yielded an RSD of 1.6 percent, indicating very good precision for the method (Table E-II-18).

K. Total Organic Carbon (TOC) Analysis of 2008 Sediment Samples — Research and Productivity Council (RPC), Fredericton, NB

1. Accuracy and Precision

Six sediment samples were analyzed for TOC at RPC in 2008, and the QA/QC results are listed in Table E-II-19. Results were below detection in the blank while the duplicate yielded an RSD of 0.3 percent.

L. Polychlorinated Biphenyls (PCBs) in Sediment Samples in 2009 — ASG, RMC

1. Accuracy and Precision

Sediment samples were analyzed at ASG for PCBs along with a control spike and analytical blank (Table E-II-20). The spike showed a recovery of 86 percent for Aroclor 1254 and the blank showed no detectable PCBs.

M. Alkalinity, Chromium VI and Total Suspended Solids (TSS) Analysis of 2009 Water Samples — ASU, Queen's University

1. Accuracy

Control spike results were 95 percent for TSS and an average of 99 percent for alkalinity. Results were below detection in the analytical blank (Table E-II-21).

2. Precision

One duplicate was analyzed for each parameter and RSDs were less than 5 percent in all three cases, indicating excellent agreement between replicates (Table E-II-21).

Table E-II-1: Inorganic Element Results for 2006 Control Standard MESS-3 Analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP/AES) at ASU

Element	MESS-3 Certified	MESS-3 Determined	ASU Control Limits
	[ppm]	[ppm]	[ppm]
2006 samples		***Sediment Samples***	
Ag	0.18 ± 0.02	<2.0	
Al	85900 ± 2300	23800	15800–33400
As	21.2 ± 1.1	17.5	13–18
B	-	-	
Ba	-	351	285–455
Be	2.3 ± 0.12	<4.0	-
Ca	14700 ± 600	13400	11000–16200
Cd	0.24 ± 0.01	<0.6	-
Co	14.4 ± 2.0	12.2	10–14
Cr	105 ± 4.0	39.5	26–54
Cu	33.9 ± 1.6	35.8	28–39
Fe	43400 ± 1100	36200	30200–42800
K	26000*	5310	4130–8630
Mg	16000*	13600	11700–15900
Mn	324 ± 12	297	273–334
Mo	2.78 ± 0.07	<2.0	-
Na	16000*	11400	9780–13400
Ni	46.9 ± 2.2	37.6	34–42
P	1200*	1040	893–1230
Pb	21.1 ± 0.7	16.3	15–21
S	1900*	1890	1450–2030
Sb	1.02 ± 0.09	<10	-
Se	0.72 ± 0.05	<10	-
Sn	2.5 ± 0.52	<2.0	-
Sr	129 ± 11	65	55–81
Ti	4400 ± 600	<10	-
Tl	0.9 ± 0.06	<1.0	-
U	4.0*	<10	-
V	243 ± 10	85.9	67–127
Zn	159 ± 8.0	131	119–153

Table E-II-2: Inorganic Element Analysis of 2006 Control Standard SS-2 Analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy at ASU

Element	SS-2 Certified [ppm]	SS-2 Determined [ppm]	ASU Control Limits [ppm]
2006 Samples		*Sediment Samples*	
Ag	1.3*	<2.0	
Al	13265 ± 1194	17100	13400–22100
As	75 ± 9.75	78.9	55–103
B	12*	-	
Ba	215 ± 13	230	200–287
Be	0.7*	<4.0	
Ca	112861 ± 4514	123000	95300–145000
Cd	2.0*	2.1	0.1–3.0
Co	12 ± 1.0	14.1	12–17
Cr	34 ± 4.08	46	36–56
Cu	191 ± 9.6	177	158–225
Fe	21046 ± 1473	27000	21300–32300
K	3418 ± 342	4460	3680–6830
Mg	11065 ± 553	12700	10700–15100
Mn	457 ± 23	528	440–662
Mo	4.0*	2.4	0.9–4.3
Na	558 ± 100	839	583–1100
Ni	54 ± 3.8	54.4	49–61
P	752 ± 15	749	427–888
Pb	126 ± 10	121	99–130
S	2193*	2480	1810–2510
Sb	0.8*	<10	
Se	0.8*	<10	
Sn		<2.0	1.0–4.4
Sr	214 ± 13	216	179–262
Ti	850 ± 111	1150	592–1660
Tl	0.3*	<1.0	
U	1.3*	<10	
V	34 ± 3.1	44	39–59
Zn	467 ± 23	454	392–544

* information only — not certified

Table E-II-3: Inorganic Element Results for Blank and Duplicate Sediment Samples Analyzed by Inductively Coupled Plasma Atomic Emission Spectroscopy at ASU

Element	**Blank [ppm]**	**06-17150**	**Duplicate**	**Average**	**Std Dev**	**RSD (%)**
2006 Samples						
Ag	<2.0	<2.0	<2.0			
Al	<50	18300	20300	19300	1420	**7.3**
As	<1.0	12.4	13	12.7	0.4	**3.3**
B	<20	<20	<20			
Ba	<5.0	218	233	226	11	**4.7**
Be	<4.0	<4.0	<4.0			
Ca	<100	42400	49400	45900	4940	**11**
Cd	<0.6	1.2	1.2	1.2	0	**0**
Co	<5.0	14.1	15	14.6	0.6	**4.4**
Cr	<20	1400	1550	1480	106	**7.2**
Cu	<5.0	39	40.3	40	0.92	**2.3**
Fe	<50	25400	28000	26700	1840	**6.9**
K	<20	3580.0	4030.0	3800.0	318	**8.4**
Mg	<20	8620	9410	9020	560	**6.2**
Mn	<1.0	515	555	540	28	**5.3**
Mo	<2.0	<2.0	<2.0			
Na	<75	581	650	620	49	**7.9**
Ni	<5.0	24.2	25.4	25	0.85	**3.4**
P	<20	933	1000	960	47	**4.9**
Pb	<10	140	155	148	10.6	**7.2**
S	<25	9830	10900	10360	760	**7.3**
Sb	<10	29.3	31.6	30	1.6	**5.3**
Se	<10	<10	<10			
Sn	<2.0	4.1	4	4.1	0.07	**1.7**
Sr	<5.0	194	214	204	14	**6.9**
Ti	<10	1240	1440	1340	141	**11**
Tl	<1.0	<1.0	<1.0			
U	<10	<10	<10			
V	<10	34.9	38.6	37	2.6	**7.1**
Zn	<15	2360	2560	2460	141	**5.7**

* information only, not certified

Table E-II-4: Inorganic Element Results for Soil Internal Standards (MESS-3 and SS-2) Analyzed at ASU

Element	**MESS-3 Certified Value [ppm]**	**Mean (n=2) [ppm]**	**ASU Control Limits [ppm]**
2006–2008 Samples			
Cu	33.9 ± 1.6	32 ± 2.0	28–39
Ni	46.9 ± 2.2	37 ± 1.0	34–42
Co	14.4 ± 2.0	12 ± 1.0	10–14
Cd	0.24 ± 0.01	<1.0	-
Pb	21.1 ± 0.7	16 ± 1.0	15–21
Zn	159 ± 8	133 ± 4.0	119–153
Cr	105 ± 4	36 ± 6.0	26–54
As	21.2 ± 1.1	16 ± 3.0	13–18

Element	**SS-2 Certified Value**	**Mean (n=2)**	**ASU Control Limits**
	[ppm]	**[ppm]**	**[ppm]**
2006–2008 Samples			
Cu	191 ± 9.0	200 ± 14	158–225
Ni	54 ± 4.0	56 ± 4.0	49–61
Co	12 ± 1.0	14 ± 1.0	12–17
Cd	2.0*	1.7 ± 0	0.1– 3.0
Pb	126 ± 10	117 ± 4.0	99–130
Zn	467 ± 23	475 ± 23	392–544
Cr	34 ± 4.0	43 ± 4.0	36–56
As	75 ± 10	79 ± 6.0	55–103

* information only, not certified

Table E-II-5: Inorganic Element Results for Sediment Analytical Blanks Analyzed at ASU

Sample	**Cu**	**Ni**	**Co**	**Cd**	**Pb**	**Zn**	**Cr**	**As**
	[ppm]	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**
Sediment samples								
2006–2008 samples								
Blank	<5.0	<5.0	<5.0	<1.0	<10	<15	<20	<1.0
Blank	<5.0	<5.0	<5.0	<1.0	<10	<15	<20	<1.0
Blank	<5.0	<5.0	<5.0	<1.0	<10	<15	<20	<1.0
Blank	<5.0	<5.0	<5.0	<1.0	<10	<15	<20	<1.0

Table E-II-6: Inorganic Element Results for Sediment Sample Analytical Duplicates, ASU

Sample	Cu	Ni	Co	Cd	Pb	Zn	Cr	As
	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
2006–2008 samples analyzed at ASU								
06-17206	55	25	13	<1.0	309	218	3760	9.5
Duplicate	53	25	13.1	<1.0	307	217	3740	9.6
Average	54	25	13		308	217	3760	9.6
Std Dev	1.3	0.09	0.01		1.2	0.65	14.3	0.07
RSD (%)	2.4	0.4	0.05		0.4	0.3	0.4	0.7
08-29649	41	29	14.3	<1.0	104	163	780	4.9
Duplicate	45	32	15.5	<1.0	111	176	780	5.5
Average	43	31	14.9		108	170	780	5.2
Std Dev	2.7	1.8	0.8		5.6	9.2	7.7	0.4
RSD (%)	6.3	5.8	5.5		5.2	5.4	1.0	8.4
08-29902	28	22	11.2	<1.0	50	118	37	1.8
Duplicate	29	22	11.8	1.1	55	122	36	1.8
Average	29	22	11.5		52	120	37	1.8
Std Dev	1.1	0.7	0.4		3.1	2.8	0.9	0
RSD (%)	3.9	3.0	3.6		5.9	2.3	2.5	0.2
08-42024	40	26	14.7	<1.0	103	149	940	6.4
Duplicate	40	26	14.6	<1.0	103	148	960	6.8
Average	40	26	14.6		103	148	960	6.6
Std Dev	0.1	0.1	0.04		0.2	0.7	13	0.3
RSD (%)	0.2	0.3	0.3		0.2	0.5	1.3	4.1
08-42051	47	31	16.1	<1.0	153	186	1380	7.6
Duplicate	47	30	16.3	<1.0	151	184	1340	7.1
Average	47	30	16.2		152	185	1360	7.4
Std Dev	0.04	0.6	0.1		0.9	1.5	27	0.3
RSD (%)	0.1	2.1	0.8		0.6	0.8	2.0	4.1
08-42119	33	24	13.1	1.2	76	140	171	3.0
Duplicate	32	23	12.5	1.1	69	135	193	2.9
Average	32	24	12.8	1.1	72	138	182	2.9
Std Dev	0.9	0.7	0.4	0.04	4.6	3.7	16	0.1
RSD (%)	2.7	3.2	3.3	3.1	6.4	2.7	8.7	4.4
08-42140	40	30	15.8	<1.0	80	143	740	4.4
Duplicate	82	23	11.1	1.1	379	342	5480	13
Average	61	26	13.5		230	243	3120	8.4
Std Dev	30	4.9	3.4		211	141	3360	5.7
RSD (%)	48	19	25		92	58	108	68
Average RSD (%)	**9.1**	**4.8**	**5.5**	**3.1**	**16**	**10**	**18**	**13**
Std Dev	**± 17**	**± 6.5**	**± 8.9**	**-**	**± 34**	**± 21**	**± 40**	**± 24**

Table E-II-7: Inorganic Element Results for Soil Internal Standard MESS-3, ASD

Element	MESS-3 Certified Value	Mean (n=3)	ASU Control Limits
	[ppm]	[ppm]	[ppm]
2006 and 2008 Samples Analyzed at ASD			
Cu	33.9 ± 1.6	24 ± 0.5	28–39
Ni	46.9 ± 2.2	32 ± 1.0	34–42
Co	14.4 ± 2.0	10 ± 0.2	10-14
Cd	0.24 ± 0.01	<1.6	-
Pb	21.1 ± 0.7	18 ± 0.5	15–21
Zn	159 ± 8	113 ± 3.5	119–153
Cr	105 ± 4	37 ± 4.1	26–54
As	21.2 ± 1.1	16 ± 0.9	13–18
Mn	324 ± 12	243 ± 3.6	273–334
Fe	43400 ± 1100	29167 ± 893	30200–42800

Table E-II-8: Inorganic Element Results for Sediment Analytical Blanks Analyzed at ASD

Sample	Cu	Ni	Co	Cd	Pb	Zn	Cr	As	Mn	Fe
	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
Sediment Samples										
2006 and 2008 Samples analyzed at ASD										
Blank	<1.65	<17.3	<2.2	<1.6	<2.2	<4.7	<7.2	<3.0	<1.7	<2.7
Blank	<1.65	<17.3	<2.2	<1.6	<2.2	<4.7	<7.2	<3.0	<1.7	<2.7
Blank	<1.65	<17.3	<2.2	<1.6	<2.2	<4.7	<7.2	<3.0	<1.7	<2.7

Table E-II-9: Inorganic Element Results for Sediment Sample Analytical Duplicates, ASD

Sample	Cu	Ni	Co	Cd	Pb	Zn	Cr	As	Mn	Fe
	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]
2006 and 2008 Samples analyzed at ASD										
06-17212	<3.0	<1.6	<2.2	41000	76	610	<17.3	2200	580	28600
Duplicate	<3.0	<1.6	<2.2	33700	71	620	<17.3	2300	490	25700
Average				37300	74	610		2300	540	27200
Std Dev				5200	4	8.7		35	63	2000
RSD (%)				14	5.4	1.4		1.6	12	7.5
08-42136	<3.0	<1.6	<2.2	19300	40	390	<17.3	210	130	8300
Duplicate	<3.0	<1.6	<2.2	16700	39	350	<17.3	200	130	8000
Average				18000	39	370		200	130	8100
Std Dev				1800	0.5	28		12	0.6	210
RSD (%)				10	1.4	7.6		5.8	0.5	2.6
Average RSD (%)				**12**	**3.4**	**4.5**		**3.7**	**6.3**	**5.1**
Std Dev				**± 2.8**	**± 2.8**	**± 4.4**		**± 3.0**	**± 8.1**	**± 3.5**

Table E-II-10: QA/QC Results for Mercury Analysis in Sediment Samples, ASG

Sample	Hg		Sample	Hg
	[ppm]			[ppm]
2006 & 2008 Samples				
Control Spike			*Analytical Duplicate*	
Control	0.32		08-42113	0.28
Control Target	0.44		Duplicate	0.31
Recovery (%)	73		Average	0.3
			Std Dev	0.02
Analytical Blank			RSD (%)	7.2
Blank	<0.1			

Table E-II-11: Aroclor Polychlorinated Biphenyl (PCB) Control Spikes for Sediment Samples at ASG

Sample	Aroclor 1242	Aroclor 1254	Aroclor 1260
	[ppm]	[ppm]	[ppm]
Control Spikes	**2006 & 2008 Soil Samples**		
Control Sample	< 3.0	< 3.0	37
Control Sample Target	< 3.0	< 3.0	50
Recovery (%)			74
Control Sample	< 3.0	< 3.0	57
Control Sample Target	< 3.0	< 3.0	50
Recovery (%)			114
Control Sample	< 3.0	< 3.0	56
Control Sample Target	< 3.0	< 3.0	50
Recovery (%)			112
Average Recovery (%)			**100**
Std Dev			**± 23**
Analytical Blanks			
Blank	< 3.0	< 3.0	< 3.0
Blank	< 3.0	< 3.0	< 3.0
Blank	< 3.0	< 3.0	< 3.0
Analytical Duplicates			
06-17100	<3.0	<3.0	<3.0
Duplicate	<3.0	<3.0	<3.0
08-29910	4.8	13	<3.0
Duplicate	5.9	17	<3.0
Average	5.4	15	
Std Dev	0.8	2.8	
RSD (%)	15	19	
08-42068	<3.0	57	130
Duplicate	<3.0	45	130
Average		51	130
Std Dev		8.5	0
RSD (%)		17	0
Average RSD (%)	**15**	**18**	**0**
Std Dev	**-**	**± 1.6**	**-**

Table E-II-12:DDT Pesticide Analysis of 2008 Sediment Samples at ASG: QA/QC Results

Sample	2,4-DDE [ppb]	4,4-DDE [ppb]	2,4-DDD [ppb]	4,4-DDD [ppb]	2,4-DDT [ppb]	4,4-DDT [ppb]
2008 Samples						
Control	<1.0	1.6	<1.0	1.5	<1.0	1.6
Control Target	<1.0	1.0	<1.0	1.0	<1.0	1.0
Recovery (%)		160		150		160
Blank	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
08-42062*	<10	<10	<10	<10	<10	<10
Duplicate	<10	<10	<10	<10	<10	<10

Table E-II-13: Polycyclic Aromatic Hydrocarbon Analysis of 2008 Soil at ASG: QA/QC Samples

PAH Compound	Control Spike [ppm]	Control Target [ppm]	Recovery (%)
2008 Samples			
Naphthalene	0.23	0.23	100
Acenaphthylene	0.14	0.2	70
Acenaphthene	0.18	0.22	82
Fluorene	0.2	0.23	87
Phenanthrene	0.19	0.22	86
Anthracene	0.21	0.25	84
Fluoranthene	0.18	0.23	78
Pyrene	0.19	0.24	79
Benzo(a)anthracene	0.17	0.23	74
Chrysene	0.17	0.21	81
Benzo(b)fluoranthene	0.18	0.22	82
Benzo(k)fluoranthene	0.23	0.26	88
Benzo(a)pyrene	0.18	0.2	90
Indeno(1,2,3-cd)pyrene	0.16	0.2	80
Dibenz(a,h)anthracene	0.17	0.2	85
Benzo(ghi)perylene	0.04	0.04	100
Total	2.8	3.4	82

PAH Compound	Blank [ppm]	08-29911 [ppm]	Duplicate [ppm]	Average [ppm]	Std Dev [ppm]	Rel Std Dev (%)
Naphthalene	< 0.06	0.11	0.12	0.12	0.01	**6.1**
Acenaphthylene	< 0.05	0.05	< 0.05			
Acenaphthene	< 0.05	< 0.05	< 0.05			
Fluorene	< 0.05	< 0.05	< 0.05			
Phenanthrene	< 0.05	0.13	0.17	0.15	0.03	**19**
Anthracene	< 0.05	< 0.05	< 0.05			
Fluoranthene	< 0.05	0.25	0.28	0.27	0.02	**8.0**
Pyrene	< 0.05	0.3	0.25	0.28	0.04	**13**
Benzo(a)anthracene	< 0.05	0.23	0.17	0.2	0.04	**21**
Chrysene	< 0.05	0.22	0.17	0.2	0.04	**18**
Benzo(b)fluoranthene	< 0.05	0.25	0.26	0.26	0.01	**2.8**
Benzo(k)fluoranthene	< 0.05	0.08	0.09	0.09	0.01	**8.3**
Benzo(a)pyrene	< 0.1	0.3	0.23	0.27	0.05	**19**
Indeno(1,2,3-cd)pyrene	< 0.1	0.27	0.23	0.25	0.03	**11**
Dibenz(a,h)anthracene	< 0.05	< 0.05	< 0.05			
Benzo(ghi)perylene	< 0.1	0.23	0.24	0.24	0.01	**3.0**

Table E-II-14: Volatile Organic Compound (VOC) Analysis in 2008 Sediment at ASG: QA/QC Samples

VOC	Control	Control Target	Recovery		Blank		08-42135	Duplicate	RSD
	[ppb]	[ppb]	(%)		[ppb]		[ppb]	[ppb]	(%)
2008 Samples									
Dichlorodifluoromethane	43	40	106		< 100		<100	<100	
Chloromethane	41	40	102		< 100		<100	<100	
Vinyl chloride	43	40	109		< 100		<100	<100	
Bromomethane	49	40	123		< 100		<100	<100	
Chloroethane	46	40	115		< 100		<100	<100	
Trichlorofluoromethane	38	40	96		< 100		<100	<100	
1,1-Dichloroethene	44	40	109		< 100		<100	<100	
Methylene chloride	44	40	109		< 100		<100	<100	
trans-1,2-Dichloroethene	40	40	100		< 20		<20	<20	
Methyl tert-butyl ether	43	40	109		< 20		<20	<20	
1,1-Dichloroethane	42	40	106		< 20		<20	<20	
2,2-Dichloropropane	37	40	92		< 20		<20	<20	
cis-1,2-Dichloroethene	39	40	97		< 20		<20	<20	
Bromochloromethane	37	40	94		< 20		<20	<20	
Chloroform	39	40	99		< 20		<20	<20	
1,1,1-Trichloroethane	40	40	99		< 20		<20	<20	
Carbon Tetrachloride	40	40	100		< 20		<20	<20	
1,1-Dichloropropene	34	40	84		< 20		<20	<20	
Benzene	39	40	97		< 20		22	38	38
1,2-Dichloroethane	38	40	95		< 20		<20	<20	
Trichloroethene	40	40	101		< 20		<20	<20	
1,2-Dichloropropane	39	40	98		< 20		<20	<20	
Bromodichloromethane	39	40	99		< 20		<20	<20	
Dibromomethane	38	40	94		< 20		<20	<20	
cis-1,3-Dichloropropene	38	40	94		< 20		<20	<20	
Toluene	39	40	97		< 20		93	130	23
trans-1,3-Dichloropropene	34	40	84		< 20		<20	<20	
1,1,2-Trichloroethane	38	40	94		< 20		<20	<20	
Tetrachloroethylene	41	40	101		< 20		<20	<20	
1,3-Dichloropropane	40	40	99		< 20		<20	<20	
Dibromochloromethane	36	40	91		< 20		<20	<20	
1,2-Dibromoethane	40	40	99		< 20		<20	<20	
Chlorobenzene	39	40	99		< 20		<20	<20	
1,1,1,2-Tetrachloroethane	39	40	96		< 20		<20	<20	
Ethylbenzene	40	40	99		< 20		240	270	8.3
m+p-Xylene	46	40	115		< 20		120	130	5.7
o-Xylene	40	40	99		< 20		34	37	6.0
Styrene	37	40	93		< 20		<20	<20	
Bromoform	37	40	91		< 20		<20	<20	
Isopropylbenzene	37	40	93		< 20		30	33	6.7
Bromobenzene	38	40	94		< 20		<20	<20	
1,2,3-Trichloropropane	38	40	94		< 20		<20	<20	
1,1,2,2-Tetrachloroethane	37	40	94		< 20		<20	<20	
n-Propylbenzene	43	40	108		< 20		26	28	5.2
2-Chlorotoluene	40	40	100		< 20		<20	<20	
4-Chlorotoluene	42	40	104		< 20		<20	<20	
1,3,5-Trimethylbenzene	40	40	100		< 20		<20	<20	
tert-Butylbenzene	41	40	102		< 20		<20	<20	
1,2,4-Trimethylbenzene	39	40	98		< 20		86	96	7.8
sec-ButylBenzene	36	40	90		< 20		<20	<20	
1,3-Dichlorobenzene	35	40	87		< 20		<20	<20	
1,4-Dichlorobenzene	39	40	98		< 20		27	31	9.8
p-Isopropyltoluene	38	40	96		< 20		<20	<20	
1,2-Dichlorobenzene	38	40	94		< 20		<20	<20	
n-butylbenzene	38	40	94		< 20		<20	<20	
1,2-Dibromo-3-chloropropan	35	40	86		< 20		<100	<100	
1,2,4-Trichlorobenzene	39	40	98		< 20		<20	<20	
1,2,3-Trichlorobenzene	38	40	96		< 20		<100	<100	
Naphthalene	38	40	94		< 20		1300	1300	0
Hexachlorobutadiene	42	40	104		< 20		<100	<100	
Average Recovery (%)			**98**						

Table E-II-15: Total Phosphorus (P), Nitrate, Nitrite and Total Kjeldahl Nitrogen (TKN) Analysis of Water QA/QC Samples

Sample	Total P [ppm]	Nitrate [ppm]	Nitrite [ppm]	TKN [ppm]
Control Spikes	**2007 Water Samples**			
Control	0.21	5.1	5.3	0.78
Control Target	0.2	5.0	5.0	0.75
Recovery (%)	105	102	106	104
Analytical Blank				
Blank	<0.01	<0.05	<0.05	<0.2
Analytical Duplicates				
07-29640	-	0.23	<0.05	
Duplicate	-	0.23	<0.05	
Average		0.23		
Std Dev		0		
RSD (%)		0		
07-29643	-	<0.05	<0.05	0.51
Duplicate	-	<0.05	<0.05	0.52
Average				0.5
Std Dev				0.01
RSD (%)				1.4

Table E-II-16: Nitrate and Nitrite Analysis of Water QA/QC Samples in 2008 Analyzed at ASU

Sample	Nitrate [ppm]	Nitrite [ppm]
Control Spikes	**2008 Water Samples**	
Control	0.5	0.4
Control Target	0.6	0.5
Recovery (%)	83	80
Control	0.5	0.4
Control Target	0.6	0.5
Recovery (%)	83	80
Average Recovery (%)	**83**	**80**
Std Dev	**0**	**0**
Blank	<0.05	<0.05
Blank	<0.05	<0.05

Table E-II-17: Total Phosphorus Analysis of Water QA/QC Samples in 2008, ASG

Sample	Total P [ppm]
Control Spikes	**2008 Water Samples**
Control	0.17
Control Target	0.2
Recovery (%)	85
Analytical Blank	
Blank	<0.01
Analytical Duplicate	
08-42055	<0.01
Duplicate	<0.01

E-II-18: Alkalinity Analysis of Water QA/QC Samples Analyzed at ASG

Sample	Alkalinity [ppm]
Control Spikes	**2007 Samples**
Control	98
Control Target	100
Recovery (%)	98
Analytical Duplicates	
07-29643	87
Duplicate	85
Average	86
Std Dev	1.4
RSD (%)	1.6

Table E-II-19: Total Organic Carbon Analysis of Sediment Samples Analyzed at RPC

Samples	Total Organic Carbon (%)
Analytical Blank	**2008 Sediment Samples**
Blank	< 0.02
Analytical Duplicate	
08-42012	9.21
Duplicate	9.25
Average	9.23
Std Dev	0.03
RSD (%)	0.3

Table E-II-20: Polychlorinated Biphenlys (PCBs) Analyzed in 2009 Sediment QA/QC Samples

Sample I.D.	Aroclor 1254 [ppm]	Aroclor 1260 [ppm]
Control Spike		
Control	0.043	<0.003
Control Target	0.05	<0.003
Recovery (%)	86	
Analytical Blank		
Blank	<0.003	<0.003

Table E-II-21: Alkalinity, Chromium VI, Total Suspended Solids (TSS) in 2009 Water Samples

Sample	Alkalinity mg CaCO3/L	Cr VI [ppm]	TSS [ppm]
Control	371		190
Control Target	384		200
Recovery (%)	97		95
Control	390		
Control Target	384		
Recovery (%)	102		
Average Recovery (%)	**99**		
Std Dev	**± 3.5**		
Blank	<15	<0.005	<1.0
09-25483			180
Duplicate			180
Average			180
Std Dev			0
RSD (%)			0
09-25681		<0.05	
09-25681		<0.05	
09-25689	75		
09-25689	73		
Average	74		
Std Dev	1.7		
RSD (%)	2.3		

II. CHAPTER II: QA/QC: PREVIOUS REPORTS FROM KINGSTON INNER HARBOUR

A. Totten Sims Hubicki Associates — Transportation Summary 1992

This report quotes unpublished data from a 1985 OMOE study performed by Dr. D. Poulton. Inorganics, PCBs and mercury were analyzed and compared to OMOE guidelines for open water disposal of dredged soils. No QA/QC information is reported with this data.

1978 OMOE data are also quoted but no results or QA/QC were provided.

B. CH2M Hill Engineering Ltd., Waterloo, ON — 1991 report by Belanger

Sediment samples were submitted to CANVIRO Analytical Laboratories Ltd for PAH analysis. All analytical methods followed a modified USEPA method SW846 using gas chromatography/mass spectrometry (GC/MS). Notes from CH2M Hill indicate that the lab uses method spikes and blanks as routine QA/QC (page 9). These were not included in the report. Each sample is also spiked with a surrogate compound and recoveries ranged from 66 percent to 143 percent. The report suggests that since results are reported as wet weight, the reported concentrations could be lower that actuality (page 10). Some samples were used as background indicators but these contained extremely variable results and so samples were compared to criteria levels instead (page 18).

C. R. Jaagumagi — Watershed Management Report, 1992

Surface sediment samples were taken in 1990 using a Ponar grab and analyzed for PAHs according to protocol described in the OMOE (1983). Three sediment samples were taken at each location, composited and homogenized and then subsampled into separate jars for different analyses. Results were compared to the CH2M Hill subsurface sample results. No QA/QC was provided for the results in this report.

D. Brooks, K., J.P.F. Fleury, J.G.Y. Raymond, A.M. Reinhardt, RMC — An Environmental Evaluation of the River Sediments Surrounding the Belle Island Landfill, Kingston, 1998

Sediment samples were taken in the fall of 1998 and analyzed for metals, pesticides, PCBs and PAHs. "A standard environmental engineering approach was followed throughout, with a stringent Quality Assurance/Quality Control program put in place to ensure the validity of the results" (page vi, Executive Summary). The program included field procedures: staff trained in the importance and techniques of good QA/QC and good recordkeeping. The authors also discuss the importance of reviewing the QA/QC provided by the analytical laboratory, including duplicates.

Field measurements using XRF and PCB test kits were run, and 10 percent of samples were run as duplicates. These duplicate analyses are not included in the report. Twenty inorganic samples were reanalyzed in the laboratory as an interlab comparison of results and these were reported in Table A-1.

Laboratory and field QA/QC results are not included in this report although one duplicate sample analyzed for PCBs and pesticides was included in the results tables (Table A-2).

E. Cross, Katherine — An Investigation of Organochlorines (Thesis), 1999

Sediment samples were analyzed for PCBs, pesticides, zinc (two) and PAHs (one) at AXYS Analytical Services, Sidney, BC and ASU, Queen's University and ASG, RMC, Kingston.

Samples were analyzed with control standards (NRC) and with the addition of surrogate standards. Samples were also analyzed along with blanks and some samples were analyzed in duplicate for QA/QC purposes. QA/QC laboratory procedures from AXYS were outlined but QA/QC results were not included in the appendices of the report with the exception of one duplicate PCB congener and pesticide sample. Duplicate results were very similar, indicating good repeatability. Cross reports that, overall, PCB duplicates showed a 30 percent variance for repeatability and pesticide samples showed a 35 percent variance for repeatability.

F. Derry, A., A. Dove, R. Fletcher, N. Benoit — PCB Source Trackdown in the Cataraqui River — 2001 Findings, prepared for Eastern Region OMOE, 2003

Sediment samples were collected in 2001, and PCB and pesticide analysis was performed by Maxxam Analytical. Total organic carbon was determined by the Laboratory Services Branch of the OMOE. Field QA/QC procedures included taking field duplicates (blind duplicate samples) at two of the sites. Field duplicate results for TOC, inorganic analysis, PCBs and pesticides are listed in Appendix A sediment data table and most replicates are very similar. One sample pair (#31) showed variable lead results of 840 ppm and 440 ppm, but results were both in agreement with respect to criteria. No other QA/QC data were reported.

G. Bennett, Joe — Phase 2 Ecological Risk Assessment of Contamination at Two Locations in Kingston Harbour, Environmental Sciences Group, RMC, 2003

Sediments were homogenized before sub-sampling. We are referencing inorganic element results for two areas — FF4 and FF6. The former area, FF4 was selected as a control site, and while most parameters showed low concentrations, lead levels were above criteria. The inorganic element analysis was performed at ASU using inductively coupled plasma atomic emission spectrometer (ICP-AES). Accuracy was monitored using NRC Canada Marine Reference sediment MESS-3 and results were within control limits established by ASU. Analytical blank samples showed no detectable inorganic elements. Analytical duplicates were run and Relative standard deviations calculated for the replicate results. Average RSDs were below 10 percent, indicating very good agreement between replicates.

H. Hamilton, T. and P.V. Hodson — Research to Evaluate the Potential Risk to Fish of Kingston Harbour Sediments, as Indicated by Bioassays of Exposure and Toxicity, School of Environmental Studies, Queen's University, Kingston, 2003

Fish (rainbow trout) exposed to sediments in five areas of Kingston Harbour, with three replicates in each area. Fish were also exposed in the lab to levels of PAHs as a comparison along with positive and negative control. The positive and negative controls provided a check on the enzyme assay of the study with each analytical run.

I. Tinney, Mark — Site Investigation and Ecological Risk Assessment of Kingston Inner Harbour (Thesis), 2006

Sediment samples were analyzed for inorganics, PCBs and PAHs at ASU, Queen's University and at ASG, RMC.

Inorganic samples were analyzed at ASU along with control standards MESS-3 and SS-2 and average determined results were all within laboratory control limits. Analytical blanks were all below detection for inorganics. Analytical duplicates showed very good agreement with average relative standard deviations below 3.3 percent, indicating very good precision.

Spiked controls run with sediment samples were all within acceptable recovery levels and blanks were below detection for PCBs. Two field duplicates showed results either below detection or with RSDs just over the acceptable level. Analytical duplicates were problematic and duplicated poorly. Surrogate recoveries were also not what was expected. Notes from the report indicate that this could be due to organic carbon in the samples or even high moisture content.

Sediment samples were analyzed for PAHs by GC/MS at ASG. For each set analyzed, a six-point calibration curve was prepared. Control spikes and blanks were within acceptable levels in the PAH analysis. Duplicate analyses showed most RSDs within acceptable levels but some compounds showed higher RSDs.

J. Benoit, Nadine and Alice Dove — Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 Monitoring Programs, 2006

The main focus of this report was PCB contamination but PAHs were analyzed in some sediments. At least three surface samples were taken at each location and sediments were homogenized prior to subsampling for analyses. PAH results were reported along with recovery rates for spiked samples. The recoveries ranged from 39 percent to 120 percent (Appendix B). Samples taken from Georgian Bay and from Lake Erie were used as control site for comparison to other locations, and PAHs were below detection in the control site samples. No other QA/QC data are provided with the PAH results.

K. Manion, Nathan — Determining the Distribution and Fate of Mercury in Sediment of the Cataraqui River at Kingston, Ontario (Thesis), Queen's University, 2007

Concentrations of THg were calculated by comparing the absorbance of the sample to the absorbance from a calibration curve created from Hg standards made up from an ICP-AES, ICP MS (PlasmaCAL) stock standard of 1000 μg g-1 Hg. In each run, a maximum of 15 samples, a duplicate sample was analyzed along with an aqueous QC (calibration check sample) that was prepared from a different Hg source from that used for the calibration standards. Duplicate samples of NCR Certified Reference Material MESS-3 were analyzed with each run.

Blanks and QA/QC spiked water samples are reported in Appendix T-4 (p. 117) along with the QA/QC targets. Control spike recoveries were within acceptable levels for all. Some blanks showed detectable levels of mercury but all were at levels very close to the detection limit of 1 ppb. Duplicate results are in Appendix T-5 and all but two were below 30 percent RSD. The average RSD was 8.6 percent (p. 118). Control standard MESS-3 was also run with the batches and results for all but one were within 30 percent of the expected range (Appendix T-6).

L. Scheider, W. and E. Awad — Methyl Mercury Study in the Kingston Inner Harbour, OMOE Water Monitoring and Reporting Section, 2009

Sediment samples were analyzed for mercury as part of this study. Three Ponar grab samples were taken at each site and homogenized into a single sediment sample. Mercury results are reported along with other parameters analyzed. No QA/QC data are provided for these results.

III. CHAPTER II: QA/QC: 2010–2011 ESG DATA

ESG follows an internal quality assurance/quality control program that was implemented to allow data quality to be monitored on an ongoing basis. This program is completely described in the QAPP (ESG 2010). The points relevant to the discussion of sediment sample QA/QC collection and analysis at Kingston Inner Harbour in 2010 are summarized here for completeness.

All samples are given sequential numerical codes before submission to the analytical firms; these codes mask any information concerning site location, sample type or possible concentration of the sample.

Accuracy is measured and controlled by instrument calibration, the use of control standards and control spikes and the collection and analysis of analytical blanks. Control standards and control spikes are reference materials with known concentrations. After analysis of a control standard or spike, the instrument's calibration is evaluated by comparing the results of the analysis with the known concentration.

Analytical blanks are processed through extraction/digestion and analysis procedures. These blanks give a measure of the quantity of any contaminant (analyte) that may be added to the overall result during the analysis.

Precision is measured and controlled by the analysis of analytical duplicates, which are replicate preparations and analyses of the same sample. Comparisons of the average relative standard deviations (RSD%), also known as coefficients of variation, which are calculated as the standard deviation divided by the mean , are used to evaluate laboratory precision. Acceptable limits are generally considered to be less than 40 percent RSD for inorganics and 30 percent for other analyses, with 20 percent or less considered good agreement.

The results of the QA/QC program for the 2010 sediment sampling program at Kingston Inner Harbour are discussed below in order of analysis type. The laboratory associated with each analysis type is listed.

A. PCBs in Sediment Samples — ASU, Queen's University

The QA/QC protocol for PCBs calls for analyses to be carried out in batches of no more than 30 samples. Each batch must include one analytical duplicate, a procedural blank and a spiked control sample. Each batch is treated as a separate unit: samples within the same batch must be worked up and analyzed continuously, and the QA/QC data must be considered with respect to each batch.

1. Accuracy

Internally, all samples were spiked with an aliquot of the surrogate standard decachlorobiphenyl (DCBP) prior to analysis by gas chromatography (GC) with electron capture detection (ECD), in order to measure recovery of PCBs. Sample results were corrected for this recovery. The method was calibrated using known standards of Aroclor 1254 and 1260. A calibration check standard was run with each batch to verify the calibration. Duplicates, blanks, the spiked control sample, DCBP recovery and the calibration check were all required to be within predetermined control limits.

Sediment samples from 2010 were analyzed along with some repeat analyses of 2004 and 2005 samples. Spiked control samples (three) were run with the sediment PCB analyses; the average recovery was 113 percent for Aroclor 1260 control spikes (Table E-II-22). Laboratory control limits allow for a 30 percent variation in spike recovery.

Each batch was monitored internally by analyzing blank samples for PCBs. All results were below detection limits in the analytical blanks (Table E-II-22).

2. Precision/Repeatability

Precision was monitored with the analysis of five sediment sample analytical replicates. The resulting average RSDs for the replicates were 9.2 percent for Aroclor 1254 and 8.2 percent for Aroclor 1260, indicating very good agreement between replicates. Notes from the laboratory indicate that Aroclor 1242 could not be reported due to interferences.

B. Mercury in Sediment Samples — ASG, RMC

1. Accuracy

Sediment samples were analyzed with one control spiked sample, and the reported recovery was 84 percent (Table E-II-23). One blank sample was analyzed for mercury and results were below detection (Table E-II-23).

2. Precision

One sediment analytical duplicate was analyzed for mercury, and the resulting RSD was 4.2 percent, indicating excellent agreement between replicates (Table E-II-23).

Table E-II-22: Aroclor Polychlorinated Biphenyl (PCB) Results for Sediment QA/QC Samples

Sample	Aroclor 1254 [ppb]	Aroclor 1260 [ppb]
Control Spikes		
Control	-	11.6
Control Target	-	10
Recovery (%)		116
Control	-	22
Control Target	-	19
Recovery (%)		115
Control	-	10.9
Control Target	-	10
Recovery (%)		109
Average Recovery (%)		**113**
Std Dev		**± 3.7**
Analytical Blanks		
Blank	<3.0	<3.0
Blank	<3.0	<3.0
Blank	<3.0	<3.0
Analytical Duplicates		
05-17352	211	268
Duplicate	236	255
Average	224	261
Std Dev	18	9.7
RSD (%)	8.0	3.7
10-20424	33	59
Duplicate	41	69
Average	37	64
Std Dev	5.4	7.0
RSD (%)	15	11
10-20470	39	328
Duplicate	31	262
Average	35	295
Std Dev	6.1	47
RSD (%)	17	16
10-20486	14	160
Duplicate	14.5	177
Average	14.3	169
Std Dev	0.3	12
RSD (%)	2.5	7.1
10-20504	164	302
Duplicate	173	288
Average	169	295
Std Dev	6.4	9.9
RSD (%)	3.8	3.4
Average RSD (%)	**9.2**	**8.2**
Std Dev	**± 6.5**	**± 5.3**

Table E-II-23: Mercury Analysis of Sediment QA/QC Samples

Sample	**Hg [mg/L]**
Control Spike	
Control Sample	0.37
Control Target	0.44
Recovery (%)	84
Analytical Blank	
Blank	<0.05
Analytical Duplicate	
10-20492	0.22
Duplicate	0.21
Average	0.22
Std Dev	0.01
RSD (%)	4.2

IV. Chapter III: QA/QC: 2008 and 2009 ESG Data on Uptake in Plant and Animal Biota

ESG follows an internal quality assurance/quality control program that was implemented to allow data quality to be monitored on an ongoing basis. This program is completely described in the QAPP (ESG 2009). The points relevant to the discussion of QA/QC sample collection and analysis of plant and tissue samples for the study of biological effects of contamination at Kingston Inner Harbour in 2008 and 2009 are summarized here for completeness.

All samples are given sequential numerical codes before submission to the analytical firms; these codes mask any information concerning site location, sample type or possible concentration of the sample.

Accuracy is measured and controlled by instrument calibration, the use of control standards and control spikes and the collection and analysis of analytical blanks.

Control standards are reference materials with known concentrations. After analysis of a control standard or spike, the instrument's calibration is evaluated by comparing the results with the known concentration.

Analytical blanks are processed through extraction/digestion and analysis procedures. These blanks give a measure of the quantity of any contaminant (analyte) that may be added to the overall result during the analysis.

Precision is measured and controlled by the analysis of analytical duplicates, which are replicate preparations and analyses of the same sample. Comparison of the average relative standard deviations (RSD%), also known as coefficients of variation, which are calculated as the standard deviation divided by the mean, are used to evaluate laboratory precision. Acceptable limits are generally considered to be less than 40 percent RSD for inorganics and 30 percent for other analyses, with 20 percent or less considered good agreement.

The results of the QA/QC program for the biological effects sampling program at Kingston Inner Harbour are discussed below in order of analysis type. The laboratory associated with each analysis type is listed.

A. Inorganic Elements in Plant Samples Analyzed in 2008 by ICP-OES — ASU, Queen's University

1. Accuracy

Accuracy was monitored internally by ASU with the analysis of Standard Reference Materials Bush, Branches and Leaves (BB&L) and Spinach Leaves (Table E-III-1). Results for most elements of BB&L (GBW 07602) were within ASU control limits or below detection limits for the element. Notes from the lab indicate that the reason that copper levels are lower than their control limits is that the limits were established prior to a change in lab materials. The filter that ASU used in the past had low levels of copper. Current lab methods use a new filter without the contributing low copper concentration. Determined copper levels were close to the BB&L reference value provided by the supplier (Table E-III-1).

Certified reference material Spinach Leaves (NIST SRM 1570a) were also analyzed, and results, where detectable, were within control limits (Table E-III-1).

Analytical blank samples were run with the 2008 plant samples. The results are presented in Table E-III-2; all elements in the analytical blanks were below detection limits.

2. Precision/Repeatability

Internal precision was monitored by ASU through the use of analytical duplicates. Plant samples (two pairs) were analyzed in duplicate for inorganic elements (Table E-III-2), and average RSDs were less than 20 percent for most detectable elements. Copper levels were below detection in one sample pair and the other pair reported an RSD of 64 percent. Concentration levels of copper were very low so the variability in the results was accepted and further analysis was not required (Table E-III-2).

B. Inorganic Elements in Tissue Samples Analyzed in 2009 by ICP-OES — ASU, Queen's University

1. Accuracy

Accuracy was monitored internally by ASU with the analysis of Standard Reference Lobster Hepatopancreas (TORT-2) (Table E-III-3). ASU has developed control limits for some inorganic elements in TORT, and all determined results were within control limits (Table E-III-3).

Analytical blank samples were run with the 2009 tissue samples. All elements were below detection in the blanks (Table E-III-4). Notes from the lab indicate that detection limits for nickel and chromium were raised in some batches because of interferences (Table E-III-4).

2. Precision/Repeatability

Internal precision was monitored by ASU through the use of analytical duplicates. Five samples were analyzed in duplicate in 2009, and when nickel and chromium results were affected by interferences, the tissue samples were reanalyzed for those elements to confirm concentrations (Table E-III-4). Average RSDs for most inorganic elements in tissue samples were 20 percent or less, indicating good agreement between replicates. Only one sample pair showed detectable lead results, and the resulting RSD was 54 percent. Lead concentrations in the pair were very low so no further action was taken (Table E-III-4).

C. Polychlorinated Biphenlys (PCBs) in Plant Samples in 2008 — ASG, RMC

1. Accuracy

Aroclor PCB control spike recoveries were 100 percent for Aroclor 1254 and 113 percent for Aroclor 1260 (Table E-III-5). Results were below detection in the analytical blanks (Table E-III-5).

2. Precision

Duplicate plant analyses are listed in Table E-III-5 and some variability was seen in analytical duplicates. Three replicates were analyzed, two of them in triplicate. The RSD was acceptable for Aroclor 1260 replicates of sample 08-42070. Sample 08-42069 showed variable results for both Aroclor 1254 and 1260 with RSDs of 66 percent and 68 percent (Table E-III-5). PCB levels in the plants were very low and not of concern in these samples. Further analysis was not required.

D. PCBs in Tissue Samples in 2009 — ASG, RMC

1. Accuracy

Average Aroclor PCB control spike recovery was 116 percent for Aroclor 1260 in tissue samples (Table E-III-6). Results were below detection in the analytical blanks (Table E-III-6).

2. Precision

Duplicate plant analyses are listed in Table E-III-6, and average RSDs were 11 percent for Aroclor 1254 and 18 percent for Aroclor 1260, well within acceptable limits (Table E-III-6).

Table E-III-1: Inorganic Element Results for Plant Standards Bush, Branches and Leaves (BB&L) and Spinach Leaves

Element	**BB&L Certified Value**	**Determined 2008**	**ASU Control Limits 2009**
	[ppm]	**[ppm]**	**[ppm]**
Cu	6.6	6.2	6.54–9.06
Ni	1.7	<2.0	<2.0
Co	0.41	<1.0	<1.0
Cd	0.38	<1.0	<1.0
Pb	47	47	35.3–73.7
Zn	55	56	47.8–66.4
Cr	2.6	<2.0	<2.0
As	1.25	1.5	0.50–1.82

Element	**Spinach Certified Value**	**Determined 2008**	**ASU Control Limits 2009**
	[ppm]	**[ppm]**	**[ppm]**
Cu	12.2 ± 0.6	12	11.4–17.4
Ni	2.14 ± 0.1	<2.0	<2.0
Co	0.39 ± 0.1	<1.0	<1.0
Cd	2.89 ± 0.07	2.4	0.9–3.3
Pb	n/a	<2.0	
Zn	82 ± 3.0	76	51.2–104
Cr	n/a	<2.0	
As	0.068 ± 0.012	<1.0	

Table E-III-2: Inorganic Element Results for Plant Sample Analytical Blanks and Duplicates

Sample	Cu	Ni	Co	Cd	Pb	Zn	Cr	As
	[ppm]	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**	**[ppm]**
Analytical Blanks								
Blank	<2.0	<2.0	<1.0	<1.0	<2.0	<5.0	<2.0	<1.0
Blank	<2.0	<2.0	<1.0	<1.0	<2.0	<5.0	<2.0	<1.0
Analytical Duplicates								
08-42070	<2.0	3.1	<1.0	<1.0	<2.0	11.4	7.7	<1.0
Duplicate	<2.0	3.0	<1.0	<1.0	<2.0	10.5	6.8	<1.0
Average		3.1				11	7.3	
Std Dev		0.1				0.7	0.7	
RSD (%)		2.5				6.0	9	
08-42236	8.1	5.4	<1.0	<1.0	2.2	17.9	8.3	1.2
Duplicate	3.0	3.4	<1.0	<1.0	2.3	14.4	8.1	1.2
Average	5.5	4.4			2.2	16.1	8.2	1.2
Std Dev	3.6	1.4			0.01	2.5	0.1	0.02
RSD (%)	64	33			0.3	15	1.6	1.7
Average RSD (%)	**64**	**18**			**0.3**	**11**	**5.3**	**1.7**
Std Dev	**-**	**± 21**			**-**	**± 6.6**	**± 5.2**	**-**

Table E-III-3: Inorganic Element Results for Tissue Standard Lobster Hepatopancreas Reference Material (TORT-2)

Element	TORT-2 Certified Value	Average Determined	*n	ASU Control Limits 2009
	[ppm]	**[ppm]**		**[ppm]**
Cu	106 ± 10	92 ± 0	2	66.2–125
Ni	2.50 ± 0.19	2.5 ± 0.4	4	<2.0–2.9
Co	0.51 ± 0.09	0.54 ± 0	2	-
Cd	26.7 ± 0.6	25 ± 0	2	20.6–30
Pb	0.35 ± 0.13	<0.5	2	-
Zn	180 ± 6	173 ± 0	2	137–200
Cr	0.77 ± 0.15	1.1 ± 0.1	4	-
As	21.6 ± 1.8	20 ± 0	2	13.1–23.7

*n = number of samples

Table E-III-4: Inorganic Element Results for Tissue Sample Analytical Blanks and Duplicates in 2009

Sample	Cu [ppm]	Ni [ppm]	Co [ppm]	Cd [ppm]	Pb [ppm]	Zn [ppm]	Cr [ppm]	As [ppm]
Analytical Blanks								
Blank	<0.5	<2.0 **	<0.5	<0.5	<0.5	<5.0	<3.0**	<1.0
Blank	<0.5	<2.0 **	<0.5	<0.5	<0.5	<5.0	<3.0**	<1.0
Blank	<0.5	<2.0 **	<0.5	<0.5	<0.5	<5.0	<3.0**	<1.0
Blank		<1.0					<1.0	
Blank		<1.0					<1.0	
Analytical Duplicates								
09-07646	2.5	<2.0	<0.5	<0.5	<0.5	81	<3.0	<1.0
Duplicate	2.7	<2.0	<0.5	<0.5	<0.5	82	<3.0	<1.0
Average	2.6					81		
Std Dev	0.1					0.8		
RSD (%)	5.5					0.9		
09-07646 repeat		1.1					1.5	
Duplicate		1.3					1.4	
Average		1.2					1.4	
Std Dev		0.1					0.1	
RSD (%)		8.4					3.9	
09-07721 / 7722	4.5	<2.0	<0.5	<0.5	7.3	51	3.0	<1.0
Duplicate	5.2	5.6	<0.5	<0.5	3.3	54	10	<1.0
Average	4.9				5.3	52	6.7	
Std Dev	0.5				2.9	2.6	5.1	
RSD (%)	10				54	4.9	77	
09-07721 / 7722 repeat		<1.0					2.2	
Duplicate		<1.0					2.1	
Average							2.2	
Std Dev							0.08	
RSD (%)							3.9	
09-07796 / 7797	4.8	<2.0	<0.5	<0.5	0.7	47	5.4	<1.0
Duplicate	4.7	<2.0	<0.5	<0.5	<0.5	53	<3.0	<1.0
Average	4.8					50		
Std Dev	0.04					4.7		
RSD (%)	0.7					9.4		
09-07796 / 7797 repeat		<1.0					1.8	
Duplicate		<1.0					1.7	
Average							1.8	
Std Dev							0.1	
RSD (%)							6.4	
09-07873		<1.0					<1.0	
Duplicate		<1.0					<1.0	
09-07879	1.7	<2.0	<0.5	<0.5	<0.5	74	4.3	<1.0
Duplicate	1.7	<2.0	<0.5	<0.5	<0.5	81	5.0	<1.0
Average	1.7					78	4.6	
Std Dev	0.04					5.0	0.5	
RSD (%)	2.1					6.5	11	
Average RSD (%)	**4.6**	**8.4**			**54**	**5.4**	**20**	
Std Dev	**± 4.2**	**-**			**-**	**± 3.5**	**± 32**	

** Detection limits raised due to interferences

Table E-III-5: Aroclor PCB Results for Plant QA/QC Samples

Sample	Aroclor 1242 [ppm]	Aroclor 1254 [ppm]	Aroclor 1260 [ppm]
Control Spike			
Control	-	-	0.013
Control Target	-	-	0.01
Recovery (%)			127
Control	-	0.01	0.0098
Control Target	-	0.01	0.01
Recovery (%)		100	98
Average Recovery (%)		**100**	**113**
Std Dev			**± 21**
Analytical Blanks			
Blank	<0.003	<0.003	<0.003
Blank	<0.003	<0.003	<0.003
Analytical Duplicates			
08-42069	<0.003	0.003	0.02
Duplicate	<0.003	0.013	0.05
Triplicate	<0.003	0.007	0.02
Average		0.007	0.03
Std Dev		0.005	0.02
RSD (%)		66	68
08-42070	<0.003	<0.003	<0.003
Duplicate	<0.003	0.01	0.01
Triplicate	<0.003	<0.003	0.012
Average		0.01	0.01
Std Dev		-	0.002
RSD (%)		-	22
08-42081	<0.003	0.004	<0.003
Duplicate	<0.003	<0.003	0.003
Average RSD (%)		**66**	**45**
Std Dev			**± 33**

Table E-III-6: Aroclor PCB Results for Tissue QA/QC Samples

Sample	Aroclor 1242 [ppm]	Aroclor 1254 [ppm]	Aroclor 1260 [ppm]
Control Spike			
Control	-	-	0.13
Control Target	-	-	0.1
Recovery (%)			130
Control	-	-	6.1
Control Target	-	-	5.0
Recovery (%)			122
Control	-	-	0.13
Control Target	-	-	0.1
Recovery (%)			130
Control	-	-	4.0
Control Target	-	-	5.0
Recovery (%)			80
Average Recovery (%)			**116**
Std Dev			**± 24**
Analytical Blanks			
Blank	<0.05	<0.05	<0.05
Blank	<0.05	<0.05	<0.05
Blank	<0.05	<0.05	<0.05
Analytical Duplicates			
09-7700	<0.05	0.05	0.06
Duplicate	<0.05	0.05	0.09
Average		0.05	0.08
Std Dev		0	0.02
RSD (%)		0	28
09-7787	<0.05	0.44	2.0
Duplicate	<0.05	0.32	1.8
Average		0.38	1.9
Std Dev		0.08	0.1
RSD (%)		22	7.4
09-7811	<0.05	<0.05	<0.05
Duplicate	<0.05	<0.05	<0.05
Average RSD (%)		**11**	**18**
Std Dev		**± 16**	**± 15**

APPENDIX F: BIOLOGICAL UPTAKE REGRESSION PLOTS

LIST OF FIGURES

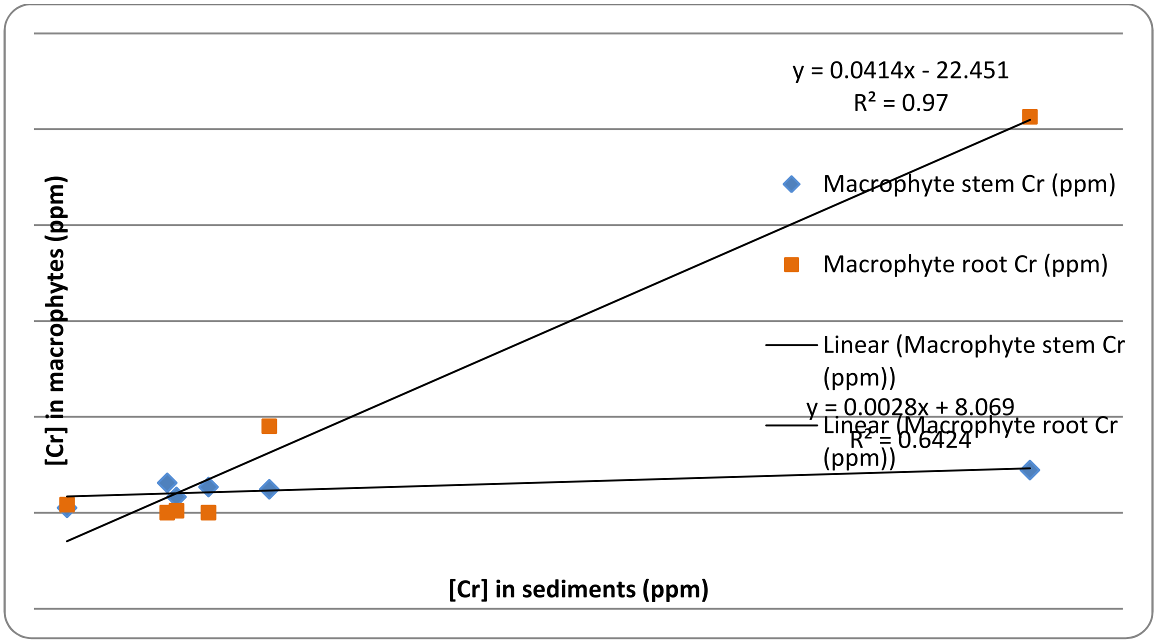


Figure F-III-1: Cr concentrations in sediments vs Cr concentrations in macrophytes for KIH locations.

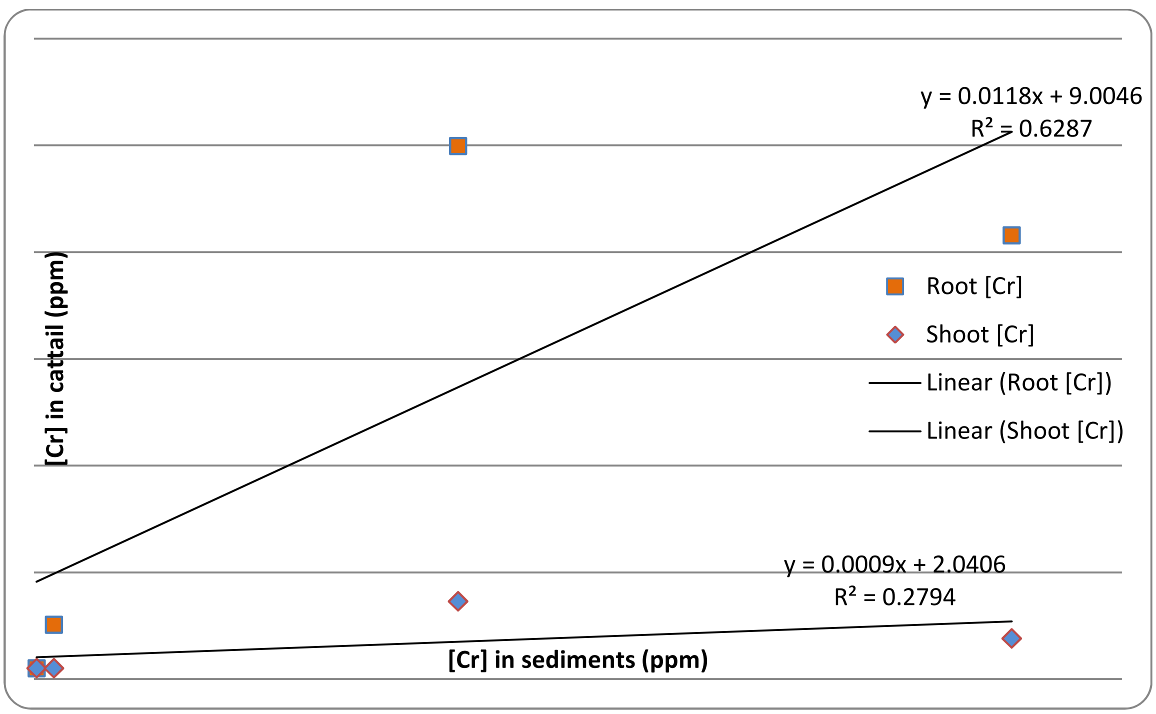


Figure F-III-2: Cr concentrations in sediments vs Cr concentrations in cattails for KIH sample sites.

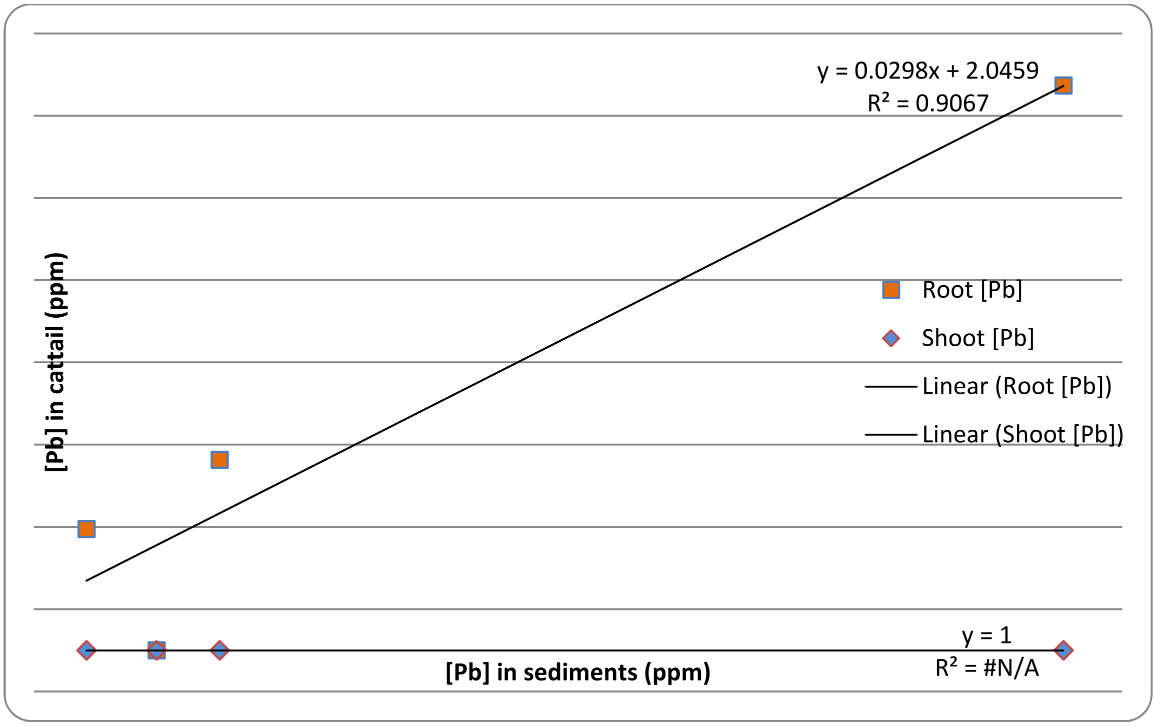


Figure F-III-3: Pb concentrations in sediments vs Pb concentrations in cattails for KIH sample sites.

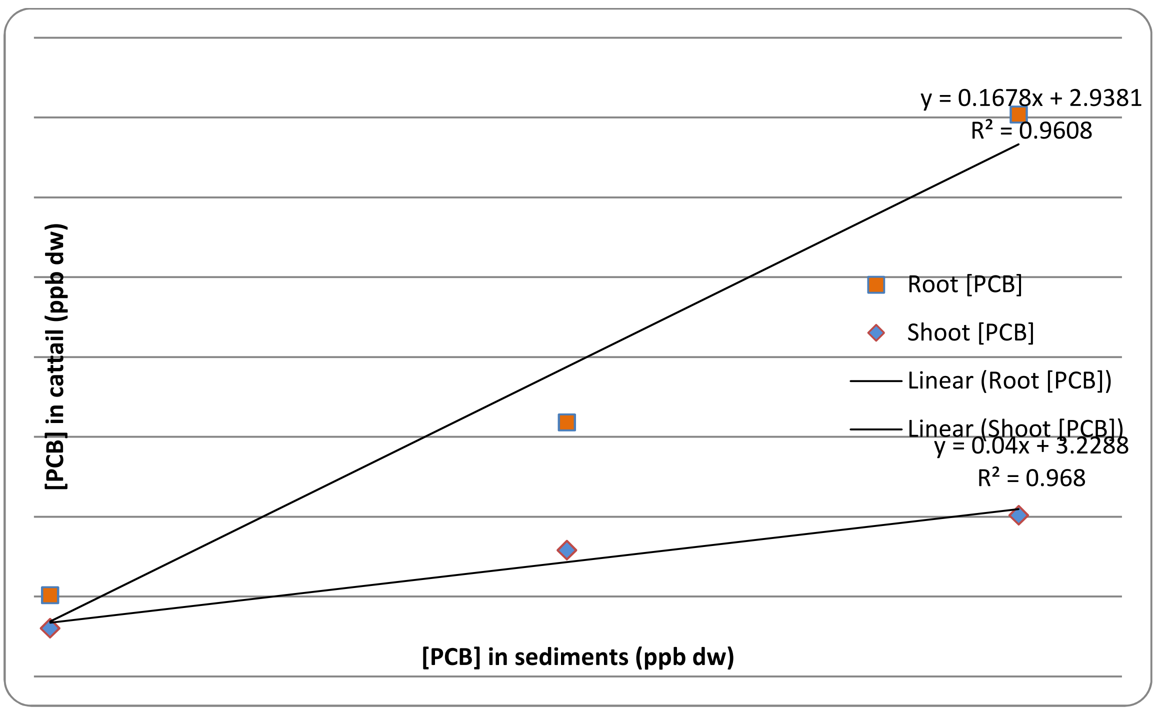


Figure F-III-4: Total PCB concentrations in sediments vs total PCB concentrations in cattails for KIH sample sites.

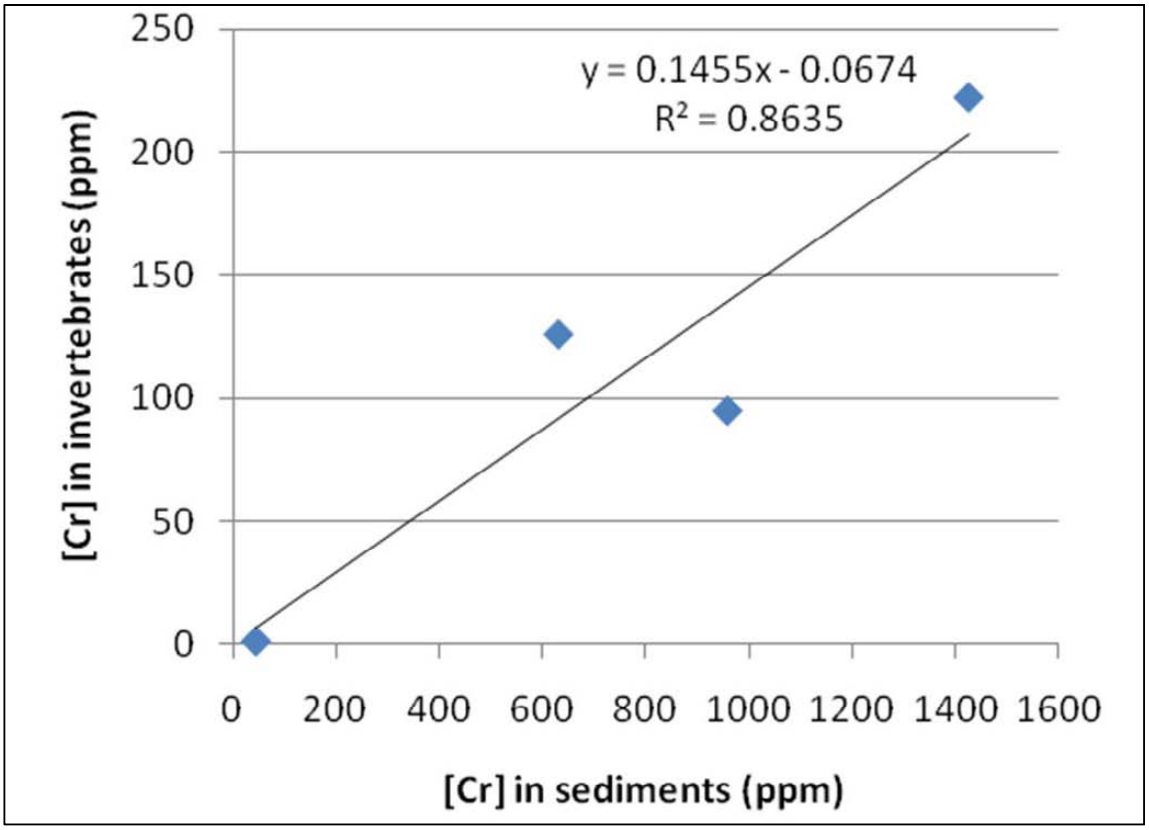


Figure F-III-5: Cr concentrations in sediments vs average Cr concentrations in field invertebrates from KIH sample sites.

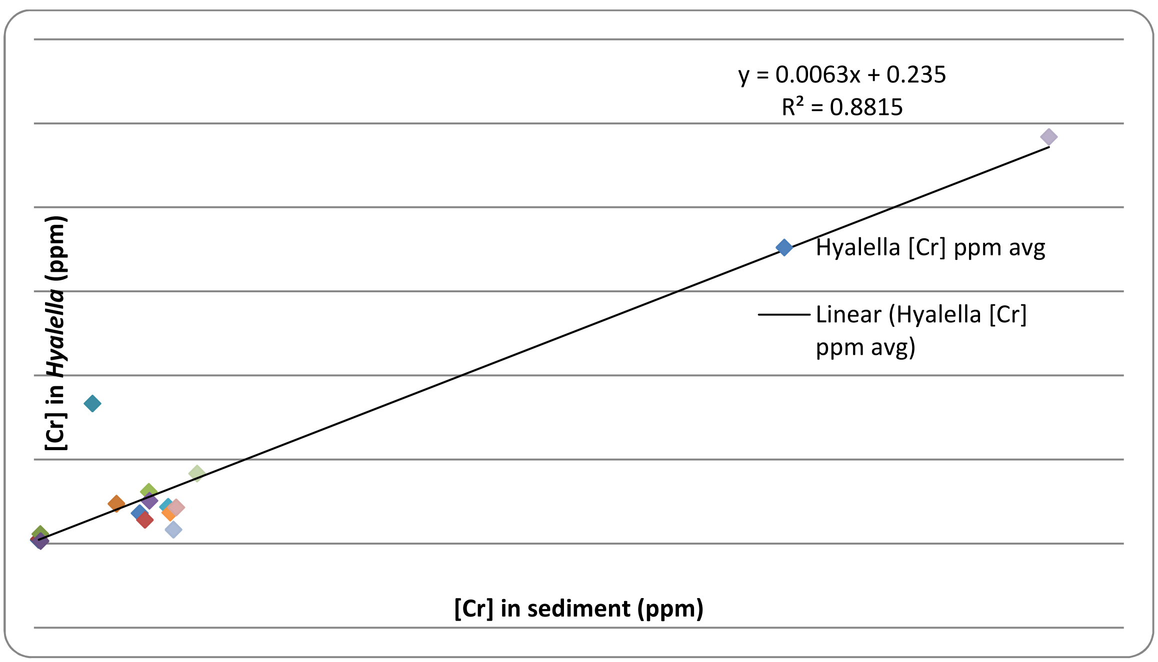


Figure F-III-6: Cr concentrations in sediments vs average Cr concentrations in *Hyalella azteca* following 28-day lab bioassays with KIH sediments.

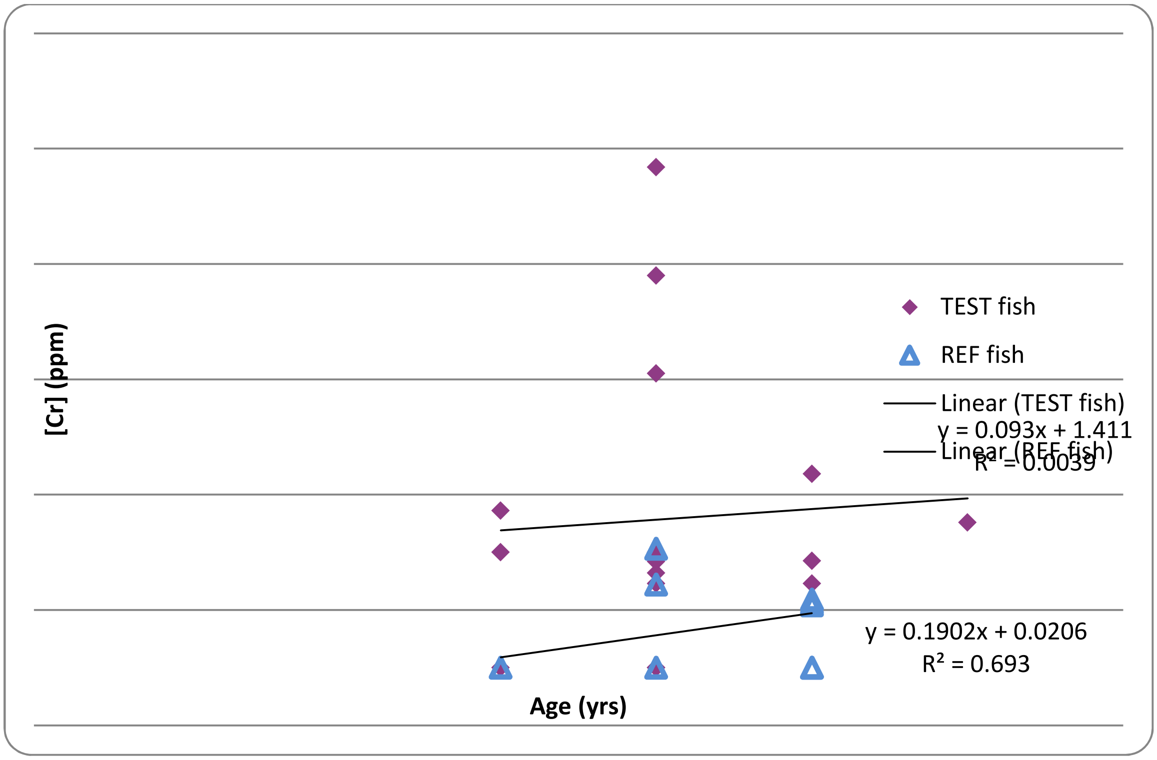


Figure F-III-7: Age of fish vs tissue Cr concentrations for fish sampled from KIH locations.

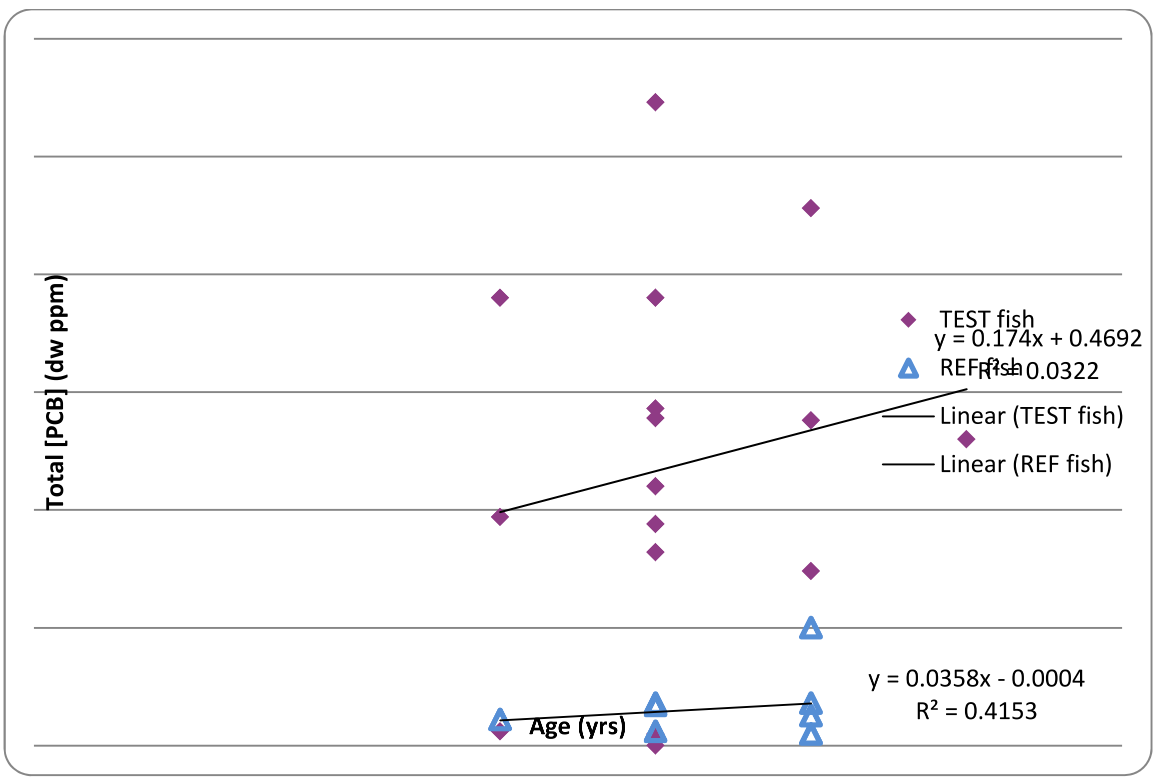


Figure F-III-8: Age of fish vs tissue PCB concentrations for fish sampled from KIH locations.

APPENDIX G: TOXICITY GRAPHS

LIST OF FIGURES

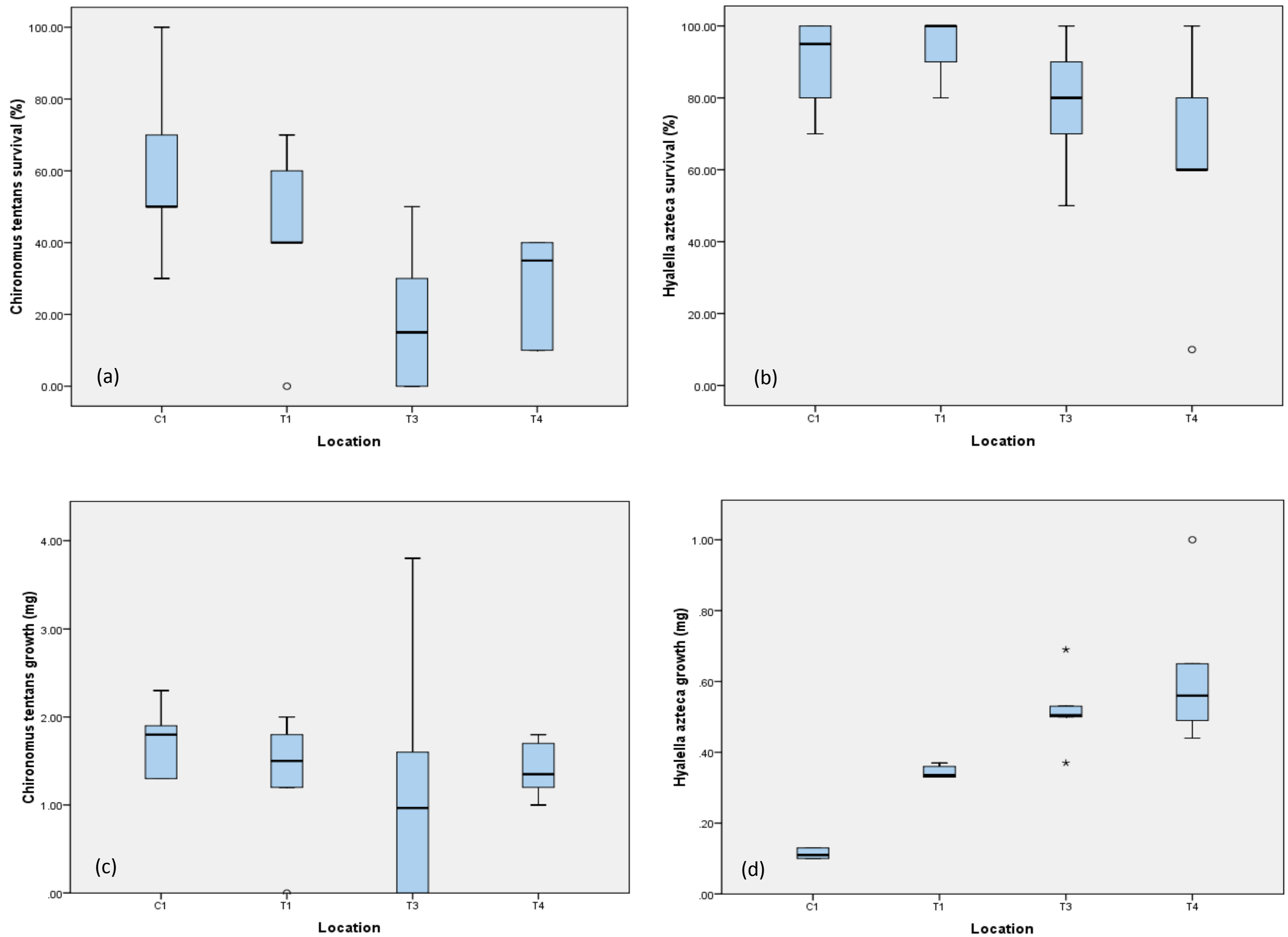


Figure G-III-1: Sediment toxicity boxplots for KIH sites T1, T3, and T4. (a) *Chironomus tentans* survival; (b) *Hyalella azteca* survival; (c) *Chironomus tentans* growth; (d) *Hyalella azteca* growth. C1 = control site; T1 = upstream reference site.

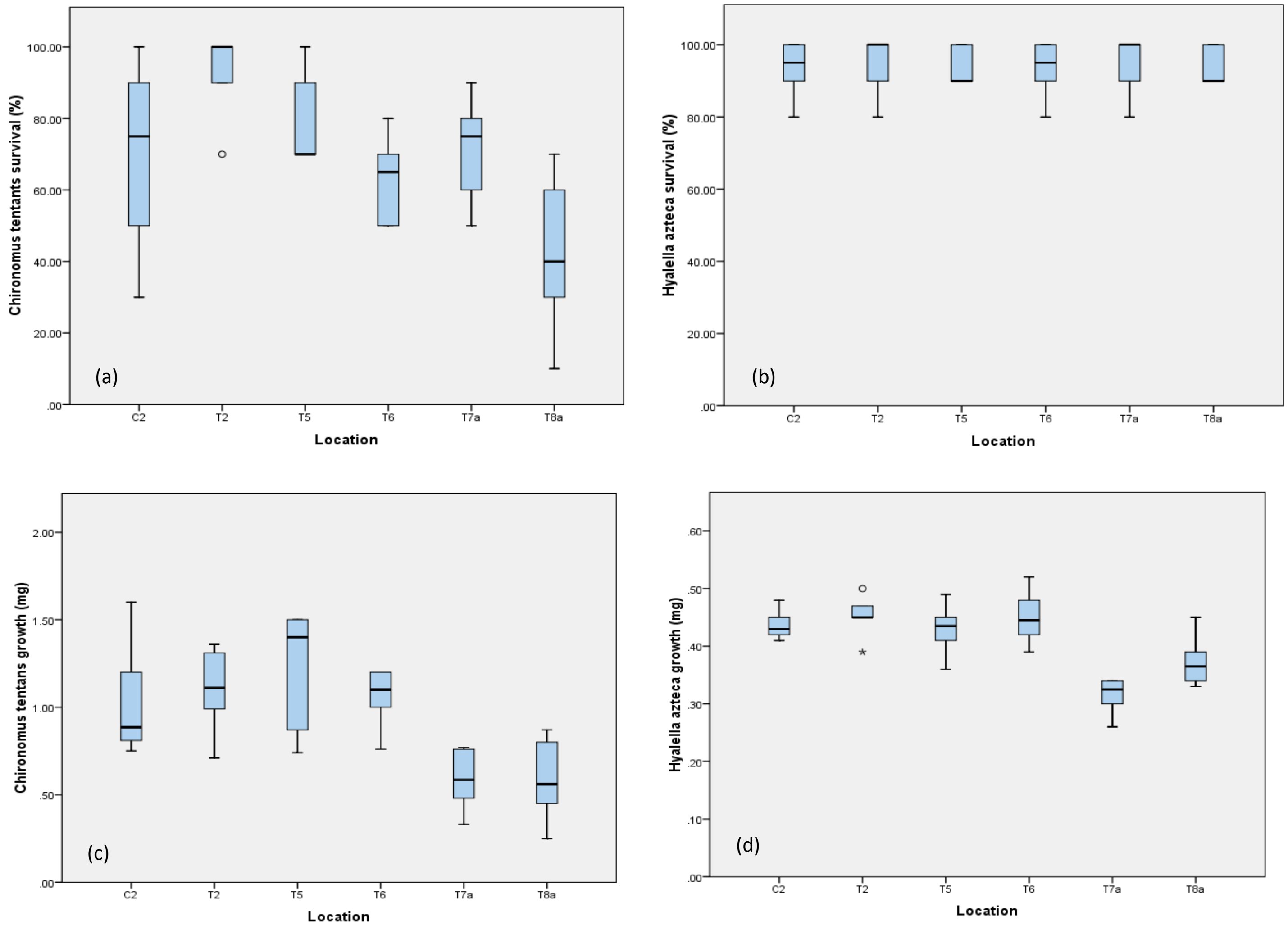


Figure G-III-2: Sediment toxicity boxplots for KIH sites T2, T5, T6, T7a, and T8a. (a) *Chironomus tentans* survival; (b) *Hyalella azteca* survival; (c) *Chironomus tentans* growth; (d) *Hyalella azteca* growth. C2 = control site; T2 = upstream reference site.

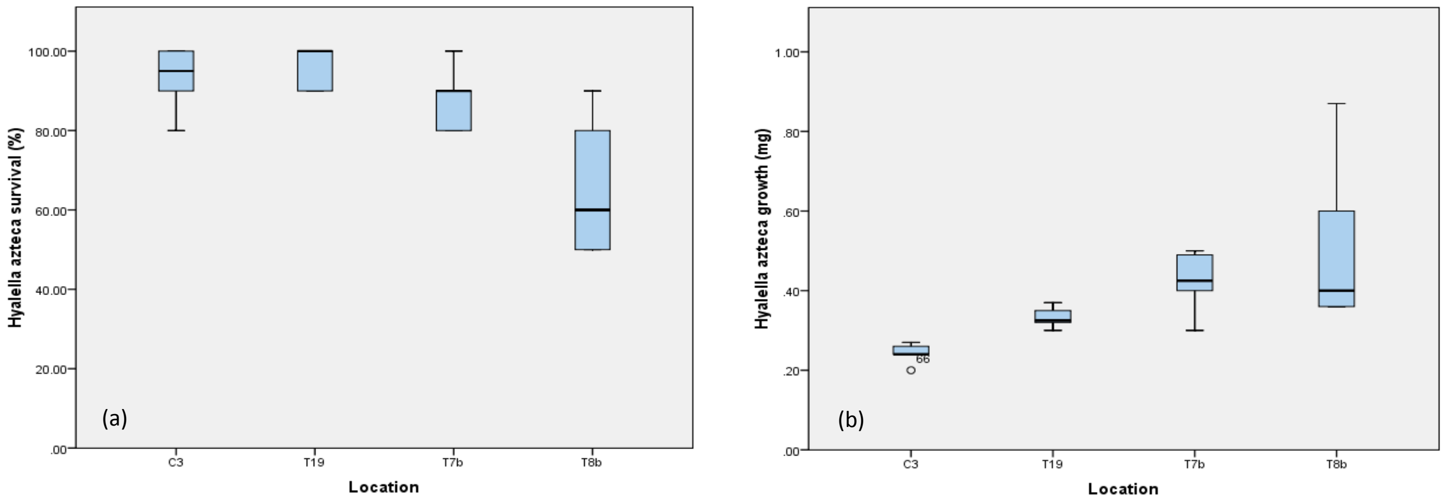


Figure G-III-3: Sediment toxicity boxplots for KIH sites T19, T7b, and T8b. (a) *Hyalella azteca* survival; (b) *Hyalella azteca* growth. C3 = control site; T19 = upstream reference site.

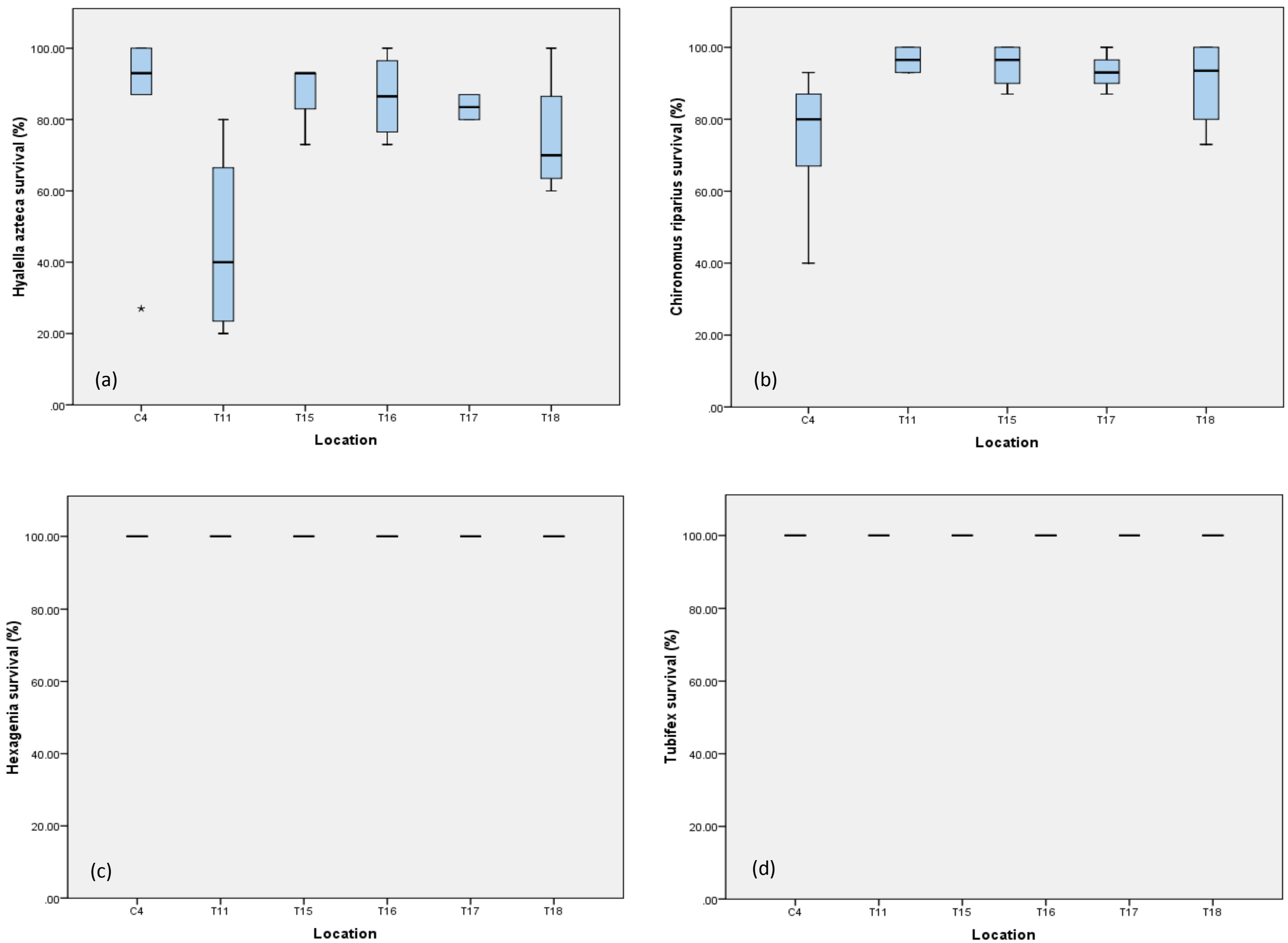


Figure G-III-4: Sediment toxicity boxplots for survival endpoints for KIH sites T11, T15, T16, T17, and T18. (a) *Hyalella azteca* ; (b) *Chironomus riparius* ; (c) *Hexagenia* ; (d) *Tubifex* . C4 = control site; T11 = upstream reference site.

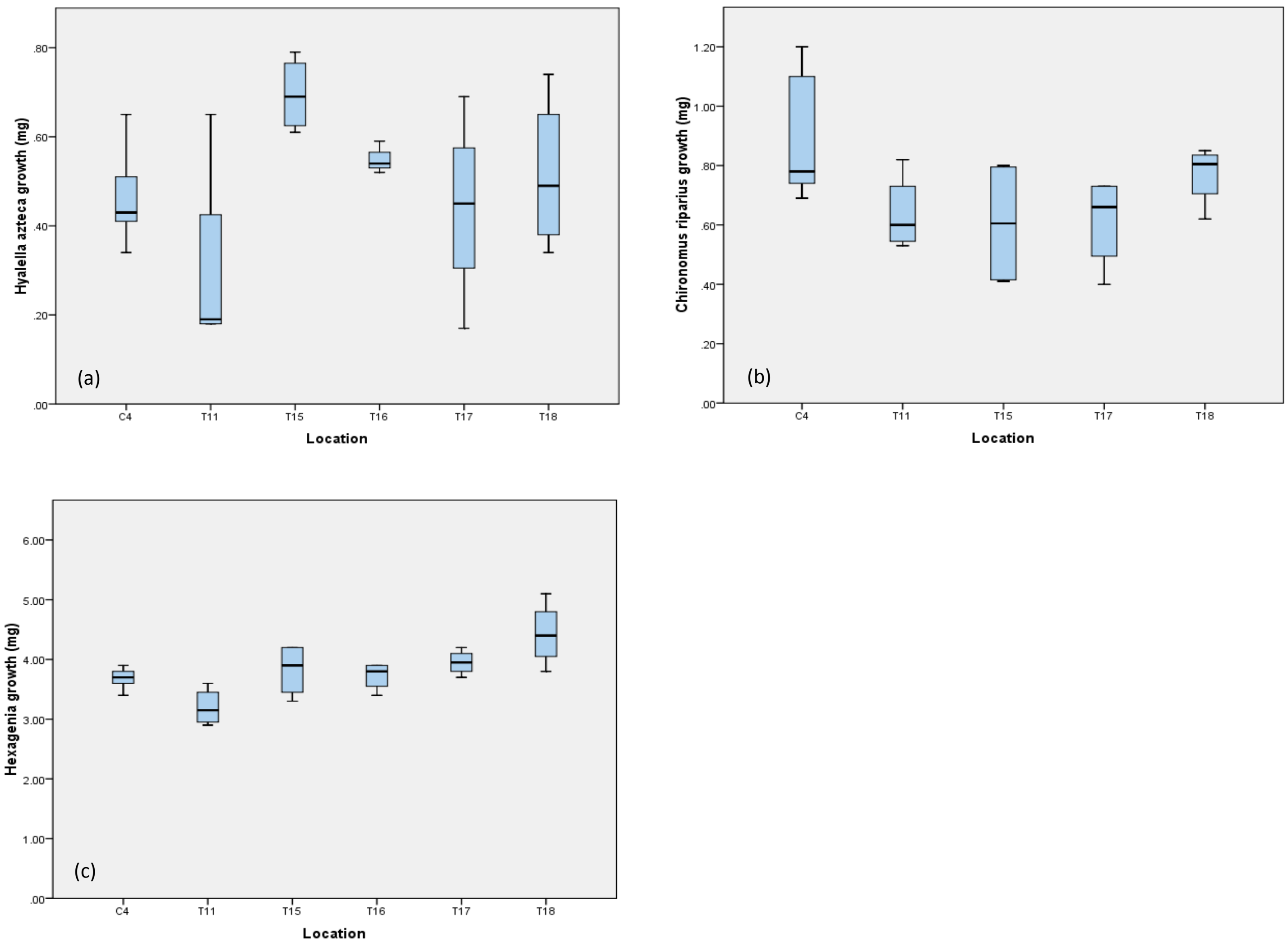


Figure G-III-5: Sediment toxicity boxplots for growth endpoints for KIH sites T11, T15, T16, T17, and T18. (a) *Hyalella azteca* ; (b) *Chironomus riparius* ; (c) *Hexagenia* . C4 = control site; T11 = upstream reference site.

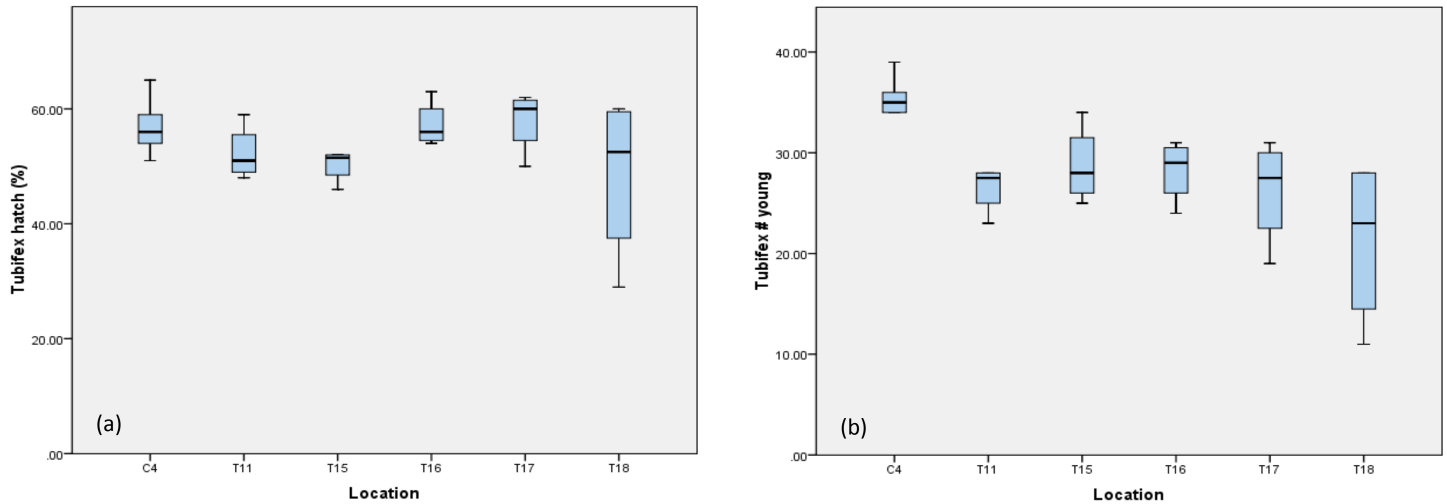


Figure G-III-6: Sediment toxicity boxplots for *Tubifex* reproduction endpoints for KIH sites T11, T15, T16, T17, and T18. (a) % cocoons hatched; (b) # young per individual. C4 = control site; T11 = upstream reference site.

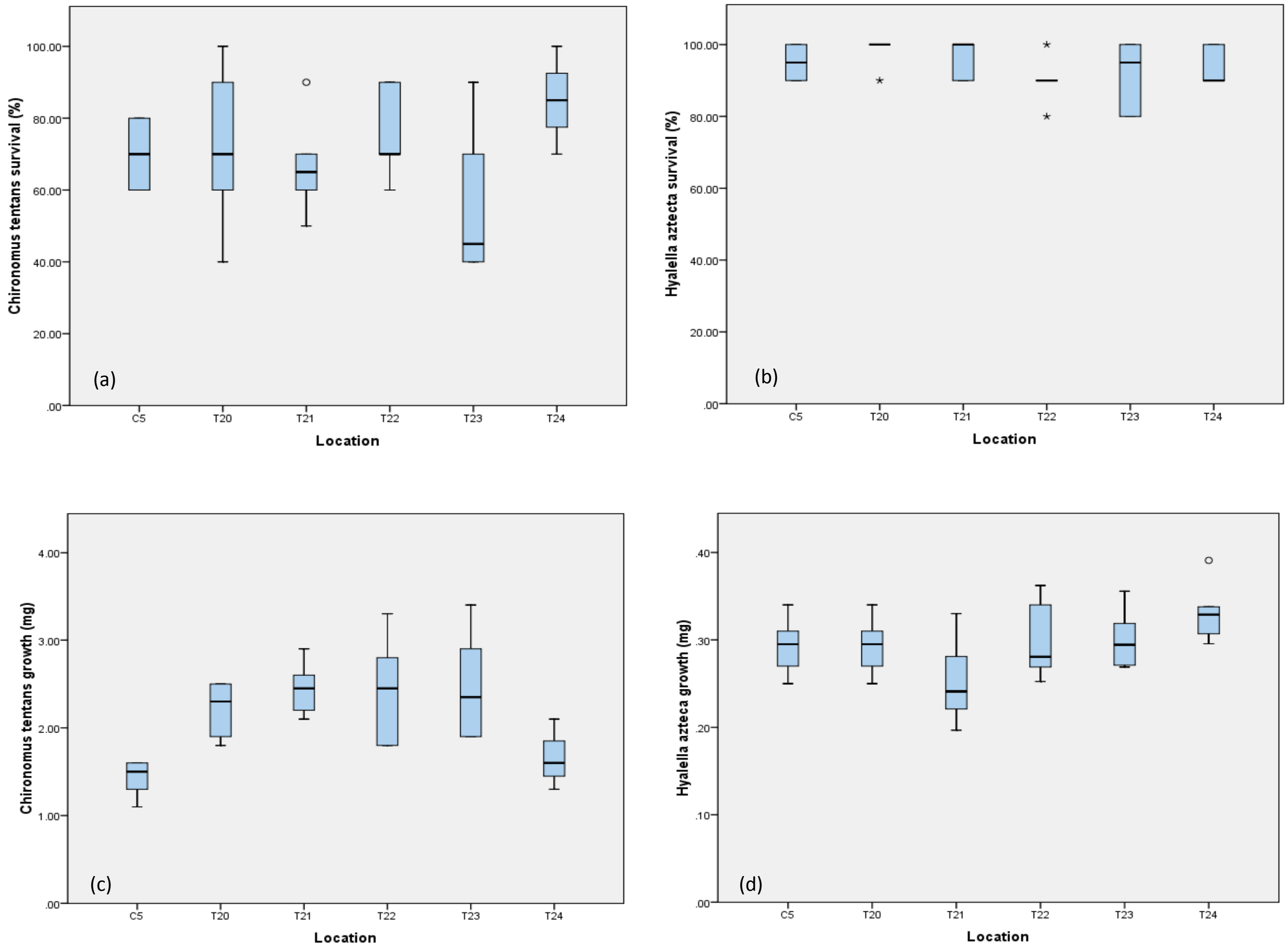


Figure G-III-7: Sediment toxicity boxplots for KIH sites T20, T21, T22, T23, and T24. (a) *Chironomus tentans* survival; (b) *Hyalella azteca* survival; (c) *Chironomus tentans* growth; (d) *Hyalella azteca* growth. C5 = control site; T20 = upstream reference site.

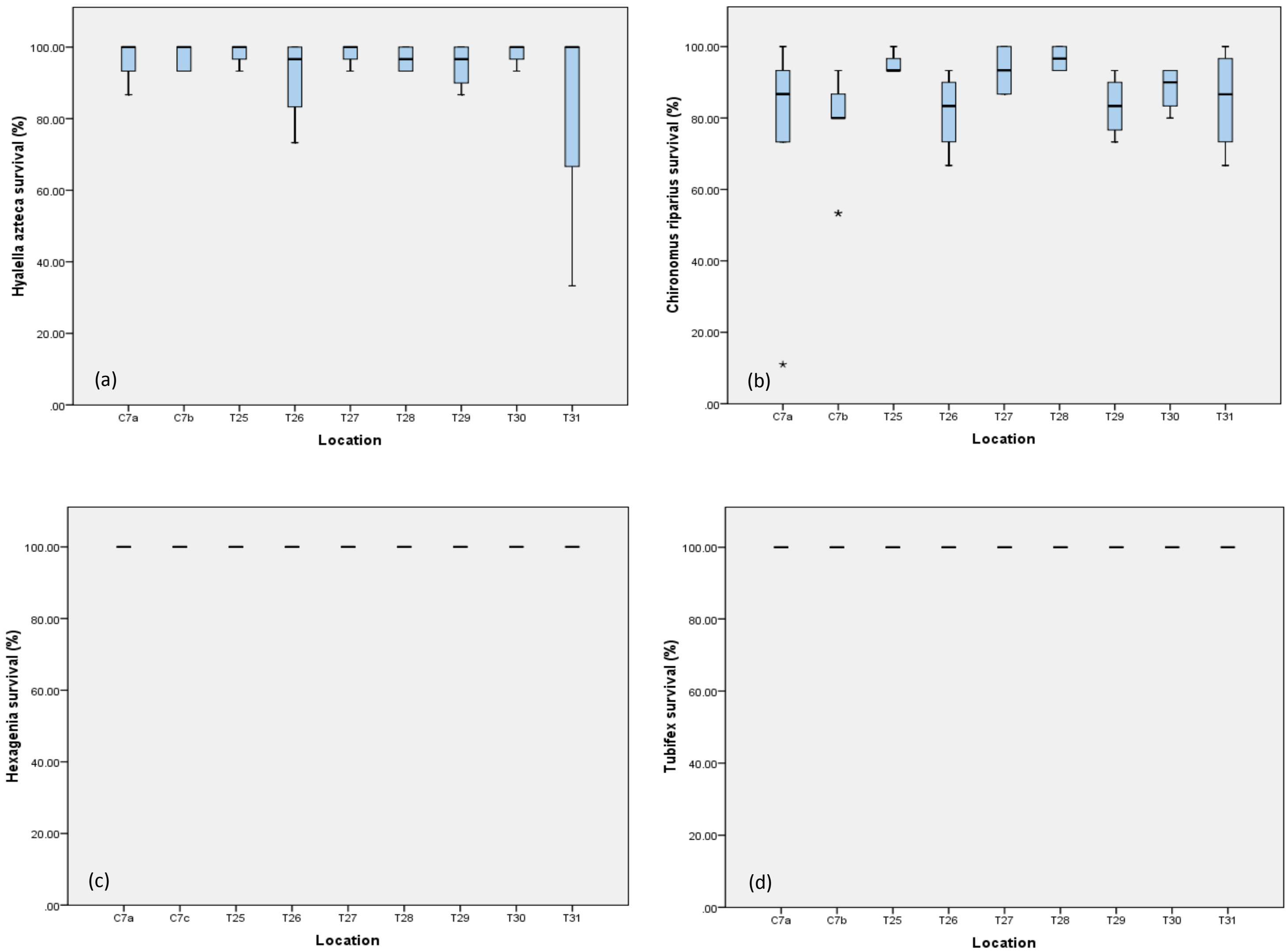


Figure G-III-8: Sediment toxicity boxplots for survival endpoints for KIH sites T25, T26, T27, T28, T29, T30, and T31. (a) *Hyalella azteca* ; (b) *Chironomus riparius* ; (c) *Hexagenia* ; (d) *Tubifex* . C7a, C7b, C7c = control sites; T27 = reference site.

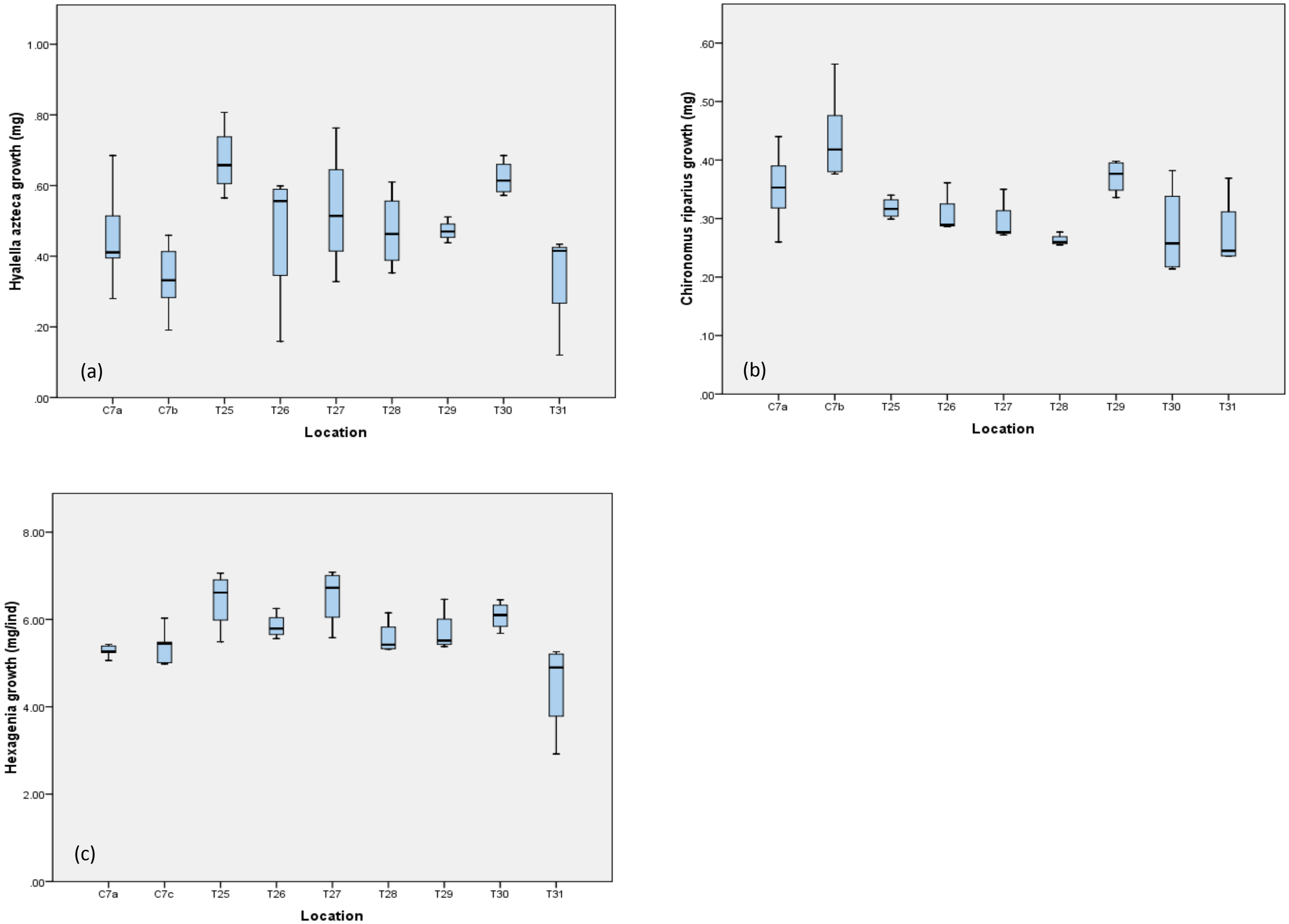


Figure G-III-9: Sediment toxicity boxplots for growth endpoints for KIH sites T25, T26, T27, T28, T29, T30, and T31.
(a) *Hyalella azteca* ; (b) *Chironomus riparius* ; (c) *Hexagenia* . C7a, C7b, and C7c = control sites; T27 = upstream reference site.

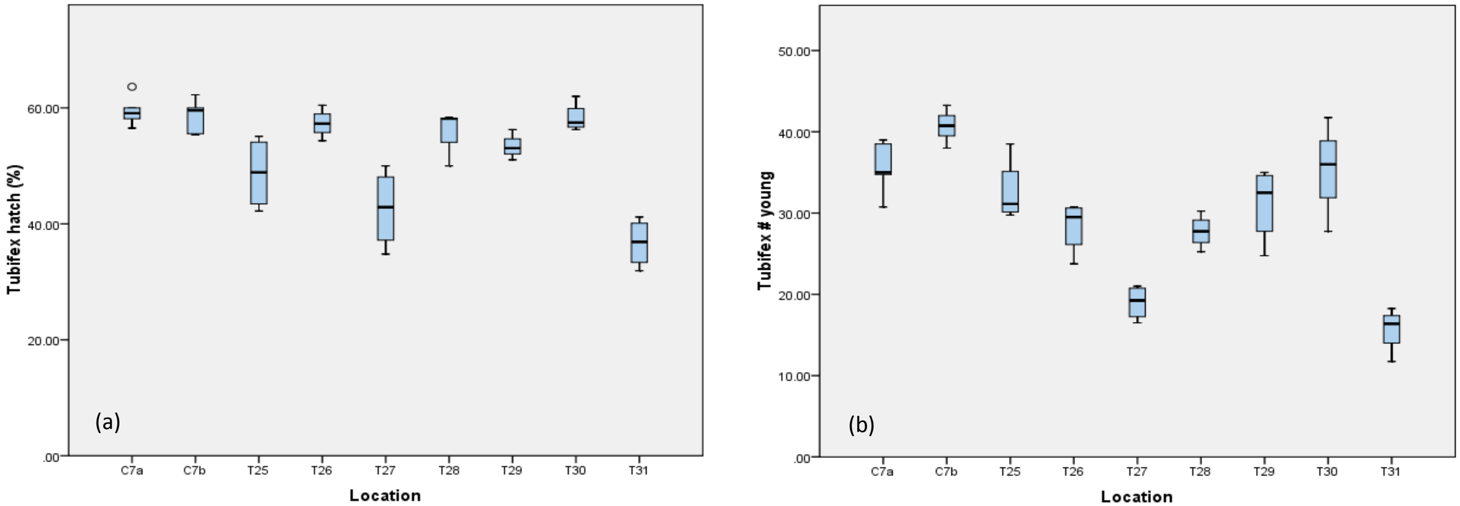


Figure G-III-10: Sediment toxicity boxplots for *Tubifex* reproduction endpoints for KIH sites T25, T26, T27, T28, T29, T30 and T31. (a) % cocoons hatched; (b) # young per individual. C7a, C7b, and C7c = control sites; T27 = upstream reference site.

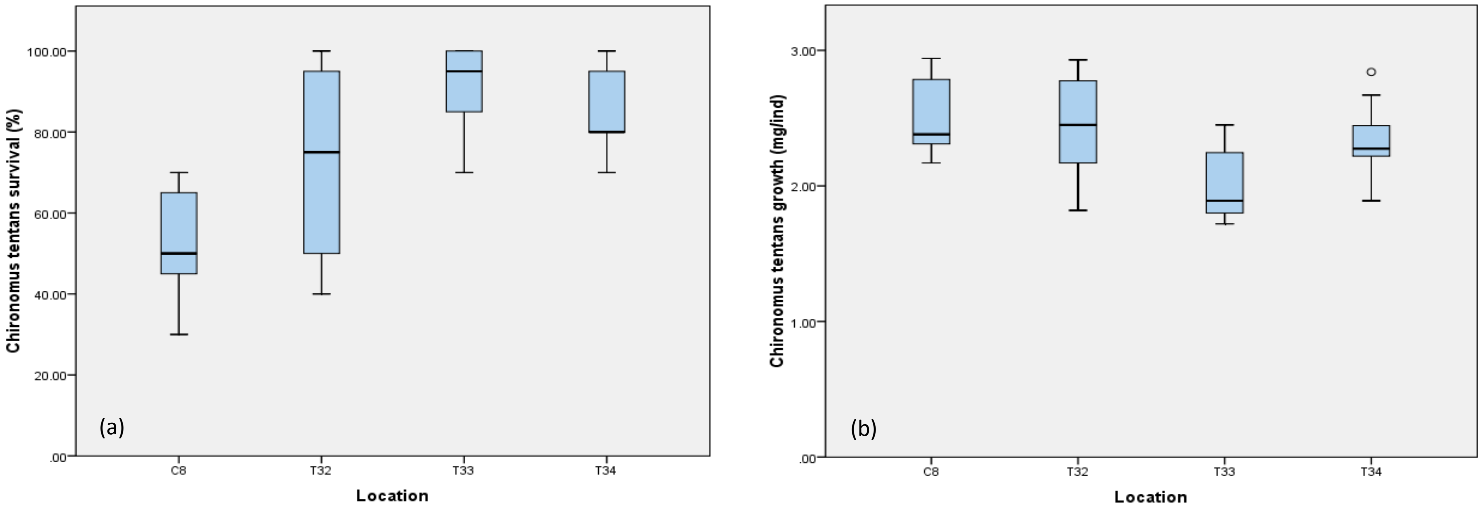
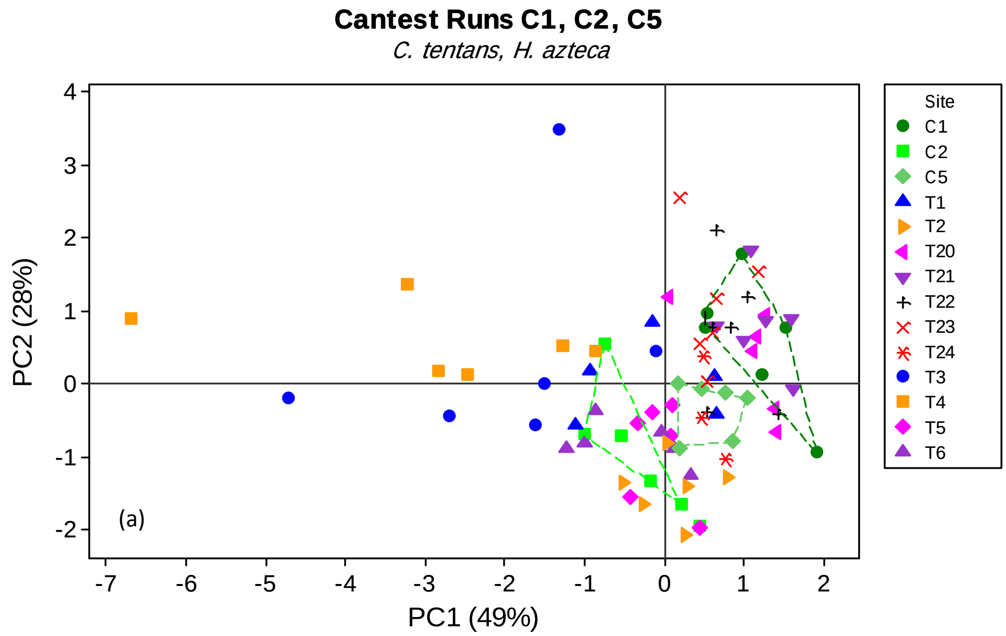


Figure G-III-11: Sediment toxicity boxplots for KIH sites T32, T33 and T34. (a) *Chironomus tentans* survival; (b) *Chironomus tentans* growth. C8 = control site; T32 = upstream reference site.



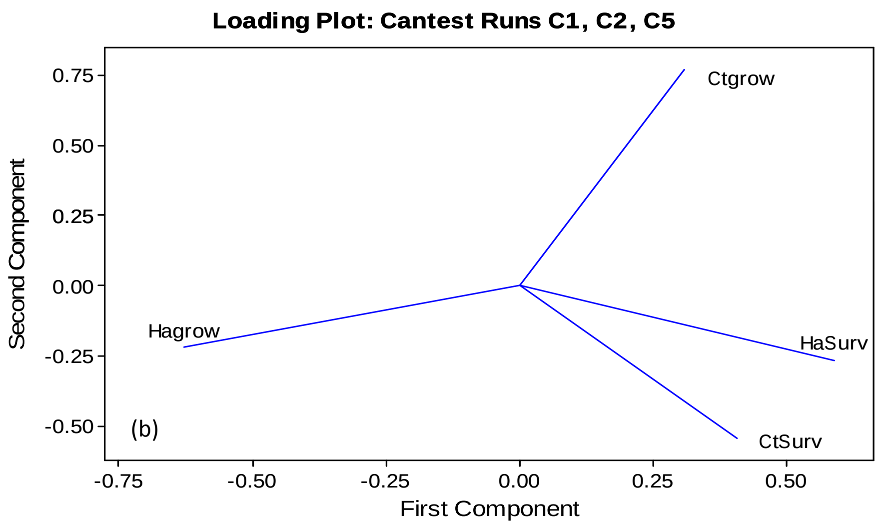


Figure G-3-12. Principle Components Analysis (PCA) of sediment toxicity endpoints from toxicity tests performed by Cantest Ltd. (a) site ordination plot showing each toxicity test replicate. Dashed lines indicates control replicates (C1, C2, and C5). T1, T2, and T20 = upstream reference sites. (b) loading plot showing relationship of toxicity endpoints to each PCA axis.

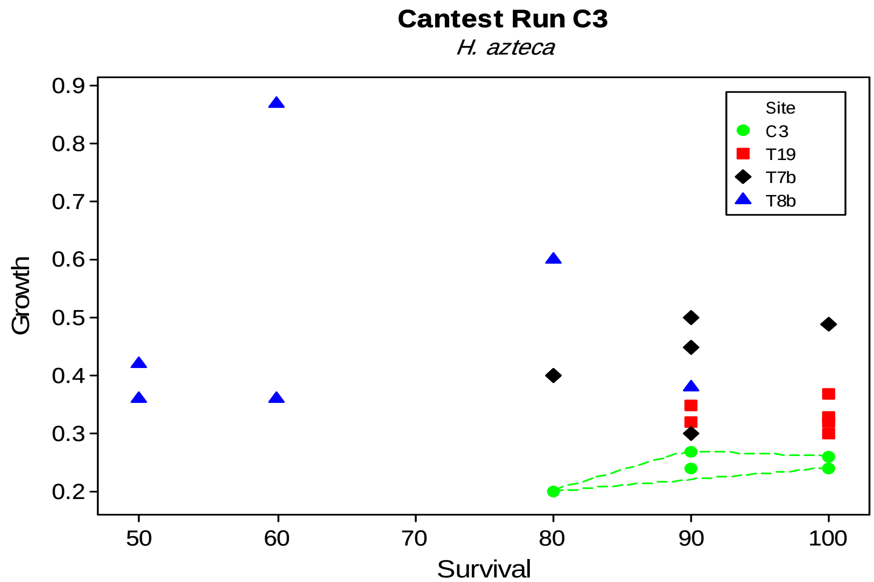


Figure G-3-13. Toxicity test replicates for KIH sites T19, T7b, and T8b plotted as a function of *Hyalella azteca* survival and growth. Dashed line indicates control replicates (C3). T19 = upstream reference site.

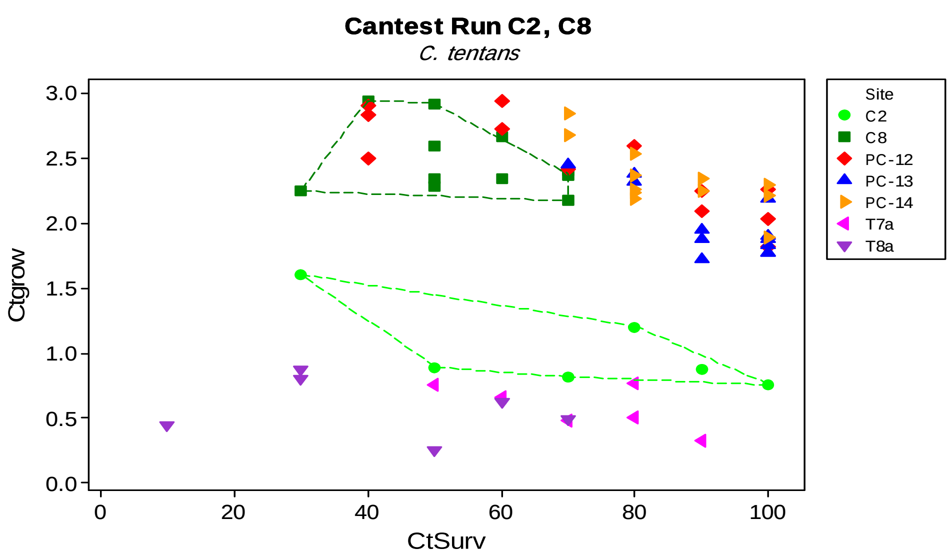
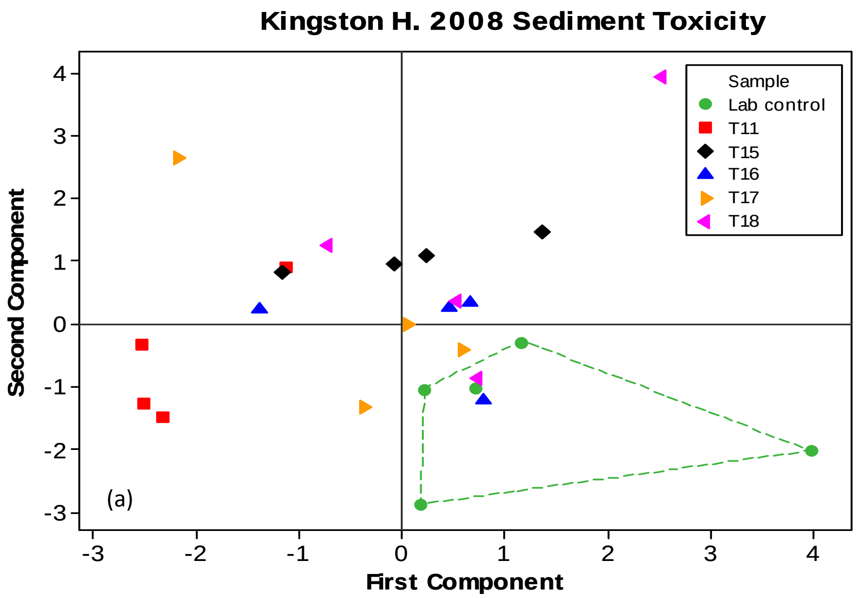


Figure G-3-14. Toxicity test replicates for KIH sites T7a, T8a, T32, T33, and T34 plotted as a function of *Chironomus tentans* survival and growth. Dashed line indicates control replicates (C2 and C8). T32 = upstream reference site.



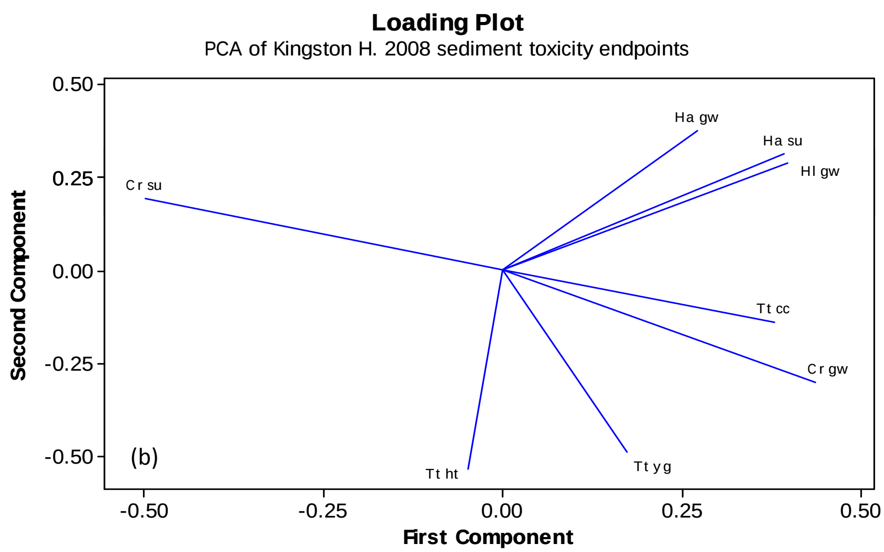
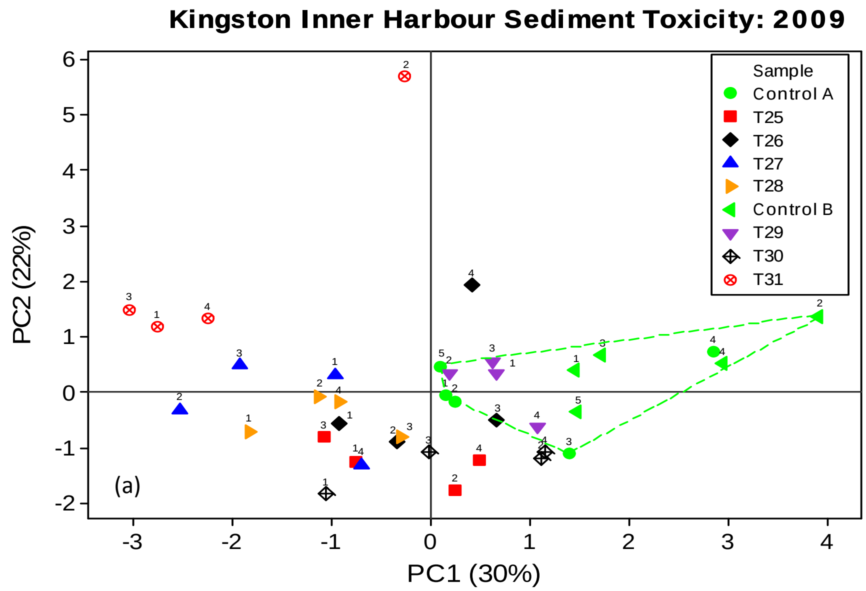


Figure G-3-15. Principle Components Analysis (PCA) of sediment toxicity endpoints for KIH sites T11, T15, T16, T17, and T18. (a) site ordination plot showing each toxicity test replicate. Dashed line indicates control replicates. T11 = upstream reference site. (b) loading plot showing relationship of toxicity endpoints to each PCA axis.



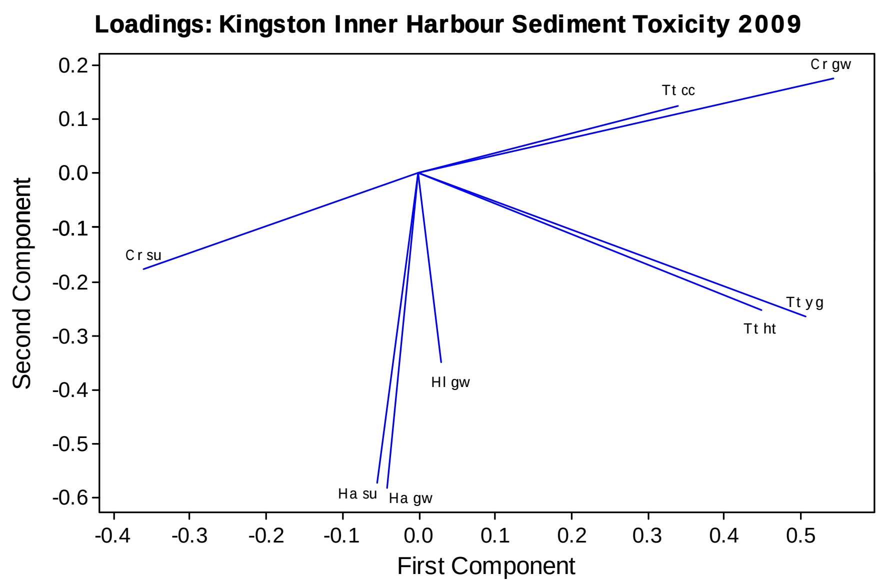


Figure G-3-16. Principle Components Analysis (PCA) of sediment toxicity endpoints for KIH sites T25, T26, T27, T28, T29, T30 and T31. (a) site ordination plot showing each toxicity test replicate. Dashed lines indicate control replicates (C7a and b). T27 = upstream reference site. (b) loading plot showing relationship of toxicity endpoints to each PCA axis.

APPENDIX H: BENTHIC INVERTEBRATES GRAPH

LIST OF FIGURES

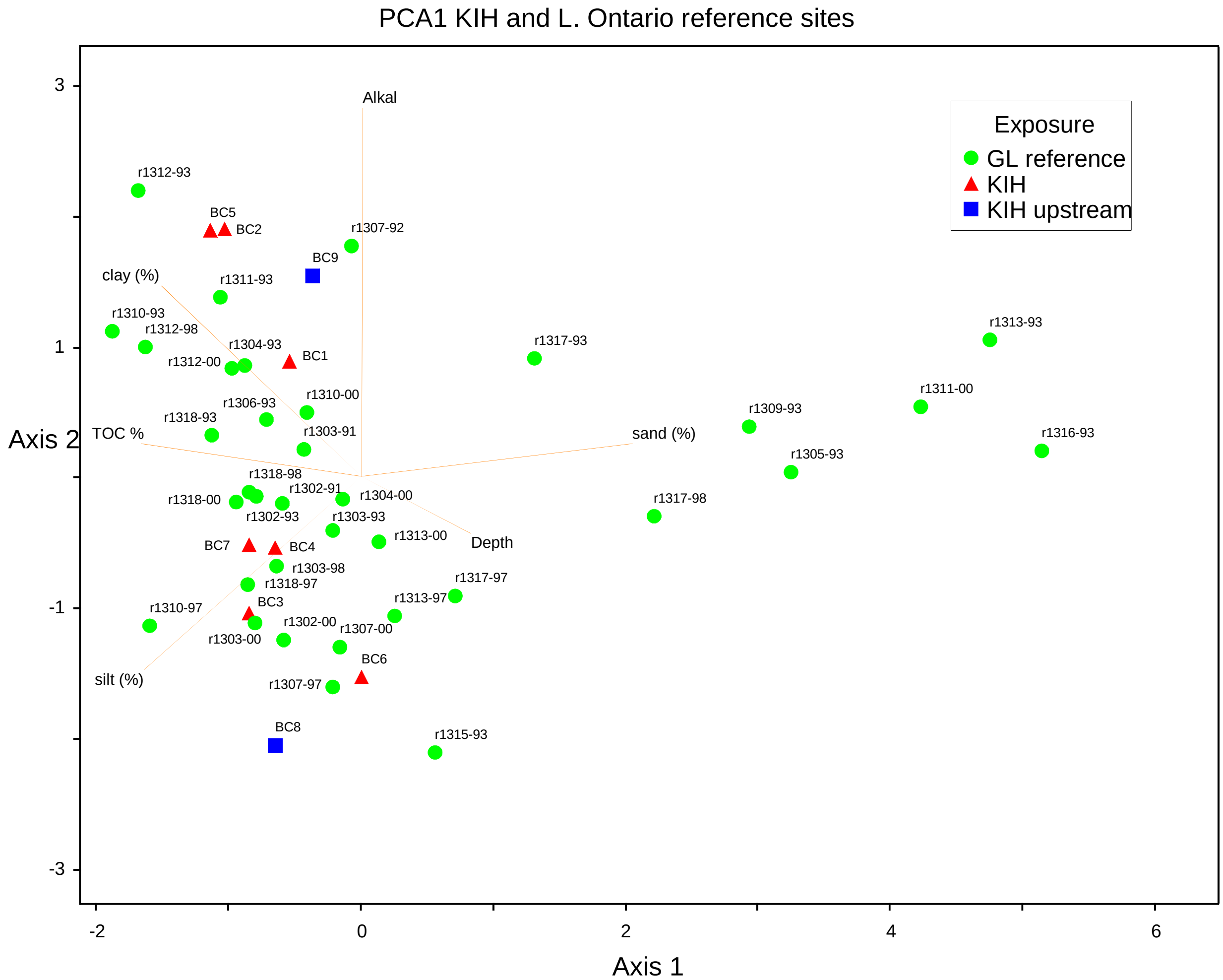


Figure H-III-1. PCA ordination of habitat variables (grain size, sediment TOC and alkalinity) for 15 Lake Ontario reference sites (some sampled more than once) and the 9 KIH sites. The first eigenvalue (λ1=2.72) explains 45.4 % and the second axis (λ2=1.17) equals 19.2 % of the variance.

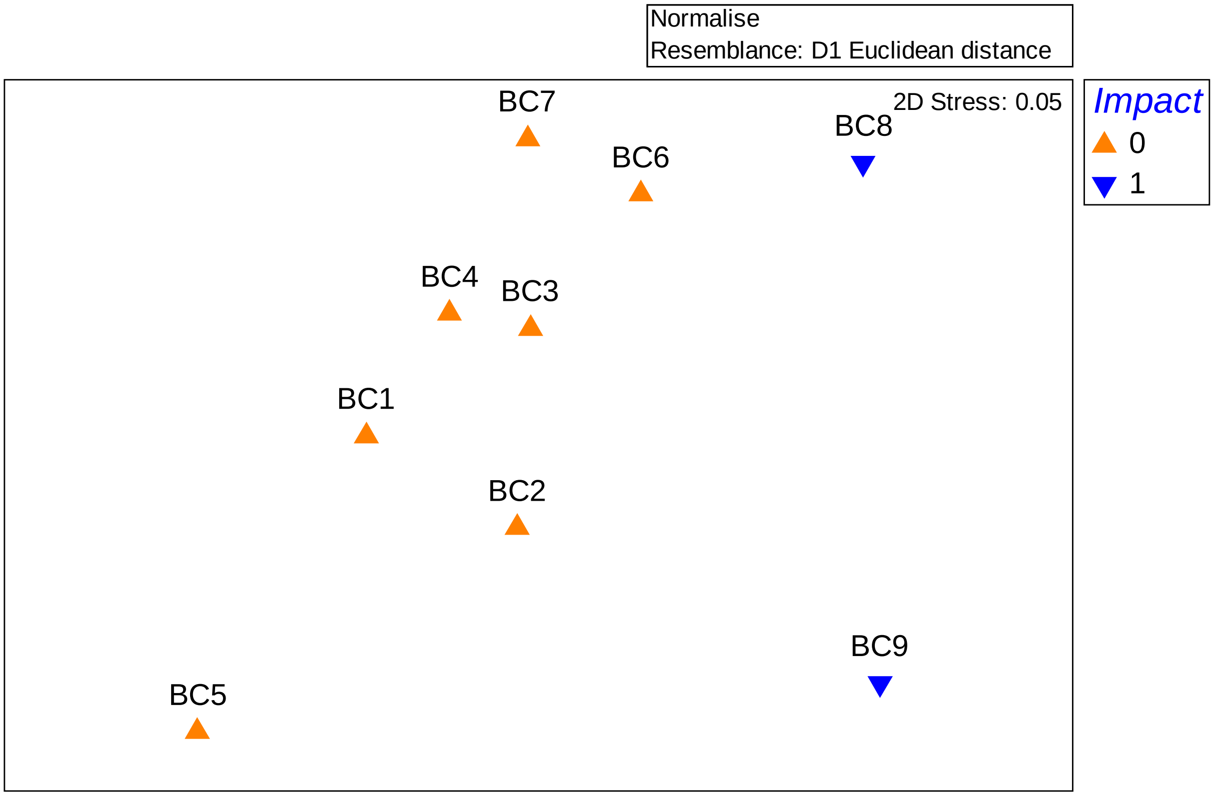


Figure H-III-2. MDS ordination plot for the nine KIH sites based on 20 environmental variables (see Chapter 3, Table 3-2). Blue triangles indicate upstream reference sites.

APPENDIX I: HHRA AND ERA CALCULATIONS

I. HHRA Calculations

1. Non-cancer Risk without Fish Ingestion

The following section presents the equations used to calculate exposures for each contaminant, where fish ingestion is not included.

a. <u>EDI Sediment Ingestion (direct)</u>

Sample Calculation for As (Adult)

$$EDI_{sed} = \frac{EPC_{sed} \times IR_{sed} \times EF_a \times EF_b}{BW}$$

Where:

EDI_{sed} = estimated daily intake (mg/kg-d)

EPC_{sed} = concentration of contaminant in sediment (mg/kg)

IR_{sed} = receptor sediment ingestion rate (kg/d)

EF_a = exposure frequency in days per week exposed

EF_b = exposure frequency in weeks per year exposed

BW = body weight (kg)

$$EDI(\frac{mg}{kg \times d}) = \frac{48.85\frac{mg}{kg} \times 0.0001\frac{kg}{d} \times \frac{7d}{7d} \times \frac{8.7wks}{52wks}}{70.7\ kg}$$

$$\boldsymbol{EDI\left(\frac{mg}{kg \times d}\right) = 1.16 \times 10^{-5}\frac{mg}{kg \times d}}$$

b. <u>EDI Sediment Ingestion (Indirect)</u>

Sample Calculation for As (Adult)

$$EDI_{sed} = \frac{EPC_{sed} \times IR_{sedin} \times EF_a \times EF_b}{BW}$$

Where:

EDI_{sed} = estimated daily intake (mg/kg-d)

EPC_{sed} = concentration of contaminant in soil (mg/kg)

IR_{sedin} = receptor soil ingestion rate indirect (kg/d)

EF_a = exposure frequency in days per week exposed

EF_b = exposure frequency in weeks per year exposed

BW = body weight (kg)

$$EDI(\frac{mg}{kg \times d}) = \frac{48.84\frac{mg}{kg} \times 0.0000015\frac{kg}{d} \times \frac{7d}{7d} \times \frac{8.7wks}{52wks}}{70.7\ kg}$$

$$\boldsymbol{EDI\left(\frac{mg}{kg \times d}\right) = 1.73 \times 10^{-7}\frac{mg}{kg \times d}}$$

c. <u>EDI_{Dermal} Dermal Absorption of Contaminated Sediments (Direct)</u>

Sample Calculation for As (Adult)

$$EDI_{derm} =$$

$$= \frac{[(EPC_{sed} \times SA_{Feet} \times SAF_{Feet}) + (EPC_{sed} \times SA_{Lower\ Hands} \times SAF_{Lower\ Hands}) + (EPC_{sed} \times SA_{A+L} \times SAF_{A+L})] \times RAF_{Derm} \times EF_a \times EF_b}{BW}$$

Where:

EDI = estimated daily intake (mg/kg-d)

EPC_{sed} = concentration of contaminant in soil (mg/kg)

SA_{Feet} = surface area of hands exposed for soil loading (cm^2)

SAF_{Feet} = Sediment Adhesion Factor hands (kg/cm^2 – event)

$SA_{Lower\ Hands}$ = surface area exposed lower hands (cm^2)

$SAF_{Lower\ Hands}$ = Sediment Adhesion Factor to exposed skin lower hands (kg/cm^2 – event)

SAF_{Hands} = Sediment Adhesion Factor hands (kg/cm^2 – event)

$SA_{Arms+Legs}$ = surface area exposed Arms+Legs (cm^2)

$SAF_{Arms+Legs}$ = Sediment Adhesion Factor Arms + Legs + hands (kg/cm^2 – event)

RAF_{derm} = Relative Absorption Factor (unitless)

EF_a = exposure frequency in days per week exposed

EF_b = exposure frequency in weeks per year exposed

BW = body weight (kg)

$$EDI_{derm}(\frac{mg}{kg \times d}) =$$

$$\frac{\left[\left(48.85\frac{mg}{kg}\times 1370cm^2\times 5.8\times 10^{-7}\frac{kg}{cm^2 d}\right)+\left(48.85\frac{mg}{kg}\times 890cm^2\times 8.8\times 10^{-7}\frac{kg}{cm^2 d}\right)+\left(48.85\frac{mg}{kg}\times 8220cm^2\times 1\times 10^{-8}\frac{kg}{cm^2 d}\right)\right]\times 0.03\times\frac{7d}{7d}\times\frac{8.7wks}{52wks}}{70.7kg}$$

$$\boldsymbol{EDI_{Derm}(\frac{mg}{kg \times d}) = 5.76 \times 10^{-6}\,\frac{mg}{kg \times d}}$$

d. EDI$_{Dermal}$ Dermal Absorption of Contaminated Sediments (Indirect)

Sample Calculation for As (Adult)

$$EDI_{derm} =$$

$$= \frac{[(EPC_{sed} \times SA_{Hands} \times SAF_{Hands}) + (EPC_{sed} \times SA_{other} \times SAF_{other})] \times RAF_{Derm} \times EF_a \times EF_b}{BW}$$

Where:

EDI = estimated daily intake (mg/kg-d)

EPC_{sed} = concentration of contaminant in soil (mg/kg)

SA_{Hands} = surface area of hands exposed for soil loading (cm^2)

SAF_{Hands} = Soil Adhesion Factor hands (kg/cm^2 – event)

SA_{other} = surface area exposed other than hands (cm^2)

SAF_{other} = Soil Adhesion Factor to exposed skin other than hands (kg/cm^2 – event)

RAF_{derm} = Relative Absorption Factor (unitless)

EF_a = exposure frequency in days per week exposed

EF_b = exposure frequency in weeks per year exposed

BW = body weight (kg)

$$EDI_{derm}(\frac{mg}{kg \times d}) =$$

$$\frac{\left[\left(48.85\,\frac{mg}{kg}\times 890cm^2\times 1\times 10^{-7}\,\frac{kg}{cm^2 d}\right)+\left(48.85\,\frac{mg}{kg}\times 16750cm^2\times 1\times 10^{-8}\,\frac{kg}{cm^2 d}\right)\right]\times 0.03\times\frac{7d}{7d}\times\frac{8.7wks}{52wks}}{70.7kg}$$

$$\boldsymbol{EDI_{Derm}(\frac{mg}{kg \times d}) = 8.9 \times 10^{-7}\,\frac{mg}{kg \times d}}$$

e. <u>Hazard Quotients</u>

Sample Calculation for As (Adult)

$$HQ = \frac{EDI}{TDI}$$

Where:

HQ = Hazard Quotient

EDI = Estimated Daily Intake (mg/kg-d) from on-site CoPCs

TDI = Tolerable Daily Intake (mg/kg-d) of CoPCs (also referred to as TRV)

$$HQ = \frac{EDI_{Sed} + EDI_{Derm}}{TRV}$$

$$HQ = \frac{(1.16 \times 10^{-5} + 1.73 \times 10^{-7} + 5.76 \times 10^{-6} + 8.9 \ \times 10^{-7})\frac{mg}{kg \times d}}{0.0003\frac{mg}{kg \times d}}$$

$$HQ = \frac{1.84 \times 10^{-5}\frac{mg}{kg \times d}}{0.0003\frac{mg}{kg \times d}}$$

$$\boldsymbol{HQ = 0.061}$$

2. Non-cancer Risk with Fish Ingestion (PCBs)

Equations are given for a sample calculation for PCBs, which is the only CoPC for which fish ingestion was included. Using the above equations, values for ingestion and dermal exposure for the adult receptor are:

$EDI_{sed(direct)}$ = 2.28 x 10^{-7} mg/kg-d

$EDI_{sed(indirect)}$ = 3.43 x 10^{-9} mg/kg-d

$EDI_{Derm(direct)}$ = 5.31 x 10^{-7} mg/kg-d

$EDI_{Derm(indirect)}$ = 8.20 x 10^{-8} mg/kg-d

The sum EDI of all these pathways is 8.44 x 10^{-7} mg/kg-d.

For fish ingestion:

$$EDI_{Food} = \frac{EPC_{Food} \times IR_{Food} \times EF_c}{BW}$$

Where:

EDI = estimated daily intake (mg/kg-d)

EPC_{Food} = concentration of contaminant in food (mg/kg)

IR_{Food} = receptor ingestion rate for food (kg/d)

EF_c = exposure frequency in days per year exposed

BW = body weight (kg)

$$EDI_{Food} = \frac{0.338mg/kg \times 0.0249kg/d \times 365d/365d}{70.7kg}$$

$$\boldsymbol{EDI_{Food}\left(\frac{mg}{kg \times d}\right) = 1.19 \times 10^{-4}\,\frac{mg}{kg \times d}}$$

The HQ is then calculated as follows:

$$HQ = \frac{EDI_{Fish} + EDI_{Sed} + EDI_{Derm}}{TRV}$$

$$HQ = \frac{(1.19 \times 10^{-4} + 8.44 \times 10^{-7})\,\frac{mg}{kg \times d}}{0.00013\,\frac{mg}{kg \times d}}$$

$$HQ = \frac{1.2 \times 10^{-4}\,\frac{mg}{kg \times d}}{0.00013\,\frac{mg}{kg \times d}}$$

$$\boldsymbol{HQ = 0.92}$$

3. Cancer Risk including Weighting for Lifetime Exposure

The following example is for As. Cancer risk is calculated by obtaining an incremental lifetime cancer risk, ILCR:

$$ILCR = LADD \times CSF$$

Where:

ILCR = Incremental Lifetime Cancer Risk

LADD = Lifetime Average Daily Dose (mg/kg-d)

CSF = Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$

The LADD is obtained from:

$$LADD = (EDI_{Fish} + EDI_{Sed} + EDI_{Derm}) \times \frac{ED}{LE}$$

Where:

ED = exposure duration (years)

LE= life expectancy (years)

In the present HHRA, exposure duration is over a lifetime, so $\frac{ED}{LE} = 1$, and LADD = EDI.

For an adult's exposure to As,

$$ILCR = 1.84 \times 10^{-5} \frac{mg}{kg \times d} \times \frac{80\ yrs}{80\ yrs} \times 1.8 \left(\frac{mg}{kg \times d}\right)^{-1}$$

$$\boldsymbol{ILCR = 3.3 \times 10^{-5}}$$

This calculation was carried out for every receptor, and the following results were obtained:

$ILCR_{adult} = 3.3 \times 10^{-5}$ mg/kg-d

$ILCR_{teen} = 3.8 \times 10^{-5}$ mg/kg-d

$ILCR_{child} = 3.2 \times 10^{-4}$ mg/kg-d

$ILCR_{toddler} = 4.3 \times 10^{-4}$ mg/kg-d

The exposure of each receptor is weighted according to the duration of their life spent in the receptor age group (Health Canada 2010b). This gives the following weighting factors:

$Weighting_{adult}$ = 60 years/80 years = 0.75

Weighting $_{teen}$ = 8 years/80 years = 0.1

Weighting $_{child}$ = 7 years/80 years = 0.0875

Weighting $_{toddler}$ = 4.5 years/80 years = 0.05625

Each of these weighting factors was used to adjust the ILCR for that receptor, and the weighted ILCRs were summed to obtain the final ILCR.

$$ILCR = ILCR_{adult} \times Weighting_{adult} + ILCR_{teen} \times Weighting_{teen} + ILCR_{child} \times Weighting_{child} + ILCR_{toddler} \times Weighting_{toddler}$$

$$ILCR = 3.3 \times 10^{-5} \times 0.75 + 3.8 \times 10^{-5} \times 0.1 + 3.2 \times 10^{-4} \times 0.0875 + 4.3 \times 10^{-4} \times 0.05625$$

$$ILCR = 8.1 \times 10^{-5}$$

4. Estimation of Background Exposures

Background exposures were estimated for CoPCs for which human health risk was indicated.

a. Arsenic

Background exposures for inorganic arsenic (iAs) were estimated for the toddler receptor from Xue et al. (2010). HQs and ILCRs were calculated as shown in the previous sections.

Calculation step	**Toddler**		**Child**
	7–9 mo	**1–4 y**	**5–11 y**
Mean iAs in food (Xue) µg/kg-d	0.10	0.08	0.04
Mean iAs in drinking water (Xue) µg/kg-d	0.031	0.036	0.03
Toddler mean iAs in food µg/kg-d	0.090		n/a
Toddler mean iAs in drinking water µg/kg-d	0.034		n/a
Sum of iAs in food+water µg/kg-d	**0.124**		**0.07**

b. PCBs

Background exposures for PCBs were estimated for all receptors from the Health Canada Total Diet Study (Ottawa 2000) (Health Canada 2011) and using a background soil concentration of 0.02 mg/kg (OMOE 2008) calculated as shown in the previous sections.

The total diet study data are as follows (ng/kg-d):

7–9 mo	**10–12 mo**	**1–4 y**	**5–11 y**	**12–19 y**	**20–39 y**	**40–64 y**	**65+ y**	**12–19 y**	**20–39 y**	**40–64 y**	**65+ y**
M & F	M & F	M & F	M & F	M	M	M	M	F	F	F	F
5.5	5.18	7.41	4.82	3.2	2.99	2.08	2.03	2.64	2.1	1.82	1.22

For toddlers, data were averaged from 7 months (mo) to 4 years (y). Child (5–11 y) and teen (12–19 y) data were used as shown. Adult data were obtained from averaging the remaining data.

Soil ingestion and dermal exposures were estimated using the scenarios in the current risk assessment. Other calculations are shown in the table below. The calculated exposures show that most of the exposure to background levels of PCBs is through diet.

Calculations	**Toddler**	**Child**	**Teen**	**Adult**
Body weight (BW) kg*	16.5	32.9	59.7	70.7
Inhalation rate (InhR) m^3/d*	8.3	14.5	15.6	16.6
Particulate concentration in air (PC) kg/m^3*	7.6E-10	7.6E-10	7.6E-10	7.6E-10
Settled indoor dust IR (DIR) mg/d**	41	32	2.1	2.5
Settled indoor dust IR (DIR) kg/d**	0.000041	0.000032	0.0000021	0.0000025
EDI				
Inhalation (24 h/7d/365 d) $EDI_{Inh} = \frac{0.02\left(\frac{mg}{kg}\right) \times PC\left(\frac{kg}{m^3}\right) \times InhR(\frac{m^3}{d})}{BW\ (kg)}$	9.2E-13	4.6E-13	2.5E-13	2.1E-13
Indoor dust ingestion (24 h/7d/365 d) $EDI_{Dust\ ing} = \frac{0.02\left(\frac{mg}{kg}\right) \times DIR\left(\frac{kg}{d}\right)}{BW\ (kg)}$	5.0E-08	1.9E-08	7.0E-10	7.1E-10
Outdoor soil ingestion (KIH calculations)	4.1E-08	2.0E-08	5.7E-09	4.8E-09
Outdoor dermal (KIH calculations)	2.7E-07	2.4E-07	1.4E-08	1.3E-08
Food ingestion	6.0E-06	4.8E-06	2.9E-06	2.0E-06
Sum EDI	6.3E-06	5.1E-06	2.9E-06	2.1E-06
HQ	**0.049**	**0.039**	**0.023**	**0.016**

*Health Canada 2010a. **SENES 2010.

c. Lead

Background exposure to lead (mean values) for toddlers was obtained from SENES (2010):

	Soil ingestion	Soil dermal	Settled dust dermal	Settled dust ingestion	Indoor air inhalation	Ambient air inhalation	Water ingestion	Food ingestion	Sum
µg/kg-d	8.2E-03	0.043	1.05	0.71	1.6E-03	1.1E-04	3.2E-02	2.5E-01	2.1
µg/kg-d dermal corrected*	8.2E-03	2.6E-4	6.3E-3*	0.71*	1.6E-03	1.1E-04	3.2E-02	2.5E-01	1.0

*Dermal corrected = value multiplied by dermal absorption factor (0.006).

HQ was calculated as shown in the previous sections.

d. Antimony and Inorganic Mercury

Antimony values were obtained directly from Environment Canada and Health Canada 2010. Only dietary mercury was used and values were used directly from Dabeka et al. 2003.

II. ERA Calculations

1. FIR for Osprey

Default receptor characteristics provided by Azimuth (2012) were used for all receptors except for osprey, for which none were given.

The food ingestion rate for osprey was thus calculated as described in US EPA 1993, Equation 4-13, and Nagy et al. 1999:

$$FIR\ (\frac{kg}{d}) = \frac{FMR}{ME}$$

And:

$$FMR = a \times BW^b$$

And:

$$ME = \sum P_i \times GE_i \times AE_i$$

Where:

FIR = Food Ingestion Rate (kg/d)

FMR = Free Metabolic Rate (kcal/d)

ME = metabolizable energy (kcal/kg)

a = 10.5; *b* = 0.681 for osprey (using kJ/d)

BW = body weight of the receptor (g), for osprey = 1500 g

P_i = proportion of total food that *i*th food item comprises (unitless), for fish =1

GE_i = gross energy of the *i*th item (kcal/kg wet weight), for fish = 1200 kcal/kg

AE_i = assimilation efficiency (unitless), for fish = 0.79

$$FMR\left(\frac{kcal}{d}\right) = 10.5 \times BW^{0.681}\frac{kJ}{d} \times 0.239\frac{kcal}{kJ}$$

$$FMR = 365.18\ \frac{kcal}{d}$$

$$ME = 1 \times 1200\ \frac{kcal}{kg}\ \times 0.79$$

$$ME = 948\ \frac{kcal}{kg}$$

$$FIR = \frac{365.18\ \frac{kcal}{d}}{948\ \frac{kcal}{kg}}$$

$$\boldsymbol{FIR = 0.385\ kg/d}$$

2. Estimated Daily Intake (EDI) and Hazard Quotient (HQ) Sample Calculations

PCB daily dose is shown for mink as follows:

$$HQ = \frac{EDI(\frac{mg}{kg \times d})}{TRV(\frac{mg}{kg \times d})}$$

And:

$$EDI = \left[\left\{\left\{\left(\sum_{i=1}^{n} EPC_{fi} \times F_i\right) + (EPC_{sed} \times F_{sed})\right\} \times FIR\right\} + (EPC_w \times WIR)\right] \times \frac{F_{site} \times ED}{BW}$$

where:

EPC_{fi} = the exposure point concentration of the receptor's *i*th dietary food item, and having units of mg/kg

F_i = the fraction of the receptor's diet that the *i*th food item comprises; this is a dimensionless quantity.

EPC_{sed} = the exposure point concentration of sediment within the APEC, and having units of mg/kg.

F_{sed} = the fraction of the receptor's diet that sediment comprises; this is a dimensionless quantity.

FIR = the food ingestion rate, defined as the total mass of dietary intake the receptor consumes on a daily basis and having units of kg/d. In this aquatic ERA, the dietary intake of a receptor can be comprised of both food and incidental sediment intake.

EPC_w = the exposure point concentration of water (unfiltered, which includes suspended sediments), and having units of mg/L. Used only for receptors that have no sediment intake.

WIR = the water ingestion rate, defined as the total mass of water the receptor consumes on a daily basis and having units of kg or L/d. Used only for receptors that have no sediment intake.

F_{site} = the fraction of the receptor's diet that is harvested from the APEC; this is a dimensionless quantity.

ED = the exposure duration, defined as the fraction of the year that the receptor feeds at that site. This quantity is important for migratory animals and is dimensionless.

BW = the body weight of the receptor, and is expressed in kg.

$$EDI = \left[\left\{\left\{\left(0.619\frac{mg}{kg} \times 1\right) + (0)\right\} \times 0.1148\ \frac{kg}{d}\right\} + (0.0186\frac{mg}{L} \times 0.0246\frac{L}{d})\right] \times \frac{1 \times 1}{0.82\ kg}$$

$$EDI\ (\frac{mg}{kg \times d}) = \frac{0.0872\ mg}{(kg \times d)}$$

$$HQ = \frac{0.0872(\frac{mg}{kg \times d})}{0.053(mg/(kg \times d)}$$

$$\boldsymbol{HQ = 1.65}$$

3. Conversion of Fish Filet Concentrations to Whole Body Concentrations

To obtain the fish concentrations that are most applicable to ecological receptors, who may eat the whole fish, conversion of filet concentrations to whole body concentrations was necessary. This was carried out both for the fish that the ecological receptors in the present ERA eat (fish <35 cm in length, pike <25 cm in length), as well as the entire fish dataset for comparison to fish toxicity threshold values.

For Hg, the conversion was applied to all fish in the same way according to Peterson et al. (2005):

$$\log_{10}[Hg]_{whole-body} = -2.712 + 0.9005\log_{10}[Hg]_{filet}$$

Where:

$[Hg]_{whole-body}$ = concentration of Hg in whole body fish, mg/kg wet weight

$[Hg]_{filet}$ = concentration of Hg in fish filet, mg/kg wet weight

For $[Hg]_{filet}$ of 0.090 mg/kg wet weight:

$$\log_{10}[Hg]_{whole-body} = -2.712 + 0.9005\log_{10}0.090$$

$$\log_{10}[Hg]_{whole-body} = -1.213$$

$$[Hg]_{whole-body} = 10^{-1.213}$$

$$[\boldsymbol{Hg}]_{\boldsymbol{whole-body}} = \boldsymbol{0.061\,mg/kg\,wet\,weight}$$

For PCBS, the following conversion factors were used:

Fish	**Conversion**	**Source**
perch	5.5	US EPA 2006
brown bullhead	2.2	This study
pike	4.1	US EPA 2006
carp	1.61	US EPA 2006

The conversions from US EPA 2006 were obtained from the following figure (pg 214 in the report):

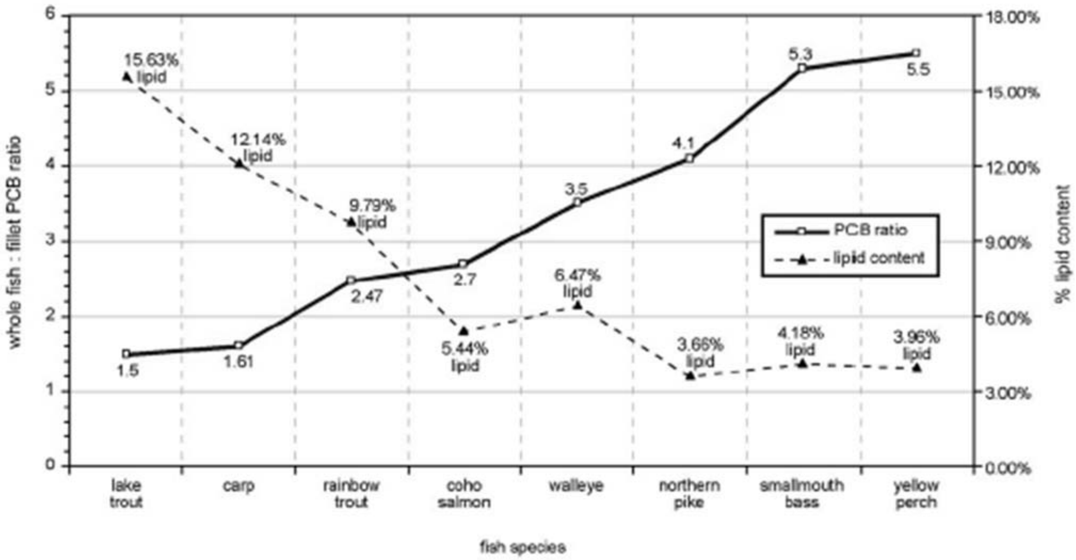


Figure A3.4.2. Comparison of whole fish to fillet PCB ratios and lipid content for various fish species.

The brown bullhead conversion factor was obtained as follows:

$$Conversion = \frac{average\ [PCB]_{whole\ body}(mg/kg)}{average\ [PCB]_{fillet}(mg/kg)}$$

Average [PCB]$_{whole\ body}$ = 0.432 mg/kg (n=5, 0.18–0.78 mg/kg)

Average [PCB]$_{filet}$ = 0.196 mg/kg (n=21, 0.04–0.54 mg/kg)

The sizes of the fish used (lengths) did not differ statistically for whole body and filet fish.

$$Conversion = \frac{0.432\ mg/kg}{0.196\ mg/kg}$$

$$Conversion = \mathbf{2.2}$$

To obtain a whole body concentration from the filet, the following calculation was carried out (brown bullhead, filet concentration = 0.22 mg/kg):

$$[PCB]_{whole\ body} = 2.2 \times [PCB]_{fillet}(mg/kg)$$

$$[PCB]_{whole\ body} = 2.2 \times 0.22\ mg/kg$$

$$[PCB]_{whole\ body} = 0.48\ mg/kg$$

4. Modeled Value for PCBs in Invertebrates

The PCB invertebrate concentration was calculated for the mallard duck receptor, according to Diep and Boyd (2007), cited in Labencki (2008).

It is based on the literature derived regression equation (sediment-benthic invertebrates uptake):

$$\log_{10} y = 0.639 \times \log_{10} x + 1.422$$

Where:

y = benthic invertebrate concentration (mg/kg lipid)

x = sediment concentration (mg/kg organic carbon, OC in sediment)

To obtain *x*, the PCB concentration in sediment (dry weight) must be normalized to organic carbon (total organic carbon, TOC) in the sediment:

$$y = [PCB]_{sed}/TOC$$

$$y = 976.9\, \mu g/kg(dw)/0.08kg\ OC/kg = 12211\, \mu g/kg\ OC$$

$$\log_{10} y = 0.639 \times \log_{10} 10618.6 + 1.422$$

$$\log_{10} y = 4.03$$

$$y = 10^{4.03} = 10800\, \mu g/kg\ \ lipid$$

To obtain a value in µg/kg of invertebrate tissue, the lipid value (2.4%) must be incorporated:

$$[PCB]_{invertebrate} = 0.024 kg\ lipid/kg\ wet\ invertebrate\ \times 10800\, \mu g/kg\ \ lipid$$

$$[PCB]_{invertebrate} = 259\, \mu g/kg\ wet\ invertebrate$$

$$[PCB]_{invertebrate} = \mathbf{0.259\, mg/kg}$$

5. Modeled Values for DDT, Chlordane and PAHs in Invertebrates and Fish

The following equations were used to obtain values for the CoPCs DDT, chlordane and PAHs in invertebrates and for chlordane in fish:

$$[COPC]_{invert}\ = BSAF\ \times [COPC]_{sed}$$

Where:

[COPC]$_{invert}$ = concentration of CoPC in invertebrates (or fish), mg/kg lipid

[COPC]$_{sed}$ = concentration of CoPC in sediment, mg/kg organic carbon (OC)

BSAF = biota sediment accumulation factor, from US EPA 2009

The BSAFs are listed as follows:

CoPC (molecular weight of PAH)	**BSAF (fish)**	**BSAF (invertebrates)**
Napthalene (low)	0.160055	0.021176
Acenaphthylene (low)	0.018187	None reported
Acenaphthene (low)	0.037007	0.021309
Fluorene (low)	0.025696	0.030702
Phenanthrene (low)	0.030816	0.010381
Anthracene (low)	0.009911	0.018435
Fluoranthene (high)	0.007503	0.025645
Pyrene (high)	0.012617	0.005729
Benzo[a]anthracene (high)	0.013542	0.005714
Chrysene (high)	0.008929	0.007128
Benzo[b]fluoranthene (high)	0.002461	0.004559
Benzo[k]fluoranthene (high)	0.002295	0.006633
Benzo(a)pyrene (high)	0.0021	None reported
Indeno[1,2,3-cd]pyrene (high)	0.014398	None reported
Dibenzo[a,h]anthracene (high)	0.002155	None reported
Benzo[g,h,i]perylene (high)	0.025034	0.00736
Low molecular weight PAH	0.0062708*	0.001389*
High molecular weight PAH	0.0078867*	0.002489*
Total PAH	0.0141575*	0.003877*
p,p'-DDD	Measured	3.045654
p,p'-DDE	Measured	1.07971
p,p'-DDT	Measured	1.44863
o,p'-DDD	Measured	0.118123
o,p'-DDE	Measured	0.015381
o,p'-DDT	Measured	0.184767
alpha chlordane	5.3412	0.862048
gamma chlordane	1.486792	0.589372

*Calculated from sum of available BSAFs for each group (low or high molecular PAHs, and total), weighted for proportion of PAH compound of the total.

a. Pesticides (DDT and Chlordane)

Calculations were carried for each congener of DDT and chlordane. A worked example is shown for p,p'-DDD:

$$[DDT]_{sed} = \frac{0.0558\, mg/kg\, dw}{TOC}$$

$$[DDT]_{sed} = 0.0558\, mg/kg(dw)/0.08kg\, OC/kg = 0.698\, mg/kg\, OC$$

$$[p,p'DDD]_{invert} = BSAF \times [DDT]_{sed}$$

$$[p,p'DDD]_{invert} = 3.0457 \frac{mg/kg\, lipid}{mg/kg\, OC} \times 0.698\, mg/kg\, OC$$

$$[p,p'DDD]_{invert} = 2.12\, mg/kg\, lipid$$

To obtain a value in mg/kg of tissue, the lipid value (2.4% for invertebrates, 2% for fish) must be incorporated:

$$[p,p'DDD]_{invert} = 0.024\, kg\, lipid/kg\, wet\, invertebrate \times 2.12\, mg/kg\ \ lipid$$

$$[p,p'DDD]_{invert} = \mathbf{0.051\, mg/kg}$$

The total DDT and chlordane concentrations were obtained by summing the results for the congeners:

CoPC	**Concentration invertebrates mg/kg ww**	**Concentration fish mg/kg ww**
p,p'-DDD	0.0510	Measured
p,p'-DDE	0.0181	Measured
p,p'-DDT	0.0243	Measured
o,p'-DDD	0.0020	Measured
o,p'-DDE	0.0003	Measured
o,p'-DDT	0.0031	Measured
Sum DDT	0.0987	Measured
alpha chlordane	0.0144	0.0417
gamma chlordane	0.00987	0.0116
Sum chlordane	0.0243	0.0533

b. Modeled Values for PAHs in Fish and Invertebrates

Concentrations of PAH compounds were obtained in the same way as shown in the previous section. To obtain each of the PAH CoPCs for which TRVs could be obtained, calculations as summarized in the following table were carried out.

PAH compound	**EPC_{sed} dw**	**PEFs***	**Fish mg/kg ww (PEF adjusted)****	**Inverts mg/kg ww (PEF adjusted)****
Napthalene	0.397	0.001	1.59E-05	2.52E-06
Acenaphthylene	0.636	0.001	2.89E-06	No BSAF
Acenaphthene	0.622	0.001	5.75E-06	3.98E-06
Fluorene	0.277	0.001	1.78E-06	2.55E-06
Phenanthrene	1.28	0.001	9.89E-06	4.00E-06
Anthracene	0.495	0.01	1.23E-05	2.74E-05
Fluoranthene	2.56	0.001	4.81E-06	1.974E-05
Pyrene	3.65	0.001	1.15E-05	6.28E-06
Benzo[a]anthracene	1.50	0.1	0.000509	0.000258
Chrysene	2.15	0.01	4.79E-05	4.59E-05
Benzo[b]fluoranthene	3.14	0.1	0.000193	0.000429
Benzo[k]fluoranthene	0.755	0.1	4.33E-05	0.000150
Benzo(a)pyrene	2.64	1	0.00138	No BSAF
Indeno[1,2,3-cd]pyrene	1.88	0.1	0.000677	No BSAF
Dibenzo[a,h]anthracene	0.249	1	0.000134	No BSAF
Benzo[g,h,i]perylene	1.63	0.01	0.000102	3.59E-05
Sum BaP equiv			0.0032	0.0010
HMW†	3.71†		0.0058†	0.0015†
LMW†	20.2†		0.040†	0.015†
Total†	18.3†		0.065†	0.021†

*PEF = potency equivalence factor from Sun et al 2012 to obtain BaP (benzo[a]pyrene) equivalent concentrations
**PEF adjusted indicates EPC was adjusted for PEF: EPC x PEF value, and then fish concentration was obtained using the calculations shown in the previous section:

$$[COPC]_{fish}\left(\frac{mg}{kg\ wet\ tissue}\right) = \frac{EPC_{sed}(\frac{mg}{kg\ dw})}{OC\ (fraction\ dw)} \times BSAF_{COPC}\left(\frac{mg/kglipid}{mg/kgOC}\right) \times fraction\ lipid\ (\frac{kg\ lipid}{kg\ wet\ tissue})$$

†Not PEF adjusted. LMW (low molecular weight), HMW (high molecular weight) and total values from all PAH compounds analyzed, not just those shown here.

III. Calculation of Site-specific Target Levels (SSTLs)

The risk calculations described in previous sections were used to calculate SSTLs.

1. Arsenic

For arsenic, the SSTL is based on determining acceptable cancer risk, using the following equation:

$$ILCR_{accept} = LADD_{accept} \times CSF$$

Where:

$ILCR_{accept}$ = Acceptable Incremental Lifetime Cancer Risk, set to 10^{-5}

$LADD_{accept}$ = Acceptable Lifetime Average Daily Dose (mg/kg-d)

CSF = Cancer Slope Factor $(mg/kg\text{-}d)^{-1}$

The $LADD_{accept}$ is obtained from:

$$LADD_{accept} = (EDI_{Fish} + EDI_{Sed} + EDI_{Derm})_{accept} \times \frac{ED}{LE}$$

Where:

ED = exposure duration (years)

LE= life expectancy (years)

Only $EDI_{Sed} + EDI_{Derm}$ are used in the present calculation. Exposure duration is over a lifetime, so ED/LE = 1, and $LADD_{accept} = EDI_{accept}$.

The $LADD_{accept}$ (= EDI_{accept}) is used to obtain exposure factors for each exposure pathway and receptor, to allow for the calculation of the sediment concentration as follows:

$$LADD_{accept} = (EDI_{Sed} + EDI_{Derm})_{accept}$$

$$(EDI_{Sed} + EDI_{Derm})_{accept} = (EDI_{sed})_{direct} + (EDI_{sed})_{indirect} + (EDI_{derm})_{direct} + (EDI_{derm})_{indirect}$$

Each EDI is calculated by:

$$EDI_{sed} = \frac{EPC_{sed} \times \text{scenario specific exposure factors} \times EF_a \times EF_b}{BW}$$

Where:

EDI_{sed} = estimated daily intake (mg/kg-d) from the specific exposure route

EPC_{sed} = concentration of contaminant in sediment (mg/kg)

EF_a = exposure frequency in days per week exposed (same for all scenarios)

EF_b = exposure frequency in weeks per year exposed (same for all scenarios)

BW = body weight (kg), specific for different receptors

Scenario specific exposure factors = ingestion rate for ingestion, and areas of skin exposed and sediment adhesion factors for dermal exposure, as described in Section I, specific for difference receptors.

The following table shows the scenario specific exposure factors for each receptor and exposure scenario:

	Ingestion direct (kg/d)	**Ingestion indirect (kg/d)**	**Dermal direct (kg/d)**	**Dermal indirect (kg/d)**
Exposure factors	$(IR_{sed})_{direct}$	$(IR_{sed})_{indirect}$	See A	See B
Adult	1.00E-04	1.5E-06	4.98E-05	7.70E-06
Teen	1.00E-04	1.5E-06	4.50E-05	6.80E-06
Child	2.00E-04	1.5E-06	5.01E-04	4.37E-06
Toddler	2.00E-04	1.5E-06	2.78E-04	3.00E-06

A=$[(SA_{Feet} \times SAF_{Feet}) + (SA_{Lower\ hands} \times SAF_{Lower\ hands}) + (SA_{arms+legs} \times SAF_{arms+legs})] \times RAF_{Derm}$

A = (adult) (1370 cm^2 × 5.8E-07 kg/cm^2-d) + (890 cm^2 × 8.8E-07 kg/cm^2-d) + (8220 cm^2 × 1E-08 kg/cm^2-d) × 0.03

A = (adult) 4.98E-05 kg/d

B = $[(SA_{Hands} \times SAF_{Hands}) + (SA_{Other} \times SAF_{Other})] \times RAF_{Derm}$

B = (adult) (890 cm^2 × 1E-07 kg/cm^2-d) + (16750 cm^2 × 1E-08 kg/cm^2-d) × 0.03

B = 7.70E-06 kg/d

For cancer, the weighting for lifetime exposure is included. The overall calculation can be represented by:

$$\text{ILCR} = \text{ILCR}_{adult} \times Weighting_{adult} + \text{ILCR}_{teen} \times Weighting_{teen} + \text{ILCR}_{child} \times Weighting_{child} + \text{ILCR}_{toddler} \times Weighting_{toddler}$$

$$\text{ILCR} = \text{CSF} \times \sum_{toddler}^{adult} \left[\frac{EPC_{sed} \times \sum \text{scenario specific exposure factors} \times EF_a \times EF_b}{BW}\right]_i \times Weighting_i$$

$$\text{ILCR} = \text{CSF} \times EPC_{sed} \times EF_a \times EF_b \times \sum_{toddler}^{adult} \left[\frac{\sum \text{scenario specific exposure factors}}{BW}\right]_i \times Weighting_i$$

The following table shows the sum of scenario specific exposure factors, body weights and weightings:

	Sum of scenario specific exposure factors (kg/d)	**Body weight (kg)**	**Weighting**	$\frac{\textbf{Sum} \times \textbf{Weighting}}{\textbf{Body weight}}$ $(\mathbf{d^{-1}})$
Adult	1.59E-04	70.7	0.75	1.69E-06
Teen	1.53E-04	59.7	0.1	2.57E-07
Child	7.07E-04	32.9	0.0875	1.88E-06
Toddler	4.82E-04	16.5	0.05625	1.64E-06
Total weighted exposure factors				5.47E-06

The total from this table is incorporated into the ILCR equation as follows:

$$\text{ILCR} = \text{ILCR}_{accept} = 10^{-5}$$

and

$$\text{ILCR}_{accept} = 10^{-5} = \text{CSF} \times EPC_{sed} \times EF_a \times EF_b \times \text{Total weighted exposure factors.}$$

Since

$$EF_a \times EF_b = \frac{61d}{365d} = 0.1671;\ CSF = 1.8\ (\frac{mg}{kg \times d})^{-1}$$

$$EPC_{sed} = \frac{10^{-5}}{1.8\ (\frac{mg}{kg \times d})^{-1} \times 0.1671 \times 5.47 \times 10^{-6} d^{-1}}$$

$$EPC_{sed} = 6.1\ mg/kg$$

2. Polycyclic Aromatic Hydrocarbons

To calculate SSTLs for PAHs, an approach similar to that taken for arsenic was used. However, only dermal exposure and its cancer slope factor was considered, since this was the predominant risk found in Chapter IV. Additionally, the LADD is calculated differently, as detailed in Chapter IV:

$$LADD = \frac{C_s \times SL \times SA_{EXP} \times RAF_{derm} \times ETF \times D_1}{SA_{ST\ EXP}}$$

Where:

Cs = concentration of PAH equivalent to each carcinogenic PAH in sediment (µg/kg)

SL = sediment loading factors (kg/cm^2-d)

SA_{EXP} = surface area of exposed skin (cm^2)

RAF_{derm} = skin absorption of B[a]P from soil relative to acetone (0.148)

ETF = adjustment for different in mouse and human epidermal thickness (0.2)

D_1 = exposure time for swimming/wading (61 d/365d), other factors are 1

$SA_{ST\,EXP}$ = surface area of mouse skin dosed with B[a]P in acetone (6 cm^2)

Using this equation and the approach described for As, the total weighted exposure factors were multiplied by 61d/365d to obtain two overall factors for two different scenarios:

$(\text{Overall factors})_{\text{all dermal}}$ = 2.98 x 10^{-6} kg/cm^2-d

$(\text{Overall factors})_{\text{indirect dermal}}$ = 1.92 x 10^{-7} kg/cm^2-d

The second factor, $(\text{Overall factors})_{\text{indirect dermal}}$, was calculated using only indirect dermal scenarios, and did not include the direct dermal exposure scenario (wading, with higher exposures).

The following calculation (example shown for benzo[a]pyrene) was carried out for all carcinogenic PAHs assessed in the present HHRA.

$$\text{ILCR}_{accept} = 10^{-5} = \text{CSF} \times EPC_{sed} \times \text{Overall factors}$$

$$EPC_{sed} = \frac{10^{-5}}{CSF \times \text{Overall factors}}$$

$$CSF = 3.5\ (\frac{\mu g}{cm^2 \times d})^{-1}$$

$$(EPC_{sed})_{all\ dermal} = \frac{10^{-5}}{3.5\ (\frac{\mu g}{cm^2 \times d})^{-1} \times 2.98 \times 10^{-6}\ \frac{kg}{cm^2 \times d}}$$

$$(EPC_{sed})_{all\ dermal} = 0.96\ \mu g/kg$$

The proportion of each of the carcinogenic PAHs was estimated by dividing the mean of each PAH compounds concentration in the KIH by the mean of total PAHs. For benzo[a]pyrene, the ratio obtained was 0.144 (benzo[a] pyrene makes up approximately 14.4% of the PAHs in KIH). This was used to obtain the total PAH concentration approximately equivalent to the benzo[a]pyrene concentration obtained above:

$$(EPC_{sed})_{all\ dermal} = \frac{0.96\ \mu g/kg}{0.144}$$
$$(EPC_{sed})_{all\ dermal} = 6.7\ \mu g/kg = 0.007\ mg/kg$$

The following table summarizes the results obtained for all of the carcinogenic PAHs.

PAH compound	CSF dermal $(\mu g/cm^2 * d)^{-1}$	SSTL all dermal mg/kg	SSTL indirect mg/kg	Proportion of total PAH	SSTL total PAH all dermal mg/kg	SSTL total PAH indirect mg/kg
Benzo[a]pyrene	3.5	0.001	0.015	0.144	0.007	0.1
Benzo[a]anthracene	0.35	0.010	0.15	0.088	0.11	1.7
Benzo[b]fluoranthene	0.35	0.010	0.15	0.167	0.058	0.9
Benzo[g,h,i]perylene	0.035	0.096	1.5	0.087	1.1	17
Benzo[k]fluoranthene	0.35	0.010	0.15	0.036	0.27	4.2
Chrysene	0.035	0.096	1.5	0.120	0.80	12
Dibenzo[a,h]anthracene	3.5	0.001	0.015	0.019	0.050	0.8
Fluoranthene	0.0035	0.96	15	0.140	6.8	106
Indeno[1,2,3-cd]pyrene	0.35	0.010	0.15	0.092	0.10	1.6
Phenanthrene	0.0035	0.96	15	0.071	13	208

The following calculations can be carried out slightly differently, where all ILCRs for the known (measured) carcinogenic compounds are summed. This allows the calculation of the SSTLs as follows:

$$\text{ILCR}_{accept} = 10^{-5} = EPC_{sed} \times \sum^{i} \text{CSF}_i \times \text{Overall factors}$$

Using this method, the following results can be obtained:

PAH compound	CSF dermal $(\mu g/cm^2 * d)^{-1}$	CSF × Overall factor (all dermal)	CSF × Overall factor (indirect)	Proportion of total PAH
Benzo[a]pyrene	3.5	1.04E-05	6.74E-07	0.144
Benzo[a]anthracene	0.35	1.04E-06	6.74E-08	0.088
Benzo[b]fluoranthene	0.35	1.04E-06	6.74E-08	0.167
Benzo[g,h,i]perylene	0.035	1.04E-07	6.74E-09	0.087
Benzo[k]fluoranthene	0.35	1.04E-06	6.74E-08	0.036
Chrysene	0.035	1.04E-07	6.74E-09	0.120
Dibenzo[a,h]anthracene	3.5	1.04E-05	6.74E-07	0.019
Fluoranthene	0.0035	1.04E-08	6.74E-10	0.140
Indeno[1,2,3-cd]pyrene	0.35	1.04E-06	6.74E-08	0.092
Phenanthrene	0.0035	1.04E-08	6.74E-10	0.071
Sum		2.52E-05	1.63E-06	0.964
SSTL carcinogenic	**µg/kg**	**0.40**	**6.13**	
SSTL total PAH	**µg/kg**	**0.41**	**6.36**	
SSTL total PAH	**mg/kg**	**0.0004**	**0.006**	

These results are more conservative than the SSTLs obtained based on the lowest of the individual carcinogenic compounds. The carcinogenic PAH compounds listed in the present HHRA may be only a fraction of those that may be present at the site; on the other hand, other non-carcinogenic PAHs (e.g., many of the alkylated PAHs) may also be present, which have the potential to change the proportion of total PAH value and the SSTL for total PAH.

3. Chromium

The chromium SSTL is based on ecological risk to the mallard duck. The mallard duck's risk was primarily a result of food ingestion, and therefore an acceptable food concentration was calculated, and then used with a sediment-to-food model to obtain sediment concentrations.

The following equation was used:

$$EDI = \left[\left(\sum_{i=1}^{n} EPC_{fi} \times F_i\right) \times FIR\right] \times F_{site} \times ED$$

$$EDI = [\{(EPC_{macro} \times F_{macro}) + (EPC_{invert} \times F_{invert})\} \times FIR] \times F_{site} \times ED$$

For the mallard duck,

EPC_{macro} = the exposure point concentration of macrophytes, mg/kg (dry weight)
EPC_{invert} = the exposure point concentration of invertebrates, mg/kg (dry weight)
FIR = food ingestion rate, 0.05 kg dry weight/kg body weight-d
F_{macro} = F_{invert} = the fraction of the receptor's diet that the food item comprises, for both food types equal to 0.5 (fraction of diet) × 0.97 (fraction of total ingested material made up of food). Sediment (F_{sed} = 0.03) is neglected in the present calculation since the risk calculations showed that this is a negligible source of exposure, compared with food.
F_{site} = the fraction of the receptor's diet that is harvested from the APEC, 1
ED = the exposure duration, defined as the fraction of the year that the receptor feeds at that site, 214 d/365 d = 0.586.

The equation becomes:

$$EDI = \left[\{(EPC_{macro} \times 0.5 \times 0.97) + (EPC_{invert} \times 0.5 \times 0.97)\} \times 0.05 \frac{kg}{kg \times d}\right] \times 1 \times 0.586$$

Using an acceptable TRV = EDI of 2.66 mg/kg-d, and gathering terms gives:

$$2.66 \frac{mg}{kg \times d} = 0.5 \times 0.97 \times 0.586 \times 0.05 \frac{kg}{kg \times d}(EPC_{macro} + EPC_{invert})$$

$$(EPC_{macro} + EPC_{invert}) = 187.2 \frac{mg}{kg}$$

The equations relating sediment to macrophytes and invertebrates are:

$$\log_{10}[Cr]_{macro} = 0.5471 \log_{10}[Cr]_{sed} - 0.774$$

$$\log_{10}[Cr]_{invert} = 1.4062 \log_{10}[Cr]_{sed} - 2.0581$$

To solve for the concentration of chromium in sediment, $[Cr]_{sed}$, which is equal to the SSTL for Cr, the relationship between EPCs for macrophytes and invertebrates was used:

$$EPC_{macro} + EPC_{invert} = 187.2 \frac{mg}{kg}$$

$$EPC_{invert} = 187.2 - EPC_{macro} \frac{mg}{kg}$$

The $[Cr]_{sed}$ was calculated iteratively by varying EPC_{macro}, until the sediment concentrations obtained using both biota-sediment equations were equal. The results are shown in the following table.

Food item	EPC_{biota} (mg/kg)	Equation	$[Cr]_{sed}$ (mg/kg)
Macrophyte	8.01	$[Cr]_{sed} = 10^{(\frac{(\log_{10} 8.1)+0.774}{0.5471})}$	1164
Invertebrate	187.2 – 8.01 = 179.18	$[Cr]_{sed} = 10^{(\frac{(\log_{10} 179.1)+2.0581}{0.1.4062})}$	1164

4. Polychlorinated Biphenyls (PCBs)

The PCB SSTL is based on human health and ecological risks through fish consumption. The toddler receptor was used for the human health SSTL calculations and mink were used as the receptor for SSTLs to address ecological risk. The risk to both receptors was primarily a result of fish consumption, and therefore an acceptable fish PCB concentration was calculated, and then used with a sediment-to-fish uptake model to obtain sediment concentrations.

The following equation was used to calculate acceptable fish PCB concentrations for toddler and mink receptors:

$$C_{target} = \frac{SAF \times BW \times TRV}{IR \times ED}$$

C_{target}	target fish tissue PCB concentration
SAF	site allocation factor
BW	body weight
TRV	toxicity reference value
IR	ingestion rate
ED	exposure duration

For the toddler receptor:

The site allocation factor (SAF) was calculated as:

$$SAF \; = (1 - background\ exposure\ HQ) \times F\_fish$$

F_{fish} = the proportion of total risk from PCBs attributable to the fish consumption pathway. This was calculated as 89% for the toddler receptor (see Figure IV-6, Chapter IV).

The PCB background exposure HQ for toddlers was estimated at 0.049 (see Section 1-4b, Appendix I).

Consistent with the HHRA, equation parameters for the toddler receptor are: BW = 16.5 kg/d, TRV = 0.00013 mg/kg-d, IR = 0.0058 kg/d, and ED =1.

The equation becomes:

$$C_{target} = \frac{((1 - 0.049) \times 0.89 \times 16.5 \times 0.0013}{0.0058 \times 1}$$

Therefore, the target fish tissue concentration that would result in acceptable risks through fish consumption for the toddler receptor is 0.31 mg/kg.

For the mink receptor, the equation parameters are as follows:

SAF	site allocation factor = 1
BW	body weight = 0.82 kg
TRV	toxicity reference value = 0.053 mg/kg-d
IR	ingestion rate = 0.14 kg/kg BW-d
ED	exposure duration =1

The equation becomes:

$$C_{target} = \frac{1 \times 0.82 \times 0.053}{0.14 \times 1}$$

Therefore, the target fish concentration that would result in acceptable risks through food ingestion for the mink is 0.31 mg/kg.

Since the same target fish concentrations were calculated for the toddler and mink receptors, the following procedure and example calculations were used to calculate PCB SSTLs for both receptors. First, the target fish concentrations were converted to whole body concentrations using the conversion factors outlined in Section II-3, Appendix I, for brown bullhead and largemouth bass. Secondly, for largemouth bass, the whole body concentrations were divided by minimum (BMF = 1.1), average (BMF = 4.6), and maximum (BMF = 12.6) biomagnification factors obtained from a literature review in order to derive target tissue concentrations that were representative of the benthivorous fish trophic level.

PCB SSTLS for sediment were derived from the benthivorous fish target tissue concentrations using two methods: (1) BSAFs calculated from paired KIH sediment and fish chemical concentrations; and (2) a sediment-biota uptake equation derived from the same fathead minnow dataset.

For the first method, the equation for BSAFs is as follows:

$$BSAF = \frac{C_b / F_l}{c_s / F_{oc}}$$

C_b Mean contaminant concentration in biota (mg/kg ww). This corresponds with the mean PCB concentration in fish (brown bullhead or largemouth bass)

C_s Mean contaminant concentration in the sediments (mg/kg dw)

F_l Fraction of lipids in the biota (g lipid/g ww)

F_{oc} Fraction of the sediments as organic carbon (g organic carbon/g dw)

Solving for C_s, the equation becomes:

$$C_s = \frac{C_b / F_l}{\mathrm{BSAF}} \times F_{oc}$$

The average lipid content for fish samples collected from the KIH was used for lipid normalization (2.2%; $F_l = 0.022$), which is similar to that reported from other studies. The average sediment TOC concentration for samples located in the southern KIH (8%; n=31; $F_{oc} = 0.08$) was used for organic carbon normalization.

Using brown bullhead (whole body conversion factor = 2.2) and the average BSAF (3.874):

$$C_s = \frac{(0.31 \times 2.2)/0.022}{3.874} \times 0.08$$

$C_s = 0.64$ mg/kg

In the second method, an empirical sediment-biota regression equation was developed to establish the relationship between PCBs in sediments and uptake by fathead minnows. TOC normalized sediment PCB concentrations (ng PCB/g TOC) were plotted against the lipid-normalized fathead minnow PCB concentrations (ng PCB/g lipid ww – corrected for pre-exposure PCB concentration) on a log scale. The resulting site-specific sediment-biota PCB uptake equation is:

$$\log (C_b/F_l) = 0.779 * \log (C_s/F_{oc}) + 1.22 \quad (R^2 = 0.63, p < 0.01)$$

Solving for C_s, the equation becomes:

$$C_s = 10^{((\log(C_b/F_l)) - 1.22))/0.779)} \times F_{oc}$$

Using largemouth bass (whole body conversion factor = 1.6) and the minimum BMF (= 1.1):

$$C_s = 10^{((\log((0.31 \times 1.6/1.1)/0.022) - 1.22))/0.779)} \times 0.08$$

C_s = 0.75 mg/kg

5. Spatially Weighted Average Concentrations (SWAC)

The SWAC is calculated as:

$$SWAC = \frac{\sum Ci \times Ai}{\sum Ai}$$

SWAC	spatially weighted average concentration
C_i	concentration of CoC in polygon i (ppm)
A_i	area of polygon i (ha)

IV. References

Azimuth Consulting Group. 2012. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Prepared for Environment Canada.

Dabeka, R.W., A.D. McKenzie and P. Bradley (Dabeka et al.). 2003. "Survey of total mercury in total diet food composites and an estimation of the dietary intake of mercury by adults and children from two Canadian cities, 1998–2000." *Food Additives and Contaminants* 20: 629–638.

Environment Canada and Health Canada. 2010. Screening Assessment for the Challenge: Antimony trioxide (Antimony oxide). Accessed from http://www.ec.gc.ca/ese-ees/9889ABB5-3396-435B-8428-F270074EA2A7/batch9_1309-64-4_en.pdf. 86 pages.

Health Canada. 2010a. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. September 2010. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals ($DQRA_{chem}$). September 2010. Prepared by the Contaminated Sites Division Safe Environments Directorate.

Health Canada. 2011. Dietary Intakes of Contaminants & Other Chemicals for Different Age-Sex Groups of Canadians. Available at http://www.hc-sc.gc.ca/fn-an/surveill/total-diet/intake-apport/index-eng.php.

Labencki, T. 2008 and references therein. An Assessment of Polychlorinated Biphenyls (PCBs) in the Hamilton Harbour Area of Concern (AOC) in Support of the Beneficial Use Impairment (BUI): Restrictions on Fish and Wildlife Consumption. Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment. On behalf of: Toxic Substances and Sediment Technical Team, Hamilton Harbour Remedial Action Plan. Available at http://www.hamiltonharbour.ca/documents/2008_Labencki_-_Hamilton_Harbour_PCB_Study.pdf

Ontario Ministry of the Environment (OMOE). 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An integrated approach.

Nagy, K.A., I.A. Girard and T.K. Brown (Nagy et al.). 1999. "Energetics of free-ranging mammals, reptiles, and birds." *Annu. Rev. Nutr.* 19: 247–77.

Peterson, S.A., J. Van Sickle, R.M. Hughes, J.A. Schacher and S.F. Echols (Peterson et al.). 2005. "A biopsy procedure for determining filet and predicting whole-fish mercury concentration." *Arch. Environ. Contam. Toxicol.* 48: 99–107.

SENES Consultants Limited. 2010. Collection of data to develop Canadian estimated daily intake rates of lead in pertinent media of exposure. Prepared for Health Canada Quebec Region, Safe Environments Programme, Healthy Environments and Consumer Safety Branch. Quebec, PQ. 96 pp.

Sun, J.L., H.G. Ni and H. Zeng (Sun et al.). 2012. "Ecological risk assessment of parent and halogenated polycyclic aromatic hydrocarbons in surface sediments from an urban river in south China." *Environ. Toxicol. Chem.* 31 (8): 1867–1873.

United States Environmental Protection Agency (US EPA). 1993. Wildlife Exposures Handbook: Volume I of II. Office of Research and Development, United States Environmental Protection Agency, Washington DC. EPA/600/R-93/187.

United States Environmental Protection Agency (US EPA). 2006. Results of the Lake Michigan Mass Balance Project: Polychlorinated Biphenyls Modeling Report. Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division, United States Environmental Protection Agency, Grosse Ile, Michigan. EPA-600/R-04/167. http://catalogue.nla.gov.au/Record/4185997. Retrieved on February 10, 2010.

United States Environmental Protection Agency (US EPA). 2009. BSAF (Biota-Sediment Accumulation Factor) database, available from http://www.epa.gov/med/Prods_Pubs/bsaf.htm

Xue, J., V. Zartarian, S.-W. Wang, L.V. Liu and P. Georgopoulos (Xue et al.). 2010. "Probabilistic Modeling of Dietary Arsenic Exposure and Dose and Evaluation with 2003–2004 NHANES Data." *Environ. Health Perspect.* 118: 345–350.

APPENDIX J: TOXICOLOGICAL PROFILES

Table of Contents

Table of Contents, cont`d

Table of Contents, cont`d

I. INTRODUCTION

For this report toxicological information was obtained from a variety of sources to compile toxicological reference values (TRVs) for each contaminant of potential concern (CoPC). The sources include Health Canada (2010), Ontario Ministry of the Environment (2011), and the US EPA Integrated Risk Information System database (IRIS).

TRVs indicate the value above which exposure is expected to cause adverse health effects in receptors. TRVs are developed for cancer-causing agents and non-cancerous endpoints.

A. Non-carcinogenic TRVs

Adverse effects from exposure to non-carcinogenic substances may occur if the dose is above a determined threshold level. Because effects depend upon a threshold dose, two measures of interest can be drawn from the dose-response curve for a particular chemical: the no observed adverse effect level (NOAEL) and lowest observed adverse effect level (LOAEL). The NOAEL benchmark is the highest dose for which no adverse effects have been observed. The LOAEL benchmark indicates the lowest dose for which adverse effects have been seen.

The reference dose (RfD) value is used to assess non-carcinogenic endpoints. It is an estimate of the lifetime daily exposure for the general human population to a non-carcinogenic substance that is without substantial risk of harmful effects, and is expressed in mg chemical/kg receptor body weight per day (e.g., mg/kg-d). RfD values are determined through laboratory analysis, and are derived using either the NOAEL or the LOAEL. Uncertainty factors (UFs) can be applied to the RfD to account for both interspecies and intraspecies variations between the test subject used in the experimental study and the receptor for which the risk of exposure is being assessed. Additional uncertainty factors are used to extrapolate between sub-chronic and chronic exposure values, or when there is insufficient toxicity data for a chemical.

Agencies providing regulations regarding exposure to chemicals may substitute the term RfD for other appropriate terms that better reflect the scope of their objectives and different toxicological endpoints. For example, Health Canada has replaced RfD with tolerable daily intake (TDI), expressed in mg/kg-day. The US Institute of Medicine (IOM) uses the tolerable upper intake level (UL) to describe the maximum daily nutrient intake that will not lead to adverse health effects, expressed in mg chemical/day. The Agency for Toxic Substances and Disease Registry (ATSDR) has defined a minimal risk level (MRL), much like the UL, which estimates the daily exposure that, over a specific duration, will not cause a significant risk of adverse effects.

The reference concentration (RfC) is used to dictate the non-carcinogenic endpoint for inhalation exposure. It is typically reported as the airborne concentration which can be converted to a RfD expressed as mg/kg-day.

B. Carcinogenic TRVs

Carcinogenic chemicals are said to exhibit non-threshold effects. This implies that there is no discrete dose below which adverse effects will not occur and that any dose can produce some effect. Further, exposure to some carcinogenic chemicals may be cumulative, meaning that the dose and associated effects may build over a lifetime. Two TRVs are used to describe carcinogenic effects: the cancer slope factor and unit risk.

Cancer slope factors (CSFs) are used to assess the carcinogenic effects of a chemical on a receptor. The CSF is an upper-bound estimate of the probability of a response per unit intake of a carcinogenic chemical over a lifetime, expressed as $(\text{mg/kg body weight-day})^{-1}$. The CSF is used to estimate the probability of the receptor developing cancer in its lifetime as a result of exposure to a particular level of a carcinogen.

Unit risks are employed to estimate the upper bound probability of a receptor developing cancer as a result of exposure to a certain level of a carcinogen (usually as 1 μg/L of water, or 1 $\mu g/m^3$ of air). Unit risk is calculated by dividing the CSF by body weight and multiplying by the intake rate of air or water for a given receptor.

Health Canada provides TRVs in the way of tumorigenic doses or concentrations for substances that are believed to have non-threshold, or carcinogenic, effects. The potency is expressed as a dose or concentration that will induce a 5% increase in the incidence of tumours or tumour related deaths as calculated from a dose-response curve. The TRV used as a benchmark for exposure to a certain substance in air is the tumorigenic concentration 05 (TC_{05}), which is associated with a 5% increase in cancer rate. Similarly, the TRV used for ingested substances is the tumorigenic dose 05 (TD_{05}).

C. Bioavailability

Bioavailability is defined as the extent to which a substance can be absorbed through all routes of exposure and reach systemic circulation (Schoof 2004), and is also referred to as absolute bioavailability. Bioavailability refers to the fraction of the total amount of material in contact with a receptor that enters the blood.

Bioavailability is dependent on the CoPC as well as the media in which the chemical resides (e.g., water, soil or food). As such, a relative bioavailability term has been developed to compare exposures through different media. Relative bioavailability is a measure of the absolute bioavailability in one route divided by the bioavailability of the contaminant in the exposure medium used in the TRV study. Relative bioavailability can be expressed as a relative absorption fraction (RAF).

Relative bioavailability was used in this risk assessment for each route of exposure that was deemed relevant. Values have been presented in the toxicity profiles. Due to a lack of sound bioavailability data by the ingestion and inhalation routes, the relative bioavailability was assumed to be 100% (RAF = 1.0). This provides the highest degree of conservatism. For dermal exposure routes, Health Canada has published default values to be used for CoPCs in the absence of site-specific information.

D. References

Schoof, R.A. 2004. “Bioavailability of soil-borne chemicals: Method development and validation.” *Human and Ecological Risk Assessment* 10: 637–46.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, PIBS 7386e01. Pp 1–571. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/ resource/stdprod_086518.pdf

United States Environmental Protection Agency (US EPA). Integrated Risk Information System database (IRIS). Available at http://www.epa.gov/iris/. Accessed March 16, 2010.

II. CONTAMINANTS OF POTENTIAL CONCERN (COPCS)

A. Antimony

Antimony (Sb) is a naturally occurring element found in the earth's crust, usually in sulfide minerals. Arsenic is found in trivalent and pentavalent oxidation states, and the trivalent form can complex easily to organic ligands. It is used in many metal applications (e.g., as a hardener in plumbing solder, batteries, etc), and also in flame retardants, paint pigments, glass and other applications (HC and EC 1997).

1. Assessment of Carcinogenicity

Antimony is classified as not having adequate data to allow its evaluation of carcinogenicity (Group V) (HC and EC 1997). Likewise, antimony has not been assessed by US EPA at a carcinogen (US EPA 1991). Health Canada does not include antimony in its list of TRVs (HC 2010).

2. Susceptible Populations

Specific populations have not been identified that are more sensitive to antimony toxicity than others. However, individuals with chronic respiratory, cardiovascular, or kidney disease may be at special risk (ATSDR 1992).

3. Selection of Toxicity Values

a. <u>Non-cancer Oral Toxicity Reference Value</u>

The non-cancer oral toxicity reference value of 0.0004 mg/kg-d was obtained from US EPA IRIS (1991). It was developed from a rat feeding study using antimony tartrate and was based on a LOEAL and uncertainty factors. Confidence in this value is low. Health Canada has not reported any value for non-cancer oral reference.

b. <u>Cancer Oral Toxicity Reference Value</u>

Antimony is not considered a human carcinogen; therefore TRVs related to cancer effects are not available.

4. Bioavailability

a. <u>Oral Bioavailability</u>

The relative oral absorption factor for antimony has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for antimony has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for antimony has been determined to be 0.1 (OMOE 2011).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by arsenic.

	Route of exposure	Non-carcinogenic	Carcinogenic
		TRV value (Tolerable Daily Intake) (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Sb	Ingestion	0.0004	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 1992. Toxicological Profile for Antimony.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

Health Canada and Environment Canada (HC and EC). 1997. Antimony. Guidelines for Canadian Drinking Water Quality: Supporting Documentation, edited 1999.

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, PIBS 7386e01. Pp 1–571. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/ resource/stdprod_086518.pdf

United States Environmental Protection Agency (US EPA). 1991. Integrated Risk Information System (IRIS): Antimony. CASRN 7440-36-0.

B. Arsenic

Arsenic (As) is a naturally occurring element found in the earth's crust. Arsenic can be found in the environment as inorganic and organic, or organoarsenic compounds. Organoarsenic compounds are defined as those where an As-C bond is present. Inorganic arsenic released into the environment can be made accessible through the mining of ores such as gold, copper, lead and zinc. Gold ore are the main source and release of arsenic in Canada, whereas copper mining is the main source of arsenic release into the environment throughout the rest of the world (CCME 2001). Inorganic arsenic can also be found in wood preservatives. Organoarsenic compounds are released into the environment through anthropogenic sources such as pesticides.

1. Assessment of Carcinogenicity

Arsenic has been classed as a human carcinogen by several regulatory agencies (HC 2010; IARC 2004; US EPA 1998).

2. Susceptible Populations

A current review did not locate any studies indicating that certain populations were more sensitive to arsenic toxicity than others. However, children are thought to be a sensitive population as their exposures will differ from those of adults and the general populations, because of their lifestyle and behaviours (ATSDR 2007).

3. Selection of Toxicity Values

a. Non-Cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value of 0.0003 mg/kg-d was obtained from US EPA IRIS (1998). This data, obtained by Tseng et al. (1968) showed increases in the prevalence of blackfoot disease with an increase in arsenic dose. With high-dose arsenic exposure, prevalence of skin lesions increased by 20% in both males and females. This study was assigned an uncertainty factor (UF) of 3 because of its lack of reproducibility, reproductive toxicology, and uncertainty as to whether the NOAEL accounted for all sensitive individuals. Confidence in this study is medium. Health Canada has not reported any value for non-cancer oral reference.

b. Cancer Oral Toxicity Reference Value

The cancer slope factor of 1.8 $(mg/kg\text{-}d)^{-1}$ was obtained from Health Canada (2010).

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for arsenic has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for arsenic has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for arsenic has been determined to be 0.03 (HC 2010).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by arsenic.

	Route of exposure	**Non-carcinogenic**	**Carcinogenic**
		TRV value (Tolerable Daily Intake) (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
As	Ingestion	0.0003	1.8

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Arsenic.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Minimal Risk Levels for Hazardous Substances. Obtained at http://www.atsdr.cdc.gov/mrls/index.html

Canadian Council of Ministers of the Environment (CCME). 2001. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Arsenic (Inorganic). Winnipeg, MB, Canada.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0, May 2009.

International Agency for Research on Cancer (IARC). 2004. Volume 84: Some Drinking-water Disinfectants and Contaminants, including Arsenic. Available at http://monographs.iarc.fr/ENG/Monographs/vol84/mono84.pdf

Tseng, W.P., H.M. Chu, S.W. How, J.M. Fong, C.S. Lin and S. Yeh (Tseng et al.). 1968. "Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan." *J. Natl. Cancer Inst.* 40: 453–463.

United States Environmental Protection Agency (US EPA). 1998. Integrated Risk Information System (IRIS): Arsenic, inorganic. CASRN 7440-38-2.

C. Chlordane

Chlordane is a synthetic chlorinated organic pesticide that was once widely used in the control of insects, particularly in agriculture and lawn care settings, and also in the control of termites in residential settings (ATSDR 1994). Chlordane use was discontinued under the Pest Control Products Act in 1991 (CCME 1999).

1. Assessment of Carcinogenicity

US EPA has included a discussion on chlordane's carcinogenicity and considers chlordane to be carcinogenic by the inhalation route (US EPA 1997). Health Canada does not include chlordane in its list of chemicals for which TRVs have been developed and thus does not consider chlordane to be a carcinogen (HC 2010).

2. Susceptible Populations

Individuals with chronic liver disease or impaired liver function may be susceptible to chlordane, and certain idiosyncratic effects (aplastic anemia and leukemias) have been speculated upon (ATSDR 1994). No data suggest that a population may be more susceptible to chlordane, although as for most toxicity, elderly populations (with declining organ function) and the youngest of the population (with immature and developing organs) were mentioned as possibly being more susceptible to toxic effects (ATSDR, 1994).

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value of 0.00033 mg/kg-d for chlordane was obtained from OMOE (2011).

b. Cancer Oral Toxicity Reference Value

No oral cancer toxicity reference value has been published for chlordane by Health Canada. Although OMOE (2011) lists a value for this route and effect, according to the Health Canada assessment this route was not considered.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for DDT has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for chlordane has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for chlordane has been determined to be 0.04 (OMOE 2011).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by chlordane.

	Route of exposure	**Non-carcinogenic**	**Carcinogenic**
		TRV value (Tolerable Daily Intake) (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Chlordane	Ingestion	0.00033	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 1994. Toxicological Profile for Chlordane.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Chlordane.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, PIBS 7386e017386e01. Pp 1–571. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_086518.pdf

United States Environmental Protection Agency (US EPA). 1987. Integrated Risk Information System (IRIS): Chlordane (Technical). CASRN 12789-03-6.

D. Chromium

Chromium is a naturally occurring inorganic element found complexed with oxygen, and in mineral forms with iron and lead. Chromium exists in several oxygen states, with the trivalent and hexavalent form being the most common species environmentally. The primary uses of chromium include metal finishing, leather tanning, corrosion control and wood treatment (CCME 1997).

1. Assessment of Carcinogenicity

Chromium has been assessed for its potential as a carcinogen and the US EPA (1987, 1998) IRIS has concluded that chromium (VI) is characterized as a known human carcinogen by the inhalation route of exposure. Health Canada (2010) classifies chromium (VI) and total chromium as human carcinogens, also by inhalation.

2. Susceptible Populations

Individuals with preexisting conditions of the respiratory, gastrointestinal, hematological, and immunological systems may be at increased risk of exposure to chromium compounds (ATSDR 2008).

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value of 0.001 mg/kg-d for total chromium was obtained from Health Canada (2010) and is based on chromium (VI) toxicity. The non-cancer oral toxicity reference for chromium (III) of 1.5 mg/kg-d was obtained from the US EPA (US EPA 1998). This TRV is based on animal studies using rats that were fed with chromium trioxide. An uncertainty factor of 100 was applied to account for interhuman and interspecies variability.

b. Cancer Oral Toxicity Reference Value

No oral cancer toxicity reference value has been published for chromium by the US EPA or Health Canada.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for chromium has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for chromium has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for chromium has been determined to be 0.1 (Health Canada, 2010).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by chromium. Only the value for Cr(III) was used in the KIH risk assessment because this was the only chromium form identified at the site.

	Route of exposure	Non-carcinogenic TRV value (Tolerable Daily Intake) (mg/kg-d)	Carcinogenic TRV value (Cancer Slope Factor) $(mg/kg\text{-}d)^{-1}$
Cr (VI)	Ingestion	0.001	n/a
Cr (III)	Ingestion	1.5	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Toxicological Profile for Chromium.

Canadian Council of Ministers of the Environment (CCME). 1997. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Chromium. Winnipeg, MB, Canada.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

United States Environmental Protection Agency (US EPA). 1987. Integrated Risk Information System (IRIS): Chromium VI. CASRN 18540-29-9.

United States Environmental Protection Agency (US EPA). 1998. Integrated Risk Information System (IRIS): Chromium III. CASRN 16065-83-1.

E. Copper

Copper is an essential trace elements used in many biological processes. It is also a naturally occurring inorganic element found in mostly in sulphide minerals. Copper exists in several oxidation states, with +2 being the most common environmentally. Copper is used in the manufacturing of textiles, paints, conductors, pipes, coins and cooking utensils. Copper compounds have also been associated with wood preservatives and in pesticides, fungicides and fertilizers (CCME, 1999).

1. Assessment of Carcinogenicity

Copper has been assessed for its potential as a carcinogen and the US EPA (1998) IRIS has concluded that it is not classifiable as to human carcinogenicity based on inadequate evidence to support carcinogenicity. Health Canada (2010) does not classify copper as a human carcinogen.

2. Susceptible Populations

Infants and toddlers have been found to be particularly susceptible to increased toxicity from exposures to copper (ATSDR, 2004). Two syndromes in particular have been identified as having increased sensitivity to copper exposures: Indian childhood cirrhosis and idiopathic copper toxicosis, and are also thought to be related to genetics (ATSDR, 2004).

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference values of 0.091 mg/kg-d for a toddler, 0.11 for a child, 0.126 for a teen, and 0.141 mg/kg-d for an adult were obtained from Health Canada (2010).

b. Cancer Oral Toxicity Reference Value

Copper is not considered a human carcinogen and therefore TRVs related to cancer effects are not available.

c. Non-cancer Inhalation Toxicity Reference Value

A non-cancer inhalation toxicity reference value is not available from Health Canada or the US EPA.

d. Cancer Inhalation Toxicity Reference Value

Copper is not considered a human carcinogen; therefore TRVs related to cancer effects are not available.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for copper has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for copper has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for copper has been determined to be 0.06 (Health Canada 2010).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by copper.

	Route of exposure	**Non-carcinogenic** **TRV value (Tolerable Daily Intake)** (mg/kg-d)	**Carcinogenic** **TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Cu	Ingestion	0.091 (Toddler) 0.11 (Child) 0.126 (Teen) 0.141 (Adult)	n/a
	Inhalation	n/a	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Copper.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Copper. Winnipeg, MB, Canada.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme.

United States Environmental Protection Agency (US EPA). 1988. Integrated Risk Information System (IRIS): Copper. CASRN 7440-50-8.

F. Dichloro-Diphenyl-Trichloroethane

Dichloro-diphenyl-trichloroethane (DDT) is a chlorinated organic pesticide that was once widely used in the control of insects in agricultural areas and to control insects carrying diseases such as malaria (ATSDR 2002). The use of DDT has been banned for use in Canada since 1985.

The toxicological endpoints that may be associated with DDT exposure are death, neurological effects, reproductive and developmental effects, hepatic effects and cancer.

1. Assessment of Carcinogenicity

DDT has been classified as a probable human carcinogen by the US EPA (US EPA 1987). Health Canada does not include DDT as a carcinogen (HC 2010).

2. Susceptible Populations

Individuals with pre-existing conditions related to the nervous system or liver may be more susceptible to the neurotoxic or hepatotoxic effects of DDT (ATSDR 2002). No data suggest that a population or individual may be more susceptible to DDT.

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value of 0.01 mg/kg-d for DDT was obtained from Health Canada (2010).

b. Cancer Oral Toxicity Reference Value

No oral cancer toxicity reference value has been published for DDT by Health Canada.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for DDT has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for DDT has been conservatively assumed to be 1.0.

c. <u>Dermal Bioavailability</u>

The relative dermal absorption factor for DDT has been determined to be 0.03 (OMOE 2011).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by DDT.

	Route of exposure	**Non-carcinogenic**	**Carcinogenic**
		TRV value (Tolerable Daily Intake) (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
DDT	Ingestion	0.01	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2002. Toxicological Profile for DDT.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, PIBS 7386e01. Pp 1–571. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/ @ene/@resources/documents/ resource/stdprod_086518.pdf

United States Environmental Protection Agency (US EPA). 1987. Integrated Risk Information System (IRIS): DDT CASRN 50-29-3.

G. Lead

Lead (Pb) is used in many anthropogenic products such as lead solder, ammunition, etc., and can be released into the environment through the disposal of these products or through the mining and smelting of commonly associated ores (ATSDR, 2007). Inorganic lead does not degrade readily in the environment and because of its numerous uses has been found in detectable concentrations at many contaminated sites.

1. Assessment of Carcinogenicity

The US EPA classifies lead as a probable human carcinogen based on sufficient animal evidence of increased renal tumours. However, there is inadequate evidence from studies with humans and the US EPA does not recommend a numerical estimate to be evaluated because of the lack of understanding of the toxicological and pharmacokinetic characteristics of lead, as well as numerous uncertainties associated with the estimate (US EPA, 1993). IARC (2006) classified inorganic lead compounds as probably carcinogenic to humans. Health Canada (2010) does not classify lead as a human carcinogen.

2. Susceptible Populations

ATSDR (2007) lists these populations as the potential to be susceptible to lead toxicity: crawling and house-bound children (<6 years old), pregnant women (and the fetus), the elderly, smokers, alcoholics, and people with genetic diseases affecting heme synthesis, nutritional deficiencies, and neurological or kidney dysfunction.

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value is currently under review (Health Canada 2010). A value of 0.00185 mg/kg-d was recommended by Health Canada and Ontario Ministry of the Environment (personal communications). The US EPA also does not currently publish a non-cancer oral toxicity reference value for lead.

b. Cancer Oral Toxicity Reference Value

Lead is not considered a human carcinogen; therefore TRVs related to cancer effects are not available.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for lead has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for lead has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for lead has been determined to be 0.006 (OMOE 2011).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by lead.

		Non-carcinogenic	**Carcinogenic**
	Route of exposure	**TRV value (Tolerable Daily Intake)** (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Pb	Ingestion	0.00185	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Lead Draft for Public Review.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

International Agency for Research on Cancer (IARC). 2006. Volume 87: Inorganic and organic lead compounds 10–17 February 2004. Available at http://monographs.iarc.fr/ENG/Meetings/vol87.php

Ontario Ministry of the Environment (OMOE). 2011. Rationale for the Development of Soil and Ground Water Standards for Use at Contaminated Sites in Ontario, PIBS

7386e01. Pp 1–571. Available at http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/ resource/stdprod_086518.pdf

United States Environmental Protection Agency (US EPA). 1993. Integrated Risk Information System (IRIS): Lead and compounds (inorganic). CASRN 7439-92-1.

H. Mercury

Mercury (Hg) is an inorganic element that occurs naturally in the environment and may be released by both natural and anthropogenic activities. Three different forms of mercury exist that each have specific effects on human health: (i) elemental mercury; (ii) inorganic mercury (e.g., mercuric chloride or $Hg(II)Cl_2$) usually in the Hg(II) form; and (iii) organic mercury (methylmercury) compounds (ATSDR 1999). Humans can be exposed to all three forms depending on the source (e.g., fish contain organic methylmercury whereas soil contains inorganic mercury).

1. Assessment of Carcinogenicity

Mercury has been assessed for the potential as a carcinogen and the US EPA (1995a) IRIS has concluded that elemental mercury is not classifiable with respect to human carcinogenicity based on inadequate evidence to support carcinogenicity from human and animal data. Mercuric chloride has been classified as a possible human carcinogen based on the absence of data in humans and limited evidence in animal by the US EPA (1995b). IARC has classed mercury and inorganic mercury compounds as not classifiable with respect to human carcinogenicity (IARC 1993). Health Canada (2010) does not classify any form of mercury as a human carcinogen.

2. Susceptible Populations

Susceptible populations to mercury exposure include those who exhibit a hypersensitivity to mercury known as acrodynia. Acrodynia symptoms include: itching; flushing; swelling of the palms, hands or soles of the feet; excessive sweating and/or salivation; elevated blood pressure; insomnia; weakness; irritability; fretfulness; and peripheral sensory disturbances. The physiological basis for this sensitivity is unknown (ATSDR 1999). Developing fetuses are also susceptible to toxic effects from mercury. Individuals with diseases of the liver, kidneys, lungs, and nerves are at greater risk of suffering from the toxic effects of both organic and inorganic mercury. Individuals with a dietary insufficiency of zinc, glutathione, antioxidants, or selenium are also more susceptible to the toxic effects of mercury.

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value for inorganic mercury of 0.0003 mg/kg-d was obtained from Health Canada (2010). The US EPA has reported the same TRV value for mercuric chloride (US EPA 1995b). This TRV was based on the conversion from the drinking water equivalent level obtained from lowest observed adverse effect levels (LOAELs) from three contributing studies. An uncertainty factor of 1,000 was applied to the animal studies using Brown Norway rats for LOAEL to NOAEL conversion, use of subchronic studies and interspecies interpolation and protection of sensitive human populations.

The non-cancer oral toxicity reference value for methylmercury is 0.0047 mg/kg-d for the general adult population, and 0.0002 mg/kg-d for women in child-bearing age and children < 12 years (HC 2010). The US EPA has reported a TRV value of 0.0001 mg/kg-d with an uncertainty factor of 10 (US EPA 2001).

b. Cancer Oral Toxicity Reference Value

Mercury is not considered a human carcinogen; therefore TRVs related to cancer oral effects are not available.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for mercury has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for mercury has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for inorganic mercury has been determined to be 1 (HC 2010) and for methylmercury 0.06.

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by mercury. Methymercury was not considered for human health risk in the KIH because the concentrations in fish were not significantly elevated compared with reference fish.

	Route of exposure	**Non-carcinogenic**	**Carcinogenic**
		TRV value (Tolerable Daily Intake) (mg/kg-d)	**TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Hg	Ingestion	0.0003	n/a
MeHg	Ingestion	0.0002 (adults)	n/a
		0.0047 (women of child bearing age & children <12 yrs)	

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 1999. Toxicological Profile for Mercury.

Agency for Toxic Substances and Disease Registry (ATSDR). 2008. Minimal Risk Levels for Hazardous Substances. Obtained at http://www.atsdr.cdc.gov/mrls/index.html

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

International Agency for Research on Cancer (IARC). 1993. Beryllium, Cadmium, Mercury, and Exposures in the Glass Manufacturing Industry: Summary of Data Reported and Evaluation, Vol. 58. Available at http://monographs.iarc.fr/ENG/Monographs/vol58/volume58.pdf

United States Environmental Protection Agency (US EPA). 1995a. Integrated Risk Information System (IRIS): Mercury, elemental. CASRN 7439-97-6.

United States Environmental Protection Agency (US EPA). 1995b. Integrated Risk Information System (IRIS): Mercuric chloride. CASRN 7487-94-7.

United States Environmental Protection Agency (US EPA). 2001. Integrated Risk Information System (IRIS): Methylmercury. CASRN 22967-92-6.

I. Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) have been widely used in applications from refrigerant coolants to lubricants in electrical equipment because of their low flammability. They are a persistent organic anthropogenic pollutant. The manufacturing of PCBs ceased in the 1970s because of this, however legacy PCB contamination still exists in products today.

1. Assessment of Carcinogenicity

There is evidence to indicate that PCBs have a potentially carcinogenic effect on the human liver, but these studies are inconclusive because of a lack of exposure quantification (US EPA 1999; ATSDR 2000). Of the studies reviewed by the US EPA that support observations of animal carcinogenicity, the most thorough is a study in which female and male Sprague Dawley rats were used to examine the carcinogenic potential of a number of different Aroclors (1260, 1254, 1242 and 1016) at a number of different dose levels (25, 50 or 100 ppm) with an exposure duration of 104 weeks. These mixtures contain overlapping groups of congeners that span the range of congeners most often found in environmental mixtures. In female rats, a statistically significant increase in liver adenomas and carcinomas was observed with exposure to all Aroclors tested. In male rats, a significant increase in liver cancers was observed for Aroclor 1260. Additionally, thyroid follicular cell adenomas or carcinomas were increased for all Aroclors in male rats only. Based on animal studies the US EPA has classified PCBs as a probable human carcinogen, though it cites a lack of supporting human epidemiological evidence to confirm this classification. Despite evidence that PCBs are linked to cancer in animal studies, Health Canada considers that PCBs are probably not carcinogenic (HC CCR 2004).

2. Susceptible Populations

ATSDR (2000) reports that women who were exposed to PCBs while pregnant gave birth to babies of lower weight than average. Children of women who were exposed to high doses of PCBs while nursing showed poor motor skills as well as short-term memory complications.

Those with compromised liver function or under-developed glucuronide conjugation mechanisms (e.g., those with Gilberts Syndrome) may also be more susceptible to the toxic effects of PCBs (ATSDR 2000).

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The non-cancer oral toxicity reference value of 0.00013 mg/kg-d was obtained from Health Canada (2010) and is based on the NOAEL of 13 ug/kg obtained from studies on rhesus monkeys (Bowman and Heironimus 1981) and an uncertainty factor of 100 was applied. Since PCBs often occur as different Aroclor mixtures they can be assessed as such. The US EPA (1996a, b, c; 1997) presents individual TRVs for the four most common Aroclors. The confidence in these values is medium, based on the methods used to obtain them. Health Canada has not published values for the non-cancer oral toxicity of specific Aroclor mixtures, only total PCBs.

b. Cancer Oral Toxicity Reference Value

Health Canada (2010) has not published values for the carcinogenic potential of PCBs from oral ingestion. US EPA has published a discussion on the derivation of slope factors for PCBs (US EPA 1996a, b, c; 1997) but based on Health Canada's position, this was not used in the present risk assessment.

4. Bioavailability

a. Oral Bioavailability

Studies have shown that animal absorbance rates can reach as high as 96 percent (ATSDR 2005), with monkeys absorbing more than 90 percent orally (US EPA 1997). A relative oral bioavailability for PCBs has been assumed as 1.0.

b. Inhalation Bioavailability

A study by Wolff (1985) demonstrated that up to 80 percent of a dose of PCBs can be absorbed into circulation via inhalation. Based on this, an inhalation bioavailability of 1.0 has been conservatively assumed.

c. Dermal Bioavailability

Relative dermal bioavailability for PCBs has been determined to be 0.14 (HC 2010).

5. Conclusion

The following table presents the toxicity reference values used in the human health risk assessment posed by PCBs.

	Route of exposure	**Non-carcinogenic TRV value (Tolerable Daily Intake)** (mg/kg-d)	**Carcinogenic TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
PCBs	Ingestion	0.00013	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Toxicological profile for PCBs, Atlanta, GA. Obtained from: http://www.cdc.gov/search.do?action=search&subset=atsdr&queryText=+PCB+toxicity.

Bowman, R.E. and M.P. Heironimus. 1981. "Hypoactivity in adolescent monkeys perinatally exposed to PCBs and hyperactive as juveniles." *Neurobehav Toxicol Teratol* 3: 15–8.

Health Canada Canadian Cancer Registry (HC CCR). 2004. Substances assessed for carcinogenicity. Ottawa, ON.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

United States Environmental Protection Agency (US EPA). 1996a. Integrated Risk Information System (IRIS): Aroclor 1254 (CASRN 11097-69-1).

United States Environmental Protection Agency (US EPA). 1996b. Integrated Risk Information System (IRIS): Aroclor 1016 (CASRN 12674-11-2).

United States Environmental Protection Agency (US EPA). 1996c. Integrated Risk Information System (IRIS): Aroclor 1248 (CASRN 12672-29-6).

United States Environmental Protection Agency (US EPA). 1997. Integrated Risk Information System (IRIS): Polychlorinated biphenyls (PCBs) (CASRN 1336-36-3).

Wolff, M.S. 1985. "Occupational exposure to polychlorinated biphenyls (PCBs)." *Environmental Health Perspectives* 60: 133–138.

J. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous chemicals across Canada, because of their many sources into the environment (CCME 2008). PAHs enter the environment from a variety of sources including the burning of petroleum or coal derived products and vehicle combustion. Of the PAHs, benzo(a)pyrene (B[a]P) is the most ubiquitous and potent (CCME 1997). The Canadian Council of Ministers of the Environment (CCME) has considered the potency of other PAHs in relation to B[a]P because there are no existing data on the carcinogenicity of individual PAHs other than B[a]P. The potency of other PAHs can be related to B[a]P by use of a potency equivalence factor (PEF). The TRVs used in the risk assessment were those referenced for B[a]P. The risk from other PAHs were calculated using their PEF and compared to the B[a]P TRVs.

1. Assessment of Carcinogenicity

B[a]P has been classed as a human carcinogen (IARC 2010) and has carcinogenicity assessments from US EPA (IRIS) (US EPA 1994) and Health Canada (2010).

2. Susceptible Populations

A number of sub-populations have been described in ATSDR (2007) who may have increased sensitivity to toxicity from exposure to PAHs. These people may include those who: have aryl hydrocarbon hydroxylase (AHH, a carcinogen-metabolizing enzyme); are nutritionally deficient; are predisposed to genetic diseases that influence the efficiency of DNA repair; are immunodeficient as a result of age or disease; are smokers; have a history of excessive sun exposure; and who have liver or skin disease. Women of childbearing age and fetuses may also be susceptible to the toxic effects resulting from exposure to PAHs. Also, individuals who rapidly reduce body fat may be at risk from increased toxicity because of the systemic release and activation of PAHs that had been stored in fat (ATSDR 2007).

3. Selection of Toxicity Values

a. Non-cancer Oral Toxicity Reference Value

The toxicity of B[a]P for non-carcinogenic endpoints has not been considered at this time. Three other PAHs are considered to pose non-cancer risks: naphthalene, 2-methylnaphthalene and pyrene (HC 2010). Their toxicological reference values are: naphthalene 0.03 mg/kg-d, 2-methylnaphthalene 0.004 mg/kg-d, and pyrene 0.03 mg/kg-d. For naphthalene, the TRV is based on a rat study NOEAL adjusted for continuous exposure (71-100 mg/kg-d), and then with an uncertainty factor of 3000 for intra and interspecies variability, less than chronic, and database deficiencies including lack of chronic oral exposure and reproductive toxicity studies. For 2-methylnaphthalene, the TRV is based on a mouse study $BMDL_{05}$ and an uncertainty factor of 1000 for intra and interspecies variability, and database deficiencies. For pyrene, the value was derived from a mouse study where NOEAL was adjusted with an uncertainty factor of 3000 for intra and interspecies variability, less than chronic, lack of toxicity studies in a second species and developmental/reproductive studies (HC 2010).

b. Cancer Oral Toxicity Reference Value

The cancer slope factor of 2.3 $(mg/kg\text{-}d)^{-1}$ for B[a]P was obtained from Health Canada (2010).

c. Non-cancer Inhalation Toxicity Reference Value

The toxicity of B[a]P for non-carcinogenic endpoints has not been considered at this time.

d. Cancer Inhalation Toxicity Reference Value

The cancer slope factor of 0.13 $(mg/kg\text{-}d)^{-1}$ for B[a]P was obtained from Health Canada (2010). This value was based on the tolerable concentration of $1.6 mg/m^3$ from Health Canada (1996).

e. Cancer Dermal Toxicity Reference Value

A cancer slope factor of 3.5 $(\mu g/cm^2\text{-}d)^{-1}$ for B[a]P has been derived by Health Canada (HC 2010).

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for B[a]P has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for B[a]P has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for B[a]P and applicable to all PAHs is 0.148 (HC 2010).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by PAHs. PAHs with B[a]P potency equivalence factors are selected according to the data available and therefore the following is an incomplete list with respect to PAHs for which potency equivalence factors are available. The complete list can be found in Health Canada (2010).

	EF	Non-carcinogenic TRV value (Tolerable Daily Intake) (mg/kg-d)	Carcinogenic TRV value (Cancer Slope Factor) Oral $(mg/kg\text{-}d)^{-1}$	TRV value (Cancer Slope Factor) Dermal $(\mu g/cm^2\text{-}d)^{-1}$	TRV value (Cancer Slope Factor) Inhalation $(mg/kg\text{-}d)^{-1}$
Naphthalene	n/a	0.02			
2-Methylnaphthalene	n/a	0.004			
Pyrene	n/a	0.03			
Benzo[a]pyrene	1		2.3	3.5	0.13
Benzo[a]anthracene	0.1		0.23	0.35	0.013
Benzo[b]fluoranthene	0.1		0.23	0.35	0.013
Benzo[g,h,i]perylene	0.01		0.023	0.035	0.0013
Benzo[k]fluoranthene	0.1		0.23	0.35	0.013
Chrysene	0.01		0.023	0.035	0.0013
Dibenzo[a,h]anthracene	1		2.3	3.5	0.13
Fluoranthene	0.001		0.0023	0.0035	0.00013
Indeno[1,2,3-cd]pyrene	0.1		0.23	0.35	0.013
Phenanthrene	0.001		0.0023	0.0035	0.00013

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2007. Toxicological Profile for Benzo(a)pyrene.

Canadian Council of Ministers of the Environment (CCME). 1997. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Benzo(a)pyrene. Winnipeg, MB, Canada.

Canadian Council of Ministers of the Environment (CCME). 2008. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: PAH 2008. Canadian Council of Ministers of the Environment, Winnipeg, MB, Canada.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

International Agency for Research on Cancer (IARC). 2010. Volume 92: Some Non-heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposures.

United States Environmental Protection Agency (US EPA). 1994. Integrated Risk Information System (IRIS): Benzo(a)pyrene. CASRN 50-32–8.

K. Zinc

Zinc (Zn) is considered an essential element in the human body and has an acceptable dietary intake of 3.3-3.8 mg of Zn/day (ATSDR 2005). Zinc is released into the environment primarily through anthropogenic activities (ATSDR 2005) such as mining and the manufacturing of galvanized products, plumbing components and tires or other rubber products (CCME 1999).

1. Assessment of Carcinogenicity

There is no evidence to indicate that zinc could potentially be a human carcinogen, and as such it is not rated as carcinogenic to humans. Health Canada does not classify zinc as being carcinogenic to humans (HC 2010).

2. Susceptible Populations

A current review did not locate any studies indicating that certain populations were more sensitive to zinc toxicity. However, some studies indicate that people who are malnourished may be more susceptible to the effects of zinc over properly nourished individuals (ATSDR 2005). In addition, increased uptake of zinc has been reported in individuals suffering from hemochromatosis (a genetic disease resulting in increased iron absorption) and in healthy elderly individuals (ATSDR 2005).

3. Selection of Toxicity Values

a. <u>Non-cancer Oral Toxicity Reference Value</u>

The non-cancer oral toxicity reference values of 0.48 mg/kg-d for toddlers and children, 0.54 for teens, and 0.57 mg/kg-d for adults were obtained from Health Canada (2010).

b. Cancer Oral Toxicity Reference Value

Zinc is not considered a human carcinogen; therefore TRVs related to cancer effects are not available.

4. Bioavailability

a. Oral Bioavailability

The relative oral absorption factor for zinc has been conservatively assumed to be 1.0.

b. Inhalation Bioavailability

The relative inhalation absorption factor for zinc has been conservatively assumed to be 1.0.

c. Dermal Bioavailability

The relative dermal absorption factor for zinc has been determined to be 0.1 (HC, 2010).

5. Conclusion

The following table summarizes the toxicity reference values used in the assessment of human health risk posed by zinc.

	Route of Exposure	**Non-carcinogenic** **TRV value (Tolerable Daily Intake)** (mg/kg-d)	**Carcinogenic** **TRV value (Cancer Slope Factor)** $(mg/kg\text{-}d)^{-1}$
Zn	Ingestion	0.48 (Toddler & Child) 0.54 (Teen) 0.57 (Adult)	n/a

6. References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Zinc.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Zinc. Winnipeg, MB, Canada.

Health Canada (HC). 2010. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs). Environmental Health Assessment Services Safe Environments Programme. Version 2.0.

APPENDIX K: BIOACCESSIBILITY OF CR IN KINGSTON INNER HARBOUR SEDIMENTS

TABLE OF CONTENTS

LIST OF TABLES

A. Methods

All sediment samples were freeze-dried and gently ground, but not sieved, prior to extraction. Grinding was carried out to ensure a homogenous sample but no efforts were made to reduce the particle size. This procedure was carried out to obtain a sample that was representative (aside from the lack of water) of a sediment sample to which a mallard duck would be exposed.

Two methods were used for the bioaccessibility extraction: the **Furman method**, based on a comparison with in vivo results (Mallard duck feeding experiment), reported by Furman et al. (2006), and the **ESG method**, based on estimates of actual mallard duck sediment ingestion rates. The Furman et al. (2006) conditions were based on the best match of the liquid-to-solid ratio of the bioaccessibility experiment to the actual dosing rate in the in vivo experiment, which was very high at 12% soil in diet. This high ratio of soil was hypothesized to not be representative of ducks living in the wild and thus a higher ratio was used for the second method. The reasoning for the chosen ratio in the ESG method is described in the following paragraph.

The liquid-to-solid ratio can be calculated in two ways: (1) using the ingestion rate of sediment per day and the gastric secretion rate per day; and (2) using the ingestion rate of sediment per day and the gizzard/stomach volume combined with the estimated clearance time of sediment (and food) from the mallard duck's gastrointestinal system. In both cases the sediment ingestion rate is used, which is based on a food ingestion rate of 0.056 kg/day dry weight. A soil ingestion rate per day of 3.3% of diet (dry weight) was used (Beyer et al. 1994)[1] (note this is lower than the 12% used by Furman et al 2006 in the mallard duck feeding study). Using 3.3% of a dietary intake of 0.056 kg dry weight/day gives 0.0018 kg dry weight sediment/day, equivalent to approximately 1.8 g /day.

(1) For the first method, the gastric secretion rate could not be found for mallard ducks and thus the gastric secretion rate of 15.4 mL/hr for chickens was used (Martinez-Haro et al. 2009); over 24 hours this gives 370 mL per day. The liquid-to-solid ratio from these calculations is thus 370:1.8 = 205:1.

[1] The study described in this appendix was completed before the publication of FSCAP guidance that lists default receptor characteristics (Azimuth 2012). For mallard duck, the default characteristics are an ingestion rate of 0.06 kg/day dry weight, and a soil ingestion rate of 2-3.3% of dry diet; these are close to the values used here.

(2) For the second method, the gizzard volume of the mallard duck was again not directly available, but the volume of the brown duck is estimated to be about 30 mL (Moore and Battley 2006). A brown duck's total body mass ranges from 375-700 g which is about half the range for the mallard, which is 850-1500 g, which may suggest that a mallard duck's gizzard volume is around 60 mL. A 50 mL estimate has been used previously (Levengood and Skowron 2001). Martinez-Haro et al. (2009) state a mallard duck's total retention time of food is 6-7 hours, and they use a 3 hr extraction to simulate the gizzard and intestinal digestion time, which is consistent with Furman et al. (2006), who also uses a total extraction time of 3 hrs. Thus, for a 3 hour extraction time, and assuming the duck eats throughout the day (meaning the sediment is ingested and spread out throughout the day), the amount of sediment calculated in 3 hrs is 1.8 x 3/24 = 0.225 g dry weight. With a 50-60 mL estimated gizzard volume (assuming the sediment stays in the gizzard for 3 hrs, which given the dynamic conditions of an actual gastrointestinal system is not strictly accurate) a liquid-to-solid ratio of 50-60 mL: 0.225g = 222-267:1 is calculated.

Considering the ratios together and that lower ratios are more favourable for obtaining meaningful detection limits, a ratio of 200:1 was selected as being representative of actual exposure conditions.

Therefore the two methods differed only in their liquid-to-solid ratios. The Furman method used a ratio of 100 mL : 2.4 g = extraction fluid : dry soil mass (this was equivalent to the 8.3 : 1 = liquid: wet sediment ratio used in Furman et al 2006, assuming sediment moisture content to be approximately 80% water, or a wet:dry ratio of 5). The ESG method used a ratio of 200:1 = liquid: dry sediment. Both methods included two phases (stomach and intestine, or gastric and gastric + intestinal). The masses of dry sediment were first weighed as 2.4 g (Furman method) and 1 g (ESG method) into Teflon® extraction vessels and then the gastric (stomach) conditions were simulated by extracting the sediments at avian body temperature (42^{o}C) with 100 ml (Furman method) or 200 ml (ESG method) of simulated gastric solution (1 M NaCl, 10 g/L pepsin) at pH 2.6 for 1 hour. After 1 hour, a 10 mL portion was removed for analysis. To simulate gastric + intestinal conditions the above samples were adjusted to pH 6.2 with saturated $NaHCO_3$, and bile (0.35%) and pancreatin (0.035%) were added. The extraction continued at these conditions for 2 hours. The filtered (0.45 µm) resulting extracts were analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) for As, Cr, and Pb.

Total Cr, As and Pb concentrations in each of the sediments (14 were available for testing) were determined after aqua regia digestion by ICP-AES analysis.

To calculate % bioaccessibility, the following equation was used for each element:

$$\% \text{ Bioaccessibility} = \frac{\text{Bioaccessible concentration (mg/kg)}}{\text{Total concentration (mg/kg)}} \times 100\%$$

B. Quality Assurance/Quality Control (QA/QC) of Bioaccessibility Measurements

The quality control (QC) tests included in the extraction and analysis steps for 14 sediments were 2 duplicates, 2 blanks, 2 spiked blanks, and 2 control samples for each phase and method, representing a frequency of 14% for each QC test.

Blank results were less than detection limits (<2.1 mg/kg for Cr, <0.45 mg/kg for As and Pb for the Furman method, and <10 mg/kg for Cr, <0.5 mg/kg for As, and <1 mg/kg for Pb for the ESG method). Duplicates had acceptable relative percent differences (%RPDs) (%RPD = absolute difference/average of 2 values x 100%) of less than 33%, except for one As duplicate in the gastric phase with a % RPD of 47%. The value was within 3x the detection limit; the nearness to the detection limit was likely the cause of the poor reproducibility.

Control samples were assessed with respect to their agreement with a range established by carrying out the extraction many times over many days with different analysts. The avian bioaccessibility method is not carried out frequently in the ESG laboratory and thus control limits have not been established for this method. To monitor control of the bioaccessibility extraction, control samples were therefore extracted using conditions more typically used in the laboratory and for which control limits have been established. CRM025-050 was used to assess the control of all three elements, and it was extracted at conditions normally used in our laboratory, using the physiologically based extraction test (PBET). All results were within the expected control ranges. NIST 2710 was also included because limited information is available about its extraction in a method similar to the avian method, the in-vitro gastrointestinal (IVG) test (Basta et al. 2007). Control limits for arsenic were established from limited results of previous experiments (unpublished) in our laboratory as well as results from two other laboratories (Ohio State University, Koch et al. 2013, and Pouchat and Zagury 2006). However, NIST 2710 was tested in the present work using a liquid-to-solid ratio of 100:1 (deviating from the IVG ratio of 150:1) and using the avian method fluids (which differed in pH and concentration of NaCl); therefore a direct comparison was difficult to make. Arsenic P2 (gastric + intestinal) values were within the calculated IVG control range of 19-42% bioaccessibility, but higher than the range for P1 (gastric only) values. The higher salt concentrations in the avian methods (1 M) compared with the IVG method (0.1 M) may have caused these differences, since the chloride in salt can interfere with As analysis.

Spiked blanks were constructed with lead acetate Pb $(C_2H_3O_2)_2 \cdot 3H_2O$, sodium arsenate $Na_2HAsO_4 \cdot 7H_2O$ and soluble Cr(III) (made from chromium nitrate $Cr(NO_3)_3$). These materials were selected to represent soluble compounds that for Pb and As are most commonly used in animal studies testing the bioavailability of soil; for Cr the compound represents the oxidation state of the compounds used in toxicity studies used to derive the applicable US-EPA wildlife TRV, as well as the oxidation state present in KIH sediments (Koch et al. 2012, Burbridge et al. 2012). The average % recoveries are summarized in the table below; the data were combined in this way because no differences were apparent with the different L:S. The high As spike recovery in the gastric phase confirms that a high bias might be present in the gastric As results, as suggested by the control SRM 2710 results.

Table K-1: Average ± standard deviation (n=2) percent spiked blank recovery results for the two avian bioaccessibility methods

Phase	Cr (%)	As (%)	Pb (%)
Gastric	104 ± 2	114 ± 3	96 ± 2
Gastric+intestinal	60 ± 11	102 ± 5	20 ± 2

C. Results

The results were corrected for spike recovery to account for methodological parameters that might have affected the solubility of the elements during the bioaccessibility test. This was carried out to ensure comparability between the bioaccessibility results (corrected results are referred to as "relative bioaccessibility") and the conditions used to establish a toxicological reference value, where soluble forms of contaminants were used. The following equations were used:

$$\text{Relative bioaccessible concentration (mg/kg)} = \frac{\text{measured bioaccessible concentration (mg/kg)}}{\text{\% spike recovery}/100}$$

$$\text{Relative \% bioaccessibility} = \frac{\text{measured \% bioaccessibility}}{\text{\% spike recovery}/100}$$

The results thus corrected, that is, the relative bioaccessibility results, obtained with the Furman method and the ESG method are shown in Table K-2 and K-3. In both cases gastric (phase 1) results are shown, since these are the highest results, and because the gastric phase was considered to be the best estimate of in vivo results for lead, using the Furman method in Furman et al (2006). For As, phase 2 (gastric + intestinal) results were occasionally higher using the ESG method, but the differences were within the %RPD seen for replicated (duplicate) extractions and analysis, and they were therefore not considered to be significant.

For all elements, the ESG method gave higher results than the Furman method. The higher results are attributable to the higher liquid-to-solid ratio used in the ESG method, since no other variables differed between the two methods; these findings are consistent with those seen for Pb by Furman et al (2006) during method development of the Furman method. These differences tend to be significant when the range of ratios includes those less than 100:1 such as 25:1 (Ruby et al. 1996; Smith et al. 2010), but they were less significant when higher ratios were tested (100:1 to 5000:1) for lead, nickel, arsenic, chromium and cadmium (Hamel et al. 1998; Meunier et al. 2010; Drexler and Brattin 2007).

For human modeling of bioavailability using a bioaccessibility test, a correlation equation between in vitro and in vivo results has been derived for one method (Drexler and Brattin), and this has been recommended for use in risk assessments (i.e. calculating bioavailability results from measured bioaccessibility results, using the correlation equation) (US EPA 2007). However, no such relationship was recommended for Pb by Furman et al (2006) and in any case the relationship was reliable only on a log scale. Therefore, the Furman method results cannot be used to predict relative bioavailability results, and the most conservative estimates of bioaccessibility at the current time, in the absence of any other information, are those obtained using the ESG method.

Table K-2: Relative bioaccessibility results from the Furman method (L:S = 41.7:1), gastric phase (P1) (corrected for spike recovery). BA conc = (relative) bioaccessible concentration, equal to the (relative) bioaccessible amount in the extract expressed as a soil concentration (mg/kg); Soil conc = total concentration in soil (mg/kg) determined by aqua regia ICP-AES; % BA = percent relative bioaccessibility (see text for more details).

SAMPLE ID	Cr	Cr	Cr	As	As	As	Pb	Pb	Pb
	BA conc (mg/kg)	Soil conc (mg/kg)	%BA	BA conc (mg/kg)	Soil conc (mg/kg)	%BA	BA conc (mg/kg)	Soil conc (mg/kg)	%BA
08-29892	10	930	1.1	0.83	3.8	22	36	71	51
08-29893	6.0	880	0.68	0.69	4.8	14	29	105	28
09-29895	6.0	660	0.91	0.76	3.9	19	29	68	43
08-29898	22	1100	2.03	0.88	5.5	16	95	135	70
08-42012	13	1400	0.90	0.69	4.3	16	48	119	40
08-42016	10	630	1.6	<0.45	3.6	<13	29	52	57
08-29891	9.2	1100	0.83	0.97	4.3	22	42	98	43
08-42041	5.5	650	0.85	2.9	17	17	50	115	44
08-42051	11	1400	0.82	0.79	7.4	11	72	152	47
09-42119	<2.1	180	<1.2	<0.45	2.9	<16	52	72	73
08-42140	4.5	740	0.61	0.70	4.4	16	21	80	27
08-42146	6.6	790	0.84	0.60	5.0	12	32	71	45
08-42147	3.6	960	0.37	0.75	6.9	11	9.2	110	8.4
08-42024	9.6	960	0.92	0.84	6.6	13	42	103	41

Table K-3: Results from the ESG method (L:S = 200:1), gastric phase (P1), corrected for spike recovery. BA conc = bioaccessible concentration, equal to the bioaccessible amount in the extract expressed as a soil concentration (mg/kg); Soil conc = total concentration in soil (mg/kg) determined by aqua regia ICP-AES; % BA = percent bioaccessibility (see text for more details).

SAMPLE ID	Cr	Cr	Cr	As	As	As	Pb	Pb	Pb
	BA conc (mg/kg)	Soil conc (mg/kg)	%BA	BA conc (mg/kg)	Soil conc (mg/kg)	%BA	BA conc (mg/kg)	Soil conc (mg/kg)	%BA
08-29892	29	930	3.1	1.1	3.8	29	62	71	87
08-29893	27	880	3.1	1.1	4.8	23	89	105	85
09-29895	23	660	3.5	1.0	3.9	26	67	68	99
08-29898	35	1100	3.1	2.0	5.5	36	124	135	92
08-42012	39	1400	2.8	0.70	4.3	16	93	119	78
08-42016	21	630	3.4	0.56	3.6	16	41	52	79
08-29891	28	1100	2.7	1.2	4.3	28	93	98	95
08-42041	20	650	3.1	5.4	17	31	104	115	90
08-42051	33	1400	2.4	1.5	7.4	20	135	152	89
09-42119	<10	180	<5.6	0.49	2.9	17	60	72	84
08-42140	21	740	2.8	1.5	4.4	34	74	80	93
08-42146	22	790	2.7	0.85	5.0	17	62	71	87
08-42147	22	960	2.3	1.5	6.9	22	87	110	79
08-42024	26	960	2.7	1.7	6.6	25	82	103	80

The statistics for the bioaccessibility results are summarized in Table K-4.

Table K-4: Statistics of Cr, As and Pb % bioaccessibility results, using the ESG method, gastric phase. For all three elements, N=14 (one non-detect in Cr was replaced with ½ the detection limit).

Statistic	Cr (%BA)	As (% BA)	Pb (%BA)
Standard deviation	0.34	6.7	6.5
Arithmetic mean	2.90	24.3	86.9
Geometric mean	2.88	23.5	86.7
Median	2.83	24.1	87.3
75th percentile	3.11	28.4	91.8
95th percentile	3.44	34.7	96.1
Maximum	3.51	35.9	98.7

D. References

Azimuth Consulting Group. 2012. Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Prepared for Environment Canada.

Basta, N.T., J.N. Foster, E.A. Dayton, R.R. Rodriguez and S.W. Casteel (Basta et al.). 2007. "The effect of dosing vehicle on arsenic bioaccessibility in smelter-contaminated soils." *Journal of Environmental Science and Health Part A* 42, no. 9 (July 15, 2007): 1275–1281.

Beyer, W.N., E.E. Connor and S. Gerould (Beyer et al.). 1994. "Estimates of soil ingestion by wildlife." *Journal of Wildlife Management* 58: 375–382.

Burbridge, D.J., I. Koch, J. Zhang and K.J. Reimer. (Burbridge et al.) 2012. "Chromium speciation in river sediment pore water contaminated by tannery effluent." *Chemosphere* 89: 838–843.

Drexler, J.W. and W.J. Brattin. 2007. "An *In Vitro* procedure for estimation of lead relative bioavailability: with validation." *Hum. Ecolog. Risk Assess.* 13: 383–401.

Furman, O., D.G. Strawn, G.H. Heinz and B. Williams (Furman et al.). 2006. "Risk assessment test for lead bioaccessibility to waterfowl in mine-impacted soils." *J. Environ. Qual.* 35: 450–458.

Hamel, S.C., B. Buckley and P.J. Lioy (Hamel et al.). 1998. "Oral bioavailability of lead and arsenic from a NIST standard reference soil material." *Environ. Sci. Technol.* 32: 358–362.

Koch, I., K.J. Reimer, M.I. Bakker, N.T. Basta, M.R. Cave, S. Denys, M. Dodd, B.A. Hale, R. Irwin, Y.W. Lowney, M.M. Moore, V. Paquin, P.E. Rasmussen, T. Repaso-Subang, G.L. Stephenson, S.D. Siciliano, J. Wragg and G.J. Zagury, G.J. (Koch et al.) 2013. "Variability of bioaccessibility results using seventeen different methods on a standard reference material, NIST 2710." *Journal of Environmental Science and Health, Part A* 48, no. 6: 641–655.

Koch, I., M. Moriarty, J. Sui, B. Gibson and K.J. Reimer (Koch et al.). 2012. "Insolubility of Cr2O3 in bioaccessibility tests points to requirement for a new human oral reference dose for trivalent chromium." *Human and Ecological Risk Assessment* 18: 1292–1306.

Levengood, J.M. and L. Skowron. 2001. A. "Use of a simulated gizzard to measure bioavailability of metals and other elements to waterfowl." *Ecotoxicology* 10 (2001): 299–304.

Martinez-Haro, M.A., M.A. Taggart, Y.J. Green and R. Mateo (Martinez-Haro et al.). 2009. "Avian digestive tract simulation to study the effect of grit geochemistry and food on Pb shot bioaccessibility." *Environ. Sci. Technol.* 43 : 9480–9486.

Meunier, L., J. Wragg, I. Koch and K.J. Reimer (Meunier et al.). 2010. "Method variables affecting the bioaccessibility of arsenic in soil." *Journal of Environmental Science and Health, Part A* 45: 517–526.

Moore, S.J. and P.F. Battley. 2006. "Differences in the digestive organ morphology of captive and wild Brown Teal *Anas chlorotis* and implications for releases." *Bird Conservation International* 16: 253–264.

Pouschat, P. and G.J. Zagury. 2006. "*In vitro* gastrointestinal bioavailability of arsenic in soils collected near cca-treated utility poles." *Environ. Sci. Technol.* 40 (2006): 4317–4323.

Ruby, M.V., A. Davis, R. Schoof, S. Eberle and C.M. Sellstone (Ruby et al.). 1996. "Estimation of lead and arsenic bioavailability using a physiologically based extraction test." *Environmental Science and Technology* 30, 422–430.

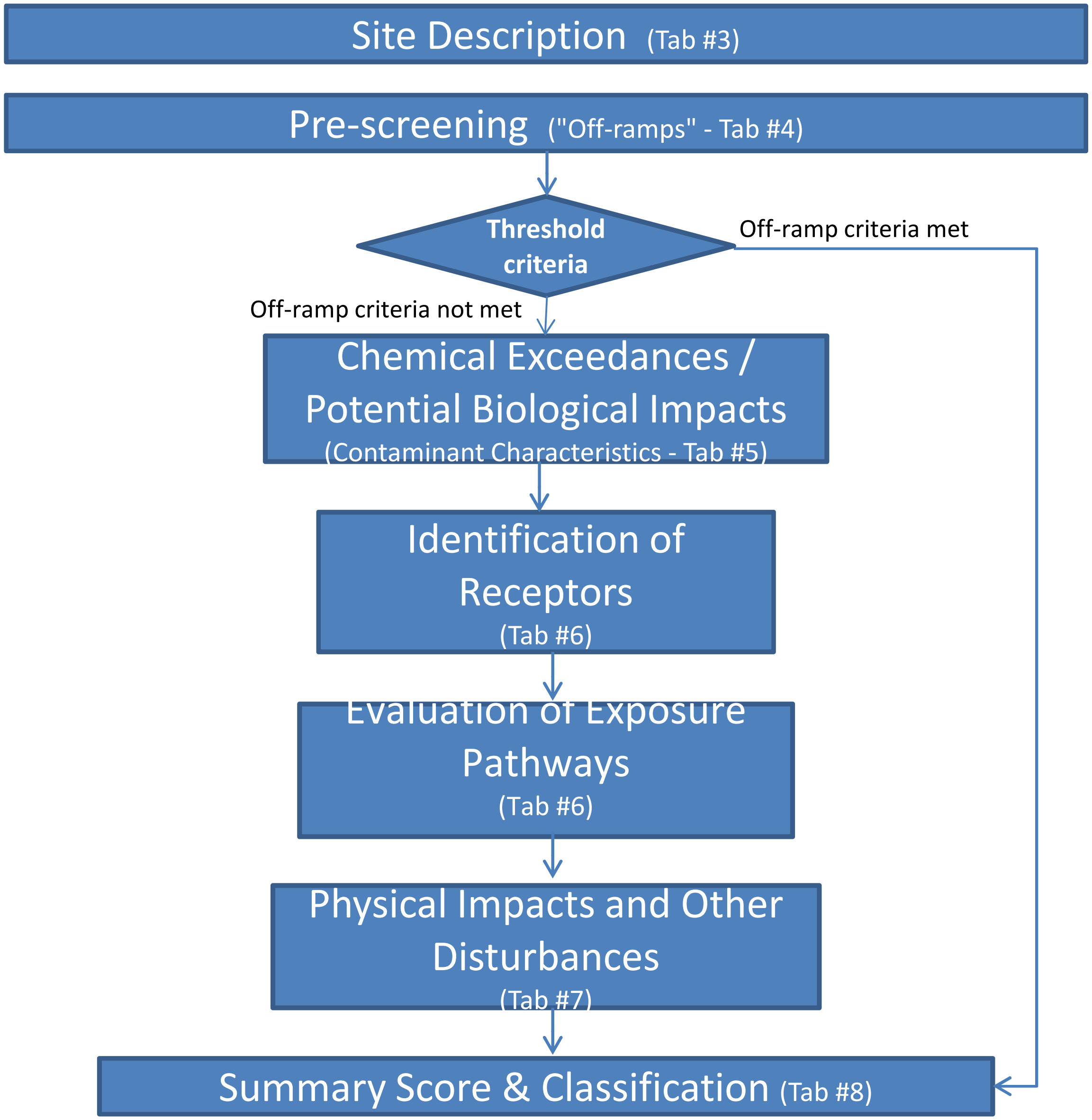
Smith, B.A., J.L. Kirk and G.L. Stephenson (Smith et al.). 2010. "The influence of liquid to soil ratios on arsenic and lead bioaccessibility in reference and field soil." *Hum. Ecolog. Risk Assess.* 16 (2010): 149–162.

United States Environmental Protection Agency (US EPA). 2007. Estimation of relative bioavailability of lead in soil and soil-like materials using *in vivo* and *in vitro* methods. Office of Solid Waste and Emergency Response. OSWER 9285.7-77.

APPENDIX L: AQUATIC SITES CLASSIFICATION FOR KIH (CHAPTER V)

FCSAP Aquatic Sites Classification System (2009)

Flowchart of Aquatic Sites Classification System



FCSAP Aquatic Sites Classification System (2009)

User's Guide - Instructions

1) Introduction: In Canada, there are thousands of contaminated sites on federal lands, or for which the federal government has accepted responsibility, that require attention. To coordinate the management of these sites among the custodial federal departments in an efficient and consistent manner, the Contaminated Sites Management Working Group (CSMWG) was established in 1995.

Under the guidance of this working group, the Federal Contaminated Sites Action Plan (FCSAP) was developed with the goal of assessing and remediating or risk managing the highest-risk federal contaminated sites within 15 years to reduce federal financial liability related to contaminated sites.

The CSMWG established a common approach to the management of contaminated sites under federal custody. In the ten-step federal approach to contaminated sites (CSMWG, 2005), classification of a site is required at Step 4 in order to prioritize the site for future investigations and/or remediation/risk management actions. Re-classification is also required at Step 6 to update the ranking based on results of detailed investigations. For terrestrial sites, classification is performed using the Canadian Council of Ministers of the Environment (CCME) revised National Classification System for Contaminated Sites (NCSCS) (2008 Version).

The NCSCS is geared towards terrestrial sites, and is not readily applicable to sites that are predominantly aquatic. The Aquatic Sites Classification System (ASCS, 2009), presented in these worksheets, was designed to be similar to the NCSCS, but specifically for aquatic sites, to aid in classifying and prioritizing these sites for FCSAP funding. The ASCS, therefore, is to be used for aquatic sites, as they are defined in item 2) below. Terrestrial sites should be classified using the NCSCS.

Users are advised that the ASCS is a tool for site classification, and not for risk assessment or risk management. The ASCS is to be used, along with other information on the site, to inform the prioritisation of the site for FCSAP funding for remediation and/or risk management. Industrial aquatic sites such as harbours can be expected to receive high scores, indicating that further action is required (see item 8, "Site Classification Categories", below). Site- or province-specific information will be considered in any subsequent decision regarding the nature of the required action.

2) Definition of an Aquatic Site: For the purposes of the Aquatic Sites Classification System, an aquatic site is defined as a water lot, or land or part of land that is completely, partially or occasionally submerged by water. This includes the hyporheic zone (where shallow groundwater and surface water mix), but excludes deep-seated groundwater, and applies to both freshwater and marine sites. Exceptions to the above definition may be established, on a case by case basis, using professional judgment.

The ASCS was designed to address aquatic sites. Terrestrial portions of primarily aquatic sites should be scored and classified using the NCSCS (2008).

3) Overview of Contents: The Aquatic Sites Classification System includes a pre-screening checklist, a site description page, a summary score sheet, and three worksheet pages for the user to complete: "Contaminant Characteristics", "Receptors and Exposure" and "Physical and Other Disturbances". Instructions regarding methods to be used in evaluating site characteristics are included on each worksheet. Reference material is also provided to assist with the evaluation. A brief description of each sheet follows.

Tab 3. Site Description - Summarizes basic information about the site and relevant environmental conditions including known and potential contaminants of concern and affected media. Assesses the level of information available to the scorer to support the classification system evaluation and assigns a site letter grade, as outlined in item 7 below.

Tab 4. Pre-Screening Checklist - Used to determine whether or not the site can be automatically designated a Class 1 site (High Priority for Action -- see item 8 below), whether more information must be collected before the site can be scored, or whether other hazards exist at the site that must be addressed before it can be scored using the ASCS.

Tab 5. Contaminant Characteristics Worksheet - Identifies contaminants of concern and assesses associated hazards and scale of chemical impact. The worksheet contains instructions and explanations to assist users in evaluating chemical impacts.

Tab 6. Receptors and Exposure Worksheet - Identifies both human and ecological receptors that are known or likely to be present at the site on a permanent or temporary basis. Evaluates potential exposure pathways by which receptors may come into contact with identified contaminants. Instructions, explanations and references are included to guide scorers in characterizing receptors at the aquatic site and scoring potential exposure pathways.

Tab 7. Physical Impacts and Other Disturbances Worksheet - Identifies non-chemical environmental impacts at the aquatic site and assesses the scale of their impact.

Tab 8. Summary Score Worksheet - Generates a total site score by summarizing scores generated on each of the three preceding worksheets and assigns the resulting site classification.

Tab 9. Reference Material - Additional information which may be useful to refer to when conducting the evaluation.

4) Format of the classification system scoring tool This is an electronic form which will prompt the user for information. Based on the answers provided in Worksheet 5 (Contaminant Characteristics), 6 (Receptors and Exposure) and 7 (Physical and Other Impacts), a score will be calculated for the contaminated site in question. Orange boxes require input from the user, either as text or a selection from a drop-down menu. Click on each orange box. If an arrow appears to the right of the box, select an option from the drop-down menu. If no arrow appears, manually enter the required data. Scores are calculated automatically in the pink score boxes.

5) Rationale/Justification for Scores When assigning scores for each factor, **it is mandatory to give a rationale for your choice**. Columns have been provided for this purpose in the scoring worksheets. Information to help justify assigned scores could include: a statement of assumptions, a description of site-specific information, or references to data sources (e.g., site visit, personal interview, site assessment reports, or other documents consulted).

FCSAP Aquatic Sites Classification System (2009)

User's Guide - Instructions

6) Level of Effort and Documentation Necessary to Complete Scoring Completion of ASCS scoring for an aquatic site should take approximately 1/2 day of work for an experienced professional familiar with the site. Depending on the experience of the user and their familiarity with the site, more time may be required to complete the scoring. **To facilitate scoring, the scorer should obtain copies of all environmental site assessment reports and/or risk assessments previously compiled for the site, and if possible, spreadsheets containing all chemical data from previous investigations should also be obtained prior to scoring.**

7) Completeness of Available Information (Site Letter Grade) A letter grade is assigned by the user according to the level of available information about the site. The purpose of the letter grade is to indicate the completeness of information, depending on the level of investigative and remedial work that has been carried out at the site. More detailed descriptions of the letter grades are provided below.

Site Letter Grade:	*Detailed Description:*
F	***Pre-Phase I ESA –*** No environmental investigations have been conducted or Phase I ESA information is incomplete. It is not recommended to continue through the classification system when insufficient data are available. In this instance, it will generally be necessary to conduct a Phase I ESA or other site investigation study before scoring the site, using the ASCS.
E	***Phase I ESA –*** A preliminary desk-top study has been conducted, involving non-intrusive data collection to determine the potential for the site to be contaminated and to inform any subsequent intrusive investigations. Data collection may include: a review of available information on current site conditions and the history of the property, a site inspection, and/or interviews with personnel familiar with the site. [Note: This stage is the "Phase I: Site Information Assessment" as described in the document entitled "Guidance Document on the Management of Contaminated Sites in Canada" (CCME 1997), available at www.ccme.ca/publications/list_publications.html#link4.]
D	***Phase II ESA –*** An initial intrusive investigation and assessment of the site has been conducted. Phase II ESAs generally focus on potential sources of contamination to determine whether contaminants exceed relevant screening guidelines or criteria, and to broadly define sediment and surface water conditions. At this stage, samples have been collected and analyzed to identify, characterize and quantify contamination in surface water, sediments, biological tissues or other materials on the site. [Note: "Phase II: Reconnaissance Testing Program" is described in the Guidance Document on the Management of Contaminated Sites in Canada (CCME 1997), available at www.ccme.ca/publications/list_publications.html#link4.]
C	***Phase III ESA –*** Further intrusive investigations have been conducted to characterize and delineate contamination, to obtain detailed information on sediment and surface water conditions, to identify contaminant pathways, and to acquire other information to support the development of a remediation plan. [Note: This stage the "Phase III: Detailed Testing Program" as described in Guidance Document on the Management of Contaminated Sites in Canada (CCME 1997), available at www.ccme.ca/publications/list_publications.html#link4.]
B	***Risk Assessment with or without Remedial Plan or Risk Management Strategy –*** A risk assessment has been completed, and if the risk was found to be unacceptable, a site-specific remedial action plan has been designed to mitigate environmental and health concerns associated with the site, or a risk management strategy has been developed.
A	***Confirmation Sampling –*** Remedial work, monitoring, and/or compliance testing have been conducted and confirmatory sampling has been carried out to demonstrate whether contamination was removed or stabilized and whether clean-up or risk management objectives were met.

8) Site Classification Categories Sites should not be ranked relative to one another; they must be assessed on the basis of their individual characteristics to determine the appropriate classification (Class 1, 2, 3, or N) with respect to their priority for action. Class INS (Insufficient Information) is reserved for sites that require further information before they can be classifed. The classification groupings are as follows:

Class 1 - High Priority for Action (Total ASCS score greater than 70)

The available information indicates that action (e.g., further site characterization, risk management, remediation, etc.) is required to address existing concerns. Typically, Class 1 sites indicate high concern for several factors, and measured or observed impacts have been documented.

Class 2 - Medium Priority for Action (Total ASCS score between 50 and 69.9)

The available information indicates that there is high potential for adverse impacts, although the threat to human health and the environment is generally not imminent. Off-site contamination may not have been detected, however, the potential for this was rated high and therefore some action is likely required.

Class 3 - Low Priority for Action (Total ASCS score between 37 and 49.9)

The available information indicates that this site is currently not a high concern. However, additional investigative work may be carried out to confirm the site classification, and some form of action may be required.

Class N - Not a Priority for Action (Total ASCS score less than 37)

The available information indicates there is probably no significant environmental impact or human health threats. There is likely no need for action unless new information becomes available indicating greater concerns, in which case the site should be re-examined.

Class INS - Insufficient Information (>30% of Responses in worksheets 5, 6 and 7 are "Do Not Know")

There is insufficient information to classify the site. In this instance, additional information is required to address data gaps.

FINAL

FCSAP Aquatic Sites Classification System (2009)

Summary of Site Conditions

Test Site and Location:	**Kingston Inner Harbour**	**Kingston, Ontario**
Site Letter Grade:	**B**	**Complete this page and continue to 4. Pre-screening**

Component	Site Description
Civic Address: *(or other description of location)*	Kingston Inner Harbour
Site Common Name (as listed on IDEA): *(if applicable)*	Kingston Inner Harbour (KIH)
Site Owner or Custodian: *(Organization and Contact Person)*	Parks Canada and Transport Canada
Federal Contaminated Site Inventory (FCSI) Number:	23391
Custodian site ID:	9412
Legal description ***or*** **metes and bounds:**	5 km stretch of the Great Cataraqui River extending from Highway 401 to the north and the LaSalle Causeway to the south
Approximate area of site (in hectares - ha):	~ 100 ha
PID(s): *(or Parcel Identification Numbers [PIN] if untitled Crown land)*	Plan 13R -13481 (Parks Canada)
Centre of site:	UTM Coordinates Datum: November 2008 Easting: 381970.95 Northing: 4900509.86 Latitude: ______ degrees ______ minutes ______ seconds Longitude:______ degrees ______ minutes ______ seconds
Aquatic Site Use: (e.g. industrial ship yard, commercial harbour with mixed light industrial boat building, etc..)	Current: Recreational Activities
	Past:Recreational Activities; receiving water body for discharge from industrial sources such as tannery and smelter operations and waste disposal areas. Shipbuilding operations and rail yards were located in Anglin Bay in the south portion of the harbour.
	Proposed future Federal use: Recreational Activities
Surrounding Land Use: (category or brief description)	Current: Mostly residential and institutional. Belle Park (designated as Open Space) is located adjacent to the site as well as the former Davis Tannery site (brownfield).
	Past: Industrial, lead smelter, tannery, woolen mill, landfill
	Proposed future Federal use: Residential development
Site Plan	**To delineate the bounds of the site, a site plan MUST be attached. The plan must be drawn to scale indicating the boundaries in relation to well-defined reference points and/or legal descriptions. Water bodies must be shown and named on the site plan. Delineation (area and depth) of contamination should also be indicated on the site plan.** ☑ Site plan attached
Water bodies, water courses on the site (type: lake, river, wetland, bay, pond, etc.): *(list all water bodies on the site; add additional lines if necessary)*	1. Name: Great Cataraqui River — Type: Marsh Depth (m): 1.2 m — Flow rate (m/s): 0.2 — Surface area (m^2): 1600 Volume (m^3): 2400 — Retention time (y): 0.013
	2. Name: — Type: Depth (m): — Flow rate (m/s): — Surface area (m^2): Volume (m^3): — Retention time (y):

FINAL

Summary of Site Conditions

Provide a brief description of the site, including water lots, water bodies, streams, wetlands, floodplains :	Historically a variety of industrial and commercial activities along the western shore of the KIH have resulted in contaminated sediments in the portion southwest of Belle Island. A wetland area is located along the west bank of the harbour just south of Belle Island. The impacted area extends along the western shoreline from the LaSalle Causeway north to Belle Island. The major CoPCs are PCBs, Hg, As, Cr and Pb. Descriptive plume maps of the depth and extent of contamination have been developed. The KIH contains > 100,000 m3 of sediments with COPCs above federal guidelines (ESG 2011). However, analytical data exceeding guidelines are not conclusive evidence of ecological degradation and the area requiring remediation will be determined using a risk-based approach. Reference: Environmental Sciences Group (ESG). 2011. Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011.	
Affected environmental media and chemical class of potential contaminants): *(add additional lines if necessary)*	**Medium**	**Potential contaminant classes (e.g. metals, PAHS, PCBs, etc.)**
	Surface Water	
	Sediment	PCBs, Hg, Cr, Pb, As
	Groundwater	
	Biological Tissues	PCBs, MeHg, Cr, Pb, As

Please fill in the letter that best describes the level of information available for the site being assessed *(see Instructions tab for descriptions of each grade)* **:**

F – Pre-Phase I
E – Phase I Environmental Site Assessment
D – Phase II Environmental Site Assessment
C – Phase III ESA
B – Risk Assessment with or without Remedial Plan or Risk Management Strategy
A – Confirmation Sampling

Site Letter Grade **B**

If letter grade is F, do not continue. You must have a minimum of a Phase I Environmental Site Assessment or equivalent.

Scoring Completed By:	**Name:**	**Dr. Astrid Michels and Megan Lord-Hoyle**
	Company/Government Department:	**Environmental Sciences Group (Royal Military College)**
Project Role of Scorer:	Consultant	
Address:	Royal Military College of Canada, PO Box 17000 Stn Forces, Kingston, Ontario K7K 7B4	
Telephone:	613 541-6000	
Fax:	613 541-6596	
E-mail address:	astrid.michels@rmc.ca	
Date Scoring Completed:	June 1, 2010	

FCSAP Aquatic Sites Classification System (2009)

Pre-Screening Checklist

Test Site and Location: **Kingston Inner Harbour, Kingston** **Kingston, Ontario**

The Pre-Screening Checklist is included in the ASCS to allow quick evaluation of some key indicators of Class 1 (Further Action Required) or Class N (Not a Priority for Action) status. If Class 1 status is automatically assigned on the basis of these "off-ramps", a score of 70 is assumed, and is automatically entered on the Summary Score sheet, unless Worksheets 5, 6 and 7 are completed for the site.

Notes: "Do Not Know" options on the pre-screening checklist are included only as an alternative to definitive answers and are not used in the overall calculation of data sufficiency in the summary score worksheet.

	Question	Response (yes / no)	Reference	Rationale	Instructions	Notes
	Automatic Class 1 Designation Criteria					
1.	Is there any evidence that **radioactive material**, **severe bacterial contamination** or **biological hazards** are likely to be present at the site?	No			If radioactive materials, bacterial contaminants or biological hazards are known or strongly suspected to be present at levels that could cause harm to humans or ecological receptors, contact applicable regulatory agency immediately, answer "Yes" to this question, and designate the site as Class 1. If not, answer "No".	Professional judgement should be used to determine whether the severity of the situation merits Class 1 designation. Any such designation must be justified in the "rationale" column, and references provided.
2.	Is there direct and signficant evidence of **impacts to humans** at the site, or off-site due to migration of contaminants from the site?	No		Human health is not known to have been directly impacted by the site. A HHRA shows the potential for risk to recreational users of this site exposed to PCBs and PAHs in sediment.	If any impacts to human health and/or safety are known to have occured at the site as a result of chemical, biological, radiological or physical hazards, answer "Yes" to this question and designate the site as Class 1. If not, answer "No". If insufficient information is available to answer this question, choose the "do not know" option.	If a Class 1 designation is assigned on this basis, rationale and references must be provided.
3.	Is there direct and significant evidence of **impacts to ecological receptors** at the site, or off-site due to migration of contaminants from the site? Examples of impacts to ecological receptors could include: •loss, reduction or impact (chemical or physical) of fish or wildlife populations; •fish tumours or other deformities; •bird or animal deformities or reproduction problems; •degradation and/or deformation of benthos; •eutrophication or undesirable algae; •degradation of phytoplankton and zooplankton populations; •loss of fish and/or wildlife habitat.	Yes Select option A on Tab #6 Receptors & Exposure Question 4a	ESG (2010). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment. Fish deformities in Brown Bullhead	**Fish deformities at impacted sites exceed** rates at unimpacted control sites in brown bullheads. 11 of 14 brown bullheads sampled from the impacted site showed orocutaneous DELTs (deformities, erosions, lesions, tumours) compared with 2 of 19 fish sampled from the upstream reference location. The DELTS observed for the 2 reference site fish were less severe than those for the impacted site. The causes of orocutaneous (skin) deformities for brown bullhead are not well established in the scientific literature, but are generally elevated in contaminated areas (Rafferty et al., 2009). Reference: Rafferty SD, Blazer VS, Pinkney AE, Grazio JL, Obert EC, Boughton L. 2009. A historical perspective on the "fish tumors and other deficiencies" beneficial use impairment at Great Lakes Areas of Concern. J. Great Lakes Res. 35:496-506.	If, in your professional judgement, any of the listed ecological impacts are evident/documented and severe, the site should be categorized as Class 1, regardless of the numerical score. For the purposes of the classification system, effects that would be considered severe degradation include observed impacts on survival, growth or reproduction which could threaten the viability of a population of ecological receptors at the site. Other evidence that qualifies as severe adverse effects may be determined based on professional judgement and in consultation with the relevant expert support department. If none of the listed impacts are evident, answer "No". If insufficient information is available to answer this question, choose the "Do Not Know" option.	Evidence of impacts to ecological receptors is primarily based on the IJC (1978) definition of "beneficial uses -- ecological components". Degradation of biological communities (fish, benthos) can include significant decline in populations, changes in community structure, or death or impaired health of a large number of individuals. Include results of any sediment toxicity testing or benthic community analysis that indicate statistically significant toxic effects or community-level effects (compared to reference sediments).
4.	Are there indicators of significant **adverse effects in the exposure zone** (i.e., the zone in which receptors may come into contact with contaminants)? For example: -Significant and persistent sheen/NAPL originating from identified or unidentified hydrocarbon source in sediments or upland soils; -Severely stressed biota or absence of biota; -Presence of material on/in sediment with suspected high concentration of contaminants such as ore tailings, sandblasting grit, slag, and coal tar.	No			If yes, answer "Yes" and automatically rate the site as Class 1, a priority for remediation or risk management, regardless of the total score obtained should one be calculated (e.g., for comparison with other Class 1 sites). If none of the effects listed in cell B16 are evident, answer "No".	Small-scale and/or temporary sheens (e.g., sheen from a boat motor in a small-craft harbour) would not be considered sufficient to support a Class 1 designation.
5.	Do measured concentrations of volatiles or unexploded ordnances represent an **explosion hazard**?	No			If yes, answer "Yes" and automatically rate the site as Class 1, a priority for remediation or risk management. Do not continue until the safety risks have been addressed. Consult your jurisdiction's occupational health and safety guidance or legislation on exposive hazards and measurement of lower explosive limits.	
	Automatic Class N Designation Criteria					
6.	Are there any **chemical exceedances or physical impacts to aquatic habitat** on the site (known or suspected)?	Yes	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour: Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour	Seven inorganic and four organic contaminants are present above the CCME probable effect level (PEL) guidelines in the surficial sediments of the KIH: Cr, Pb, Zn, Cu, Hg, As, PCBs, PAHs, and DDT. Statistical tests demonstrated that mean concentrations of Cr, Pb, Cu, As, PCBs and PAHs are significantly higher ($p<0.05$) than the mean at reference sites located upstream of Belle Park. Hg is not statistically different, but the mean is 1000% higher than the reference mean. Chromium and PAHs are the most widespread contaminants in the KIH. Based on other guidelines, Sb (soil quality guidelines) and chlordane (MOE sediment LEL) have also been evaluated for human health and ecological risk.	An exceedance occurs when measured concentrations in the exposure zone are higher than both 1) background or reference concentrations, and 2) environmental quality guidelines (EQG). Appropriate EQGs are: 1) CCME Canadian Environmental Quality Guidelines (to be used if available); 2) **equivalent** provincial guidelines/standards if no CCME guideline exists for a specific chemical in a relevant medium; or 3) background/reference values. (Equivalent guidelines or standards must offer at least the same level of protection as the CCME guidelines.) If there are any statistically significant exceedances and/or known or suspected physical impacts to fish habitat on the site, answer "Yes" to this question. Otherwise answer "No" and designate the site as Class N, "Not a priority for action".	Where background/reference concentrations exceed guidelines, the nature of background samples should be taken into account. Ideally, background/reference samples should be collected from sites that are similar in as many ways as possible to the water lot samples, but with the absence of apparent sources of contamination. **If the entire surrounding area is highly polluted, the use of local background levels is not recommended and the class N assignment is not appropriate.** If a sufficiently comprehensive environmental site assessment has been completed at the site, beginning with a Phase I ESA and including subsequent intrusive investigation phases, and there are no exceedances (known or suspected) of the relevant CCME or provincial guidelines/standards at the site, and chemicals for which there are no guideline/standard do not exceed defensible toxicity benchmarks, it is not necessary to rank the site.

FCSAP Aquatic Sites Classification System (2009)

Test Site and Location: Kingston Inner Harbour, Kingston   Kingston, Ontario

Contaminant Characteristics Worksheet

Question I. Contaminant Characteristics

Instructions: The results of intrusive testing should be used to evaluate the degree of known contamination on the site. **When completing the tables below, it is important to remember the following:**

1) Each row represents a specific chemical class in a specific medium on the site, for example, metals in surface water, or PAHs in sediments, therefore all data on a given row should correspond to the same combination of medium and chemical class. As such, each combination of medium and chemical class should be listed **only once** in columns B and C.

2) It is not necessary to evaluate every tested substance in every chemical class. Only two substances should be evaluated from a given combination of chemical class and medium, as described in the instructions specific to each column.

3) For any media where **intrusive testing results are not available, use Question 1b** to evaluate the degree of suspected contamination.

4) **Instructions specific to each column are encapsulated in the comment boxes** attached to each column heading. **To view additional instructions, place cursor over a cell with a red triangle in the upper right-hand corner.**

Question 1a: Degree of KNOWN contamination

						Highest exceedance detected in medium/chemical class									Most prevalent COC detected in medium/chemical class										
Medium	Chemical class	biomagnifier or persistent organic	# of substances exceeding criteria	Total # of substances tested	Score A (/10)	Chemical Name	# samples exceeding EQG for this substance in this medium	total # samples analyzed for this substance in this	Score B (/10)	Maximum measured concentration	EQG used	EQG value	Reference value	Exceedance factor	Chemical Name	# samples exceeding EQG for this substance in this medium	total # samples analyzed for this substance in this	score C (/10)	Maximum measured concentration	EQG used	EQG value	Reference value	Exceedance factor	Medium/chemical class total score	Source document(s)
Example:																									
Surficial Sediment	Metals/Inorganics	No	4	9	4.4	Arsenic	2	3	0.10	87	CCME ISQG	5.9	2	1.4	Chromium (total)	15	28	5.36	20	CCME ISQG	8.9	2	6.68	12.50	Phase II ESA, DFO, 2008
Surface water	Pesticides	Yes	2	20	1.0	Lindane	2	30	0.67	0.05	CCME FWAL	0.01		2.7	Hexachlorobutadiene	6	10	6.00	3.5	CCME FWAL	1.3		10.15	18.82	Phase II ESA, DFO, 2008
Surficial Sediment	Metals/Inorganics	Yes	6	25	2.4	Cadmium	5	25	2.00	200	CCME ISQG	37.3	8	8.7	Copper	10	20	5.00	250	CCME ISQG	35.7	20	30.01	46.14	Phase II ESA, DFO, 2008
Surficial Sediment	PAHs	No	1	1	1.0	Naphthalene	2	15	1.33	0.1	CCME	0.0346	0	2.5	Dibenzo(a,h)anthracer	1	1	0.10	0.008	CCME ISQG	0.00622		0.03	3.55	Phase II ESA, DFO, 2008
																				Total Score - Known contamination in all media and chemical classes:				**81.01**	
Enter data below (add lines if required):																									
Surface water	Metals/Inorganics	No	3	30	1.0	Chromium	6	39	1.54	22	Health Canada	0.05	<0.005	675.4	Pb	9	39	2.31	1.1	Health Canada	0.01	<0.01	251.54	927.92	
Surficial Sediment	PCBs & PCDD/Fs	Yes	1	1	1.0	PCBs total	200	232	8.62	12000	CCME ISQG	34.1	76	1352.5				0.00					0.00	1358.54	
Surficial Sediment	PAHs	Yes	1	1	1.0	PAHs total	61	127	4.80	62.6	MOE LEL	4.0	1.6	70.4				0.00					0.00	76.37	
Surficial Sediment	Pesticides	Yes	2	2	1.0	DDT total	35	49	7.14	145	CCME ISQG	1.19	15.6	59.2	Chlordane	12	48	2.50	41	CCME ISQG	4.5	<4.0	20.28	85.53	
Surficial Sediment	Metals/Inorganics	No	7	30	2.3	Chromium total	372	373	9.97	15000	CCME ISQG	37.3	65	2291.5	Pb	370	381	9.71	1087	CCME ISQG	35	53	189.46	2483.33	
Deep Sediment	PCBs & PCDD/Fs	Yes	1	1	1.0	PCBs total	4	10	4.00	861	CCME ISQG	34.1	76	41.3				0.00					0.00	47.32	
Deep Sediment	Metals/Inorganics	No	7	30	2.3	Cr	37	76	4.87	42737	CCME ISQG	37.3	65	3196.1	Pb	48	75	6.40	3246	CCME ISQG	35	53	385.57	3583.98	
Biological Tissue	PCBs & PCDD/Fs	Yes	1	1	1.0	PCBs total	69	104	6.63	2.7	IJC TRG	0.1	0.06	172.5				0.00					0.00	178.50	
Biological Tissue	Metals/Inorganics	No	1	8	1.3	Methylmercury	96	104	9.23	0.5	CCME TRG	0.033	0.07	56.7				0.00					0.00	57.95	
																				Total Score - Known contamination in all media and chemical classes:				**8799.4**	

Question 1b: STRONGLY SUSPECTED contamination

Instructions: This section should be used to evaluate contamination that is strongly suspected to be present in site media, based on available documentation, but for which chemical analysis has not yet been carried out. Scores from this section will be added to the score from question 1a, if any, to a combined total of 200 points. This approach is intended to ensure that possible impacts from known and strongly suspected contamination are evaluated. It is especially important to document the rationale for listing suspected contaminants/media in this section, as illustrated in the example below.

Medium	Chemical class	Rationale	Source Document	Author(s)	Year
Example:					
Surficial Sediment	Metals/Inorganics	Site receives drainage from upgradient copper mine.	Phase II report	Franz	2007
Groundwater	PHCs & BTEX	PHC impact < 10 m from shoreline.	Phase III report	Franz	2009
Score:	20				
Enter data below:					
Score:	0				

Combined score 1a & 1b: (maximum 200)	200

Question 2. Scale of Chemical Impacts

2a. Area of Known or Strongly Suspected Contamination

Choose A, B, C, D or E from the list below:

A	No chemical impact (i.e., responses to 1a and 1b are blank)
B	< 10 m radius in a lake, pond or marine habitat OR <10 m downstream in a flowing watercourse
C	10-50 m radius **OR** 10-50 m downstream in a flowing watercourse
D	> 50 m radius **OR** >50 m downstream in a flowing watercouse
E	Do Not Know

Overall Score - Chemical Impacts: (maximum 230)	**230.0**
Number of "Do Not Knows":	0

Question	Score	Rationale for response	Reference	Instructions	Notes
CHARACTERIZATION OF RECEPTORS					
1. Characterization of Human Receptors					
1a. Human use of the aquatic site and aquatic environments up to 1 km downstream (in a flowing watercourse) or within a 1 km radius (marine or lake/pond/wetland environments).	Recreational	Site is lcoated in downtown Kingston. Residents frequently use the site for recreational activities.	ESG (2010). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment.	From the list of options, choose the highest-scoring activity for which the site is used by humans. "Subsistence" implies that the site is used as a source of food, medicinal plants, drinking or irrigation water by local human populations. "Recreational" encompasses sites used for recreational boating, sport fishing, swimming or other leisure activities. "Commercial" and "Industrial" activities are those related to buying, selling or trading of merchandise or services (commercial), or to the production, manufacture or storage of materials (industrial). If more than one category applies, choose the highest-scoring applicable option.	This is the main human receptor factor used in site scoring. A higher score implies greater exposure and/or exposure of more sensitive human receptors (e.g., children).
Score	2				
2. Characterization of Ecological Receptors					
2a. Are water bodies and water courses on the site freshwater, marine, or brackish?	Freshwater		ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review	Review site assessment reports to determine whether surface waters on the site are marine, freshwater or brackish. If more than one aquatic environment is present on the site, choose the "2-3 types" option.	
Score	0				
2b. How many watercourses and/or water bodies are present on the site?	1		ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review	If the site encompasses more than one flowing watercourse (river, stream) and/or water body (marine, lake, pond), choose "2" or ">2", as appropriate.	
Score	0				
2c. Indicate the sensitivity of ecological receptors whose range includes the area where the site is located. Base your score on the most sensitive species from each category.		SARA Schedule One species list provided by Jacquie Bastick (PCA).	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review.	Review site assessment reports to determine whether the specified types of ecological receptors are likely to be present on the site, or to use the site as a source of food, or as temporary or permanent habitat (e.g. migration habitat, spawning habitat). Note that the definition of "fish" under the *Fisheries Act* includes: (a) parts of fish (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals. "Inappropriate Habitat" should be selected if the types of water bodies present on the aquatic site would not normally be expected to be used by the organism being evaluated, without taking into consideration anthropogenic alterations to the habitat. Physical impacts to aquatic sites are evaluated in worksheet #7.	Species at risk include those that are extirpated, endangered, threatened, or of special concern. For a list of species at risk, consult Schedule 1 of the federal Species at Risk Act (http://www.sararegistry.gc.ca/species/schedules_e.cfm?id=1). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent advisory organization that evaluates Canada's wild species and maintains a searchable database of their designated species (www.cosewic.gc.ca). Many provincial governments also provide regionally applicable lists of species at risk.
i) Piscivorous (fish-eating) wildlife (including semi-aquatic mammals)	Special Concern				
ii) Migratory birds using the water resource (e.g. as a source of food, drinking water, bathing water, etc.)	Endangered or Threatened				
iii) Fish	Endangered or Threatened				
iv) Invertebrates	Unlisted Species Only				
v) Animals using the site as a drinking water supply	Endangered or Threatened				
vi) Aquatic vegetation	Unlisted Species Only				
vii) Riparian vegetation	Endangered or Threatened				
Score (maximum 10)	10				
2d. Sensitivity of the aquatic habitat on the site.	Do Not Know	The majority of warm-water fish species identified at the site are regionally common, relatively pollution-tolerant, and are reproductive generalists in terms of spawning behaviour and habitat (Personal Communication, from Ecological Services to ESG; April 14, 2009). Spawning areas for common carp and young-of-the-year fish are present in the dense weed beds off-shore at the site, but there are comparable spawning sites in other areas of the harbour. However, map turtles and stinkpot turtles have been observed on the site and the sensitivity of the aquatic habitat for these species is unknown.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review. Section C7.	Review site assessment reports to determine the sensitivity of the ecological habitat.	Critical habitat is the habitat necessary for the survival or recovery of a listed endangered, threatened or extirpated species on Schedule 1 of SARA. (www.mb.ec.gc.ca/nature/endspecies/faq/index.en.html#5) Highly sensitive habitats are those that are rare, host species that are highly sensitive to perturbations (e.g. many salmonidae), and/or are critical to survival of species (e.g. spawning habitat). Less sensitive habitats are prevalent, host species that are resilient to change, and/or are not used by fish or are used as migratory corridors, feeding and rearing habitat only.
Score	2				
Total Score - Human and Ecological Receptors	14				
(Maximum 25)					

Question	Score	Rationale for response	Reference	Instructions	Notes
CURRENT AND PAST EXPOSURE					
3. Current/past exposure of human receptors to contaminants in site media					
3a. Choose A, B, C or D from the list below by selecting the desired letter from the drop-down list in cell C43:					
A Documented adverse impact or quantified exposure level which has or will likely result in an adverse effect, injury or harm or impairment of the safety to humans as a result of the contaminated site. (Class 1 Site)				A: Where adverse effects on humans are documented, the site should be automatically designated as a Class 1 site (i.e., action required). However, a scoring range is provided in case a numerical score for the site is still desired (e.g., for comparison with other Class 1 sites). Known impacts can be evaluated based on blood testing (e.g. blood lead >10 µg/dL) or other health-based testing.If this option is selected, choose "not scored" for Questions 3 b through 3 h.	Known adverse impacts include impacts to domestic and traditional food sources. Adverse effects based on food chain transfer to humans and/or animals can be scored in this category, but the weight of evidence must show a direct link between a contaminated food source/supply and subsequent ingestion/transfer to humans. Any adverse effects to ecological receptors are scored separately in question 2 of this worksheet. A person with demonstrable experience in the assessment of human health risks must provide a thorough description of the sources researched to evaluate and quantify the exposure/impact (adverse effect) in the vicinity of the contaminated site. **Selected References:** Health Canada – Federal Contaminated Site Risk Assessment in Canada Parts 1 and 2 Guidance on Human Heath Screening Level Risk Assessments (www.hc-sc.gc.ca/ewh-semt/pubs/contamsite/index_e.html) United States Environmental Protection Agency, ECOTOX database – http://cfpub.epa.gov/ecotox/ecotox_home.cfm
B Same as above, but "Strongly Suspected" based on observations or indirect evidence.	A sport fish consumption advisory for the area is currently in effect for PCBs. The OMOE Guide to Eating Ontario Sport Fish (OMOE, 2009) has recommended that certain populations (women of child-bearing age and children under 15 because of their higher sensitivity to contaminants) should not consume northern pike, brown bullhead greater than 25 cm length or carp greater than 55 cm in length caught within the KIH.		ESG (2010). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment.	B: Scoring for this category can be based on the outcome of a human health risk assessment and applies to sites which have reported hazard quotients (HQ) > 0.2 (or other target HQ value, as specified by Health Canada) for noncarcinogenic chemicals, and incremental cancer risks that exceed acceptable levels for carcinogenic chemicals as defined by the jurisdiction (typically either $>10^{-5}$ for federal sites, as specified by Health Canada). If this option is selected, choose "not scored" for Questions 3 b through 3 h.	
C No quantified or suspected exposures/impacts in humans.				C: Scoring for this category can be based on the outcome of a human health risk assessment and applies to sites which have reported hazard quotients (HQ) of < 0.2 (or other target HQ value, as specified by Health Canada) for noncarcinogenic chemicals, and incremental cancer risks that do not exceed acceptable levels for carcinogenic chemicals as defined by the jurisdiction (typically either $>10^{-5}$ for federal sites, as specified by Health Canada). If this option is selected, choose "not scored" for Questions 3 b through 3 h.	
D Do Not Know				D: If "Do Not Know" is selected, Questions 3b through 3h must be scored.	
Selected option:	A				
Score:	22	(maximum 22)			
NOTE: Skip questions 3b through 3h if you answered "A", "B", or "C" to question 3a (above). Questions **3b through 3h need only be scored if you answered "D" ("Do Not Know")** to question 3a.					
3b. What is the **frequency of human land and water use** on the site or in areas up to 1 km downstream (flowing stream or river) or within a 1 km radius of the site (marine site or lake/pond)?	Not Scored			"Regular use" implies frequent (at least weekly) use of the site by humans, year-round. "Seasonal use" implies site use by humans primarily during specific times of the year, e.g. summer or winter months only. "Infrequent" use implies that humans use the site only occasionally. If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3b.	
Score	0				
3c. Are surface waters on the site or in areas up to 1 km downstream (flowing stream or river) or within a 1 km radius of the site (lake/pond) used as a source of **drinking water**?	Not Scored			If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3c.	
Score	0				
3d. Is surface water on the site or in areas up to 1 km downstream (flowing stream or river) or within a 1 km radius of the site (lake/pond) used as a source of irrigation water?	Not Scored			If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3d.	
Score	0				
3e. Is surface water on the site or in areas up to 1 km downstream (flowing stream or river) or within a 1 km radius of the site (lake/pond) used as a source of water for manufacturing processes?	Not Scored			If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3e.	
Score	0				
3f. Is the site, or an area within 1 km downstream (flowing stream or river), or an area within a 1 km radius of the site (lake/pond/marine site) used as a swimming area?	Not Scored			If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3f.	
Score	0				
3g. Approximate distance to fish harvesting areas (including aquaculture sites).	Not Scored			Note that the definition of "fish" under the Fisheries Act includes: (a) parts of fish (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals. If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3g.	
Score	0				
3h. Strong reliance of local people on natural resources for food, water, shelter, etc.	Not Scored			If A, B or C was selected in Question 3a, choose "Not Scored" for Question 3h.	
Score	0				
Potential for Human Exposure (maximum 22)	**22**				

4. Current/past exposure of ecological receptors

4a. Choose A, B, C or D from the list below **by selecting the desired letter from the drop-down list in cell C78**:		Rationale		Reference(s)	Instructions	Notes
A	Documented adverse impact or high quantified exposure to contaminated water, sediments, foods, vapour or dust which has or will result in an adverse effect, injury or harm or impairment of the safety to terrestrial or aquatic organisms as a result of the contaminated site. (Class 1 Site)	Ecological effects were documented using the Canada-Ontario Decision-Making Framework, as well as completing an ecological risk assessment (ERA). Selected receptors for the ERA included fish (brown bullhead, yellow perch and northern pike), herbivorous mammals (muskrat), piscivorous mammals (mink), non-piscivorous birds (red-winged blackbird), waterfowl (mallard duck), and piscivorous birds (osprey, great blue heron). The COA assessment found (1) sediment toxicity (reproductive, survival and growth endpoints) to benthic invertebrates in 8 of 32 test sites; (2) benthic community impairment at test sites relative to reference sites; and (3) significantly higher biological uptake of contaminants at test sites compared with reference sites. Brown Bullhead sampled from the impacted area had significantly higher occurances of orocutaneous DELTs (deformities, erosions, lesions, tumours) compared with fish from the upstream reference location. The results from the ERA indicated that (1) Cr presents a potential risk (HQ>1) to muskrat, red-winged blackbird, mallard duck, and great blue heron receptors; (2) PCBs present a potential risk (HQ>1) to mink. Sediments are the main source of contaminants. Exposure pathways include direct contact with sediments, ingestion of sediments, and/or ingestion of contaminated prey for those contaminants that undergo biomagnification (e.g., PCBs, MeHg).		ESG (2010). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 3: Ecological effects: Evaluation of bioaccumulation of contaminants in biota, sediment toxicity, and benthic community structure ESG (2010). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment.	With the exception of SARA species, which are protected at the individual level rather than the population level, some low levels of impact to ecological receptors may be considered acceptable, where sites are used for commercial or industrial purposes. However, if ecological effects are deemed to be severe, the site may be categorized in Class 1 (i.e. a priority for remediation or risk management), regardless of the total ASCS score. For the purposes of the ASCS, effects that would be considered severe include observed effects on survival, growth or reproduction which could threaten the viability of a population of ecological receptors at the site. Alternately, severe adverse effects may be determined based on professional judgement and in consultation with the relevant jurisdiction. A scoring range is provided for this category for use in the event that a score is desireable for comparison purposes, even if ecological effects are deemed severe and the site is automatically designated as Class 1. If this option is selected, choose "Not Scored" for Questions 4b through 4e.	CCME, 1999: Canadian Water Quality Guidelines for the Protection of Aquatic Life. www.ccme.ca CCME, 1999: Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses. www.ccme.ca Sensitive receptors- review: Canadian Council on Ecological Areas; www.ccea.org. Ecological effects should be evaluated at a population or community level, as opposed to at the level of individuals. For example, population-level effects could include reduced reproduction, growth or survival in a species. Community-level effects could include reduced species diversity or relative abundances. Further discussion of ecological assessment endpoints is provided in A Framework for Ecological Risk Assessment: General Guidance (CCME 1996). Notes: A person with demonstrable experience in the assessment of risks to ecological receptors must provide a thorough description of the sources researched to classify the environmental receptors in the vicinity of the contaminated site. This information must be documented in the worksheet including contact names, phone numbers, e-mail addresses (to be listed in "Rationale" column) and/or reference maps, reports, internet links and other resources (to be referenced in the "Reference" column).
B	Same as above, but "Strongly Suspected" based on observations or indirect evidence.				This category can be based on the outcomes of risk assessments and applies to studies which have reported Hazard Quotients >1. Alternatively, known impacts can also be evaluated based on a weight of evidence assessment involving a combination of site observations, tissue testing, toxicity testing and quantitative community assessments. Scoring of adverse effects on individual rare or endangered species will be completed on a case-by-case basis with full scientific justification. If this option is selected, choose "Not Scored" for Questions 4b through 4e.	
C	No quantified or suspected exposures/impacts in ecological receptors.				This category can be based on the outcomes of risk assessments and applies to studies which have reported Hazard Quotients of less than 1 and no other observable or measurable sign of impacts. Alternatively, it can be based on a combination of other lines of evidence showing no adverse effects, such as site observations, tissue testing, toxicity testing and quantitative community assessments.If this option is selected, choose "Not Scored" for Questions 4b through 4e.	
D	Do Not Know				D: If "Do Not Know" is selected, Questions 4b through 4e must be scored.	
	Selected Option:	B				
	Score:	8	(maximum 18)			

NOTE: Skip questions 4b through 4e if you answered "A", "B", or "C" to question 4a (above). Questions 4b through 4e need only be scored if you answered "D" ("Do Not Know") to question 4a.

Question	Selection / Score	Rationale	Reference(s)	Instructions	Notes
4b. Are terrestrial or aquatic/semi-aquatic animals or avian species likely to be **ingesting contaminated water** at the site?	Not Scored	Concentrations of CoPCs in water at the site are below criteria values		If there is contaminated surface water at the site, assume that terrestrial or aquatic/semi-aquatic organisms or avian species will ingest it. If A, B or C was selected in Question 4a, choose "Not Scored" for Question 4b.	
Score	0				
4c. Proximity of contaminated area(s) on the site to ecologically sensitive habitat.	Not Scored			Score Question 4c according to the shortest distance from a contaminated area on the site to an ecologically sensitive area on or off the site. To determine whether an area is sensitive or not, refer to the definition of a sensitive site in Question 2c on the Receptors worksheet. If A, B or C was selected in Question 4a, choose "Not Scored" for Question 4c.	
Score	0				
4d. Access to contaminated sediment by piscivorous wildlife or other organisms at lower trophic levels.	Not Scored			If piscivorous wildlife or lower trophic level organisms are known or strongly suspected to have access to contaminated sediments or contaminated food organisms, choose "Probable". If there is a possibility of access but contact is unlikely, choose "Unlikely". If A, B or C was selected in Question 4a, choose "Not Scored" for Question 4d.	
Score	0				
4e. Proximity of contaminated area(s) to spawning, rearing and migration habitat of fish populations.	Not Scored			Under the Fisheries Act, fish habitat means spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes. Fish habitat includes ephemeral streams that may be wetted only at certain times of the year, and may include man-made watercourses. If A, B or C was selected in Question 4a, choose "Not Scored" for Question 4e.	
Score	0				
Potential for Ecological Exposure (max 18)	**8**				

5. POTENTIAL CONTINUED OR NEW EXPOSURE (IN FUTURE - Human and Ecological)

5a. Have there been upstream or upgradient contamination events of soils, surface water or groundwater?	Probable	Historical industrial operations along the western shore included shipbuilding, locomotive building, a coal gasification plant, a lead smelter, a tannery, battery-manufacturing plants, a variety of mill works, fuel gas stations, a woolen mill and waste disposal sites. The Davis Tannery discharged liquid wastes containing chromium directly into Orchard Marsh north of the site, which drains into the KIH. Elevated concentrations of Cr and Pb (from historical lead smelting) have been found in Orchard Marsh sediments. The Belle Park landfill is a suspected former source of PCBs to the KIH. Soils contaminated with Hg and As in the Emma Martin Park/Rowing Club area also appear to have been a source of contamination for the KIH.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review. Section C6a. ESG (2011). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011. Section B-b.	Score should be based on review of environmental site assessment reports, as well as federal and provincial databases on spills, contaminated sites, violations etc	See Provincial Database Descriptions in the reference section.
Score	3				
5b. Is there evidence of migration of COCs from terrestrial sources to surface water in run-off?	Probable	Surface water run-off containing soils contaminated with Cr has been identified from the Orchard Marsh area (north of the former Davis Tannery site) during periods of high precipitation. Surface water run-off containing soils contaminated with Hg was identified as a probable source of contamination to the KIH from the Rowing Club in 2007; subsequent mitigation measures to prevent soil erosion appear to be effective in controlling this source.	ESG (2011). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011. Section B-b.	Based on knowledge of containment measures, distance from terrestrial contamination to surface water, topography, run-off potential, flood potential.	
Score	3				
5c. Is there evidence that COCs have or may have migrated from the site to downstream habitat by surface water transport or other means (e.g. dredging activity, maintenance or construction)?	Unlikely	Transport of contaminants by surface water in the dissolved phase is considered unlikely for the following reasons: (1) surface water analyses have indicated that the water quality is generally good with respect to water quality guidelines; (2) contaminant concentrations in porewater samples have generally been below water quality guidelines.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review. Section D.	Evidence of COC migration to downstream habitat could include, for example, surrounding topography characteristics, flood potential, etc. Score should be based on review of analytical data, of federal and provincial databases, environmental infractions, etc.	
Score	0				
5d. Does groundwater discharging to an aquatic habitat exceed applicable provincial standards for the protection of aquatic life at the point of discharge?	Yes	Nearshore groundwater monitoring wells from the Emma Martin Park/Rowing Club area contain arsenic concentrations that exceed provincial standards (OMOE, 2011). Groundwater from this area is also a potential source of Hg. Groundwater samples from the former Davis Tannery property and in the discharge zone to the KIH sediments were below the applicable criteria for inorganic elements.	ESG (2011). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011. Section B-b. OMOE (2011). Memo report to the City of Kingston from Frank Crossley (OMOE), dated September 16, 2011.	Groundwater concentrations of contaminants at the point of contact with an aquatic receiving environment can be estimated in three ways: 1) by comparing existing nearshore groundwater data to the CCME water quality guidelines (this will be a conservative comparison, as contaminant concentrations in groundwater often decrease between nearshore wells and the point of discharge). 2) by conducting groundwater modeling to estimate the concentration of groundwater immediately before discharge. 3) by analyzing groundwater at the point where it will come into contact with aquatic receptors, usually within the top 1 m of sediments.	
Score	2				
5e. Is there evidence that sediments on the site are located in an erosional or depositional zone?	Do Not Know			Scoring should be based on reported results of site inspection by a person with demonstrable knowledge of environmental site assessment and of erosion and sediment transport processes.	
Score	0.5				
5f. Is there evidence of migration of contaminated sediments?	Probable	Contaminant profiles in core samples and radioisotopic dating analyses indicate that the upper 15 to 20 cm of the sediments are mixed. These findings suggest that there is little dilution with clean sediments due to continual mixing and resuspension of contaminated sediment. This may be due in part to shallow depths of the KIH, which facilitate resuspension of sediments through wind action and boat activity, as well as the influence of the Kingscourt stormsewer discharge adjacent to Belle Park and the former Davis Tannery. The extent of surface sediment Cr contamination in the KIH appears to have increased since the 1970's, reflecting resuspension and redistribution of contaminated sediments from near the Kingscourt stormsewer outflow.	ESG (2011). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011. Section B-a.	Impediments to sediment migration could include, for example, the presence of a clean sediment cap or other stabilizing improvement. Factors that promote sediment migration include wave/tidal action or propeller wash (lakes & marine sites), or scouring (rivers and streams).	
Score	3				
Total continued/future (maximum 15)	**11.5**				
Total Exposure (Maximum 80)	**55.5**				
Number of "Do Not Knows":	2				
Number of possible "Do Not Knows" on this worksheet:	28				

FCSAP Aquatic Sites Classification System (2009)				
Test Site and Location:	**Kingston Inner Harbour, Kingston**		**Kingston, Ontario**	
Physical Impacts and Other Disturbances				
Purpose: To identify and quantify the scale of physical impacts and other disturbances related to site use.				
Component	**Score**	**Rationale**	**Reference**	**Instructions**
1. Physical Impacts				
1a. Please rate the severity of known or potential geotechnical failure scenarios that have taken place or could take place on the site, based on documented conditions.	Not Applicable			Examples of failures include: dam breaches, erosion or collapse of embankments, reservoir dikes, retaining walls or other structures that could result in the release of suspended solids, contaminated water or toxic substances. Evaluate the severity of known or potential geotechnical failures based on results of geotechnical investigations, and using professional judgement.
Score:	0			
1b. Evidence of debris in the water resulting from site use.	No			Score based on results of any site inspections documenting indications of debris in the water.
1c. Docks, buildings or other structures that have fallen or may fall into a watercourse or water body.	No			Score based on results of site inspections documenting any evidence of the failed structures in the watercourses/waterbodies, or the potential for structures to fall into the water in future.
1d. Evidence of sunken vessels with contamination potential.	No			
1e. Evidence of disposal of dredged or excavation material on the site.	No			Examine site inspection reports, contact local, provincial and/or federal agencies to assess the potential for past dredgate disposal on the site.
1f. Obstruction of water flow in a river or stream as a result of site use.	No	The historical infilling of the marshy area between Belle Island and the western shore means that all water flowing downstream now travels around the east side of Belle Island.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review. Section I-3.	Score based on results of site inspections documenting any evidence of obstructions to water flow.
1g. Has fish habitat been destroyed by infilling, shoreline armouring, elimination or unauthorized diversion of watercourses?	No	IThe historical infilling of the marshy area between Belle Island and the western shore likely resulted in a loss of fish habitat.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 1: Literature review. Section C3 and Section C7c.	
1h. Is there evidence of physical impacts and/or sediment instability of deeper contaminated sediment?	Yes	In KIH, core samples indicate that similar concentrations of Cr are seen in the top 0-15 cm of sediment, and that these concentrations are generally much higher than the CCME PEL. Furthermore, radioisotope dating analyses indicate that the top layers of sediment are mixed (Tinney, 2006). These findings suggest that there is little dilution with clean sediments due to continual mixing and resuspension of contaminated sediment. As a result, physical isolation of the contaminants through burial with clean sediments is not occurring at rates high enough to permit natural recovery. This may be due in part to shallow depths of the KIH, which facilitate resuspension of sediments through wind action and boat activity, as well as the influence of the Kingscourt stormsewer discharge adjacent to Belle Park and the former Davis Tannery. During high precipitation events, resuspension and mixing of contaminated sediments is likely occurring.	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour: Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour. Section II-D. & Environmental Sciences Group (ESG). 2011. Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour. Chapter 5: An options analysis of management scenarios for the Kingston Inner Harbour. Draft report, March 2011. Section III-B1.	

1i. Has fish passage been obstructed as a result of site use?	No			Score based on results of site inspections documenting any evidence of obstructions to fish passage.
1j. Are there potential hazards to navigation resulting from site use?	No			Score based on results of site inspections documenting any evidence of obstructions to navigation.
1k. Is there documented evidence of actual or potential activities that would disturb **contaminated or clean** sediment, for example: navigational dredging of harbours/waterways, pier or seawall construction and maintenance?	No			Score based on results of site inspections documenting any evidence of factors that could disturb sediment. Disturbance of clean sediment can be a violation of Section 36 of the *Fisheries Act*.
1l. Is there a physical pathway which can transport soils (including soils released by damaged permafrost) to a nearby aquatic environment?	No			Melting permafrost leads to decreased stability of underlying soils. Wind or surface run-off erosion can carry soils into nearby aquatic habitats. The increased soil loadings into a river can cause an increase in total dissolved solids and a resulting decrease in aquatic habitat quality. In addition, the erosion can bring contaminants from soils to aquatic environments.
1m. Is there evidence of stream channelization on the site?	No			
1n. Have smooth concrete or metal shoreline erosion walls been installed at the site?	No			
1o. Has significant cement/pavement been deposited on the bottom of the water body (e.g. for boat ramps, etc.)?	No			
Score - Physcial Impacts: (maximum 19)	1			
2. Other Disturbances				
2a. Do previous reports document any water temperature impact resulting from site use?	No			Assess water temperature relative to comparable sites that are not impacted by any influences on water temperature (i.e. discharges of warmer- or colder-than-ambient water from industrial or other anthropogenic sources.) Canadian Council of Ministers of the Environment, 2009. Factsheets, Temperature (marine), Canadian Water Quality Guidelines for the Protection of Aquatic life (http://ceqg-rcqe.ccme.ca/).
2b. Has evidence of excessive plant growth been documented in previous reports?	No	Kingscourt storm sewer discharges into lower KIH. During periods of high precipitation, combined sewer overflows (CSOs) result in	ESG (2009). Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston	A distinct increase of plant growth in an aquatic environment may suggest enrichment. Nutrients (e.g. nitrogen or phosphorous) released to an aquatic body act as fertilizers and promote eutrophication.
2c. Have any negative aesthetic impacts been reported?	No			Score any documented evidence of impacts to the visual appeal of the site.
2d. Do previous reports mention total suspended sediments exceeding Canadian Water Quality Guidelines?	No	Elevated total suspended sediments in surface runoff from adjacent sites have been reported during precipitation events, but were not	Environmental Sciences Group (ESG). 2011. Application of the Canada-Ontario Decision-Making Framework for	Guidelines pertaining to particulate matter in surface water can be obtained from the Canadian Water Quality Guidelines for the Protection of Aquatic life (http://ceqg-rcqe.ccme.ca/).
2e. Is there evidence in previous reports that fish or meat taken from or adjacent to the site smells or tastes unpleasant (i.e. unusual smell or odour)?	No			Some contaminants can result in a distinctive change in the way food gathered from the site tastes or smells. Reference any documents reporting evidence of olfactory impacts to food species.
2f. Is there any previously recorded olfactory impact (unpleasant smell) to water or sediments as a result of anthropogenic activity?	No			Examples of olfactory change can include the smell of a COPC or of decaying vegetative or other organic material in an aquatic habitat.
Total Score - Other Disturbances: (Maximum 6)	**0**			
3. Scale of Physical or Other Non-Chemical Impacts				
3a. Choose A, B, C, D or E from the list below by choosing the corresponding letter in cell C46:				
A No physical or other non-chemical impact	Reference:			
B < 10 m radius **OR** < 10 m downstream in a flowing watercourse	Rationale:			
C 10-50 m m radius **OR** 10-50 m downstream in a flowing watercourse				
D > 50 m radius **OR** > 50 m downstream in a flowing watercourse				
E Do Not Know				
Selected option:	**D**			
Total Score - Scale (maximum 5**):**	5			
Overall Score - Physical and Other Non-Chemical Impacts: (maximum 30)	**6**			
Number of "Do Not Knows":	**0**			
Number of possible "Do Not Knows" on this worksheet:	22			

FINAL

FCSAP Aquatic Sites Classification System (2009)

Score Summary

Test Site and Location: **Kingston Inner Harbour, Kingston** **Kingston, Ontario**

Scores from individual worksheets are automatically tallied in this worksheet.

Contaminant Characteristics (Tab #5)	Score
1. Degree of chemical contamination	200.0
2. Scale of chemical impacts	30.0
Raw Total Score (max. 230):	**230.0**
Total Score (max. 50):	**50.0**

Receptors and Exposure (Tab #6)	Score
1 & 2. Receptor Characterization	14
3. Current/Past Human Exposure	22
4. Current/Past Ecological Exposure	8
5. Potential Future Exposure	11.5
Raw Total Score (max. 80):	**55.5**
Adjusted Total Score: (max. 40)	**27.8**

Physical Impacts and Other Disturbances (Tab #7)	Score
1. Identification of physical impacts	1
2. Identification of other disturbances	0
3. Scale of non-chemical impacts	5
Raw Total Score (max. 30):	**6.0**
Adjusted Total Score (max. 10):	**2.0**

Total combined score from Tabs 5, 6, 7: 79.8

Site Score

Site Letter Grade	**B**
% Responses that are "Do Not Know"	**4%**
Total ASCS Score for site	**79.8**
Site Classification Category	**1**

Site Classification Categories*:

Class 1 - High Priority for Action (Total NCS Score ≥70)

Class 2 - Medium Priority for Action (Total NCS Score 50 - 69.9)

Class 3 - Low Priority for Action (Total NCS Score 37 - 49.9)

Class N - Not a Priority for Action (Total NCS Score <37)

Class INS - Insufficient Information (>30% of responses to applicable questions are "Do Not Know")

* NOTE: The term "action" in the above categories does not necessarily refer to remediation, but could also include risk assessment, risk management or further site characterization and data collection.

FCSAP Aquatic Sites Classification System (2009)

Reference Material (Information to assist in scoring)

Persistent Substances

Persistent chemicals, e.g. PCBs, chlorinated pesticides, etc., either do not degrade or degrade very slowly, and therefore may be available to cause effects for long periods of time. The Canadian Environmental Protection Act (CEPA) classifies a chemical as persistent when it has at least one of the following characteristics:
(a) in air,
(i) its half-life is equal to or greater than two days, or
(ii) it is subject to atmospheric transport from its source to a remote area;
(b) in water, its half-life is equal to or greater than 182 days;
(c) in sediment, its half-life is equal to or greater than 365 days; or
(d) in soil, its half-life is equal to or greater than 182 days.
This list does not include metals or metalloids, which in their elemental form do not degrade. However, metals and metalloids form chemical species in the environment, many of which are not readily bioavailable.

Examples of Persistent Substances:

aldrin	dieldrin	PCBs
benzo(a)pyrene	hexachlorobenzene	PCDDs/PCDFs (dioxins and furans)
chlordane	methylmercury	toxaphene
DDT	mirex	alkylated lead
DDE	octachlorostyrene	

Bioaccumulating and Biomagnifying Substances

Under CEPA, a substance is bioaccumulative:
(a) when its bioaccumulation factor is equal to or greater than 5000;
(b) if its bioaccumulation factor cannot be determined in accordance with an acceptable method (see below), when its bioconcentration factor is equal to or greater than 5000; and
(c) if neither its bioaccumulation factor nor its bioconcentration factor can be determined in accordance with an acceptable method, when the logarithm of its octanol-water partition coefficient (log K_{ow}) is equal to or greater than 5.

Acceptable methods under CEPA include "generally recognized methods of the Organisation for Economic Co-operation and Development (OECD) or of some other similar organisation or, if no such methods exist, in accordance with generally recognized methods within the scientific community and taking into account the intrinsic properties of the substance, the ecosystem under consideration and the conditions in the environment."

The term "biomagnification" has been summarized by Gobas and Morrison (2000), as:
"the process in which the chemical concentration in an organism achieves a level that exceeds that in the organism's diet, due to dietary absorption."

Examples of Bioaccumulating and/or Biomagnifying Substances:

Some substances are both persistent and bioaccumulative or biomagnifying, for example, DDT, methylmercury, PCBs and PAHs with log Kow between 5.0 and 5.6 (including anthracene, phenanthrene, pyrene, benz(a)anthracene and benzo(a)pyrene). For additional information regarding bioaccumulation or biomagnification potential of specific organic substances, refer to CCME fact sheets, available at http://ceqg-rcqe.ccme.ca/.

Chemical-specific Properties (Adapted from USEPA Soil Screening Criteria)						
CAS No.	**Compound**	**Solubility in Water @ 20-25°C (mg/L)**	**Henry's Law Constant (atm-m3/mol)**	**Dimensionless Henry's law constant (HLC [atm-m3/mol] * 41) (25 °C)**	**log Kow**	**Log Koc (L/kg)**
83-32-9	Acenaphthene	4.24E+00	1.55E-04	6.36E-03	3.92	3.85
67-64-1	Acetone	1.00E+06	3.88E-05	1.59E-03	-0.24	-0.24
309-00-2	Aldrin	1.80E-01	1.70E-04	6.97E-03	6.5	6.39
120-12-7	Anthracene	4.34E-02	6.50E-05	2.67E-03	4.55	4.47
56-55-3	Benz(a)anthracene	9.40E-03	3.35E-06	1.37E-04	5.7	5.6
71-43-2	Benzene	1.75E+03	5.55E-03	2.28E-01	2.13	1.77
205-99-2	Benzo(b)fluoranthene	1.50E-03	1.11E-04	4.55E-03	6.2	6.09
207-08-9	Benzo(k)fluoranthene	8.00E-04	8.29E-07	3.40E-05	6.2	6.09
65-85-0	Benzoic acid	3.50E+03	1.54E-06	6.31E-05	1.86	—
50-32-8	Benzo(a)pyrene	1.62E-03	1.13E-06	4.63E-05	6.11	6.01
111-44-4	Bis(2-chloroethyl)ether	1.72E+04	1.80E-05	7.38E-04	1.21	1.19
117-81-7	Bis(2-ethylhexyl)phthalate	3.40E-01	1.02E-07	4.18E-06	7.3	7.18
75-27-4	Bromodichloromethane	6.74E+03	1.60E-03	6.56E-02	2.1	1.74
75-25-2	Bromoform	3.10E+03	5.35E-04	2.19E-02	2.35	1.94
71-36-3	Butanol	7.40E+04	8.81E-06	3.61E-04	0.85	0.84
85-68-7	Butyl benzyl phthalate	2.69E+00	1.26E-06	5.17E-05	4.84	4.76
86-74-8	Carbazole	7.48E+00	1.53E-08	6.26E-07	3.59	3.53
75-15-0	Carbon disulfide	1.19E+03	3.03E-02	1.24E+00	2	1.66
56-23-5	Carbon tetrachloride	7.93E+02	3.04E-02	1.25E+00	2.73	2.24
57-74-9	Chlordane	5.60E-02	4.86E-05	1.99E-03	6.32	5.08
106-47-8	*p-Chloroaniline*	5.30E+03	3.31E-07	1.36E-05	1.85	1.82
108-90-7	Chlorobenzene	4.72E+02	3.70E-03	1.52E-01	2.86	2.34
124-48-1	Chlorodibromomethane	2.60E+03	7.83E-04	3.21E-02	2.17	1.8
67-66-3	Chloroform	7.92E+03	3.67E-03	1.50E-01	1.92	1.6
95-57-8	2-Chlorophenol	2.20E+04	3.91E-04	1.60E-02	2.15	—
218-01-9	Chrysene	1.60E-03	9.46E-05	3.88E-03	5.7	5.6
72-54-8	DDD	9.00E-02	4.00E-06	1.64E-04	6.1	6
72-55-9	DDE	1.20E-01	2.10E-05	8.61E-04	6.76	6.65
50-29-3	DDT	2.50E-02	8.10E-06	3.32E-04	6.53	6.42
53-70-3	Dibenz(a,h)anthracene	2.49E-03	1.47E-08	6.03E-07	6.69	6.58
84-74-2	Di-n-butyl phthalate	1.12E+01	9.38E-10	3.85E-08	4.61	4.53
95-50-1	1,2-Dichlorobenzene	1.56E+02	1.90E-03	7.79E-02	3.43	2.79
106-46-7	1,4-Dichlorobenzene	7.38E+01	2.43E-03	9.96E-02	3.42	2.79
91-94-1	3,3-Dichlorobenzidine	3.11E+00	4.00E-09	1.64E-07	3.51	2.86
75-34-3	1,1-Dichloroethane	5.06E+03	5.62E-03	2.30E-01	1.79	1.5
107-06-2	1,2-Dichloroethane	8.52E+03	9.79E-04	4.01E-02	1.47	1.24
75-35-4	1,1-Dichloroethylene	2.25E+03	2.61E-02	1.07E+00	2.13	1.77
156-59-2	cis-1,2-Dichloroethylene	3.50E+03	4.08E-03	1.67E-01	1.86	1.55
156-60-5	trans-1,2-Dichloroethylene	6.30E+03	9.38E-03	3.85E-01	2.07	1.72
120-83-2	2,4-Dichlorophenol	4.50E+03	3.16E-06	1.30E-04	3.08	—
78-87-5	1,2-Dichloropropane	2.80E+03	2.80E-03	1.15E-01	1.97	1.64
542-75-6	1,3-Dichloropropene	2.80E+03	1.77E-02	7.26E-01	2	1.66
60-57-1	Dieldrin	1.95E-01	1.51E-05	6.19E-04	5.37	4.33
84-66-2	Diethylphthalate	1.08E+03	4.50E-07	1.85E-05	2.5	2.46
105-67-9	2,4-Dimethylphenol	7.87E+03	2.00E-06	8.20E-05	2.36	2.32
51-28-5	2,4-Dinitrophenol	2.79E+03	4.43E-07	1.82E-05	1.55	—
121-14-2	2,4-Dinitrotoluene	2.70E+02	9.26E-08	3.80E-06	2.01	1.98
606-20-2	2,6-Dinitrotoluene	1.82E+02	7.47E-07	3.06E-05	1.87	1.84
117-84-0	Di-n-octyl phthalate	2.00E-02	6.68E-05	2.74E-03	8.06	7.92
115-29-7	Endosulfan	5.10E-01	1.12E-05	4.59E-04	4.1	3.33
72-20-8	Endrin	2.50E-01	7.52E-06	3.08E-04	5.06	4.09
100-41-4	Ethylbenzene	1.69E+02	7.88E-03	3.23E-01	3.14	2.56
206-44-0	Fluoranthene	2.06E-01	1.61E-05	6.60E-04	5.12	5.03
86-73-7	Fluorene	1.98E+00	6.36E-05	2.61E-03	4.21	4.14
76-44-8	Heptachlor	1.80E-01	1.09E-03	4.47E-02	6.26	6.15
1024-57-3	Heptachlor epoxide	2.00E-01	9.50E-06	3.90E-04	5	4.92
118-74-1	Hexachlorobenzene	6.20E+00	1.32E-03	5.41E-02	5.89	4.74
87-68-3	Hexachloro-1,3-butadiene	3.23E+00	8.15E-03	3.34E-01	4.81	4.73
319-84-6	a-HCH (a-BHC)	2.00E+00	1.06E-05	4.35E-04	3.8	3.09
319-85-7	b-HCH (b-BHC)	2.40E-01	7.43E-07	3.05E-05	3.81	3.1
58-89-9	g -HCH (Lindane)	6.80E+00	1.40E-05	5.74E-04	3.73	3.03
77-47-4	Hexachlorocyclopentadiene	1.80E+00	2.70E-02	1.11E+00	5.39	5.3
67-72-1	Hexachloroethane	5.00E+01	3.89E-03	1.59E-01	4	3.25
193-39-5	Indeno(1,2,3-cd)pyrene	2.20E-05	1.60E-06	6.56E-05	6.65	6.54
78-59-1	Isophorone	1.20E+04	6.64E-06	2.72E-04	1.7	1.67
7439-97-6	Mercury	—	1.14E-02	4.67E-01	—	—
72-43-5	Methoxychlor	4.50E-02	1.58E-05	6.48E-04	5.08	4.99
74-83-9	Methyl bromide	1.52E+04	6.24E-03	2.56E-01	1.19	1.02
75-09-2	Methylene chloride	1.30E+04	2.19E-03	8.98E-02	1.25	1.07
95-48-7	2-Methylphenol	2.60E+04	1.20E-06	4.92E-05	1.99	1.96
91-20-3	Naphthalene	3.10E+01	4.83E-04	1.98E-02	3.36	3.3
98-95-3	Nitrobenzene	2.09E+03	2.40E-05	9.84E-04	1.84	1.81
86-30-6	N-Nitrosodiphenylamine	3.51E+01	5.00E-06	2.05E-04	3.16	3.11
621-64-7	N-Nitrosodi-n-propylamine	9.89E+03	2.25E-06	9.23E-05	1.4	1.38
1336-36-3	PCBs	—	—	—	5.58	5.49
87-86-5	Pentachlorophenol	1.95E+03	2.44E-08	1.00E-06	5.09	—
108-95-2	Phenol	8.28E+04	3.97E-07	1.63E-05	1.48	1.46
129-00-0	Pyrene	1.35E-01	1.10E-05	4.51E-04	5.11	5.02
100-42-5	Styrene	3.10E+02	2.75E-03	1.13E-01	2.94	2.89
79-34-5	1,1,2,2-Tetrachloroethane	2.97E+03	3.45E-04	1.41E-02	2.39	1.97
127-18-4	Tetrachloroethylene	2.00E+02	1.84E-02	7.54E-01	2.67	2.19
108-88-3	Toluene	5.26E+02	6.64E-03	2.72E-01	2.75	2.26
8001-35-2	Toxaphene	7.40E-01	6.00E-06	2.46E-04	5.5	5.41
120-82-1	1,2,4-Trichlorobenzene	3.00E+02	1.42E-03	5.82E-02	4.01	3.25
71-55-6	1,1,1-Trichloroethane	1.33E+03	1.72E-02	7.05E-01	2.48	2.04
79-00-5	1,1,2-Trichloroethane	4.42E+03	9.13E-04	3.74E-02	2.05	1.7
79-01-6	Trichloroethylene	1.10E+03	1.03E-02	4.22E-01	2.71	2.22
95-95-4	2,4,5-Trichlorophenol	1.20E+03	4.33E-06	1.78E-04	3.9	—
88-06-2	2,4,6-Trichlorophenol	8.00E+02	7.79E-06	3.19E-04	3.7	—
108-05-4	Vinyl acetate	2.00E+04	5.11E-04	2.10E-02	0.73	0.72
75-01-4	Vinyl chloride	2.76E+03	2.70E-02	1.11E+00	1.5	1.27
108-38-3	m-Xylene	1.61E+02	7.34E-03	3.01E-01	3.2	2.61
95-47-6	o-Xylene	1.78E+02	5.19E-03	2.13E-01	3.13	2.56
106-42-3	p-Xylene	1.85E+02	7.66E-03	3.14E-01	3.17	2.59

Source: United States Environmental Protection Agency. 1996. Soil Screening Guidance: Technical Background Document. EPA/540/R-95/128 (http://www.epa.gov/superfund/health/conmedia/soil/tox.htm)

CAS = Chemical Abstracts Service

Kow = Octanol/water partition coefficient

Koc = Soil organic carbon/water partition coefficient

Provincial Guidance on Contaminated Sites:

Alberta	Alberta Environment, 2009. Alberta soil and groundwater rememdiation guidelines (http://environment.alberta.ca/777.html).
British Columbia	British Columbia Ministry of Environment, 2009. CSR/Land remediation website: www.env.gov.bc.ca/epd/remediation/
Manitoba	Government of Manitoba, 2009. The Contaminated Sites Remediation Act. (http://web2.gov.mb.ca/laws/statutes/ccsm/c205e.php)
Northwest Territories	NWT Department of the Environment and Natural Resources, 2007. Contaminated Sites on Federal Land (http://www.federalcontaminatedsites.gc.ca/general_generale/factsheet_feuillet-eng.aspx).
Nunavut	Government of Nunavut, Department of Sustainable Development, Environmental Protection Service. 2002. Environmental Guideline for Site Remediation. (http://www.gov.nu.ca/env/site.pdf).
Nova Scotia	Nova Scotia Department of Environment, Energy and Forestry, 1996. Guideline for Management of Contaminated Sites in Nova Scotia (http://www.gov.ns.ca/nse/contaminatedsites/docs/ContaminatedSiteManagementGuidelines.pdf).
New Brunswick	Government of New Brunswick, Department of Environment and Local Government, 2003. Guideline for the Management of Contaminated Sites (http://www.atlanticrbca.com/data_eng/nb_guideline_v2.pdf).
Newfoundland	Government of Newfoundland and Labrador, Department of Environment and Conservation. 2004. Guidance Document for the Management of Impacted Sites. (http://www.env.gov.nl.ca/env/Env/pollprev/waste_manag/Guidance%20Doc%20v.1.2%20External.pdf).
Ontario	Government of Ontario, Ministry of the Environment, 1997. Guidelines for Use at Contaminated Sites in Ontario. http://www.ene.gov.on.ca/envision/land/decomm/index.htm
Prince Edward Island	Prince Edward Island Department of Technology and Environment. 2006. Petroleum Hydrocarbon Remediation Regulations and Contaminated Sites Registry Regulations (http://www.atlanticrbca.com/eng/pei_regulations.html)
Quebec	Government of Quebec, Department of Environment. 2002. Soil Protection and Rehabilitation of Contaminated Sites (http://www.mddep.gouv.qc.ca/sol/inter_en.htm.)
Saskatchewan	Saskatchewan Petroleum Industry/Government Environmental Committee, 2000. Saskatchewan Upstream Petroleum Sites Remediation Guideline (http://www.er.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=3891,3620,3384,5460,2936,Documents&MediaID=5006&Filename=PDB+ENV+07+-+SPIGEC4+Site+Remediation.pdf).
Yukon	Government of Yukon, Department of Environment, 1995. Yukon State of the Environment Report Government of Yukon, Department of Environment, 2000. Yukon State of the Environment Interim Report. (http://environmentyukon.gov.yk.ca/monitoringenvironment/stateenvironment.php)

Species at Risk References (relevant to Tab #6 "Receptors & Exposure")

BCMWLAP. 2005. Endangered Species and Ecosystems in British Columbia. Provincial Red and Blue lists. Ministry of Sustainable Resource Management and Water, Land and Air Protection. (http://srmwww.gov.bc.ca/atrisk/red-blue.htm)

Environment Canada. 2005. Species at Risk website (http://www.cws-scf.ec.gc.ca/theme.cfm?lang=e&category=12).

Federal Species at Risk Act. 2002. SCHEDULE 1 (Subsections 2(1), 42(2) and 68(2)) List of Wildlife Species at Risk (http://www.sararegistry.gc.ca/species/schedules_e.cfm?id=1)

Government of Canada. 2002. Species at Risk Act (http://www.sararegistry.gc.ca/approach/act/default_e.cfm).

Government of Canada. 2001-present. Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (http://www.sararegistry.gc.ca/sar/assessment/default_e.cfm).

Provincial Spills Databases:

For New Brunswick, Nova Scotia, Newfoundland, Manitoba, Quebec, British Columbia: Department of National Defence. 1999-2007. National Defence and Canadian Forces Spills (http://www.army.forces.gc.ca/cfb_gagetown/english/bservices/emergency/index.asp_).

Government of NWT, Department of Environment and Natural Resouces. 1971. NWT Hazardous Materials Spill Database. (http://www.enr.gov.nt.ca/_live/pages/wpPages/Hazardous_Materials_Spill_Database.aspx)

Government of Ontario, Ministry of the Environment. 1988. Ontario Spills (http://www.ene.gov.on.ca/en/emergency/index.php).

Additional References Cited in the Scoring Worksheets

Arnot JA, Gobas FA. 2006. A review of bioconcentration factor (BCF) and bioaccumulation factor (BAF) assessments for organic chemicals in aquatic organisms. Environ Rev 14(4):257-297.

Canadian Council of Ministers of the Environment, 1997. Guidance Document on the Management of Contaminated Sites in Canada.

Canadian Council of Ministers of the Environment, 1999. Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Available at http://ceqg-rcqe.ccme.ca/.

Canadian Council of Ministers of the Environment. 2001. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Introduction. Updated. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg. Available at www.ceqg-rcqe.ccme.ca/download/en/317/.

Canadian Council of Ministers of the Environment (CCME). 2008. National Classification System for Contaminated Sites Guidance Document. Available at http://www.ccme.ca/assets/pdf/pn_1403_ncscs_guidance_e.pdf

Contaminated Sites Management Working Group (CSMWG), 2005. Taking Action on Federal Contaminated Sites: An Environmental and Economic Priority Available at https://www.ec.gc.ca/etad/csmwg/pub/taking_action/en/toc_e.html

Environment Canada, 1999. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Available at http://www.ccme.ca/assets/pdf/sedqg_protocol.pdf.

Environment Canada, 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Available at http://www.ccme.ca/assets/pdf/wqg_aql_protocol.pdf.

Environment Canada, 2002. Contaminated Sites Remediation Framework (CSRF)-Environment Canada. This is one in a series of Technical Assistance Bulletins (TABs) prepared by Environment Canada-Ontario Region for Federal Facilities operating in Ontario. Available at http://www.on.ec.gc.ca/pollution/ecnpd/tabs/tab14-e.html

Environment Canada and Ministère du Développement durable, de l'Environnement et des Parcs du Québec. 2008. Criteria for the Assessment of Sediment Quality in Quebec and Application Frameworks: Prevention, Dredging and Remediation. (www.planstlaurent.qc.ca/archives/articles/2008/20080409_sediments_e.html)

Gobas FA, Morrison HA. 2000. Bioconcentration and biomagnification in the aquatic environment. In: Boethling RS and Mackay D, editors. Handbook of property estimation methods for chemicals, environmental and health sciences. Boca Raton (FL): CRC Press. p. 189-231.

Government of Canada, 2008. Federal Contaminated Sites. Available at http://www.federalcontaminatedsites.gc.ca/links_liens/index-eng.aspx

Habitat Management Program, Fisheries and Oceans Canada. 2007Practitioner's Guide to the Risk Management Framework for DFO Habitat Management Staff, Version 1.0.

Health Canada, 1999. Summary of Information Critical to Assessment of "Toxic" under CEPA1999. Available at http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/2_ethoxyethanol/summary-resume-eng.php.

APPENDIX M: FCSAP EXPERT SUPPORT AND THIRD-PARTY PEER REVIEW OF KIH CHAPTERS I–V

Health Canada Santé Canada

Environmental Health Programme, RAPB
180 Queen St. W., 10th Floor
Toronto, Ontario M5V 3L7

June 18, 2010

Hillary Knack
Ecosystem Management Adviser
Rideau Canada National Historic Site of Canada, Parks Canada
34a Beckwith Street South
Smith Falls, Ontario K7A 2A8

Dear Ms. Knack,

Subject: Peer Review Comments for Kingston Inner Harbour

Health Canada received and reviewed the April 2010 draft Environmental Sciences Group human health risk assessment (HHRA) for the Kingston Inner Harbour, titled "*Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment*" as part of our role as an Expert Support Department under the Federal Contaminated Site Program (FCSAP). The review was completed to ensure that the HHRA was done in a manner that is consistent with Health Canada guidance, and the Detailed Quantitative Risk Assessment (DQRA) checklist was used to highlight all comments from our review.

Please note that a cursory review of relevant information from Chapters 1 (Literature Review) and 2 (Spatial Distribution of Contaminants in Sediments of the Kingston Inner Harbour) was also completed.

Staff from Health Canada's Contaminated Sites Program would like to thank Parks Canada for your consideration of human health risks and collaboration regarding Park Canada's Ontario FCSAP contaminated sites. We value our relationship with you, and will continue to provide you with expert support on human health risks under the FCSAP.

Please contact the undersigned if you have any questions with respect to this letter or human health risk associated with contaminated site management at this or any other federal site.

Sincerely,

H. Jones-Otazo

Heather Jones-Otazo
Health Risk Assessment & Toxicology Specialist

cc: Dan Roumbanis, Rui Fonseca, Shawn Michajluk, Environment Canada
Sara Eddy, Department of Fisheries and Oceans

HEALTH CANADA

Checklist for Peer Review of Complex Human Health Risk Assessment (HHRA) for Federal Contaminated Sites in Canada

The purpose of this Checklist is to provide a structured and consistent framework for undertaking such peer reviews. This Checklist is intended to complement, and be completed with reference to, Health Canada's guidance on the conduct of HHRA in Canada (www.hc-sc.gc.ca/ewh-semt/contamsite/risk-risque_e.html) as well as other Health Canada Guidance documents.

ACRONYMS

In order to keep the Checklist to a reasonable length, numerous acronyms and abbreviations have been employed throughout this document. Acronyms employed herein are as follows:

AEC	Area of Environmental Concern
APEC	Area of Potential Environmental Concern
CALA	Canadian Association Laboratory Accreditation
CCME	Canadian Council of Ministers of the Environment
CEQG	Canadian Environmental Quality Guidelines
CEAA	Canadian Environmental Assessment Act
CEM	conceptual exposure model
CSM	conceptual site model
CSA	Canadian Standards Association
CWS-PHC	Canadian Wide Standards - Petroleum Hydrocarbon Compounds (CCME guidance)
DQRA	Detailed Quantitative Risk Assessment
DRA	detailed risk assessment
ESA	environmental site assessment
ESI	environmental site investigation
HI	hazard index (sum of HQs)
HQ	hazard quotient
HHRA	human health risk assessment
IAQ	indoor air quality
INAC	Indian and Northern Affairs Canada
IRIS	Integrated Risk Information System
NOAEL	No observed adverse effect level
PAH	Polycyclic Aromatic Hydrocarbons
PQRA	Preliminary Quantitative Risk Assessment
QA/QC	quality assurance/quality control
RA	risk assessment
RL	reporting limit
RPD	relative percent difference
RSD	relative standard deviation (standard deviation divided by mean), same as coefficient of variation)
SF	slope factor
SSRA	site specific risk assessment
TC	tolerable concentration
TRV	toxicity reference value
UR	unit risk
USEPA	US Environmental Protection Agency
VOC	volatile organic compound
WHO	World Health Organization

Name of Contaminated Site:	Kingston Inner Harbour, Ontario
Report Title:	Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment
Report Date:	April 2010
Date Reviewed:	June 18, 2010
Report Author:	Environmental Sciences Group, Royal Military College, Kingston, Ontario
Peer Reviewed By:	Heather Jones-Otazo

SUMMARY OF ALL MAJOR COMMENTS:
1.0 PURPOSE, OBJECTIVES AND BACKGROUND
Have the purpose, objectives, scope and rationale for the risk assessment been described?
The objective of the risk assessment is clear, but it is unclear how the results of the human health risk assessment (HHRA) will be used in the overall contaminated site management process. Further, the intended complexity of the HHRA appears to be a detailed quantitative risk assessment (DQRA) which is intended to support risk management decisions at the site, however many assumptions were made to be consistent with a very conservative, preliminary quantitative risk assessment (PQRA) have been made. Some of the conservative assumptions do not appear to be consistent with the complexity of the available data and will provide an overestimate of exposure and potential risk. If the HHRA is intended to support risk management decisions, it is suggested that more realistic assumptions be used and that the appropriate guidance be applied.
2.0 PROBLEM FORMULATION
Has the site contamination been adequately characterized, and have potential exposure pathways and potential receptors been synthesized to develop a comprehensive conceptual site and exposure model?
Based on information reviewed by HC for this site, the contractor appears to have adequately characterized the site contamination, most potential exposure pathways, and most potential receptors. A conceptual site model has been developed, but could be further refined. Please provide further information on the background reference location selected for fish analyses, on the COPC screening process, and on the commercial fishery in the Kingston Inner Harbour. Please provide additional rationale regarding the selection of receptors for the site, and whether there are operable exposure pathways for potential oral and dermal exposure to contaminated sediment.
3.0 EXPOSURE ASSESSMENT
Have correct and statistically valid site exposure concentrations been incorporated in the risk assessment?
Adequate and statistically valid site exposure concentrations have been incorporated into the risk assessment for most parameters. However, exposure to sport fish assumed maximum concentrations despite a large amount of data available for the fish (n=23-81), which is a very conservative approach. It is suggested that the Contractor identify whether there are sufficient data to use a more statistically valid exposure concentration for fish tissue concentrations or whether additional sampling is required in this area in order to obtain a more representative exposure

concentration.
Is the quantitative fate and transport model appropriate for the site and available data? Has the model been calibrated with site data and was a sensitivity analysis conducted?
This section is not applicable to this HHRA.
Were the receptor characteristics science-based and supportable? Were assumptions on exposure reasonable based on the site conditions and common risk assessment practice?
The receptor characteristics were mostly science-based, supportable, and based on site conditions and common risk assessment practice. Although the PQRA provides a consumption rate for fish, a more site-specific sport fish consumption rate would be more applicable and relevant for this HHRA. This value is available from the Ontario MOE, and is suggested for exposure calculations.
Are exposure estimation calculations adequately described and scientifically supported?
Exposure estimation calculations have been adequately described and scientifically supported. Please consider the possible existence of microenvironments at the site under current and future site use.
4.0 TOXICITY ASSESSMENT
Have appropriate toxicity reference values been selected for each chemical?
Appropriate toxicity reference values have been selected for each chemical. Please note that Health Canada does not support use of the USEPA slope factor for PCBs, and use of the USEPA slope factor for DDT is not recommended. Interim draft guidance on lead is available from Health Canada which suggests use of a different TRV.
5.0 RISK CHARACTERIZATION
Is the risk characterization for all chemicals and exposures appropriate for the site and are uncertainties assessed?
The high degree of conservatism of the HHRA may not be conducive for remedial/risk management decisions. Suggestions on ways to improve realism in the HHRA have been provided. Separate risk estimates for exposures to contaminants via suspended sediments and sport fish consumption may be useful for risk management purposes. PCB congener-specific analyses could be completed at the site should further assessment be required. Elements of the uncertainty discussion could be expanded.
6.0 RISK MANAGEMENT
Will proposed risk management options address the source(s) of unacceptable risk, if necessary?
Recommendations or risk management options have not been provided for the site, other than indicating there may be a need to revisit fish consumption advisories for the area. The purpose of an apparent recalculation of fish consumption advisories in the report is not clear.
7.0 OVERALL COMMENTS
Provide comments and recommendations on adequacy of the risk assessment.
Overall, the HHRA was completed in a manner that is generally consistent with current HC guidance and is considered acceptable. However, the report makes key decisions based on very conservative assumptions more suitable for a PQRA than a DQRA. Please consider improving the level of realism in the HHRA in order for conclusions to be conducive for risk management decisions.

QUERY		Page in HHRA	Comments
[redacted]			
Have the purpose, objectives, scope and rationale for the risk assessment been described?			
The objective of the risk assessment is clear, but it is unclear how the results of the human health risk assessment (HHRA) will be used in the overall contaminated site management process. Further, the intended complexity of the HHRA appears to be a detailed quantitative risk assessment (DQRA) which is intended to support risk management decisions at the site, however many assumptions were made to be consistent with a very conservative, preliminary quantitative risk assessment (PQRA) have been made. Some of the conservative assumptions do not appear to be consistent with the complexity of the available data and will provide an overestimate of exposure and potential risk. If the HHRA is intended to support risk management decisions, it is suggested that more realistic assumptions be used and that the appropriate guidance be applied.			
Is the purpose of the risk assessment clear?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 4 IV-1	The report states that the objective of the HHRA was to assess the potential human health risks associated with exposure to contamination in the Kingston Inner Harbour during recreational use of the harbour. Please clarify the purpose with respect to the use of the results of the HHRA in the overall contaminated site management
Is the scope and complexity of the risk assessment clear?	☐ **YES** ■ **NO** ☐ **N/A**		The scope is clear, but the complexity The HHRA appeared to be conducted at the detailed quantitative risk assessment (DQRA) level, based on the variety of environmental media sampled, the quantity of data collected, the statistics sometimes used to represent chemical concentrations, characterization of the site and of its receptors, and because the results are being used to draw risk management conclusions. It is noted that Health Canada guidance on preliminary quantitative risk assessment (PQRA) was consulted, which is a more conservative guidance document, designed for standardizing assessments or the purpose of ranking sites. Please refer to Table 1 in PQRA (2009) for more information distinguishing PQRA from Please consult Health Canada's draft DQRA guidance (available on the IDEA website or by emailing cs-sc@hc-), as this will be more applicable for an assessment of this complexity and for risk management

Does the report indicate who currently owns the site, or whether there are plans for divestiture of the site and to whom? If the site is not federally owned, does the report indicate the scope of federal responsibility for management of the site?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1; I-2; Fig 2	Sections of the Inner Harbour are under the jurisdiction of Parks Canada and Transport Canada, while the adjacent lands are owned by the City of Kingston, Department of National Defence, Parks Canada and various private owners.
Has the site investigation report that supplied the data for the risk assessment been reviewed by a qualified professional?	■ **YES** ☐ **NO** ☐ **N/A**		Data have been reviewed by the ESG RMC group, as well as by other qualified
Have previous site investigations been conducted and have they been adequately summarized? Has the extent to which each previous report is relied upon been described?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1	ESG reviewed existing data available for the site, and supplemented it with Previous studies completed at the site are summarized in Chapter 1.
Does the report include a description of the site? Are both current and historical land uses of the site and surrounding land described?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1; III; 6.	
Has the site been adequately described in terms of physical setting by maps and site plans?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1	A map showing the exact boundaries of the upper and lower Kingston Inner Harbour would be helpful. Further, it would be helpful if the exact site boundaries under assessment were further clarified in Chapter 4 (ie. within

Has the site contamination been adequately characterized, and have potential exposure pathways and potential receptors been synthesized to develop a comprehensive conceptual site and exposure model?
Based on information reviewed by HC for this site, the contractor appears to have adequately characterized the site contamination, most potential exposure pathways, and most potential receptors. A conceptual site model has been developed, but could be further refined. Please provide further information on the background reference location selected for fish analyses, on the COPC screening process, and on the commercial fishery in the Kingston Inner Harbour. Please provide additional rationale regarding the selection of receptors for the site, and whether there are operable exposure pathways for potential oral and dermal exposure to contaminated sediment.

Are all relevant site characteristics documented?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1 and 2	Sediment characteristics are addressed in Chapter 2. Other site characteristics are documented in Chapter 1 and 4.
Have all relevant media been investigated and have other data (*e.g.*, physical properties, hydrogeological information) needed for risk assessment been presented?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4	Sediment, surface water and sport fish have been investigated in the HHRA.
Have contaminant concentrations and supporting information for each relevant medium been adequately documented?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4: IV-4 to IV-9	Supporting information has been documented for sediment, surface water

Were sufficient samples collected from known/suspected locations to adequately characterize the site with respect to the likely maximum concentration? Where warranted, were representative data used for estimation of statistical parameters (or probability distributions) for the site, or applicable parts of the site?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4: IV-8	It appears that sufficient sediment, fish and surface water data existed to calculate a 95%UCL. Maximum fish concentrations were used as the exposure point concentration (EPC), with the rationale that "all calculations in this risk assessment are meant to incorporate the most conservative estimates of risk." Assumptions made in this HHRA were very conservative (consistent with a PQRA), however, where there are sufficient data, use of a 95%UCL would provide more accurate estimates of potential exposure. If very conservative risk estimates are retained, conclusions of this assessment could only indicate whether further risk assessment work is required at the site, and may not be conducive for basing remedial/risk management decisions. It is recommended that the Contractor identify whether more realistic estimates of exposure are appropriate based on
Have areas of contamination been delineated spatially, both horizontally and vertically?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 2	Health Canada completed a cursory review of Chapter 2, and it appears that sediment contamination has been horizontally and vertically delineated.
Did the list of contaminants that were selected for analysis include all those typically associated with the historical and current uses of the site and their potential degradation products?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1	The historical land use included shipbuilding. Antifouling paints sometimes contain tributyltin, which is relatively persistent and can bioaccumulate. Has the possible presence of tributyltin compounds been
Was the compositing of samples avoided and were the samples that were analyzed discrete samples?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 2: II-5	Fish samples were discrete. Some compositing of sediment samples was performed by ESG staff – a composite sample of 3 different grab samples was collected at each sediment sampling location. ESG indicates that sediment samples were collected by ESG according to standard practice.
Are borehole logs and details of the monitoring well installations available in ESA reports, where applicable?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 2; App C	Soil was not sampled at the site. The report did include the sediment sampling site location, date, depth and GPS coordinates for all sediment samples
Are details available of both the sampling and analytical testing quality assurance and quality control measures employed, and was the QA/QC acceptable?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 3; App D	QA/QC information for fish data was provided in Chapter 3 Appendix D. QA/QC data for sediment were not
Are details of sampling methodologies and chemical analysis protocols available (in ESA reports) and did they follow a standard method?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 2: II-5	The sediment sampling methodology is described, and is stated to have been collected according to standard practice. Sampling methods for surface water and fish were not described, thus it is not known whether they followed a standard

Were the chemical analyses completed by a laboratory that was accredited in accordance with the requirements of CALA and/or the ISO 17025 Standard?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4: IV-3	Samples collected by ESG were analysed by laboratories accredited by
Does the report include laboratory Certificates of Analysis or are they available (in ESA reports)?	☐ **YES** ■ **NO** ☐ **N/A**		Lab certificates of analysis were not
Was the current and potential future land use identified (*e.g.*, residential, parkland, commercial, industrial, etc.)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 1: III-11 to III-13	Current and potential future land use was described for the areas surrounding the harbour. Current use of the harbour is defined as recreational, including swimming and sport fishing. Please identify whether future site use is likely
Were all COPCs screened using CCME guidelines; or if guidelines other than CCME were used, was their use appropriate?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4: IV-3	Upstream reference site concentrations were also used to screen COPCs, as were Ontario Ministry of the Environment
Were COPCs screened using the maximum measured on-site concentrations?	■ **YES** ☐ **NO** ☐ **N/A**		
Was the screening process transparent and were screening guidelines used correctly?	■ **YES** ☐ **NO** ☐ **N/A**		
Were chemicals whose detection limit was greater than the screening guidelines screened out of the risk assessment?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-7	Detection limits for silver, cobalt and PCBs in surface water samples were higher than the screening criteria used. Please address this discrepancy, and consider carrying these COPCs forward in the risk assessment.
If chemicals were screened out in previous site investigations, was there sufficient information provided in the HHRA to evaluate whether the screening was conducted appropriately and correctly?	☐ **YES** ☐ **NO** ■ **N/A**		
If chemicals were screened out for reasons other than comparison to screening guidelines, were the reasons for exclusion adequately justified and referenced (including rationale for exclusion of naturally occurring innocuous chemicals, and essential nutrients)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-6	Aluminum in surface water was screened out, and appropriate rationale

If chemicals were screened out because their concentrations fell within background levels, were background concentrations determined appropriately and used correctly?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-8 and IV-9	a) Fish concentrations were screened using background concentrations. Please provide additional rationale for the selection of the ESG fish background location. It is specified as "north of Belle Island and east of the Great Cataraqui Marsh." The area described appears to be close to the impacted area, and it is not clear whether the fish's habitat range may include both the impacted area and the ESG background area. Please highlight the precise ESG background sampling area on a map, and provide further rationale as to its selection. b) Please explain why lead and zinc were screened in as COPC in fish when measured maximum concentrations were well within background c) Table IV-6 shows that maximum measured arsenic concentrations in the impacted area were 0.2 mg/kg, but a "*" states that it was "a measurable trace amount." Please state what exactly is meant by the *, and what kind of uncertainties exist regarding the arsenic in fish data. Further, please discuss whether the arsenic in fish is likely found as organic or inorganic arsenic, as this has implications for the risk assessment.
Have all relevant receptor groups been identified (*e.g.*, fishers, hikers, commercial workers, industrial workers, First Nations)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-9	a) The commercial fishery is described as being within the Kingston Inner Harbour, but is not included in the impacted area. Please show the exact location/area of the commercial fishery on a map, and consider whether the commercial fish habitat range would be sufficiently large to include contributions from the impacted area. b) The report describes use of the site by people canoeing and rowing, by sport fishers, and by swimmers. Please state in the report whether a receptor who both swims and eats sport fish from the Harbour is considered in the HHRA. Further, please describe whether the selection of receptors is protective of the people canoeing and rowing. A conceptual site model including all of the ways in which each receptor is potentially exposed to sediment would be helpful (as per for example, Figure 1 in the Golder, 2010 sediment report prepared for Health Canada (provided to Parks Canada with these comments).
Have all relevant receptor age groups been identified (*e.g.*, infant, toddler, child, teen, adult)?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 4; IV-9	Please identify whether teenaged and senior receptors should be included.

If relevant, have all potentially-sensitive receptor population groups been identified (e.g., children, the elderly, women of child-bearing age/pregnant women, First Nations communities)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-16	Young children and women of childbearing age are also implicitly included through the selection of the more conservative MeHg TRV of 2x10-4 mg/kg-d and age-specific Zn
Have all relevant direct and indirect exposure pathways been considered?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 4; IV-11	a) Direct ingestion and dermal exposure to bulk dry sediments were not explicitly assessed. It is not clear in the text whether potential direct exposures to bulk dry sediments (such as by exposure at a beach) are possible; please clarify. Please also expand in Table IV-8 on why direct ingestion of sediment is considered only possible unless via intentional ingestion (for example, unintentional soil ingestion is common). For example, if children play in the shallow water, they would be exposed to sediment on their hands, and likely have some incidental ingestion. b) Note that while the risk assessment described the assessment of direct exposure to sediment while swimming, this should more appropriately be considered indirect exposure to sediment via ingestion of and dermal exposure to suspended Consider the use of an estimate of 1-1.5 mg/day for ingestion of suspended sediments (assessed in this HHRA), and a bulk sediment ingestion rate of 100-200 mg/day (not assessed in this HHRA). Dermal exposure to suspended sediment could also be considered essentially negligible, and sediment-specific dermal adherence/absorption factors from Schoaf (2005) could be used to estimate dermal exposure to bulk sediments (not assessed in this HHRA). For more information on this, please consult Health Canada. c) Please identify whether direct exposure pathways to dry bulk sediment are operable exposure pathways and if so, add them to
Have potential contaminant release mechanisms been described (*e.g.*, volatilization, fugitive dust emission, surface runoff/overland flow, leaching to groundwater, tracking by humans/ animals, biogenic soil gas generation and radioactive decay)?	■ **YES** ☐ **NO** ☐ **N/A**		Contact with suspended sediment in surface water while swimming, and
Have potential contaminant transport mechanisms been described (*e.g.*, diffusion, advection, sorption, bioaccumulation, biomagnification, biodecay)?	■ **YES** ☐ **NO** ☐ **N/A**		

For those pathways that were excluded, was their exclusion adequately justified?	☐ YES ☐ NO ■ N/A	Chp 4; IV-11	It is not clear in the text whether potential direct exposures to bulk dry sediments (such as by exposure at a beach) are included in the risk assessment or plausible at the site; please clarify. See above.
Was a conceptual site model which identifies contamination sources and associated COPCs, receptor groups, critical receptors, and potential exposure pathways provided?	■ YES ☐ NO ☐ N/A	Chp 4; IV-12	The conceptual model could have specified that dermal contact and ingestion occurs via suspended sediment in surface water.
Is adequate information available to characterize the sources, exposure pathways, receptors and receptor exposures?	■ YES ☐ NO ☐ N/A		

Have correct and statistically valid site exposure concentrations been incorporated in the risk assessment?

Adequate and statistically valid site exposure concentrations have been incorporated into the risk assessment for most parameters. However, exposure to sport fish assumed maximum concentrations despite a large amount of data available for the fish (n=23-81), which is a very conservative approach. It is suggested that the Contractor identify whether there are sufficient data to use a more statistically valid exposure concentration for fish tissue concentrations or whether additional sampling is required in this area in order to obtain a more representative exposure concentration.

Was the sampling design appropriate given the nature of the data, the hypothesis on contaminant distribution across the site, and site characterization objectives?	☐ YES ☐ NO ■ N/A		Health Canada completed a cursory review of Chapter 2 (sediment), and the sampling design for sediment appeared rigorous. Fish concentration data were gathered from the Ministry of the Environment's (MOE) Sport Fish Contaminant Monitoring Program, and supplemented with ESG-sampled fish from the harbour south of Belle Island Park. Information was not provided on the sampling design for surface water; please include in this in the Please note that fish data from the MOE was from 1999 and 2002, and that more recent data may be available. Please consult the MOE Sport Fish Contaminant Monitoring Program directly for more
When statistical analyses are performed to calculate exposure concentrations, are the data from a single population?	■ YES ☐ NO ☐ N/A		
Have appropriate distributional tests and statistical methods been used for the given data distribution?	■ YES ☐ NO ☐ N/A		The USEPA ProUCL software was used to calculate the 95%UCL for media
Have appropriate methods been used to infer values when the analytical results were non-detect?	☐ YES ☐ NO ■ N/A	Chp 2; II-6; Chp 4	The report states that sediment concentrations below the detection limit were replaced with a value equal to half the detection limit. Please clarify how non-detects were treated for fish and surface

Was an appropriate exposure site concentration used? If a statistic other than the maximum concentration was used for exposure site concentrations in a HHRA, is a statistical analysis of the data presented and is the selected statistic (mean, upper confidence limit of the mean, specified percentile value, etc.) appropriate and defensible given the sample size, the HHRA objectives and other factors?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 4; IV-8	Maximum measured fish concentrations were used as the exposure point concentration (EPC), with the rationale that "all calculations in this risk assessment are meant to incorporate the most conservative estimates of risk." While this is appropriate for a PQRA designed for ranking of sites under FCSAP, it is not a tool recommended for risk management decisions. Overall, the scope of this risk assessment appears to be a DQRA, not a PQRA, and it is not clear why the 95%UCL was not used for all relevant exposure media. Please identify whether a more realistic estimate of exposure could be used based on the

Is the quantitative fate and transport model appropriate for the site and available data? Has the model been calibrated with site data and was a sensitivity analysis conducted?

This section is not applicable to this HHRA.

If models were used to predict the environmental fate and transport of a contaminant from one media to another, was their use appropriate?	☐ **YES** ☐ **NO** ■ **N/A**		
Is the source of the model documented and are the main assumptions of the model explained? Are the model equations either provided or referenced?	☐ **YES** ☐ **NO** ■ **N/A**		
Have the values of all the model input parameters been justified and has a sensitivity analysis been performed? Has the uncertainty in key input parameters been qualitatively discussed?	☐ **YES** ☐ **NO** ■ **N/A**		
Have the model predicted values been calibrated to or compared against measurement data from the site? Where applicable, has a mass balance check been performed? Do the comparisons of model predictions to measured values and checks make sense?	☐ **YES** ☐ **NO** ■ **N/A**		
Is the experience and qualifications of the modeler commensurate with the complexity of the model used?	☐ **YES** ☐ **NO** ■ **N/A**		

Were the receptor characteristics science-based and supportable? Were assumptions on exposure reasonable based on the site conditions and common risk assessment practice?

The receptor characteristics were mostly science-based, supportable, and based on site conditions and common risk assessment practice. Although the PQRA provides a consumption rate for fish, a more site-specific sport fish consumption rate would be more applicable and relevant for this HHRA. This value is available from the Ontario MOE, and is suggested for exposure calculations.

Were all receptor exposure characteristics drawn from Health Canada guidance?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-14; App H Chp 4; IV-13	a) Exposure time on site (in min/day) is only used for inhalation exposures and is not relevant in any of the b) Health Canada provides generic guidance that is information. Fish consumption rates were taken from HC guidance (Richardson 1997) on the assumption that these represent an "average meal size" for sport fish. However, these are in fact fish consumption rates estimated from a 24 hour recall survey by Nutrition Canada in 1970-72, and likely are not representative of an average sport fish meal size. Further, they consumption, including marine fish, canned fish and possibly sport fish, but are not specific to sport fish overestimate sport fish consumption in the Harbour. More sites-specific information is available on sport fish consumption rates in Ontario from the MOE Sport Fish Contaminant Monitoring Program in their 2006 "Results of the 2003 Guide to Eating Ontario Sport Fish Questionnaire," which was a targeted survey at anglers questionnaire was used to estimate a consumption rate for sport fish of 24.9 g/day based on eaters only (as per Richardson, 1997), and based on an average number of 39 fish meals per year. Age-specific consumption rates are not available, but could be calculated by requesting the raw data from the MOE (please contact Satyendra Bhavsar at 416-327-5863). While a lower sample size exists for the 2003 MOE data than the Richardson (1997), it is more site-specific and would likely be more representative of sport fish consumption in the Kingston Harbour. Please consider calculating age-specific fish consumption rates based on this recent MOE data for use in the risk assessment. When using MOE rates, note that sport fish consumption should be assumed to occur throughout the year, not just for 121 days (frozen fish, ice fishing), unlike swimming exposures. Please contact Health Canada for further clarification on this issue, if needed. c) Please consider use of a "total body" exposed surface area for use in exposure calculations due to the likelihood of suspended sediment getting into bathing suits. A "total body" surface area is available from PQRA (2009). Dermal exposure would need to be summed as "total body minus hands" plus "hands."

If an alternative source of receptor characteristics was used, was this because no Canadian data or value has been published?	☐ **YES** ☐ **NO** ■ **N/A**		Professional judgment was used to estimate the number of swimming days per year (61 days), the number of days consuming sport fish (121 and 365 days), and the number of days per week swimming (7
Was the source/citation for alternative source(s) for exposure characteristics clearly documented? Were the assumptions used appropriate and adequately justified for the alternative source(s) of exposure characteristics?	■ **YES** ☐ **NO** ☐ **N/A**		
Were assumptions regarding exposure duration and exposure frequency appropriate and adequately justified?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 4; Table IV-10; App H	Exposure duration and averaging time/life expectancy were not consistent between Chapter 4 Table IV-10 and Appendix H. Please note that an exposure duration of 80 years, and a life expectancy of 80 years would be appropriate, as per most recent HC guidance (PQRA,
Have factors relating to local regions, specific cultural groups and lifestyle been considered?	■ **YES** ☐ **NO** ☐ **N/A**		Factors relating to the use of the harbour by locals for swimming and sport fish consumption have been
Are exposure estimation calculations adequately described and scientifically supported?			
Exposure estimation calculations have been adequately described and scientifically supported. Please consider the possible existence of microenvironments at the site under current and future site use.			
Were Health Canada equations used to estimate dose (*i.e.,* exposure)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; App H	
If no, were alternative equations provided, fully justified, referenced and all assumptions explained?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 4; App H	
Does the report include sample calculations for estimating dose via each exposure pathway?	■ **YES** ☐ **NO** ☐ **N/A**	App H	
Can those calculations be reproduced (*i.e.,* check the math)?	■ **YES** ☐ **NO** ☐ **N/A**	App H	
Are all equations dimensionally consistent and are all units correct?	■ **YES** ☐ **NO** ☐ **N/A**	App H	
Has 100% oral bioavailability been assumed (If a variable representing bioavailability is not included, then 100% is implicitly assumed)?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; IV-16	
If no, then were the values based on tests of on-site soil?	☐ **YES** ☐ **NO** ■ **N/A**		
Was the number of samples sufficient to support application of a site specific bioaccessibility assessment?	☐ **YES** ☐ **NO** ■ **N/A**		

If no, was the value based on scientific literature, properly referenced and defensible?	☐ YES ☐ NO ■ N/A		
If dermal absorption was a pathway evaluated, were dermal absorption factors drawn from Health Canada advice?	■ YES ☐ NO ☐ N/A	Chp 4; IV-17	
If no, was the value based on scientific literature, properly referenced and defensible?	☐ YES ☐ NO ■ N/A		
If inhalation was a pathway evaluated, was absorption by this pathway assumed to be 100% (if a variable representing inhalation bioavailability is not included, then 100% is implicitly assumed)?	☐ YES ☐ NO ■ N/A		
If no, was the value based on scientific literature, properly referenced and defensible?	☐ YES ☐ NO ■ N/A		
Has the risk assessor properly distinguished absolute bioavailability versus relative bioavailability?	☐ YES ☐ NO ■ N/A		
In calculating lifetime average daily dose for cancer risks, was the assumption of lifetime exposure included?	■ YES ☐ NO ☐ N/A	Chp 4; IV-15	
used to account for different cancer risk based on life stage of exposure?	■ YES ☐ NO ☐ N/A	Chp 4; Table IV-11	The Contractor could consider calculating a lifetime average daily dose for carcinogens by calculating and summing exposures for each life stage over an exposure duration
If exposures of less-than-chronic duration are considered, was their use appropriate and justified with references?	■ YES ☐ NO ☐ N/A		
Have any exposures been amortized using frequencies that are less than once per week?	☐ YES ■ NO ☐ N/A		
Do exposures that occur from the site match the toxicological dataset to the greatest extent possible?	■ YES ☐ NO ☐ N/A		
If persons are not spending time year round at the site, have exposure estimates to non-carcinogens been provided for the maximum exposure period?	■ YES ☐ NO ☐ N/A	Chp 4; Table IV-9	Exposure during the summer months is
Are any chemicals known to be particularly potent from an acute perspective?	☐ YES ■ NO ☐ N/A		
If so, have the acute exposures been properly amortized?	☐ YES ☐ NO ■ N/A		

3.4.4 Microenvironments			**N/A ☐**
Are there any areas of the site that are more likely to be used by human receptors than other areas or otherwise considered to be "microenvironments"?	☐ **YES** ☐ **NO** ■ **N/A**	Chp 4; IV-2	Since it appears that "the docks located near the LaSalle Causeway and Anglin Bay are often used for swimming and other water-related recreational activities," The Contractor could consider microenvironment for purposes of estimating sediment exposure.
If so, have these areas been specifically evaluated in the risk assessment?	☐ **YES** ☐ **NO** ■ **N/A**		
If no microenvironments currently exist, is it possible that future development may result in microenvironments?	☐ **YES** ☐ **NO** ■ **N/A**		Unknown. Please consider whether future development along the western shore may result in the creation of beach areas where exposure to contaminated bulk dry sediment may be possible.
If so, have these areas been specifically evaluated in the risk assessment?	☐ **YES** ☐ **NO** ■ **N/A**		
3.4.5 Alternate Exposure Estimation Methods			**N/A ☐**
Have any alternative exposure methods been used in the risk assessment?	☐ **YES** ■ **NO** ☐ **N/A**		
If so, has proper justification been provided?	☐ **YES** ☐ **NO** ■ **N/A**		
3.4.6 Probabilistic Exposure Assessment			**N/A ☐**
Has the justification for using a probabilistic exposure and risk assessment been provided?	☐ **YES** ☐ **NO** ■ **N/A**		The current RA is a deterministic
Has the probabilistic exposure and risk assessment provided justification for distributions chosen for input parameters and considered possible correlations between different input parameters?	☐ **YES** ☐ **NO** ■ **N/A**		
Has the influence of variability and uncertainty been considered separately, where possible, as part of the probabilistic exposure and risk assessment?	☐ **YES** ☐ **NO** ■ **N/A**		
Has the probabilistic exposure assessment included a sensitivity analysis?	☐ **YES** ☐ **NO** ■ **N/A**		

Have appropriate toxicity reference values been selected for each chemical?			
Appropriate toxicity reference values have been selected for each chemical. Please note that Health Canada does not support use of the USEPA slope factor for PCBs, and use of the USEPA slope factor for DDT is not recommended. Interim draft guidance on lead is available from Health Canada which suggests use of a different TRV.			
Are the selected TRVs clearly stated, with references, for each chemical and for each pathway?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; Table IV-12	
If Health Canada TRVs were not used, was it because Health Canada had no TRV for the particular COPC (see sources of TRVs in notes and list sources used in Table 1)?	☐ **YES** ■ **NO** ☐ **N/A**	Chp 4; Table IV-12	a) When HC TRVs were not available, TRVs were appropriately selected from b) HC provides tolerable daily intakes (TDIs) for both PCBs and DDT. However, an upper bound cancer slope factor from USEPA was also used for PCBs, and a slope factor from USEPA was also used for DDT, in addition to the HC TRVs. Note that Health Canada considers that carcinogenicity of PCBs is not the most sensitive endpoint for PCBs based on its mode of action, and therefore does not support use of the The report states "Health Canada has classified DDT as a human carcinogen" and cites PQRA (2009). Please note that PQRA (2009) guidance provides only a TDI of 0.01 mg/kg-d for DDT. Therefore, use of the USEPA slope factor for DDT is not recommended. c) Note that Health Canada draft interim guidance on Pb (available upon request) suggests interim use of the MOE TRV
If Health Canada TRVs were not used, was it because there is a more appropriate TRV hierarchy that should be used?	☐ **YES** ■ **NO** ☐ **N/A**		
Are any of the TRVs used extrapolated from an oral route to an inhalation route?	☐ **YES** ■ **NO** ☐ **N/A**		
If so, was it justified to complete this extrapolation?	☐ **YES** ☐ **NO** ■ **N/A**		
Are the health effects associated with each COPC and the basis for the TRV described?	■ **YES** ☐ **NO** ☐ **N/A**	Chp 4; App I	
If slope factors for carcinogens have been derived from TD_{05} or other values, were the proper conversion factors used?	☐ **YES** ☐ **NO** ■ **N/A**		
If bioavailability has been incorporated into the TRV, has this been done correctly?	☐ **YES** ☐ **NO** ■ **N/A**		
Does the toxicity data match the exposure data to greatest extent possible?	■ **YES** ☐ **NO** ☐ **N/A**		

Are there alternative TRVs available that are more specific to the route of concern from other recognized agencies that should have been considered?	☐ YES ☐ NO ■ N/A		
Are any TRVs specific to a certain age group?	■ YES ☐ NO ☐ N/A	Chp 4; Table IV-12	The TRV for MeHg for women of child bearing age and children under 12 was used. Age-specific TRVs were used for
Have any TRVs been developed *de novo*?	☐ YES ■ NO ☐ N/A		
If so, was adequate documentation provided?	☐ YES ☐ NO ■ N/A		
For genotoxic carcinogens, are TRVs for both cancer and non-cancer endpoints provided?	☐ YES ☐ NO ■ N/A		

TABLE 1: SOURCE OF TOXICITY REFERENCE VALUES *(indicate for each pathway, if different)*

	Chemical	HC?	USEPA IRIS?	WHO?		
1.	Arsenic	■ YES	■ YES	☐ YES	☐ YES (list)	**Oral (Cancer and non-cancer)**
2.	Chromium (VI)	■ YES	☐ YES	☐ YES	☐	
3.	Chromium (III)	☐ YES	■ YES	☐ YES	☐	
4.	Mercury	■ YES	☐ YES	☐ YES	☐	
5.	MeHg	■ YES	☐ YES	☐ YES	☐	
6.	Lead	■ YES	☐ YES	☐ YES	☐	
7.	Zinc	■ YES	☐ YES	☐ YES	☐	
8.	DDT	■ YES	■ YES	☐ YES	☐	**Oral (Cancer and non-cancer)**
9.	PCBs (total)	■ YES	■ YES	☐ YES	☐	**Oral (Cancer and non-cancer)**

		Page in HHRA	

Is the risk characterization for all chemicals and exposures appropriate for the site and are uncertainties assessed?

The high degree of conservatism of the HHRA may not be conducive for remedial/risk management decisions. Suggestions on ways to improve realism in the HHRA have been provided. Separate risk estimates for exposures to contaminants via suspended sediments and sport fish consumption may be useful for risk management purposes. PCB congener-specific analyses could be completed at the site should further assessment be required. Elements of the uncertainty discussion could be expanded.

Are the results of the risk assessment presented clearly including the identification of COPCs associated with unacceptable risk?	■ YES ☐ NO ☐ N/A	Chp 4; pgs IV-18 to IV-20; App H	Provision of separate hazard quotients and cancer risks for exposure contaminants via suspended sediments and sport fish consumption could be useful for risk

QUERY		Page in HHRA	
Were risk assessment calculations completed correctly (e.g. correct units) with examples provided for both threshold and non-threshold acting contaminants?	■ YES ☐ NO ☐ N/A	App H	
Where pathway specific TRVs were used, were Hazard Quotients calculated for individual exposure pathways?	☐ YES ☐ NO ■ N/A		
If a Hazard Quotient > 0.2 was used to identify acceptable risks, were background exposures adequately estimated?	☐ YES ☐ NO ■ N/A		
If exposure was adjusted for bioavailability, was the adjustment relative to that associated with the study upon which the TDI was based?	☐ YES ☐ NO ■ N/A		
Are all cancer risks greater than 1 x 10^{-5} defined as unacceptable (or as appropriate for other jurisdictions)?	■ YES ☐ NO ☐ N/A		
Where pathway-specific slope factors or unit risks exist, were the risks estimated separately?	☐ YES ☐ NO ■ N/A		
For threshold-acting chemicals and for non-cancer effects for carcinogens, were HQs assumed to be additive and summed for substances determined to have the same target organ, effect and mechanism of action?	☐ YES ☐ NO ■ N/A		
For carcinogens, have risks been summed for chemicals causing the same form of cancer in the same target organ?	☐ YES ☐ NO ■ N/A		
If carcinogenic PAHs, PCDD/PCDFs or dioxin-like PCBs were assessed, was Health Canada guidance used regarding summation of toxic equivalence factors (TEF) or potency equivalence factors (PEF)?	☐ YES ☐ NO ■ N/A		Dioxin-like PCBs are not explicitly addressed in the risk assessment. Note that PCB congener-specific analyses could be completed at the site if further
5.4 Locally-Acting Chemicals			**N/A ☐**
Were any of the COPCs considered to be locally-acting chemicals (*e.g.*, irritants such as ammonia, sulphur dioxide)? If so, were they evaluated using an appropriate exposure limit?	☐ YES ☐ NO ■ N/A		
5.5 Probabilistic Analysis			**N/A ☐**
Was a HQ of ≤ 1.0 (for threshold-acting chemicals) associated with the 95th percentile dose estimate considered to be negligible or acceptable?	☐ YES ☐ NO ■ N/A		

QUERY		Page in HHRA	
Was a risk estimate of 1:100,000 (for nonthreshold-acting chemicals) associated with the 95th percentile dose estimate considered to be negligible or acceptable?	☐ YES ☐ NO ■ N/A		
Was the uncertainty in the risk assessment addressed to the satisfaction of the reviewer?	☐ YES ■ NO ☐ N/A	Chp 4; Sectio n F	It would be helpful to discuss further uncertainties. For instance, assuming soil exposure, in terms of whether this is likely to under or over estimate exposure. For example, the assumption of a dermal adherence factors for bulk soil to estimate loading of suspended sediments may be very conservative. Further, the assumption of a bulk soil ingestion rate for ingestion of suspended sediments seems unnecessarily conservative given than an alternative is readily available (please consider the information provided in the Golder, 2010 contractor report prepared for Health Canada, provided to Parks Canada with
Were the pathways and COPCs that drive the risk estimates identified and uncertainties associated with these discussed in particular?	■ YES ☐ NO ☐ N/A	Chp 4; IV-25	Uncertainties with the fish consumption pathway were discussed briefly but could be The uncertainty introduced by the use of whole fish minus one fillet for As and Cr was
Were risks calculated for all chemicals and receptors of concern identified in the Problem Formulation?	☐ YES ■ NO ☐ N/A		Exposures and risks were calculated for a single receptor who was assumed to both swim in the harbour on a daily basis and consume a significant quantity of sport fish. Please consider whether potential risks should be calculated for additional receptors at the site, such as the rower/canoer.
Were any unusual site-related assumptions or professional judgments made earlier in the risk assessment re-iterated in the conclusions of the risk assessment?	■ YES ☐ NO ☐ N/A		The high degree of conservatism was re-iterated but an HHRA that is not realistic is not conducive to remedial/risk management decisions. Suggestions were provided above on ways to improve realism with this appropriate exposure concentrations, and more site-specific sport fish consumption
If the risk assessment focused on maximally exposed receptors and risks were deemed unacceptable, were risks to other receptors evaluated?	☐ YES ■ NO ☐ N/A		Potential risks for a single receptor who was maximally exposed were calculated. Please consider whether potential risks to other receptors such as the rower/canoer should

QUERY		Page in HHRA	Comments
Were risk estimates evaluated within the context of uncertainty and variability?	■ YES ☐ NO ☐ N/A		The high degree of conservatism of the risk assessment was clearly stated throughout, but as noted above, may not be conducive for risk management decisions. Suggestions were provided above on ways to improve

Will proposed risk management options address the source(s) of unacceptable risk, if necessary?

Recommendations or risk management options have not been provided for the site, other than indicating there may be a need to revisit fish consumption advisories for the area. The purpose of an apparent recalculation of fish consumption advisories in the report is not clear.

If any non-cancer hazard quotients exceed 0.2 or any cancer risks exceed 1 x 10^{-5}, are remedial or risk management measures proposed?	■ YES ☐ NO ☐ N/A		Other than a need to revisit the fish consumption advisories in the Cataraqui River, Belle Island Area, remedial/risk management measures have not been proposed. Chapter 5 of the report is meant to discuss these recommendations, but The last section appears to provide a re-calculation of fish consumption advisories for the area based on the results of the conservative HHRA which applied maximum measured concentrations. The purpose of this information is not clear given that the MOE calculates their advisories using a specific methodology (for consistency across Ontario), and using the most recent fish data. Note that more recent fish data than that used in the HHRA (from 1999 and 2002) may be available from the Ontario MOE Sport Fish program; please consult them directly.
Are recommendations proposed, and is the responsible agency, department or responsible person identified, if different than the client department that solicited the risk assessment?	☐ YES ■ NO ☐ N/A		Chapter 5 of the report is meant to discuss recommendations, but was not provided.
Will proposed risk management options address the source(s) of unacceptable risk, if necessary?	☐ YES ☐ NO ■ N/A		

Provide comments and recommendations on adequacy of the risk assessment.

Overall, the HHRA was completed in a manner that is generally consistent with current HC guidance and is considered acceptable. However, the report makes key decisions based on very conservative assumptions more suitable for a PQRA than a DQRA. Please consider improving the level of realism in the HHRA in order for conclusions to be conducive for risk management decisions.

QUERY	ANSWER TO QUERY		
		Page in HHRA	Comments
Is the risk assessment report complete and generally acceptable (*i.e.*, are there only minor or no issues)? If gaps or outstanding issues exist, are they insufficient or insignificant and do not preclude a generally acceptable evaluation of potential human health risk?	■ **YES** ☐ **NO** ☐ **N/A**		

SUMMARY OF ALL MINOR COMMENTS:
1.0 PURPOSE, OBJECTIVES AND BACKGROUND
2.0 PROBLEM FORMULATION
4.0 TOXICITY ASSESSMENT
5.0 RISK CHARACTERIZATION
6.0 RISK MANAGEMENT
7.0 OVERALL COMMENTS

Note: N/A = not applicable

REFERENCES

CCME (Canadian Council of Ministers of the Environment), 1993. *Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites* - Volume I: Main Report. CCME PN 1101, Volume II: Analytical Method Summaries. CCME PN 1103.

Canadian Council of Ministers of the Environment (CCME). 2006. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines [Revised].* Report CCME PN 1332, CCME, Winnipeg, MB. ISBN 13-978-1-896997-45-2.

CCME (Canadian Council of Ministers of the Environment), 1994. *Subsurface Assessment Handbook for Contaminated Sites*. CCME PN 1144.

HC (Health Canada). 2005. *Health Canada Workshops on Screening Level Risk Assessment Guidance: Summary of Comments*. Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa, ON.

HC. *Federal Contaminated Site Risk Assessment in Canada: Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA),* Version 2. Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part I: PQRA)

HC. *Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors,* Version 2.0. Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part II: TRVs)

HC. *Federal Contaminated Site Risk Assessment in Canada, Part III: Guidance on Peer Review of Human Health Risk Assessments for Federal Contaminated Sites,* Version 2.0. Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part III: Checklist)

HC. *Federal Contaminated Site Risk Assessment in Canada, Part IV: PQRA Spreadsheet Tool and User Documentation.* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part IV: PQRA Spreadsheet)

HC. *Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Complex Human Health Detailed Quantitative Risk Assessment ($DQRA_{Chem}$).* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part V: $DQRA_{Chem}$)

HC. *Federal Contaminated Site Risk Assessment in Canada, Part VI: Guidance on Detailed Human Health Radiological Risk Assessment ($DQRA_{Rad}$).* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part VI: $DQRA_{Rad}$)

HC. *Federal Contaminated Site Risk Assessment in Canada: Part VII: Manual for Environmental Site Characterization in Support of Human Health Risk Assessment.* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part VII: ESA)

HC. *Federal Contaminated Site Risk Assessment in Canada: Part VIII: Guidance for Soil Vapour Intrusion Assessment at Contaminated Sites.* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC Part VIII: VI Guidance)

HC. *Federal Contaminated Site Risk Assessment in Canada: Supplemental Guidance on Human Health Risk Assessment on Air Quality ($HHRA_{Air}$).* Contaminated Sites Division, Safe Environments Directorate, Health Canada, Ottawa. (HC $HHRA_{Air}$)

Helsel, D. 2005. *More than Obvious: Better Methods for Interpreting Nondetect Data*. Environ. Science and Technol., October 15.

US NAS (US National Academy of Sciences). 2003. Bioavailability of Contaminants in Soils and Sediments: Processes, Tools and Applications. Committee on Bioavailability in Soils and Sediments, Water Science and Technology Board, National Research Council, US NAS, The National Academy Press, Washington, DC.

PROUCL (USEPA) http://www.epa.gov/nerlesd1/tsc/software.htm

U.S. Environmental Protection Agency, 1996. *Soil Screening Guidance: User's Guide.* United States Office of Solid Waste and Publication 9355.4-23. Washington, DC, July.

US EPA (United States Environmental Protection Agency). 1997. *Exposure Factors Handbook.* EPA/600/P-95/002Fa. National Center for Environmental Assessment. Office of Research and Development. US EPA, Washington, DC. Available online at: http://www.epa.gov/ncea/pdfs/efh/front.pdf

US EPA. 1989. *Risk Assessment Guidance for Superfund, Part A*. Report 540/1-89/002.

US EPA. 2000. *Guidance for Data Quality Assessment: Practical Methods for Data Analysis*. EPA QA/G-9. QA00 UPDATE. EPA/600/R-96/084. Office of Environmental Information. US EPA, Washington, DC. Available online at: http://www.epa.gov/quality/qs-docs/g9-final.pdf

US EPA. 2002. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*. Office of Emergency and Remedial Response. OSWER 9285.6-10. US EPA, Washington, D.C. Available online at: http://www.epa.gov/oswer/riskassessment/pdf/ucl.pdf

US EPA. 2005a. *Guidelines for Carcinogen Risk Assessment*. EPA/630/P-30/001F. US EPA, Washington, DC. Available online at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=116283

US EPA. 2005b. *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens*. EPA/630/R-03/003F. US EPA, Washington, DC. Dated March 2005. Available online at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=116283

US EPA. 2008. *Children's Exposure Factors Handbook,* EPA-600-R-06-096B. US EPA, Washington, DC. September. Available online at: http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=56747

WESA. 2005. Incorporating Background Soil Quality Into Risk Assessment. Contract report to Environmental Health Assessment Services, Health Canada, Ottawa.

Environment Canada – FCSAP Expert Support Peer Review Comments

Site: Kingston Inner Harbour (Parks Canada & Transport Canada)

Report Title: *"Application of the Canada-Ontario Decision Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment"* prepared for Parks Canada by Environmental Sciences Group, April 2010.

Date Reviewed: 10 September 2010

Reviewed by: Dan Roumbanis, EC and Sara Eddy, DFO

==

Overview:

- This review was specific to Section III (Ecological Risk Assessment) of Chapter 4 (HHERA) of the aforementioned ESG report.
- In addition, a cursory review of the relevant information in Chapter 3 was conducted by EC sediment specialists.
- A separate review of the *"FCSAP Aquatic Sites Classification System (ASCS)"* draft scoring was also completed. Comments on the ASCS scoring will be provided separately.

Receptor Characterization (Section III.B. page IV-29f):

- Section III.A.2. page IV-29, second paragraph – The assessed receptor classes are mentioned, included *"piscivorous birds"*. Given the ecological importance of the upstream Cataraqui Marsh to migrant waterfowl, the chosen species (VECs) for this receptor class should also be representative of this local off-site population (as on-site receptors).
- Section III.B.1. page IV-30, first paragraph – The osprey and the great blue heron are given as the VECs for the piscivorous birds receptor class. Since ducks commonly inhabit marshland and parkland areas such as the adjacent Belle Park, please provide rationale why geese or ducks (e.g. mallards and mergansers) were not considered as VECs in this assessment.
- Section III.B.1.a. page IV-30 – It is noted that Brown Bullhead commonly burrow in the sediment, and that *"its health could potentially be greatly impacted by the sediment quality"*. It should also be noted that Brown Bullhead are more tolerant of pollution and conditions that may be limiting for other species. If sediment capping is one of the considered management options for this site, then this characteristic will be an important consideration in design of the cap and the options evaluation.
- Section III.B.1.e. page IV-32 – Justification is provided for including the mink as a piscivorous mammal VEC, although it is noted that because of the proximity to urban development *"mink populations may be unlikely in this area"*. The reasoning provided is that this conservatism would *"be protective of other piscivorous mammals"*. Given their larger home range (up to 2.8 km as noted on page IV-41), unless mink or some other like species is active within the impacted area, we recommend removing it as a VEC in this ERA.
- Section III.B.1.i. page IV-34 – The map and stinkpot turtles are known to inhabit the impacted area, as are various species of frogs. We recommend that these omnivorous amphibians be included in the quantitative assessment if appropriate toxicological data can be found.
- Section III. B.3. page IV-37 - Assessment endpoints have been selected as herbivorous mammals, piscivorous mammals, non-piscivorous birds and piscivorous birds. Please provide rationale for not selecting piscivorous fish, such as pike, as an assessment endpoint.
- Section III.B. General Comment – Where available, the structural attributes of each selected VEC should also be presented (e.g. population, density, age, status). Except for the great blue heron, and to some degree the fish, no such VEC-specific information has been presented.

Exposure Assessment (Section III.C. page IV-38f):

- Section III.C.7. page IV-42 – For consistency with the ADD equation given on page IV-39, Table IV-19 Column 3 should be Fi, not Pi. Also Column 8 should be BW, not Wt.
- Section III.C.8. page IV-43 – Table IV-20 Column 5 lists EPC values of mercury (Hg) as N/A. Please clarify if this is total Hg (including MeHg) or MeHg? If MeHg is known to be present in fish and Hg is present in fish tissue, then why was Hg not sampled here? For consistency throughout the report, you should specify if you mean Total Hg or MeHg. Also, is data available as to what % of the Total Hg is MeHg?
- Section III.C. General Comment – The shallow water depth at the impacted site, the fine-grained nature of the sediments, coupled with recreational boat traffic and local winds is known to result in sediment re-suspension of the contaminants into the water column. Is this considered in the exposure pathway analysis?
- Section III.C.9. page IV-44 – Table IV-21 Column 5 lists EPC values of mercury (Hg) as N/A. Again, please clarify if this is total Hg (including MeHg) or MeHg?
- Section III.C.9. page IV-44 – Table IV-21 provides EPC values for cattail seed consumption. Mercury is cited as N/A. Is there any established correlation between MeHg in foliage and MeHg in surface water? Also is there any evidence of seasonal flux in follicular Hg (say cattail growing season vs. sprouting)?
- Section III.C.10. page IV-44f – References Autumn 2009 sampling from the *"affected site and a reference site located approximately 2 km upriver"*. Are the subsequent EPV values presented in Table IV-22 calculated using the UCL95 from the combined site and reference data or just from the impacted site data? Please clarify.
- Section III.C.11. page IV-46 – Table IV-23 Column 5 lists calculated Average Daily Dose of Hg for receptors. Please clarify if this is total Hg (including MeHg) or MeHg?

Hazard Assessment (Section III.D. page IV-46f):

- Section III.D.1. page IV-47 – Table IV-24 Column 5 lists calculated Toxicological Reference Values (TRVs) of Hg for receptors. Please clarify if this is total Hg (including MeHg) or MeHg? Also, is this value more or less conservative than using just MeHg in the calculation?
- Section III.D.2. page IV-47 – Table IV-25 Column 5 lists Toxicity Thresholds for fish tissue specific metals COPCs. In particular it is noted that a toxicity threshold could not be found for Cr in fish tissue. One reference citing Cr in yellow perch may be relevant: "Metal Levels in Fish from the Savannah River: Potential Hazards to Fish and Other Receptors." Burger, J et al., Environmental Research Volume: 89 Issue: 1 (2002) p. 85-97.

Ecological Risk Characterization (Section III.E. page IV-49f):

- Section III.E.1. page IV-50 – Table IV-25 lists calculated Hazard Quotients (HQs) for PCBs in mink as 2.66 As mentioned under Receptor Characterization, we recommend removing mink as a VEC unless it can be confirmed to be active within the impacted area.
- Section III.E.1. page IV-50, second paragraph – Sensitivity analysis is presented assuming Fsite = 1.0 for the great blue heron and the osprey. Since these are migratory birds, the previously assumed Fsite = 0.50 is more appropriate. This would leave the HQs for the great blue heron and osprey for Hg as 0.648 and 0.574 respectively, as previously given in Table IV-28.
- Section III.E.2. page IV-51, fourth paragraph – Comparison of PCB tissue residue concentrations in the impacted area vs. the reference site is made. We note that the site PCB fish tissue concentrations are approximately 30x greater than reference using the maximum measured value. We note that although the fish sample size is > 10, no mention is made as to whether the maximum value or UCL95 was used. For calculation of the PCB toxicity threshold (Table IV-26), was the UCL95 value used?

- Section III.E.3. page IV-53, second paragraph – Reference is made to ". . . inconsistency in risk estimation for comparisons of fish tissue residue concentrations to the CTRGs, and the results of HQ calculations", which "leads to an evaluation of greater apparent risk". The objective of the ERA is to provide conclusions that are justified in relation to risk characterization. However, the subsequent conclusions reached in the risk assessment for fish (Section III.E.6 – page 55) appear to be based on the field observations of morphological abnormalities, and not on the risk assessment outcomes. Is any further analysis planned to resolve this? In DFO's Fact Sheet on the brown bullhead (http://www.dfo-mpo.gc.ca/regions/central/pub/factsheets-feuilletsinfos-ogla-rglo/brownbullhead-barbottebrune-eng.htm) it is stated that *"they seem particularly resistant to domestic and industrial pollution, as was seen in some heavily polluted streams near Montreal where the brown bullhead was the only fish species present."*
- Section III. E.3. page IV-54 - is additional analysis planned to determine the cause of the abnormalities found in Brown Bullhead and/or undertake further comparisons to other sites? Was the sample size (14 & 19 fish at the impacted and reference sites, respectively) large enough to make conclusions?

Sources of Uncertainty (Section III.F. page IV-56f):

- Section III.F.1. page IV-56 – It is noted that "reported values may not reflect the characteristics that receptors actually exhibit in KIH" and thus home range values were used to provide a conservative scenario for this ERA. A lesser degree of conservatism would be inherent if a spatially-weighted assessment were used instead to determine potential exposures based upon typical foraging ranges of birds and mammals.

Ecological Risk Assessment (Section III.G. page IV-58):

- Section III.G. page IV-59 - It is noted that Brown Bullhead have morphological abnormalities at the impacted site. Is there a link between this finding and the fish community as a whole or the site's productive capacity?

General Comments (as referenced):

- Section III.A.1. page IV-28 – For the purposes of the ERA, the stated definition of the "impacted site" is the KIH south of Belle Park and the Orchard Street Marsh. The federal properties owned by Parks Canada and Transport Canada are aquatic sites, comprising only a small portion of the Orchard Marsh. Also, the historic sources of contamination (tannery, lead smelter, etc…) are all upland from the Orchard Marsh, from where these contaminants eventually mobilized into the KIH sediments over time. As there is no apparent pathway from these KIH sediments back into the Orchard Marsh, the federal responsibility for site management would only extend to the boundaries of the federal custodians. Thus, the greater portion of the Orchard Marsh and the upland sources would likely not be eligible for FCSAP funding.
- Section III.A.2. page IV-29, first paragraph – It is stated that baseline sediment, plant and fish samples from the upstream reference sites *"have not been impacted by contamination"*. Please elaborate on this statement. Including the Ontario background concentrations in the tables would make this clearer (i.e. MOE Table 1 Full Depth Background Site Condition Standards for sediment).
- Section IV Executive Summary, page IV-iii, first paragraph – States that biota are accumulating contaminants more than those found in other areas. This implies an on-going source of contamination. Please clarify?
- Section IV Executive Summary, page IV-iii, second paragraph – Reference is made to swimming and sportfishing in the harbour. There is no evidence of swimming in the southwest portion of the KIH, which is the focus of this study.
- Section IV Executive Summary, page IV-iii, third paragraph – The exposure scenarios for swimming and consuming fish appear to be highly conservative.

- Section IV Executive Summary, page IV-iv, fourth – States that *"toxicity thresholds do not account for possible additive or synergistic effects resulting from the complex mixture of contaminants".* How does the consultant propose to quantify or address this point?
- Section IV Executive Summary, page IV-v, last paragraph – States that "management actions are needed to address risks". It is not clear how the ERA results will be used in the development of these "management actions". We presume this will be addressed in the forthcoming Chapter 5: Remediation Options Evaluation, which will provide a recommended management strategy consistent with the risks.
- Generally, the ERA is well written and appears to follow sound scientific principles. A large volume of data is presented and analysed. The selected VECs seem appropriate, except for the chosen piscivorous mammal (mink). The exposure and hazard assessments are plausible, and the conclusions seem justified in relation to the risk characterization.
- Chapter 3: Ecological Effects – Evaluation of bioaccumulation of contaminants in biota, sediment toxicity, and benthic community structure – In general, the report sections are very well written and easy to read. The text is clear and practically error-free, and we have no concern with the overall approach, methods, analyses, and interpretations. By and large, the presentation of a large amount of evidence and analyses and the conclusions made are convincing. We agree with the development of specific remediation objectives as a next step.

July 14, 2010 Project No. 09-1122-1020

Mitra Saidi, Environmental Officer
Public Works and Government Services Canada
Environmental Services, Ontario Region
Real Property, Professional & Technical Programs
4900 Yonge Street, 11th Floor
Toronto, Ontario
M2N 6A6

TECHNICAL REVIEW AND DATA GAP ASSESSMENT OF CHAPTERS 3 AND 4 OF THE RMC REPORT (DATED MARCH 2010)

Dear Ms. Saidi

This letter provides a summary of the technical review of the following documents.

Royal Military College (RMC). 2010a. *Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 3: Ecological Effects: Evaluation of Bioaccumulation of Contaminants in Biota, Sediment Toxicity and Benthic Community Structure*. Prepared by RMC Environmental Sciences Group, Royal Military College, Kingston ON. March 2010.

Royal Military College (RMC). 2010b. *Application of the Canada-Ontario Decision-Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment*. Prepared by RMC Environmental Sciences Group, Royal Military College, Kingston ON. April 2010.

General Comments

At the outset, I believe that it is worth stating that these Chapters include some of the clearest risk assessment materials that I have encountered in many years of performing external reviews of ERAs. The documents convey that the investigators have a solid understanding of the underlying technical issues, and the authors have documented the information in a manner that is readily understandable and useful for site managers.

One of the strengths of the chapters is that the uncertainties are, for the most part, well understood and described. For example, the potential environmental significance of exceeding sediment quality guidelines, and of statistical associations between sediment chemistry and responses, are conveyed in a way that strikes the appropriate balance between what is known and what is unknown. There are a few areas where I disagree with the specific language used, or in the level of uncertainty inherent in an analysis approach, but these are nuances rather than major technical flaws.

Golder Associates Ltd.
32 Steacie Drive, Kanata, Ontario, Canada K2K 2A9
Tel: +1 (613) 592 9600 Fax: +1 (613) 592 9601 www.golder.com

The report is very well written and shows the value of a thorough editorial review prior to release. There are a few minor typos, but overall the document is of high quality in terms of clarity of presentation, organization, grammar, and succinctness.

As the purpose of my review was to frame issues for the attention of Public Works and Transport Canada, I have emphasized information gaps in the course of conducting the review. Because the overall quality of the RMC work is quite high, I do not recommend that PWGSC/TC reconstruct much of the work that is presented in these chapters. Instead, it would be more beneficial to all parties to do the following:

- Address specific technical issues (identified below in text boxes for ease of identification);
- Prepare a companion document under the *Canada-Ontario Decision-Making Framework* that references the RMC work, but focuses on residual uncertainties and data gaps; and,
- Provide a more spatially explicit analysis of the risk estimates for use in decision-making (identification of potential management units, and required supplemental investigations).

A limitation of these Chapters is that conclusions are often rendered without a spatial context. The KIH water lot is a large area, and even when reduced to the area southwest of Belle Island, the contaminated sediment zone is large and complex, with heterogeneous findings. From a management perspective, it will be important to parcel the harbour into management units for which weight-of-evidence determinations can be made. The authors identify such as a next step; however, it is important that the spatially-explicit approach be conducted soon, such that key data gaps can be filled, and priorities for future study and risk management identified.

Information Gap – Spatial characterization is not the focus of the RMC report – most conclusions are rendered on a broad basis rather than parcels of sediment.

Resolution – Golder staff have already partitioned KIH into zones for which sediment substrate is assumed to be relatively consistent, and for which trends in sediment chemistry have been delineated. There are some areas (particularly along the southwest shoreline toward Kingston Marina) that have not been sampled with sufficient density to support risk management. By integrating the historical sampling data with the recent RMC material, we have identified sampling needs.

Another limitation of the RMC work is that the vast majority of the analyses are based on data collections from 2006-2009. Although this is helpful in terms of avoiding redundancy with previous site documentation (such as the Tinney [2006] thesis), there are several studies that should be combined with the recent RMC investigations to make the most from available information. As part of Golder's scope, we are currently providing this synthesis (particularly in a spatial context), and as such are attempting to glean information from RMC while also providing additional value to the broader KIH investigations.

A final general comment concerns the presentation of study conclusions. My impression is that a lot of complex and detailed information was distilled down to some very sweeping conclusions. In some places, there is danger that the risk narrative could be interpreted in too simplistic a fashion, without proper consideration of uncertainties, conservatism, and complexity of spatial responses. The authors strived to follow the framework diligently, but in reducing the weight-of-evidence to simplified categories (such as Table III-5 for the sediment quality Triad), there is potential loss of information. The narratives "potential", "possible", and "possibly different" can take on different meanings, and the management consequences of being in this "zone of uncertainty" are potentially different to different readers. Overall, while I thought that the authors did a good job of presenting uncertainty in a fair and balanced way, when it come to rendering implications for management, there was a tendency to abandon tiered risk assessment in favour of the precautionary principle.

For the remaining specific comments, there are multiple potential applications of the findings:

- Corrections to RMC Draft report – There are some specific places where some corrections could be made, although the current report quality is sufficiently high that this is not a show-stopper. In some comments below I have provided detailed comment on specific wording that I was uncomfortable with; it may not be necessary to actually edit the comment based on this discussion.
- Identification of Issues for Further Analysis – This is the main role of the review. Early on, it became apparent that there were opportunities to build upon and enhance the RMC work (i.e., clarify specific technical issues, reduce uncertainty through parallel analyses, provision of additional context) without needing to open up the draft report content. Instead, I recommend that the Golder document focus on evaluating some alternate approaches (and addition of additional information) to assess the impact on the broad study findings. This can be implemented as a revised uncertainty assessment.
- Data Gaps – Linked to the above objective is the identification of specific site-specific data needs. The most obvious need is for improved profiling of sediment quality (particularly toxicity and benthic community endpoints) south of Emma Martin Park and Molly Brant Point along the western shoreline. The RMC report evaluates the area southwest of Belle Island in considerable detail (including Parks Canada water lots); however, PWGSC/TC require decision making over a much larger area. Specific recommendations for studies in 2010 to address these gaps (numbers and positions of stations, target analytes) will be provided to PWGSC under separate cover.

Specific Comments

The chapter titles could be simplified and clarified as:

- Chapter 3: Sediment Quality and Bioaccumulation Assessment.
- Chapter 4: Wildlife and Human Health Risk Assessment.

It does make sense to have these chapters as distinct pieces, however, because the methods used to evaluate ecological risk are quite different between the aquatic community and the wildlife components. Overall I really appreciate the organization of the material.

Chapter 3, Executive Summary

Page III-ii – The text "did not find any differences between test and reference stations" should be clarified. Presumably the authors are referring to *ecologically* significant differences, but the types of differences or decision rules are unclear.

Page III-ii – The text "consistent evidence of ecological effects" is a little strong given the equivocal findings in some areas. Although there is fairly definitive evidence of harm for some stations, the consistency of responses over space and time is not sufficient to merit the term "consistent evidence of ecological effects." The majority of biological and toxicological endpoints and stations indicated negligible to weak evidence for harm.

Page III-ii – The text "management actions are required for the area immediately south of Belle Park" should be corrected to read "management actions are required for <u>some parts</u> of the area immediately south of Belle Park" as unacceptable responses were only observed over a portion of that area of KIH. Throughout the Chapters, there are other suggestions of management intervention; it is not clear whether this means physical management or alternatively whether non-invasive risk management is deemed acceptable. There are large portions of bed sediments for which the latter should still be considered.

Chapter 3, Section A – Introduction

No comments, other than that this section is very well written, accurate, and provides excellent context for the material that follows.

Chapter 3, Section B – Bioaccumulation and Biomagnification

Page III-3 – The text describes two methods for assessing whether biomagnification is a potential concern; specifically modelling and site-specific measurement of tissues. This is accurate in terms of the exposure aspect of the assessment; however, this section and the remainder of the chapter does not give much consideration to the effects side of the equation.

Information Gap – The site tissue chemistry data are evaluated mainly for spatial trends and gradients, rather than comparison to effects benchmarks. For some sample media (e.g., plants) there is not much that can be done given the limitations of toxiciological knowledge; however there are other media (invertebrates, fish) for which more data are available.

Resolution – Golder is addressing this component in the companion PWGSC deliverable, by introducing tissue residue thresholds from available literature. In particular, tissue residue effects information from Jarvinen and Ankley (1999; see footnote 1) would assist in placing the observed concentrations in context.

Page III-3 (Aquatic macrophytes / cattails) – The technical analysis here is sound, and the data support the conclusion that chromium appears to be more bioavailable in the area immediately adjacent to the Belle Landfill near the creek mouth. The problem is that the *ecological significance* of this relationship is not explored. The text states that "there are no guidelines for evaluating Cr, Pb, or PCB concentrations in plants", so it is unclear how the findings should be interpreted in the weight-of-evidence for aquatic health.

Page III-4 (line 6) – should read "was an order of magnitude lower"

Page III-4 to III-8 – The figures in this section are based on clustered bars. As such the x-axis is not proportional to the concentration of contaminant (although absolute concentrations are depicted as labels). These figures do a good job of illustrating that the most contaminated sediments yield increased uptake into macrophyte rhizomes, but the strength of the correlations across the exposure gradient are difficult to discern. An XY scatterplot (with different symbols for stem versus rhizome) is a more effective way of presenting the quantitative relationship between sediment and plant tissue concentrations – I note that such plots are provided in Appendix 3-E.

Page III-8 – The text indicates that "there are no guidelines to evaluate Cr concentrations in biological tissue." As effects data are available for chromium and other COPCs, these should be considered[1].

[1] Jarvinen, A. W. and Ankley, G. T. 1999. Linkage of Effects to Tissue Residues: Development of a Comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals. Society for Environmental Toxicology and Chemistry. SETAC Press: Pensacola, FL.

Page III-9 – The PCB concentration data are assessed in the context of dioxin-like PCB concentrations relative to tissue residue guidelines to consumers of aquatic biota. This type of comparison is more appropriate for Chapter 4 because it pertains to wildlife health effects, not to aquatic life. In Chapter 3, it would be more relevant to assess the total PCB concentrations (mg/kg wet weight) against benchmarks for the protection of aquatic life. For that assessment, TEQ-based assessments are not appropriate because benthic invertebrates lack the *Ah* receptor mechanism that mediates the responses of wildlife to PCBs. Furthermore, there are toxicity study data available for PCBs (specifically Aroclor 1254) that could be used to assess the potential risks to invertebrates.

Information Gap – The site tissue chemistry data for PCBs and mercury are not compared to thresholds relevant to aquatic life (wildlife screening values are used).

Resolution – Golder can incorporate tissue-based thresholds for these substances and compare against measured concentrations from the field collections in KIH.

Page III-11 – The assessment of chromium bioaccumulation in fish provides very important context to the assessment of risk magnitude. Specifically, the increases in chromium concentrations in fish were small (on the order of two-fold) despite samples being collected immediately south of the Belle Landfill, in the zone of highly elevated sediment chemistry concentrations. This stands in marked contrast to the plant tissue and invertebrate tissues, which showed order-of-magnitude differences in concentrations across the study area. Several explanations for this are possible, including: (1) the fish are highly mobile and are intergrating exposures over areas that include lower Cr concentrations in sediment; or (2) the process by which chromium is transferred from prey items to fish is limited by biological processes.

Information Gap – The speciation of chromium has not been rigorously assessed in tissue samples, in spite of its importance for risk calculations to higher-trophic organisms.

Resolution – Collection of speciated Cr data for invertebrates and tissues could be considered in 2010 to reduce uncertainty.

Page III-11 – The fish tissue PCB data are assessed relative to the IJC tissue residue guideline (0.1 mg/kg ww). Although relevant from the perspective of human health and wildlife screening, these comparisons do have relevance for assessing effect to the aquatic organisms themselves. Our past experience with risk assessment of PCBs suggests that adverse responses to invertebrates and/or fish are not expected at the concentrations observed in KIH (aside from the possible onset of tumours/lesions in bottom fish). Critical effects concentrations for survival, growth, and reproduction of aquatic life are at least an order of magnitude greater than the IJC guideline. This is important information for the weight-of-evidence assessment of PCBs. The discussion that follows on page III-13 is appropriate from the perspective of wildlife and human consumers of aquatic biota, but should not be interpreted to imply that responses to the benthic communities or fish populations are expected.

Page III-14 – The spatial distribution of mercury in fish tissue samples illustrates the importance of background contamination and the need to identify the receptor that drives the tissue benchmark applied. The generic mercury threshold from CCME is designed to protect all wildlife species (mammals and birds). The tolerable daily intake used to calculate the CCME thresholds was drawn from the most sensitive species (mink and mallards); furthermore, the tissue residue guideline incorporated an additional adjustment (safety factor) based on maximum potential feeding rates. The CCME derivation document[2] states that:

> *The avian RC was calculated to be 33 µg·kg^{-1} from the TDI above [mallard duck], and the FI:bw for Wilson's storm petrel (*Oceanites oceanicus*) of 0.94. Wilson's storm petrel consumes almost its entire body weight each day, potentially resulting in the bioaccumulation of more MeHg than species that consume much less than their body weight each day.*

This is important in the context of the KIH assessment because the receptors of concern in the region of elevated tissue mercury are not well represented by the species used in the generic CCME derivation. For example, quality mink habitat is not found in this area, and the Wilson's storm petrel is not representative of the local avian fauna. As such, the mercury concentrations observed in local fish samples (less than 100 µg·kg^{-1}) do not necessarily suggest elevated risk. A casual reader might look at the red symbols in Map III-9 and incorrectly assume that risks are high, when in fact the risks are close to background and below levels protective of nearly all candidate organisms. Moreover, the technical rationale for the legend ranges are unclear, particularly given that the human health screening level (i.e., Health Canada guideline for total mercury content in retail fish) is 500 µg·kg^{-1} and that effects thresholds for freshwater fish[3] fall are on the order of 3,000 µg·kg^{-1}.

Page III-15 (Summary) – The conclusions presented here are accurate; however, the summary focuses on screening for wildlife consumers of biota (risk to aquatic organisms are not discussed) and the magnitude of contamination relative to background is not discussed. From the information presented in this section, I agree that there is strong evidence of localized increases in biomagnification relative to reference areas (for PCBs, chromium, and mercury). However, these increases are, on their own, insufficient to indicate actual harm. Given the conservatism in the screening benchmarks applied, the magnitude of the observed increases (for fish, at least) are within the range for which ecological risks could be negligible.

Chapter 3, Section C – Sediment Toxicity

Page III-15 – Concerning the comment that "test with longer exposure times are more likely to detect effects than short-term tests", I understand the point being made, but there is danger in use of such a sweeping statement. The test duration is one of many factors influencing test sensitivity, and such a statement could be interpreted to imply that longer tests are necessarily better, which is not the case. Some very sensitive tests have short exposure times (e.g., echinoid fertilization tests, for which actual exposure is conducted on the order of minutes during a sensitive reproductive period). This is a minor point, and overall the introduction to sediment toxicity testing is quite well written.

Page III-15 – The text describing sediment toxicity tests mentions 22 test sites plus 7 references, with sample locations shown on Map III-10. Map III-10 shows more stations than are referenced in the text, including some that fall outside the 2006-2009 sampling window. Although the data sources are shown in the map, it is unclear why rationale was applied to plot (or not plot) toxicity stations. The text should provide a rationale for filtering the sediment toxicity information.

2 Canadian Council of Ministers of the Environment. 2000. Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Methylmercury. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

3 Wiener, J.G. and D.J. Spry. 1996. Toxicological significance of mercury in freshwater fish. Chapter 13 in: W.N. Beyer, G.H. Heniz, and A.W. Redmon-Norwood (eds.), *Environmental Contaminants in Wildlife*, pp. 297-339.

Information Gap – Parts of the sediment toxicity section (e.g., Table III-1) appears to restrict the analysis to samples collected from the KIH between 2006 and 2009. These sampling events include the recent sampling of 12 test locations for two species (Cantest samples) and earlier sampling of 10 locations for four species (Environment Canada samples). However, additional samples have been collected that are relevant to this study. Some of these sample location are plotted on Map III-10, and partially discussed in report narrative, but the available sediment toxicity data are not evaluated in detail or comprehensively.

Resolution – Golder can incorporate findings from other toxicity investigations in the last decade, including:

- In 2002, as part of the PCB Trackdown study (Watson-Leung, 2004), the Ontario Ministry of the Environment (MOE) and Environment Canada (EC) conducted biological tests and chemical analyses using sediments from eight field locations on the Cataraqui River. The laboratory organisms included a midge (*Chironomus tentans*), a mayfly (*Hexagenia* sp.) and fathead minnow (*Pimephales promelas*).
- In conjunction with the RMC Triad investigations (Tilley, 2006), Microtox™ toxicity analyses were conducted on 20 sediment samples using the luminescent bacteria *Vibrio fischeri*. Five sediment samples from the Triad design (ERA1, ERA2, ERA5, ERA9 and ERA11) were also tested for toxicity to the freshwater amphipod *Hyalella azteca* using a 14-day exposure with survival and growth endpoints.

These studies will be combined with the very useful and relevant information summarized in the RMC report.

Page III-17 to III-18 – It would be helpful to explain the differences between the *Hyalella* and *Chironomus* tests applied by Cantest and Environment Canada. For example, one used *Chironomus riparius* and one used *Chironomus tentans*. Are these actually different species, or are they the same species documented differently due to historical changes in the description of chironomid taxonomy in the laboratories? A reference to the test protocols applied may help to resolve why some subtle differences in test methods appear to have occurred (e.g., test duration for *Chironomus*; 3-5 day *Hyalella* used by Cantest and 2-10 day *Hyalella* for Environment Canada). In Table III-1, the *Hyalella* results are combined across the two laboratories, whereas the *Chironomus* results are kept distinct, so it appears that the *Hyalella* testing is considered equivalent, whereas the *Chironomus* testing is not.

Table III-1 – The column labelled “reference” needs to be explained more fully. Presumably, this refers to the choice of reference sediment that was used to standardize responses in test sediments such that the 20% and 50% effect size thresholds could be applied. However, explanation of the blank cells and the general procedure used to select an appropriate matched reference would be helpful in the main text even if these are explained in the Appendix.

Page III-21 – typo – Should be “Principal Components Analysis” not “Principle” (here and other places, such as F-12)

Page III-21 – The description of the additional studies here begs the question of why there were not included in Table III-1. The multiple-species testing from Watson-Leung (2004) is sufficiently recent to include explicitly in the analysis, rather than only in the narrative.

Chapter 3, Section D – Benthic Invertebrate Community Analysis

Page III-23 – In general I agree with the discussion here, although I view multivariate analyses as complimentary (not necessarily superior) to the suite of univariate metrics, The former can elucidate patterns and complex relationships that can be overlooked by univariate measures; the downside is that the multidimensional axes are often difficult to interpret. A combination of both approaches is recommended (and was applied appropriately in this study).

Table III-2 – The table should clearly label the two reference stations (BC-8, BC-9) as such. Prior to statistical analyses, it is essential that the relevance of the reference stations be assessed in terms of chemical parameters and physical/substrate parameters. In this regard, the references are reasonable, but not ideal, stations against with the exposed stations can be quantitatively assessed. The TOC content in BC-9 is twice that observed in any of the other stations, and the sand content in BC-8 (approximately 20%) is higher than any of the other stations. That said, the overall texture and chemical composition of the reference stations is generally comparable.

Page III-26 – typo – should be “Reynoldson”

Page III-26 to III-27 – Data Analysis – The selection of univariate measures was appropriate. The consideration of taxa richness, diversity, evenness, Hilsenhoff Biotic Index, percent shredders, and EPT index provides a solid representation of the major benthic community metrics, without providing excessive redundancy. Also, the presentation of the major taxonomic groups in Figure III-12 is very helpful in providing a breakdown of the major functional groups. One caveat – The EPT index may have limited utility for a site such as this where the sediments have a very high percentage of fines; mayflies and particularly stoneflies are more abundant in coarser substrates, so it is really more of “Trichopteran Index” in this site context.

Information Gap – The benthic community analyses in Figure III-12 are based on relative abundances. This is very useful, but would benefit from a similar plot of non-normalized abundances

Resolution – Golder or RMC could prepare a figure (stacked bar plot) that shows the total abundance (or bimass) of each major taxonomic group. This would provide complimentary information to the proportion-based analysis already shown in the Figure.

Page III-27 – In terms of the narratives applied to the various indixes (e.g., “poor water quality”), it is important to place the metrics in the regional context rather than interpreted only at face value. Because the harbour falls in a region of high organic carbon loadings and nutrient enrichment (from both background sources and anthropogenic sources), there is potential for misinterpretation of the data. For example, the Hilsenhoff “pollution” indices were developed based on tolerance to enhanced nitrification rather than to specific COPCs such as metals, PAHs, PCBs, etc.

Page III-28 – The multivariate methods applied here appear sound, and the statistical assumptions (transformations, use of NMDS, etc.) are consistent with the state of the science. The CABIN protocol is appropriate, although the interpretation is strongly reliant on the suitability of the reference stations within the Great Lakes reference database.

Information Gap – The benthic community analyses presented emphasize the nine most recent samples (BC1-BC9), with lesser attention give to other recent sampling. The comment made concerning the changes in sieve sizes over time is valid. However, because historical sampling events have collected reasonable reference station data, normalization to reference can facilitate the use of (and comparison with) other data sets.

Resolution – Golder has assessed normalized responses for a suite of benthic community parameters that is very similar to what RMC selected. These findings can be integrated as used to provide a spatial and temporal coverage that is broader than what is provided in the RMC document.

Figure III-12 – The trichopterans are represented in the Figure by the Leptoceridae family (blue bars). Although the text explains that the vast majority of the caddisflies were *Leptocerus* sp., it would be better to label the blue bars as “Caddisflies (mainly Leptocerids)”. This would be more consistent with the other categories that were based on common names and broader taxonomic designations (e.g., “amphipods” for the order Amphipoda)

Page III-33 – Although it is true that the Shannon-Wiener diversity values cannot be directly compared between sampling events conducted with different sieve sizes, the Tinney (2006) results could be compared to these recent studies by scaling to reference.

Page III-34 – The FBI metric is not really an indicator of “tolerance to environmental stress” overall but rather only one type of environmental stress. This is acknowledged later on the page.

Page III-34 – It is somewhat misleading to apply the narratives shown on Figure III-16, as the background biological and habitat conditions in the Great Cataraqui River are poorly suited to most EPT taxa (for reasons unrelated to contamination). The comparison of variations among stations and comparisons to reference are appropriate, however.

Page III-35 – The ecological significance of the “percent shredders” metric is difficult to evaluate due to the confounding effect of physical/habitat parameters (water depth, macrophyte coverage, etc.). However, this is probably moot given that the statistical analyses did not identify any significant differences.

Page III-37 – As stated above, the strength of the CABIN assessment comes from having a broad physical/habitat condition in the study area that is well represented by the database of BEAST reference stations. Table III-3 should include the results for BC-8 and BC-9 to underscore the fact that relatively uncontaminated stations (already demonstrated to be reasonably representative of the substrate, flow conditions, nutrient status, etc. of the study area) do not match favorably with the BEAST references. As such, the narratives (e.g., severely stressed) may not be appropriate as they do not account for the significant differences in the background biological conditions expected for a quasi-wetland environment with nutrient enrichment. The PCA analysis may show that the KIH sites are “within the range” of conditions in the Lake Ontario BEAST sites, but this does not equate with a conclusion that the latter provide an unbiased reference condition against which to assess KIH responses.

Page III-40 – In the NMDS plot, it would be helpful to label the two axes (Dim1 and Dim2) and provide an indication (either qualitative, or based on correlations with family-level abundances) of what defines the composition of a community plotted at either axis extreme. This would help to describe how BC-8 and/or BC-9 differ from the other stations.

Page III-42 – If particle size distributions “best explain the biotic data”, then the differences described above in terms of increased sand content at reference BC-8 are relevant. Specifically, the lower “similarity” of the BC-8 community could be explained on the basis of physical factors rather than sediment quality. In contrast, BC-9 exhibited substrate physical parameters more comparable to the exposed sites, and had high similarity to the other benthic communities.

Page III-43 – I concur with this entire paragraph; it is well thought-out and relevant to the main conclusions of the study.

Page III-44 – I’m not convinced that the MDS “clearly separated test sites from reference”. Although two (2) BC-8 replicates ordinated outside the “20 percent similarity” line on Figure III-19, the remaining four (4) replicates were inside the 20 percent similarity bounds. Here and in the dendograms, BC-9 was shown to be reasonably well matched to the seven exposure stations. When combined with the indications of substrate influence on biology, it is unclear whether the observed differences among stations are ecologically meaningful, and I do not believe that they indicate evidence of contaminant-induced degradation.

Page III-44 – The discussion of high boat traffic in the vicinity of BC-8 is curious. Although not discussed previously in the Chapter, the potential for mechanical disturbance is important, especially as scouring of fines in the sediment bed could lead to the increased sand content observed in the sample. Caution needs to be applied in terms of describing perceived differences between exposed and reference stations given these findings.

Page III-44 – The last paragraph is very good and is important for the interpretation of results. I agree with the recommendation to increase the proportion of reference sites in future studies. However, better use could be made of historical studies (which also incorporated multiple references) to determine whether any consistent relationships between exposed/reference conditions are apparent.

Chapter 3, Section E – Integration of the LOE

Page III-46 – I am concerned about the conclusion: “The overall WOE assessment for this area of the KIH is that potential adverse effects are occurring” (emphasis added). The language implies that there is actual environmental harm occurring over a broad area, when the findings from the individual lines of evidence are equivocal, and often suggestive of lack of significant harm. For most stations, the indications are of negligible to low response magnitude. The conclusion could be improved by:

- More neutral language. The conclusion was for “potential adverse effects”. Additional phrases such as “are occurring” or “may not be occurring”, affect the interpretation for most readers.
- Acknowledging the differences between effects (differences) and impacts (loss of ecological function or value). A difference between exposed and reference sites (particularly for benthic communities) is not necessarily indicative of an adverse response; rather the net impact of positive and negative differences, plus the magnitudes of the changes in term of functional status of the community, need to be explicitly considered.
- Frame the spatial context – Rendering of a single conclusion is not appropriate for a site of this magnitude, even when conclusions are restricted to the area south of Belle Park. The results of the study need to convey the spatial distribution of “effects”, and their consistency. Observations of responses in a minor of endpoints and/or minority of stations does not imply that responses would be expected over broad areas.

- Frame the magnitude of response – Because there is uncertainty regarding the ecological significance of the various indicators (e.g., exceedances of criteria do not indicate actual harm, toxicity tests have laboratory-to-field extrapolation issues), it is helpful to provide context for the strength and consistency of the observed responses. This is partly done by using the intermediate category in Table III-5, rather than one of the two extremes. However, additional refinement/context can be provided by communicating the station-specific results (e.g., how many toxicity tests showed responses, effect sizes observed, magnitude of guideline exceedances, etc.)

Information Gap – The weight-of-evidence assessment in Table III-5 does not partition the KIH site into spatial units or management areas.

Resolution – Golder has assessed normalized responses for a suite of benthic community parameters that is very similar to what RMC selected. These findings can be integrated as used to provide a spatial and temporal coverage that is broader than what is provided in the RMC document.

Chapter 3, Section F – Conclusions

Page III-48 – Conclusions – The report states that “biological effects are occurring in the southwest portion of the harbor”, and that “management actions are required to address sediment contamination in this area”. I believe that this conclusion is biased toward consideration of differences in the study measurement endpoints, but without: (1) considering the *lack of differences* observed for a large proportion of endpoints and stations; and (2) explanations for observed differences that are unrelated to contamination (e.g., habitat, physical variables) at that do not justify management intervention.

Page III-48 – Conclusions – I agree that definition of the spatial extent of any areas requiring management is a priority. However, map III-11 shows that most stations are not toxic, and the benthic community assessment presents evidence of (in my opinion) a weak response at exposed stations relative to reference.

Chapter 3, Appendices

Page E-4 – The relationships between PCB concentrations and fish age may not be statistically significant (and have low R^2 values); however, I suspect that the underlying relationship would be significant. As the authors point out in the main text, the lack of relationship is driven by significant variability (as expected) combined with a narrow age range. For any project analyses where assumptions regarding tissue concentration relationships with age are required (e.g., human health or wildlife analyses based on size range preferences of consumers), caution should be applied in applying/extrapolating these statistical results.

Chapter 4, Executive Summary and Introduction

The executive summary is very well written and does a nice job summarizing the major findings from the risk assessment. The only comments I have are:

- With respect to brown bullhead tumours, the text suggests that the risk assessment may not be suitably protective of this species. However, an alternate explanation is that biological stressors (or natural factors) unrelated to sediment contaminants are the cause for the morphological abnormalities. There is not sufficient evidence in the study to advance one theory at the exclusion of the other; both are possible.

- With respect to the conclusion, it is not clear how potential human health or ecological risks necessitate "management actions" to address these risks. If the risk management framework is being applied, the trade-offs between risks of active intervention versus no-action or monitored natural recovery need to be evaluated. For some pathways, additional investigation can be applied prior to making management decisions, particularly given the uncertainty and conservatism inherent in the analyses.

Chapter 4, Section II, Human Health Risk Assessment

Page IV-3 – Concerning 2009 ESG fish data, it is unclear why "whole fish minus one fillet" were used to estimate exposures to humans (for which the fillet is more relevant). If the fillet measurement was not available because the available was used for an alternative measurement, such should be explained in a footnote. I do not recall reading anywhere in the main text where the missing fillet went.

Page IV-4 – Concerning the statement that "the maximum concentration was used for the water and fish tissue data", it is unclear why the maximum would be used for these media, particularly as the preceding text describes the preferred use of the 95% UCLM for sample sizes of 10 or greater. In the COPC screening stage, as there are more than 10 samples available for fish tissues, it seems unnecessarily conservative to adopt the maximum concentration, and inconsistent with other procedures.

Page IV-5 – If Table IV-2 only includes the parameters carried forward in the risk assessment, a listing of the COPCs (or COPC groups) eliminated from further consideration should be provided here.

Page IV-7 – Regarding the statement "only methylmercury (MeHg) has been carried forward", the text should indicate that this means that only the organic form of mercury was considered, not that MeHg was the only COPC in harvested foods. The former is an acceptable assumption, as for purposes of health risk assessments; Health Canada typically assumes that 100% of the "total mercury" is in the methylated form as methylmercury.

Page IV-8 – The text states that "guidelines are not available for COPCs in fish tissue regarding the protection of human health." This is inaccurate; there are guidelines available from multiple jurisdictions for COPCs such as MeHg and PCBs. For example, the Health Canada guideline for total mercury content in commercial fish species is 0.5 part per million (ppm; mg/kg wet weight) and this value is based on consideration of human health. Other jurisdictions also promulgate thresholds for these substances based on the frequency of fish consumption.

Page IV-13 – The exposure assumptions from Richardson (1997) are based average meal sizes for the three receptor types. The resulting daily ingestion rates (grams per day) appear to be high relative to other estimates that I have seen in HHRAs for Great Lakes and other Canadian risk assessments of the fish consumption pathway. The adult exposure of 111 grams/day is higher than most estimates for recreational fishers. This is an important parameter because the HHRA showed that most COPCs have risk estimates strongly driven by the fish consumption pathway.

Information Gap – The ingestion rate of fish appears to be over-conservative for a non-subsistence receptor.

Resolution – Golder can incorporate an analysis of the ranges of fish tissue ingestion rates as part of an uncertainty analysis to complement the RMC report.

Page IV-16 – If there is site-specific evidence for the lack of hexavalent chromium in contaminated site media, it seems excessively conservative to assume 100% of chromium to be hexavalent. It would seem more reasonable to apply a ratio of Cr^{3+} to Cr^{6+} that reflects site-specific knowledge.

Page IV-24 – The analysis of number of meals that can be consumed is informative. However, it would also be helpful to conduct a similar analysis for reference concentrations, particularly as some COPCs (including PCBs) are present at concentrations that would indicate potential risk even at reference locations. In these circumstances, a *relative* risk assessment is as important as the absolute magnitude of derived risks, especially as the absolute risks are driven by some highly conservative assumptions for fish ingestion and COPC concentrations in tissue.

Chapter 4, Section III, Ecological Risk Assessment

Section B – The receptor selection process in this document is very well done in terms of the choice of candidate organisms, discussion of biological characteristics, representation of feeding guilds, and in the level of detail. Golder has conducted an independent evaluation of the KIH ecosystem and identified very similar candidate receptors, providing confidence that the choices are not arbitrary.

Page IV-34 – Although I agree that acquiring relevant toxicological information for herptiles is more challenging than some other COPCs, there are some other studies for which benchmarks can be evaluated. There will be uncertainty in cross-site extrapolation, but the data would provide useful context for this situation. For example, as part of the Housatonic River investigations under a CERCLA Consent Decree, a number of amphibian toxicity tests were performed (including the leopard frog, relevant to KIH).

Information Gap – The report cites lack of toxicological information for herptiles.

Resolution – Golder can incorporate studies of PCB thresholds (sediment and tissue) relevant to protection of amphibians.

Page IV-37 – The listed assessment endpoints do not include fish or herptiles. Fish are discussed in terms of measurement endpoints only; articulation of assessment endpoints for fish is important because it may affect the significance of the DELTs (deformities, erosions, lesions, tumours) from the brown bullhead study. Specifically, would individual-level morphological anomalies be considered ecologically relevant if they do not affect the survival, growth, or reproduction of fish? The answer appears to be yes, based on information later in the report that tumors and deformities are considered a “beneficial use impairment: under the Great Lakes Water Agreement; however, this needs to be clarified. Amphibians and reptiles are not discussed in terms of assessment or measurement endpoints; they drop out of the ERA without further assessment.

Page IV-38 – For the wildlife ERA, the chromium is assumed to be 100% trivalent, which contradicts the assumption of the HHRA discussed above.

Page IV-44 – The exposure point concentrations for fish need to ensure that the fish tissue samples are for representative species and size classes. The receptors (e.g, mink, heron) have size-specific foraging preferences, and the concentrations of some COPCs (particularly mercury and PCBs) are size and age-specific. If all fish samples were combined in the calculations of EPC values, the uncertainty assessment needs to evaluate whether the empirical values are likely to over- or under-estimate the exposures to the ROCs based on their size preferences.

Information Gap – The exposure concentrations do not consider size/age preferences of the receptors.

Resolution – Golder can assess the relevance of the sampled fish in terms of prey-selectively of piscivorous birds and mammals.

Page IV-45 – Concerning the extrapolation of fillet-only data to whole-body concentrations, it is most reliable to extrapolate PCBs based on the lipid content in the fillet and carcass components, rather than to extrapolate from another site, where the lipid ratios may be different. Although the factor of 5.5 is certainly within the range of plausible values, it should be cross-checked through examination of the site-specific data in Appendix C.

Information Gap – The site-specific and species-specific lipid ratios should be used to convert fillet to whole body PCB concentrations.

Resolution – Golder can examine the data in Appendix C to provide a check on the literature-based factor of 5.5.

Page IV-46 – The text describes a rationale for the use of allometric scaling, using several citations including Sample et al. (1996). There are some problems with this approach, including:

- The scientific basis for allometric scaling of wildlife TRVs has been called into question. The relationships are based on the scaling of acute responses, and insufficient evidence exists for the extrapolation of these responses to chronic effects that are used to develop TRVs.
- A panel of senior risk practitioners (Allard et al. 2010[4]) has recently suggested that the default procedure not be to apply allometric scaling of TRVs as a default procedure.
- Brad Sample (who was part of the panel described above) has acknowledged that the Sample et al. (1996) document is now stale and he now does not recommend some of the thresholds and procedures derived therein. Note that even Sample et al. (1996) did not incorporate allometric scaling for birds (the exponent was 1.0).

Information Gap – The uncertainty associated with the application of allometric scaling has not been rigorously assessed.

Resolution – The use of allometric scaling is not wrong; rather it is highly contentious and can influence risk estimates significantly depending on the nature on the extrapolations. As such it would be useful for Golder to document the magnitude of the allometric conversions applied in the RMC study and incorporate these in a revised uncertainty assessment (i.e., conduct a bounding analysis) In this manner, the risk range can be clarified and the influence of allometric scaling determined.

[4] Allard P, Fairbrother A, Hope BK, Hull RN, Johnson MS, Kapustka L, Mann G, McDonald B, Sample BE. 2009. Recommendations for the development and application of wildlife toxicity reference values. *Int. Environ. Assess. Manage.* 2009: 6:28–37.

Page IV-47 – Wildlife TRVs – For several COPCs, the RMC report applied Eco-SSL values, which are a good repository of information, and suitable for use in a screening-level ERA. For the remaining COPCs (particularly PCBs), it is important to provide supporting information for the choice of TRV.

Information Gap – The basis for the PCB TRV benchmarks needs to be presented in more detail, as there is no Eco-SSL for use in the ERA. The Brunstrom (2001) study needs to be placed in the context of other studies of mink reproductive toxicity.

Resolution – I have significant experience with PCB benchmarks for wildlife, and am aware of some meta-analyses which are superior to the use of a single study. This information can be incorporated in a revised uncertainty assessment for wildlife PCB risks.

Page IV-25 – Fish Tissue Benchmarks – Table IV-25 presents some "toxicity thresholds" for the COPCs but does not provide a rationale for why these values (or references) are considered appropriate for use in the ERA.

Information Gap – The technical basis for the fish toxicity benchmarks is not fully presented.

Resolution – We have already summarized some literature-based information for several of the COPCs which will help to provide context for the values in Table IV-26. For total PCBs, the toxicity threshold appears to be similar to what I have previously derived at other PCB sites for freshwater fish species. For mercury, the threshold appears to be about one order of magnitude lower than what I have expected from other studies. This supplemental information can be incorporated into a revised uncertainty assessment.

Page IV-50 – The HQ for mink and PCBs (2.66) needs to be interpreted in the context of the habitat suitability of the study area. Whereas the up-river marsh areas of the Cataraqui River are suitable mink habitat, the area south of Belle Landfill is marginal to poor quality mink habitat. Therefore, the ecological significance of the HQs for mink must be considered carefully, along with some of the other uncertainties discussed above.

Page IV-51 – Once additional toxicological information for mercury is incorporated, the risks to fish from Hg contamination will remain negligible, but will have improved confidence (lower uncertainty).

Page IV-52 – As discussed earlier, the federal TRGs for consumers of aquatic life are based on protection of the most sensitive species. Replacement of the default exposure assumptions is recommended by CCME, and this would reduce the frequency and magnitude of exceedances.

Page IV-54 – The documentation of anomalies in the brown bullhead is assigned more weight/strength in the ERA than can be justified based on the current level of mechanistic understanding of cause. The text recognizes that such anomalies can arise from infectious disease, yet the observations are deemed "the most direct and compelling evidence of the ecological impacts of the contaminated sediments." A more detailed histopathogy assessment would be required to warrant the "compelling" label.

Page IV-55 – Concerning the suggestion that toxicity thresholds were not developed for bullheads, and therefore potentially under-protective, there is no evidence provided to support the statement that "brown bullheads are known to be especially sensitive to this COPC." From my review of the toxicological literature for PCBs, the most sensitive species are salmonids (particularly lake trout); warmwater species have generally exhibited far less sensitivity relative to coldwater species. In addition, the Housatonic River in Western Massachusetts contains freshwater sediments (with fine-grained shallow waters and macrophytes similar to KIH) that exhibit concentrations on the order of 80 mg/kg wet weight, without any overt signs of population impairment or loss of productivity of brown bullhead. The latter concentrations are substantially higher than those observed in KIH. Interestingly though, in the Housatonic river work, there *were* some tumors observed in bottom fish in some portions of the study area; histopathology results found little evidence of infectious biological agents and no evidence of viral infection in the fish samples, so PCB influence could not be ruled out. The photo below shows a goldfish from the Housatonic River sampled in a river segment with elevated PCB concentrations. It would be informative to compare the findings of the studies.

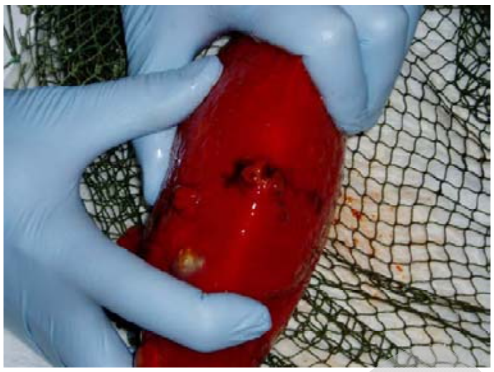


Photo: Lesions on Woods Pond Goldfish sampled in the Housatonic River in areas of high sediment PCB concentrations (photo obtained from final ecological risk assessment document available to public on EPA website)

Pages IV-56 to IV-58 – The Sources of Uncertainty section could be bolstered through consideration of some of the issues identified above. Because the RMC ERA is well-conducted overall, this could be done as a separate deliverable, without requiring major modifications to the RMC documentation.

Information Gap – The RMC report suggests that brown bullhead are "especially sensitive" without technical basis. However, there are some interesting commonalities to another site with elevated PCB concentrations. It would be helpful to obtained more documentation from RMC and integrate such with our information.

Resolution – RMC should be asked to provide their scientific rationale for the statement. In addition, the DELTs information from other PCB sites containing brown bullhead (particularly Housatonic River) can be examined and pertinent information applied here. Clear distinction should be made between endpoints that are related to lesions/tumours versus those related to survival, growth, and reproduction.

Closure

Thank you for the opportunity to review this material. We trust that this memorandum provides sufficient information for your present needs. If you have any questions, please do not hesitate to contact the undersigned.

Yours truly,

GOLDER ASSOCIATES LTD.

Mike Z'Graggen, M.R.M., QPRA
Associate, Environmental Risk & Toxicology Team Leader

Gary Lawrence, M.R.M., R.P. Bio.
Associate, Senior Environmental Scientist

MZ/GL/em

\\ott1-s-filesrv1\data\active\2009\1122-clg\09-1122-1020 kingston inner harbour transport canada\peer review document\draft ltr01_rmc chapters 3-4 review july2010.docx

PCA comments on Chapter 4.

Page IV-iv, first paragraph: implies that fish advisories do not already exist, when in fact they do (as indicated later in the text)

Page 2, last paragraph of introduction: is the proposed waterfront trail on the eastern or western shore? I thought it was the western.

Table IV-1: why is Hg data not available?

Table IV-2: why is the mean value of DDT used instead of the max?

Page 5, potential hazards: why is DDT and PAHs not tested in water? Not appropriate?

Page 7, potential hazards in harvested foods: "These species are reported in Schneider as part of **the MOE's** sport fish monitoring program"

Page 8, third paragraph: is there really no guidelines for CoPC in fish tissue – what are the MOE's fish consumption guidelines based on? Also, I would think that humans would preferentially eat some fish species, such as pike and bass over brown bullhead and carp.

Page 9, identification of receptors: I know there are some people that live on their moored boats in the harbour for the majority of the year – what do they use for drinking water?

Table IV-8 – what about flooding as a possible pathway – sediments washing up to shore and mixing with soils.

Table IV-11 – 80 years doesn't match the 60 years in Table 10.

Page 16 – add a "t" to relevant, just under the table.

Page 20, second paragraph: I'm not clear how the risk from lead from eating fish all year relates to "The primary diver of risk posed by these CoPC is consumption of fish throughout the summer" Also, which values imply that fish is the primary risk (its not entirely clear)? Also (third paragraph), it could be added that toddlers are used in the example as they are the most sensitive group.

Page 21: "certain species of fish caught in the KIH **already** exist".

Page 28, last paragraph: "as well as to model the effect of ingestion **to** these…"

Page 29, first paragraph: which species have home ranges that extend the distance of the site to the reference site (e.g. northern pike)? Would it not be that the same individuals could be found at either site.

Page 31, muskrat: "as a VEC because (delete **of**) its home.."

Page 34, reptiles: could add the SARA designation of the turtles. Also (amphibians): possibly change habitat to inhabit?

Page 39, second paragraph: fFor should be changed. Also, in the discussion of average daily dose is there a way to estimate additive effects of many CoPCs?

Page 43, first paragraph: From the south shore of Belle Island, two cattail **samples** were obtained?" Also, why is Hg not available for cattails – is this mentioned somewhere?

Page 44, exposure points for fish consumption: why was Hg and PCPs not measured in fish tissue – is this mentioned somewhere?

Page 47, toxicity thresholds: does it not matter what fish species the threshold values are derived from?

Table 28 – if muskrat and mink are at risk to CoPC, would they have predators that could be at risk as well?

Page 54: what does 11 percent of fish from the reference area with anomalies suggest? Are there also potential sediment issues at the reference locations?

Page 56, red-winged blackbird diet: high CoPC in benthics could affect amphibians also.

Page 58, summary: what do results relating to the measurement endpoints contribute to the assessment endpoint outlined earlier?

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000
Stn. Forces

5 November 2010

Subject: Response to Environmental Health Programme Technical Review and Data Gap Assessment of Chapter IV of the RMC Report

Site: Kingston Inner Harbour (Parks Canada & Transport Canada)

Report Title: "***Application of the Canada-Ontario Decision Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter IV: Human Health and Ecological Risk Assessment***" prepared by the Environmental Sciences Group, April 2010.

Date Reviewed: June, 2010

Reviewed by: Heather Jones-Otazo, Environmental Health Programme, RAPB

===

Thank you for reviewing our report summarizing the human health and ecological risk assessment for the Kingston Inner Harbour. We appreciate the time you have taken to review this report and provide feedback.

Please find our responses to the review comments listed below.

General Comments

1. *Is the purpose of the risk assessment clear? (i.e., why is the risk assessment being conducted?)*

   The objective of the HHRA has been expanded and it has been included in the updated text that the main pathways contributing to risk will be determined and the need for management actions identified.

2. *Is the scope of the risk assessment clear?*

   The complexity of the HHRA has been clarified and it has been added in the text that this HHRA follows DQRA guidance.

3. *Does the report include a description of both current and historical land uses of the site and surrounding land?*

   The area of the KIH has been clearly defined in the updated report and a reference to a map showing the exact boundaries of the upper and lower KIH and the exact site boundaries has been included.

Specific Comments

Section 2.1 Site Characterization

4. *Were sufficient samples collected from known/ suspected locations at the site that the likely maximum concentration was measured? Where warranted, were representative data used for estimation of statistical parameters (or probably distributions) for the site, or applicable parts of the site?*

   More realistic estimates of exposure have been evaluated and are included in the revised document: i) the 95 UCL for fish tissue has been used; ii) fish consumption was calculated based on the MOE ingestion rate for consumption of sport fish; iii) direct and indirect ingestion of sediments and direct and indirect dermal exposure have been assessed.

5. *Did the list of contaminants that were selected for analysis include all those typically associated with the historical uses of the site or their potential degradation products?*

   A study carried out in 2010 by Transport Canada has shown that tributylin (TBT) occurs at concentrations above conservative screening guidelines near the Kingston marina. However, based on a preliminary assessment of bioaccumulation potential and comparison to tissue effects thresholds, the TBT concentrations do not appear to be at a level expected to cause major responses.

6. *Are details available of both the sampling and analytical testing quality assurance and quality control measuresemployed, and was the QA/QC acceptable?*

   QA/QC for sediment data has been included in Chapter II.

7. *Are details of sampling methodologies and chemical analysis protocols available (in ESG reports) and did they follow a standard method?*

   Methods for surface water sampling and fish sampling have been included in the revised report.

8. *Does the report include laboratory Certificates of Analysis?*

   Laboratory Certificates of Analysis can be made available upon request.

Section 2.2 Identification of Chemicals of Potential Concern (COPCs)

9. *Was the current and potential future land use identified (e.g. residential, parkland, commercial, industrial, etc.)?*

   Possible change in future land use is very unlikely and is discussed in the revised version of this report.

10. *Were chemicals whose detection limit was greater than the screening guidelines screened out of the risk assessment?*

Cobalt, silver and PCB detection limits in water samples were compared to the MOE drinking water standards in the revised version of the HHRA. PCB concentrations in the water samples were below the MOE drinking water standards and PCBs were therefore not carried forward in the HHRA. The MOE does not list any criteria for silver and cobalt. These elements have not been carried forward in the risk assessment because currently available data indicates that they pose no health risk or cause any aesthetic problems at the levels generally found in drinking water in Canada. In addition, the concentrations measured in the impacted area are below the analytical detection limit, similarly to the concentrations in the reference area and they haven't been detected as potential sedimentary COCs in the KIH.

11. *If chemicals were screened out because their concentrations fell within background levels, were background concentrations calculated appropriately and used correctly?*

a) For the ESG fish sampling program two locations have been selected: 1) the reference location just south of the 401, and 2) area southwest of Belle Park representing the most contaminated portion of the KIH. The reference area is located upstream of Belle Park and is minimally affected by historic industrial activities; inorganic and organic contaminant concentrations do not exceed the federal guidelines. A map showing the fish sampling locations is included in the updated version of this report.

b) Maximum lead and zinc concentrations in fish were within background concentrations and were therefore not carried forward as COPCs.

c) The MOE (2006) report has been used as a source for fish tissue contaminant concentration data; arsenic is reported as "a measurable trace amount" with no further explanation. The arsenic measured in fish tissue refers to inorganic arsenic.

Section 2.3 Receptors and Pathway

12. *Have all relevant receptor age groups been identified (e.g., fishers, hikers, commercial workers, industrial workers, First Nations)?*

The commercial fishery is located north of Belle Island in an area that has not been affected by historical contamination; concentrations of COCs in sediments are comparable to background concentrations. Therefore, there is no need to assess the risk for a commercial worker. Receptors that swim, eat sport fish and canoe or row are included in this HHRA and the conceptual model has been updated.

13. *Have all relevant receptor age groups been identified (e.g., infant, toddler, child, teen, adult)?*

The teen has been included in the revised version of the HHRA. A senior receptor has not been included because he is not considered a unique receptor who would be exposed to increased levels of risk in the KIH.

14. *Have all relevant direct and indirect pathways been considered?*

The Conceptual model has been updated and direct ingestion and dermal exposure to bulk dry sediments were assessed (such as by exposure at a beach). Bulk sediment ingestion rates of 100 mg/day (adult, teen) and 200 mg/day (toddler, child) were used. Exposure to bulk sediment has been taken into account using Schoaf (2005) absorption factors. Indirect exposure to sediment and dermal exposure to suspended sediments have been included in risk calculations for the swimming pathway. As suggested in the document, the value of 1-1.5 mg/d was assumed for ingestion of suspended sediments.

15. *Have potential contaminant release mechanisms been described (e.g. volatilization, fugitive dust emission, surface runoff/overland flow, leaching to groundwater, tracking by humans/animals, biogenic soil gas generation and radioactive decay)?*

Contact with suspended sediments while swimming and consumption of sport fish have been included in the updated version of this HHRA.

16. *For those pathways that were excluded, was their exclusion adequately justified?*

It has been clarified in the text that potential direct exposures to bulk dry sediments (such as exposures at a beach) are included in the risk assessment.

17. *Was a conceptual site model which identifies contamination sources and associated COPCs, receptor groups, critical receptors, potential exposure pathways provided?*

The conceptual site model has been updated to reflect that dermal contact and ingestion occurs via suspended sediment in surface water.

Section 3.1 COPC Exposure Estimation

18. *Was the sampling design appropriate given the nature of the data, the hypothesis on contaminant distribution across the site, and site characterization objectives?*

Information on methodology for surface water sampling has been included. MOE has been consulted for more recent sport fish data, but no new data is available.

19. *Have appropriate methods been used to infer vales when the analytical results were non-detect?*

Non-detects for fish and surface water data were replaced with a value equal to half the detection limit.

Section 3.2 Receptor Characterization

20. *Were all receptor exposure characteristics drawn from Health Canada guidance?*

a) Exposure time is only used for inhalation exposure and is considered negligible in this HHRA.
b) Fish consumption rates were changed as recommended and the consumption rate of 24.9 g/day published by the MOE Sport Fish Contaminant Monitoring Program in 2006 (Results of the 2003 Guide to eating Ontario Sport Fish Questionnaire" was used. The assumption that sport fish can be consumed throughout the year was included.
c) Swimming: Dermal exposure through suspended sediments has been calculated for "total body" ("total body minus hands" + "hands") exposed surface area according to PQRA (2009).

21. *Were assumptions regarding exposure duration and exposure frequency appropriate and adequately justified?*

Exposure time and averaging time/life expectancy were corrected between Table IV-10 and Appendix H (80 years is appropriate).

Section 3.4.2 Bioavailabilty and Bioaccessibility Assessment

22. *In calculating lifetime average daily dose for cancer risk, was the assumption of lifetime exposure used to account for different cancer risk based on life stage of exposure?*

Lifetime average dose for carcinogens has been calculated by summing exposures for each life stage over an exposure duration of 80 years.

Section 3.4.4 Microenvironments

23. *Are there any areas of the site that are more likely to be used by human receptors than other areas or otherwise considered to be "microenvironments"?*

The HHRA has shown that exposure through swimming does not pose any risk to any of the COCs in the impacted area. Since COC concentrations in sediments near LaSalle Causeway and Anglin Bay are lower than in the impacted area swimming would not result in any risk.

24. *If no microenvironments currently exist, is it possible that future development may result in microenvironments?*

It is extremely unlikely that beach areas will be created using contaminated sediments and presently there are no beach areas within the shoreline. Therefore exposure to dry bulk sediment through inhalation has been considered negligible.

Section 4.0 Toxicity Assessment

25. *If Health Canada TRVs were not used, was it because Health Canada had no TRV for the particular COPC (see sources for TRVs in notes and list sources in Table 1) Were all toxicological reference values (TRVs) drawn from Health Canada? If no, was it because Health Canada had no TRV for the particular COPC?*

    In the updated version of this report it is clearly specified that Health Canada does not recognize PCBs and DDT as carcinogens. For lead the MOE TRV of 1.85 ug/kg-day was used.

Section 5.0 Risk Characterization

26. *Are the results of the risk assessment presented clearly including the identification of COPCs associated with unacceptable risk?*

    Separate HQs and cancer risk for exposures to contaminants via suspended sediments and sport fish consumption are provided in the updated version of this HHRA.

Section 5.6 Uncertainty and Variability

27. *Was the uncertainty in the risk assessment addressed to the satisfaction of the reviewer?*

    Ingestion of sediments has been revised using the values recommended by Health Canada; ingestion rates are higher than soil due to elevated moisture and adherence of sediments relative to soil. Dermal adherence factors for bulk sediment to estimate loading of suspended sediments while swimming has been assessed using the Health Canada soil adherence values. The uncertainty related to using these parameters is discussed in the updated HHRA.

28. *Were the pathways and COPCs that drive the risk estimate identified and uncertainties associated with these discussed in particular?*

    Uncertainties with fish consumption were discussed in more detail.

Section 5.7 General Interpretation

29. *Were risks calculated for all chemicals and receptors of concern identified in the problem formulation?*

    The potential risk for a rower/canoer through direct dermal contact has been included in the updated version of the HHRA.

30. *Are the results of the risk assessment presented clearly including the identification of*

COPCs associated with unacceptable risk?

Separate HQs and cancer risk for exposures to contaminants via suspended sediments and sport fish consumption are provided in the updated version of this HHRA.

31. *Were any unusual site-related assumptions of professional judgments made earlier in the risk assessment re-iterated in the conclusions of the risk assessment?*

This HHRA follows a DQRA and more realistic assumptions such as the MOE sport fish ingestion rate and more appropriate fish contaminant concentrations were used to calculate more realistic exposure scenarios.

32. *If the risk assessment focused on maximally exposed receptors and risks were deemed unacceptable, were risks to other receptors evaluated?*

Potential risks were calculated for the individual pathways in the updated version of this HHRA and are included in Appendix I.

33. *Were risk estimates evaluated within the context of uncertainty and variability?*

Suggestions to improve the realism of this risk assessment have been followed and are included in this updated version of the HHRA.

Section 6.0 Risk Management

34. *If any non-cancer hazard quotients exceed 0.2 or any cancer risks exceed 1 x 10^{-5}, are remedial or risk management measures proposed*?

Chapter V is summarizing management measures for the KIH and will be finalized on 30 March 2011. The section on how many fish meals are safe for each receptor per year has been deleted, as the more realistic exposure scenarios showed that dermal exposure and incidental sediment ingestion are becoming more important.

35. *Are recommendations proposed, and is the responsible department or agency clearly identified, if other than the Client department that solicited the risk assessment?*

Chapter V and the determination of sediment management objectives will be finalized by March 30 2011.

36. *Will proposed risk management options address the source(s) of unacceptable risk, if necessary?*

Chapter V will address the uncertainty of unacceptable risk.

We hope that our comments are useful and would be happy to participate in further discussion.

Sincerely,

Dr. Ken Reimer

Viviane Paquin

Dr Astrid Michels

Dr Tamsin Laing

Response to Golder Associates Technical Review and Data Gap assessment of Chapters III and IV of the RMC report)

Subject: Response to Golder Associates Technical Review and Data Gap assessment of Chapters III and IV of the RMC report

Site: Kingston Inner Harbour (Parks Canada & Transport Canada)

Report Title: "***Application of the Canada-Ontario Decision Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter IV: Human Health and Ecological Risk Assessment***" prepared by the Environmental Sciences Group, April 2010.

Date Reviewed: July 14, 2010

Reviewed by: Mike Z'Graggen and Gary Lawrence, Golder Associates Ltd.

==

Thank you for reviewing our report summarizing the human health and ecological risk assessment for the Kingston Inner Harbour. We appreciate the time you have taken to review this report and provide feedback.

Please find our responses to the review comments listed below.

General Comments

1. *Information Gap: Spatial characterization is not the focus of the RMC report -most conclusions are rendered on a broad basis rather than parcels of sediment*

   Parcelling the Kingston Inner Harbour into management units for integration of the weight-of evidence determinations is complicated because not all sampling stations have the full information on the three lines of evidence. Chapter IV shows that the major line of evidence driving human and ecological risk is biomagnification of PCBs and MeHg in fish tissue. Fish are mobile and their habitat range is larger than the impacted area southwest of Belle Park in the KIH. Therefore partitioning into zones using the three lines of evidence would not be an appropriate approach, because it doesn't account for the mobility of fish. Chapter V of this report will summarize the site-specific SeQGs developed for the KIH. Based on the site-specific SeQGs prioritized zones for management will be established for the KIH. At a workshop on remediation options for the KIH, expert review did not support making remedial decisions for spatial units using the COA approach – the use of a risk-based approach to derive SeQGs was strongly supported.

2. *Narratives "potential", "possible" and "possibly different"*

   These descriptions are directly adopted from the COA document using the criteria defined for each of these categories

Specific Comments
Chapter III Executive Summary

3. *Page III-ii: differences between test and reference sites*

   The text has been updated to specify that "statistically" significant differences between test and reference sites are meant.

4. *Page III-ii "consistent evidence of ecological effects"*

   We agree with the reviewer that at a station- by-station basis the evidence for ecological effects is sometimes ambiguous in the KIH. However, if the whole area southwest of Belle Park is considered, all three biological lines of evidence (benthic community impairment, sediment toxicity and bioaccumulation/biomagnification) as well as sediment chemistry show potential or significant effects in the area southwest of Belle Park. This has been also confirmed by several studies, such as the "PCB Trackdown studies" and results (i.e. biomagnification potential) can easily be reproduced over time. We therefore believe that the term "consistent evidence" is appropriate in the context of summarizing the biological results.

5. *Page III-2: "management actions are required for some parts of the area immediately south of Belle Park"*

   The conclusion that management actions are required is a direct outcome of the COA decision matrix. In the context of the COA framework is not necessary to determine the extent of the area that has to be managed; this will be discussed in more detail in Chapter V. See also comment 1.

Section B - Bioaccumulation and biomagnification

6. *Information gap: "The site tissue chemistry data are evaluated mainly for spatial trends and gradients, rather than comparison to effect benchmarks. For some media there is not much that can be done given the limitation in toxicological information; however there are other media (invertebrates, fish) for which more data are available." The site tissue chemistry data for PCBs and mercury are not compared to thresholds relevant to aquatic life."*

The ecological significance of the elevated site tissue chemistry data is evaluated in Chapter IV in the Ecological Risk Assessment (ERA), and it would be repetitive to discuss this also in Chapter III. The tissue chemistry data for all media (plants, invertebrates, and fish) has been used to assess the risk posed to higher trophic level receptors of the KIH in Chapter IV. Tissue-based toxicity thresholds derived from the literature are also used to assess the risk to fish in Chapter IV as the reviewer suggests. Insufficient toxicological information is available in the scientific literature that would permit an assessment of risk to aquatic plants. Concentration-based threshold values could be developed for invertebrates through a detailed literature review; however, the results for such an approach would not change the outcome of the risk assessment and management decisions for the KIH.

7. "*The speciation of chromium has not been rigorously assessed in tissue samples, in spite of its importance for risk calculations to higher-trophic organisms.*"

   The analytical chemistry for detecting hexavalent Chromium is difficult and results would not change risk assessment outcomes:

   - All available data indicates that chromium in sediments and water is present as trivalent chromium
   - It is highly unlikely that transformations in biological tissue would lead to increased hexavalent chromium

8. *Page III-14: "The generic mercury threshold from CCME is designed to protect all wildlife species"*

   Since there are no tissue residue guideline to assess adverse effects for fish the CCME Tissue Residue Guidelines (TRG's) derived for avian and mammalian receptors have been used to interpret the data. While we agree with the reviewer that TRG's are very conservative, it is still appropriate to apply them to any aquatic species consumed by wildlife, including fish, shellfish, other invertebrates, or aquatic plants, because they refer to the maximum concentration of a chemical substance in the tissue of aquatic biota that is not expected to result in adverse effects in wildlife.

   The comparison of fish tissue concentrations with Health Canada's guideline for total mercury content in retail fish doesn't seem to be appropriate, because it addresses human health risks from fish consumption and doesn't allow any conclusions on fish health. In this context it should be noted that the Health Canada document states a guideline of 0.2 ppm for mercury content in retail fish for young children (12 years of age and younger). From the results presented in chapter III it cannot be concluded that "*the risk is close to background"* without performing risk calculations. Mercury is a biomagnifying substance and therefore the risk to higher trophic organisms has to be assessed. This has been done in the Human Health and

Ecological Risk Assessment (HHERA) in Chapter IV. The HHRA concluded that methylmercury concentrations in fish collected in the KIH pose risk to all receptors if an ingestion rate of 24.9 g/day normalized to body weight is used. The benefit of deriving a concentration-based threshold for fish is to evaluate if methylmercury has any adverse effects on fish, but this would not change overall management decisions.

9. *Page III-15 Summary.*

   The reviewer agrees with our interpretation that there is strong evidence of localized increases in biomagnification relative to upstream reference sites for contaminants such as PCBs, chromium and mercury. However, they point out that the potential ecological risks associated with this biomagnification have not been discussed. We agree – this is why a human health and ecological risk assessment was performed, which is presented in Chapter IV of the report. Discussing potential ecological risks in both Chapters III and IV would be repetitive.

Section C Sediment toxicity test

10. *"Tests with longer exposure times are more likely to detect effects than short-term tests"*

    The text in the report has been updated in the revised version.

11. *Address MAP III-10 and mention that it includes all locations where toxicity tests have been performed*

    A more comprehensive description of Map III-10 and the sample location presented has been included in the text.

12. *"Part of the sediment toxicity section appears to restrict the analysis to samples collected from the KIH between 2006 and 2009. These sampling events include the recent sampling of 12 test locations for two test species".*

    The results of sediment toxicity findings from other toxicity investigations are discussed in more detail in Chapter I of the report and are incorporated in the toxicity assessment in Chapter III.

13. *Chironomus tentans versus Chironomus riparius*

C. tentans and *C. riparius* have been treated as two different toxicity tests in the toxicity assessment because two different species were used and the length of the tests varied. Nevertheless, the scientific literature demonstrates that the pattern of response is similar for the two species, and that both *C. riparius* and *C. tentans* are suitable test organisms for acute exposure assays.

14. *Test duration: C. tentans 20 days versus C. riparius10 days*

The *Chironomus* tests carried out by Environment Canada and Cantest are part of the standard list of toxicity tests performed by these agencies. The EC and Cantest toxicity results were discussed separately in the data analysis and the interpretation. The long-term 20 day test as well as the 10 day test are both assessing the same endpoints such as survival and growth.

15. *Age of juvenile Hyalella: Cantest: 3-5 days versus Environment Canada 2-10 days*

Studies comparing the sensitivity of different age groups of juvenile *Hyalella azteca* show that there is little sensitivity to toxic substances of different ages of young in the first few weeks.[1]

16. *Watson-Leung 2004 multi species toxicity results*

The results of the Watson-Leung 2004 toxicity tests are discussed in detail in Chapter I and are integrated in the overall toxicity results for the KIH.

Section D Benthic Community Invertebrate Community Analysis

17. *Table III-2:*

BC8 and BC9 have been labelled as reference sites in Table III-2.

[1] U.S. EPA (United States Environmental Protection Agency) (2000) Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates, Second Edition, EPA 600/R-99/064.

18. *Information Gap: The benthic community is based on relative abundance. This is very useful, but would benefit from a similar plot of non-normalized abundances.*

    A plot of non-normalized abundances has been performed, but doesn't add any new information and therefore has not been incorporated in the main report.

19. *Page III-27 Hilsenhoff index developed based on tolerance to enhanced nitrification rather than to specific CoPCs such as metals, PAHs, PCBs.*

    It is mentioned in the text that the Hilsenhoff index represents tolerances to eutrophication.

20. *Information Gap: The benthic community analyses presented emphasize the nine most recent samples, with lesser attention to other sampling. ... because historical sampling events have collected reasonable reference station data, normalization to reference can facilitate the use of other data sets.*

    Modeling species abundances from historic benthic community data with different study designs (i.e. sampling techniques, i.e. sieve size) is based on the assumptions that 1) environmental variables are constant at all time and 2) species are near equilibrium and always present with the same proportions. However, the modeling approach ignores the complexity of biological systems and the diversity of factors affecting benthic communities, such as: seasonal dynamics in species abundances and distribution, life-histories, and the fact that relationships between species and measured environmental variables are not always linear. Therefore, the modeling approach does not seem to be appropriate to integrate historic benthic community analyses and assess impairment. In addition, it does not comply with the standardized sampling protocols developed by Environment Canada as part of the Canadian Aquatic Biomonitoring Network (CABIN).

21. *Page III-12 Figure III-2*

    *Leptoceridae label has be*en updated*.*

22. *Page III-33 Comparison of Tinney (2006) results*

    Scaling is not a scientifically defensible approach (see Comment 20 on modeling species abundances).

23. *Page III-37:Update Table III-3 and include station BC8 and BC9*

    Table III-3 has been updated with the BEAST assessment for BC8and BC9.The summary of Chapter III (page III-48) discusses the importance of finding appropriate reference for benthic community assessment and indicates that a comparison of the KIH benthic community data with data from reference sites with similar environmental conditions, such as naturally eutrophic and shallow systems (St. Lawrence River system), may allow further determination of the level of stress on the benthic community.

24. *Page III-40: describe what defines the composition of a community plotted at either axis extreme*

    The description of the NMDS results has been updated and includes references to families that influence the observed patterns along the two axes.

25. *Page II-42: Particle size: Differences can be explained in terms of physical parameters rather than sediment quality.*

    The text emphasizes that variables both related to environmental variables and contamination gradients are influencing the benthic community structure. The multivariate analysis looks at the influence of multiple environmental variables on the benthic community structure of all nine locations. Multivariate analysis therefore does not allow for conclusions on the influence of individual environmental variables on a single site; this would correspond to a univariate approach. On page III-47 the suitability of BC 8 as an appropriate reference site is discussed in more detail and it is indicated in the text that BC 8 lies close to the Rideau Canal in an area with high boat traffic which may explain the high sand content.

26. *Page II-44*: *NMDS and clear separation of test sites from reference*

    NMDS is one of the best ordination techniques with a great ability to represent more complex relations accurately in low-dimensional scale. While it is true that BC9 is more similar to test sites BC1, BC2 and BC5 than to BC8, the statistical test ANOSIM indicates that test sites are significantly dissimilar than reference sites. These results can be reproduced if the benthic community replicate data is used, thus confirming the robustness of the method.

Chapter III. Integration of LOEs

27. *Neutral language*:

The reviewer is suggesting the use of more neutral language for the integration for the three lines of evidence. The language used in the table such as “potential adverse effects” has been directly adopted from the COA guidance document. However, the wording of the overall conclusion statement has been altered to use more neutral phrasing.

28. *Difference between effects and impacts*

While it is true that differences between test and reference sites are not necessarily indicative of an adverse response, this question is a major decision step within the three lines of evidence of the COA framework. The ecological significance of the results is explored in Chapter 4 – human health and ecological risk assessment.

29. *Framing the spatial context*

Since biomagnification is the major driver for risk in the KIH, management options have to consider the risk to higher trophic level receptors and site-specific sediment quality guidelines will be calculated using a risk-based approach in Chapter V. This will permit identification of the area of the harbour that requires management action. Our response to the spatial assessment of the harbour is outlined under Comment 1.

Regarding the integration of normalized responses for benthic community parameters (outlined as an information gap), we feel that this is problematic as discussed in comment 20.

30. *Framing the magnitude of response*

Detailed results for the three lines of evidence (i.e. how many toxicity tests showed responses, magnitude of guideline exceedances) are discussed in the individual sections of Chapter II and III. Biomagnification is the major driver for ecological risk to upper trophic level receptors due to consumption of fish, which are mobile. The ecological significance of biomagnification is explored in more detail in Chapter IV. See also comment 31.

Chapter III Conclusions:

31. *Page III-48*

The conclusion of consistent evidence for biological effects is based on the integration of the three biological lines (benthic community impairment, sediment toxicity and bioaccumulation/biomagnification) of evidence for the area southwest of Belle Park.

A station- by-station basis is challenging to apply, because not all stations have information on the three lines of evidence. However, if the whole area southwest of Belle Park is considered, all three biological lines of evidence as well as sediment chemistry show potential or significant effects. This has been also confirmed by several studies, and results (i.e. biomagnification potential) can easily be reproduced over time (PCB Trackdown studies). Biomagnification is the major driver for ecological risk to upper trophic level receptors due to consumption of fish, which are mobile. The ecological significance of biomagnification is explored in detail for higher trophic receptors in chapter IV. It is important to point out in this context that in cases where significant risk through biomagnification is indicated, even in the absence of sediment toxicity and benthic community impairment, the COA framework specifies that management actions are required. We therefore believe that the term "consistent evidence" is appropriate in the context of summarizing the biological results.

32. *Conclusions Page III-48*

Toxicity responses and Map III-11 are discussed in detail in section C of chapter III, where it is mentioned that generally evidence for toxicity is mixed. Benthic community analyses clearly showed that test sites are different than reference sites and observed differences can be attributed to environmental variables related to contamination such as chromium. According to the COA framework, management actions are required even in the absence of sediment toxicity or benthic community impairment in cases where the risk from biomagnification is significant, such as the south-western portion of the KIH (see comment 31).

Chapter IV. Executive Summary and Introduction

33. *Tumours in brown bullhead*

This is discussed in detail under comment 53.

34. *Trade-off between active intervention and no-action and MNR needs to be evaluated*

    A management options analysis will be carried out in Chapter V.

Chapter IV Section II. Human Health Risk Assessment

35. *Page IV-3: "whole fish minus fillet" definition*

    The text has been updated to define more clearly "whole fish minus fillet".

36. *Page IV-4: Maximum concentrations were used for water and fish tissue.*

    The HHRA has been updated and the 95% UCL was calculated for fish tissue. Maximum water concentrations were used to compare to federal and provincial drinking water guidelines all CoPCs were below guidelines and therefore have not been carried forward in the risk assessment.

37. *Page IV-5: List of CoPCs eliminated from further consideration*

    Table IV-2 has been updated as suggested.

38. *Page IV-7: Only methylmercury has been carried forward*

    Text has been updated to reflect that only the organic form of mercury was considered for the fish consumption pathway in the risk assessment.

39. *Page IV-8: "Guidelines are not available for COPCs in fish tissue regarding the protection of human health".*

    The text has been updated and the MOE fish consumption guidelines which were developed for use by Ontario anglers and are based on tolerable daily intake guidelines provided by the Food Directorate of Health Canada were included.

40. *Page IV-13: Exposure assumptions from Richardson*

Fish consumption calculations have been updated in the risk assessment using the MOE ingestion rate of 24.9 g/day developed from the 2003 Ontario Sport-Fish questionnaire applied year-round.

41. *Page IV-13: Lack of hexavalent chromium*

The text has been revised to reflect that health risks to total chromium are being assessed. The TRV developed by Health Canada for chromium is based on the toxicity of hexavalent chromium. Studies of sediment chromium, sediment pore water, and soils from adjacent sites indicate that chromium in the KIH is present as the less toxic, trivalent form (Cr (III)).

42. *Page IV-13: Number of meals using reference concentrations*

The analysis of number of meals has been deleted in the updated version of the report, because the use of the 95 UCL for fish tissue concentration and a much smaller ingestion rate (MOE) have decreased the risk from fish consumption significantly. Nevertheless, the number of fish meals that can be consumed safely has been calculated using the fish tissue concentrations from reference sites of the KIH. For PCBs, fish from the reference sites can be consumed year round by all receptors. For MeHg, fish can be consumed on 207 days by all receptors.

Chapter IV, Section III, Ecological Risk Assessment

43. *Page IV-34: toxicological information for herptiles.*

We agree that this information could be incorporated through literature review to identify sediment and tissue-based toxicity thresholds for herptiles. However, there are generally greater uncertainties in the assessment of ecological risk using this approach, especially given the lack of measured tissue contaminant concentrations for amphibian and reptile species in the KIH. Furthermore, it should be noted that inclusion of this information would not alter the classification of the site as a Class I (Action required) because of potential risks to humans and other higher trophic level receptors. Using sediment and tissue-based toxicity thresholds would permit the development of herptile-specific risk-based sediment quality guidelines for remediation; however, there could be large uncertainties about these guidelines given the lack of measured data.

44. *Page IV-37: assessment endpoints do not include fish or herptiles.*

Our response regarding the lack of inclusion of herptiles is discussed under comment 1 above. The text has been edited to include assessment endpoints for fish and for the brown bullhead fish health study.

45. *Page IV-38: chromium assumed to be 100% trivalent.*

The rationale for the assumption that chromium is present only in the trivalent form is presented in the text, with supporting data in Chapter II of the KIH report. As addressed in comment 41, it should be noted that the HHRA did not assume that the chromium was present as Cr (VI): rather, the chromium TRV recommended by Health Canada for use in HHRAs is based on lab studies with the hexavalent form (Cr(VI)). Health Canada does not distinguish between the two forms for the purpose of human health risk assessment.

46. *Page IV-44: fish exposure point concentrations need to ensure that the fish tissue samples are for representative species and size classes.*

This was taken into account in the original ERA and the report text has been clarified in this regard.

47. *Page IV-45: extrapolation of fillet-only data to whole-body concentrations.*

As suggested, we have re-calculated the whole-body PCB concentrations using site-specific and species-specific lipid ratios for brown bullhead, yellow perch, and northern pike. The original report used a conversion factor of 5.5, while site-specific conversion factors for KIH fish ranged from 5.4 (brown bullhead) to 7.4 (yellow perch). The risk assessment outcomes do not change significantly when site-specific conversion factors are used, although mink would be at higher potential risk from PCBs using the yellow perch conversion factor. However, the % lipid content for KIH yellow perch was measured for samples comprising the whole body minus one fillet and it is possible that the lipid content could be over-estimated in comparison with a complete whole body sample. For this reason, the literature conversion factor was retained for the ERA calculations. Comparison of the results using the site-specific vs literature conversion factors are discussed under the uncertainty section of the report (Section F: Sources of Uncertainty).

48. *Page IV-46: assessing the uncertainty associated with allometric scaling.*

Allometric scaling was used to adjust toxicological reference values (TRVs) for two of the CoPCs: PCBs and methyl mercury. In order to assess the uncertainty associated with using allometric scaling, we reran all of the risk calculations for these two CoPCs using unadjusted TRVs. The risk assessment outcomes do not change significantly when allometric scaling is not used (i.e., risk is identified for the same receptors and contaminants using both methods). We have included discussion of the uncertainty associated with allometric scaling in Section F of the report (Sources of Uncertainty).

49. *Page IV-47: providing supporting information for the choice of TRV used for PCBs and Hg.*

TRV benchmarks for PCBs and Hg were selected based on a review of the scientific literature. The report text has been edited to include reference to supporting information for the derivation and selection of these TRVs as suggested. The uncertainty associated with the choice of TRV has been discussed in Section F (Sources of Uncertainty).

50. *Page IV-25: the technical basis for the fish toxicity benchmarks is not fully presented.*

The fish toxicity benchmarks presented in Table IV-30 were derived from a review of the relevant scientific literature. The report text has been edited as suggested to include reference to supporting information for the derivation and selection of these toxicity thresholds.

51. *Page IV-50: ecological significance of the HQs for mink should be considered carefully given the habitat suitability of the study area.*

Since completion of the report, mink have been confirmed to be present in the impacted site area through visual observations by residents. They are also the most common species reported as roadkill on Highway 401 north of the KIH (Parks Canada, personal communication). For these reasons, we retained mink as an ecological receptor for the ecological risk assessment. Habitat suitability for mink will be taken into consideration during development and prioritization of the risk-based sediment quality guidelines for remediation, which is the focus of Chapter V of the KIH report.

52. *Page IV-52: conservativeness of the federal TRGs*

We agree that the federal Tissue Residue Guidelines (TRGs) are very conservative, and this was explained on Page IV-48 of the original report. Replacement of the default exposure assumptions could be completed as suggested. However, risks to upper trophic level aquatic consumers are better assessed through a site-specific ecological risk assessment as we have done for this report. The comparisons of fish tissue concentrations to TRGs were presented in the original report for informational purposes only. We have removed reference to the TRGs in the updated report text.

53. *Page IV-54: documentation of anomalies in the brown bullhead.*

We recognize that the causes of orocutaneous (skin) fish tumours for brown bullhead are not well established in the scientific literature, although higher rates are usually found in contaminated areas and a viral etiology for these tumours has not been found for brown bullhead (Rafferty et al., 2009[2]). It seems unlikely that the substantially higher rates of brown bullhead tumours noted at the impacted KIH site compared with the upstream reference site are not related to sedimentary contaminants. However, we have edited the report text to place less strength on the brown bullhead anomalies as documentation of ecological effects.

54. *Page IV-55: sensitivity of brown bullheads to PCBs should be supported with reference to the literature.*

The results from the KIH study on brown bullhead DELTs (deformities, erosions, lesions, tumours) have been compared to similar studies from other aquatic sites, including the suggested reference from the Housatonic River. The report text has been updated with these findings and the text clarified with respect to the sensitivity of brown bullheads to PCBs.

55. *Pages IV-56 to IV-58: Sources of uncertainty section could be expanded based on the above comments.*

The report text in this section has been edited to include discussion of the sources of uncertainty identified in the above comments.

---

[2] Rafferty et al., 2009. A historical perspective on the “fish tumors or other deformities” beneficial use impairment at Great Lakes Areas of Concern. Journal of Great Lakes Research 35: 496-506.

We hope that our comments are useful and would be happy to participate in further discussion.

Sincerely,

Dr Ken Reimer

Viviane Paquin

Dr Astrid Michels

Dr Tamsin Laing

December 24, 2013

Response to Environment Canada and DFO Technical Review and Data Gap Assessment of Chapter IV of the RMC Report

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

Site: Kingston Inner Harbour (Parks Canada & Transport Canada)

Report Title: "***Application of the Canada-Ontario Decision Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment***" prepared for Parks Canada by Environmental Sciences Group, April 2010.

Date Reviewed: September 10, 2010

Reviewed by: Dan Roumbanis, EC and Sara Eddy, DFO
===

Thank you for reviewing our report summarizing the human health and ecological risk assessment for the Kingston Inner Harbour. We appreciate the time you have taken to review this report and provide feedback.

Please find our responses to the review comments listed below.

General Comments:

1. *Section III.A.1. page IV-28 – ownership boundaries of the Orchard Marsh and FCSAP funding.*

   Orchard Marsh was included in the ERA because it is hydrologically and ecologically linked with the adjacent river ecosystem. Orchard Marsh has been defined as the area of marsh north of the former Davis Tannery property that is dominated by emergent plants (e.g., cattails). It grades into a floating-leaved shallow marsh in the embayment south of Belle Park on the Parks Canada waterlot, which forms part of the river ecosystem. This area also contains the most highly contaminated sediments in the KIH. Seasonal fluctuations in water levels for the Cataraqui River inundate the Orchard Marsh area and provide hydrological connectivity between the two systems. Furthermore, a biological survey carried out in the area identified that all of the receptors in the ERA use both the Orchard Marsh and the adjacent river/marsh ecosystem as habitat. Excluding the Orchard Marsh from the ERA could result in an under estimation of risk.

   We recognize that the upland terrestrial areas around the Orchard Marsh would not be eligible for FCSAP funding. However, the Orchard Marsh is an aquatic site that is inextricably linked with the adjacent shallow marsh and river ecosystem, and that has shared federal and municipal ownership. As such, it appears to meet the criteria for a shared responsibility site under FCSAP.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

2. *Section III.A.2. page IV-29, first paragraph – upstream reference sites not impacted.*

   This statement has been supported in more detail in the report text. Sediment concentrations for the upstream reference sites summarized in Table IV-1 have been compared with the MOE Table 1 Full Depth Site Condition Standards for Sediment as recommended. The 95UCL of all of the CoPCs for the upstream reference area is below the relevant Ontario background sediment concentration with the exception of Cr and Pb; the latter elements are slightly elevated as can be expected for urban sites.

3. *Section IV Executive Summary, page IV-iii, first paragraph – site biota accumulating contaminants.*

   Studies assessing the possibility of existing terrestrial or groundwater sources of contamination to the impacted area of the KIH have not located a present source to date. However, a number of scientific studies investigating plants, invertebrates, and fish from the impacted area of the KIH have noted that all of these groups are accumulating higher levels of contaminants compared with upstream references sites. The most likely explanation is that contaminants in the sediments are bioavailable and are accumulating in the food chain through ingestion of incidental sediment and aquatic prey items. Fathead minnow sediment uptake bioassays with KIH sediments support this conclusion: minnows exposed to contaminated sediments from the impacted area accumulated Pb and PCBs in their tissue to a much greater extent than minnows exposed to upstream reference sediments.

4. *Section IV Executive Summary, page IV-iii, second paragraph – swimming in the south-west portion of the KIH.*

   At the CRSG meeting on November 29, 2010, representatives from the City of Kingston commented that both children and adults have been observed swimming and fishing in this part of the riverFurthermore, risk assessments must also take into account future recreational use scenarios when estimating potential risks to human health. If residential development of the former Davis Tannery property occurs as planned, than the likelihood of people swimming in this area would be greatly increased.

5. *Section IV Executive Summary, page IV-iii, third paragraph.*

   Health Canada expert support review of the human health risk assessment advised the use of a more site specific sport fishing scenario (based on a 2003 MOE survey of fish consumption by recreational fishers in the Great Lakes). This provides a more realistic exposure scenario for the KIH site but did not change the HHRA outcome.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

The swimming scenarios were considered by Health Canada to be sufficiently protective of human receptors.

6. *Section IV Executive Summary, Page IV-iv, fourth paragraph – additive or synergistic effects.*

   At this date, the scientific knowledge does not exist for assessing the potential additive or synergistic effects of a complex mix of contaminants. In fact, the need for further research in this area has been clearly identified as an objective for future ecotoxicology studies by Health Canada. Current standard practice for risk assessment is to assess the risk of each Contaminant of Potential Concern individually – as was done for the KIH ERA.

7. *Section IV Executive Summary, page IV-v, last paragraph – use of ERA results to develop management actions.*

   The results from the KIH ERA will be used to develop risk-based remediation criteria for the clean up of the Kingston Inner Harbour. The development of these criteria and the related management strategy will be detailed fully in Chapter 5 of the KIH report, which is anticipated to be complete by March 31, 2011.

Specific Comments

Section III.A Introduction

8. *Section III.A.2 page IV-29, second paragraph – Inclusion of waterfowl as a VEC.*

   Mallard ducks have been included as a VEC in the revised Ecological Risk Assessment as a waterfowl representative.

Section III.B Receptor Characterization

9. *Section III.B.1. page IV-30, first paragraph - Inclusion of waterfowl as a VEC.*

   See comment 1.

10. *Section III.B.1.a page IV-30 – brown bullhead as indicator species.*

    Assessment studies in the KIH have indicated that the sediments contain contaminant concentrations that exceed the relevant guidelines in some cases by several orders of magnitude, while chemical concentrations in water samples are

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

generally below the relevant water quality guidelines. Therefore, contact with contaminated sediments through skin contact or ingestion of prey items represents the main pathways of contaminant exposure in the KIH. Benthivorous species such as brown bullhead that have a close association with sediments are important indicators of potential ecological effects due to their high levels of exposure. Brown bullhead are commonly used as indicator species for Great Lakes Areas of Concern (AOCs) because of their close association with sediments and small home ranges. They are one of three species in the KIH that currently have fish consumption advisories due to elevated levels of PCB concentrations (MOE sport fish contaminant program). See also comments 20 and 21 below.

Sediment capping is likely not a viable remedial technology for the KIH given the shallow water depths. However, should sediment capping be considered as a management option for the site, burrowing by brown bullhead will be taken into account for the cap design and options analysis.

11. *Section III.B.1.e page IV-32 – Inclusion of mink as a VEC.*

    Mink have been confirmed to be active within the KIH through visual observation from waterfront residents. They are also the most common roadkill species on Hwy 401 at the north end of the KIH (Parks Canada, personal communication). For these reasons, they have been retained as a VEC in the KIH ERA.

12. *Section III.B.1.i. page IV-34 – Inclusion of map and stinkpot turtles.*

    A recent review of the literature and ecotoxicological databases has confirmed that no suitable dose-based toxicological reference values (TRVs) are currently available for amphibians or reptiles. Consequently, risk calculations cannot be completed for these species. An alternative approach would be to identify sediment and tissue-based toxicity thresholds for herptiles through literature review. However, there are generally greater uncertainties in the assessment of ecological risk using this approach, especially given the lack of measured tissue contaminant concentrations for amphibian and reptile species in the KIH. Furthermore, it should be noted that inclusion of this information would not alter the classification of the site as a Class I (Action required) because of potential risks to humans and other higher trophic level receptors. Using sediment and tissue-based toxicity thresholds would permit the development of herptile-specific risk-based sediment quality guidelines for remediation; however, there could be large uncertainties about these guidelines given the lack of measured data.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

13. *Section III. B.3. page IV-37 – Inclusion of piscivorous fish.*

    Like the turtles, no suitable dose-based toxicological reference values (TRVs) are currently available to assess ecological risk for piscivorous or benthivorous fish. However, tissue-based toxicity thresholds for piscivorous fish have been identified through literature review and used to assess potential ecological risks to three species of fish (brown bullhead, yellow perch, and northern pike).

14. *Section III.B. General comment – VEC structural attributes.*

    The population structural attributes specific to the chosen KIH VEC receptors are largely unknown. Carrying out studies to assess population density and age structure of the selected VECs is beyond the scope of a standard risk assessment. However, the report text has been edited to indicate the status of each of the selected VECs.

Section III.C Exposure Assessment

15. *Section III.C.7. page IV-42 – ADD equation abbreviations.*

    Addressed.

16. *Section III.C.8. page IV-43 – Total Hg or MeHg.*

    References to mercury have been clarified throughout the report as total Hg or MeHg. Regarding the available data about the fraction of total Hg present as MeHg: this varies depending on the media sampled. For example, mercury in fish is almost always present as MeHg due to biomagnification and biological methylation processes. Therefore, common practice is to assume that measured total Hg in fish is composed of 100% MeHg as was done in this study. For sediments, the MeHg fraction is very low: a recent study of KIH sediments found that 0.01 to 1.04% of the total Hg measured was present as MeHg (Manion 2010[1]). These details have been included in the report text.

17. *Section III.C. General Comment – sediment resuspension.*

    Risk calculations have been redone including incidental sediment ingestion for the muskrat, red-winged blackbird, the mallard duck, and the heron and are included in the revised report. A review of the relevant scientific literature indicated that

[1] Manion, N., Campbell, L., and A. Rutter. 2010. Historical brownfields and industrial activity in Kingston, Ontario: assessing potential contributions to mercury contamination in sediments of the Cataraqui River. Science of the Total Environment 408:2060-2067.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

incidental sediment ingestion for the mink and osprey is expected to be negligible given the feeding habits of these two receptors; therefore, sediment ingestion was not included in the mink and osprey diet.

18. *Section III.C.9. page IV-44 - Total Hg or MeHg.*

    Addressed.

19. *Section III.C.9. page IV-44 – uptake model for Hg to cattails.*

    We are not aware of any established uptake models to predict follicular Hg uptake from surface water. However, mercury uptake into the cattails is expected to be low given that the highest sedimentary concentrations of Hg are in the vicinity of the Rowing Club, where conditions are not suitable for cattail growth. The scientific literature indicates that seasonal changes in plant inorganic element concentrations (including Hg) occur, but seasonal patterns of uptake vary greatly with the type of metal and the species of plant. Overall, older leaves generally acquire greater concentrations of inorganic elements over their life span. For the KIH, cattail samples were collected during the fall at the end of the growth season when plant concentrations should reach maximum seasonal levels.

20. *Section III.C.10, page IV-44f – area used for EPC calculations.*

    Clarified in text.

21. *Section III.C.11. page IV-46 – Total Hg or MeHg in Table IV-23.*

    Addressed.

Section III.D Hazard Assessment

22. *Section III.D.1. page IV-47 – TRVs for total Hg/MeHg.*

    Clarified in text.

23. *Section III.D.2. page IV-47 – Toxicity thresholds for fish specific metals COPCs.*

    The suggested reference was reviewed. Unfortunately, the scientific methodology used in the paper is inappropriate for determining fish tissue toxicity thresholds. Further literature review did not identify any appropriate toxicity thresholds to assess Cr concentrations in fish tissue.

December 24, 2013

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

Section III. E Ecological Risk Characterization

24. *Section III.E.1. page IV-50 – mink HQs.*

    Mink have been confirmed to be active within the study area (see comment 4) and therefore this species was retained as a VEC in the ERA.

25. *Section III.E.2. page IV-50, second paragraph – osprey and heron site use.*

    Point is noted regarding the fraction of the receptor's diet that is harvested from the impacted site (F_{site}) for osprey and heron. However, the new ERA calculations for Cr including incidental sediment ingestion (see Comment 10) for heron find HQs>1 even when the F_{site} is 0.5.

26. *Section III.E.2. page IV-51, fourth paragraph – maximum or UCL95 of fish tissue residue concentrations.*

    As indicated in Section C.10 of the report, the UCL95 of fish tissue concentrations was used to calculate exposure point concentrations (EPCs) for the risk assessment. The fish toxicity thresholds listed in the original Table IV-26 (now Table IV-30) are values identified in the aquatic toxicity scientific literature and are not derived from site data.

27. *Section III.E.3. page IV-53, second paragraph – risk analysis for fish.*

    As outlined in the report, there are currently no suitable dose-based toxicological reference values (TRVs) for fish that can be used to calculate a site-specific hazard quotient. Therefore, alternative methods of assessing potential ecological effects to fish must be used. Fish tumours are widely used as an indicator of detrimental ecological effects and are designated as one of the beneficial use impairments for the Great Lakes Areas of Concern, with brown bullhead commonly used as an indicator species for fish tumour studies in the southern Great Lakes. There is strong evidence to indicate that exposure to chemical carcinogens is a primary factor in liver tumours for various species of fish (Rafferty et al., 2009[2]). The causes of orocutaneous (skin) fish tumours are less established, but higher rates are usually found in contaminated areas and a viral etiology for these tumours has not been found for brown bullhead (Rafferty et al., 2009). It seems unlikely that the substantially higher rates of brown bullhead tumours noted at the impacted KIH site compared with the upstream reference site are not related to sedimentary

---

[2] Rafferty et al., 2009. A historical perspective on the "fish tumors or other deformities" beneficial use impairment at Great Lakes Areas of Concern. Journal of Great Lakes Research 35: 496-506.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

contaminants. However, we have edited the report text to place less strength on the brown bullhead anomalies as documentation of ecological effects.

28. *Section III.E.3. page IV-54 – abnormalities in Brown Bullhead.*

A literature review was completed with the following goals: 1) to review the available scientific information on brown bullhead tumours; and 2) to compare the approach used for the KIH with fish tumour studies conducted at other Great Lakes AOCs. The review identified that the approach used to describe orocutaneous tumours and abnormalities for the KIH fish was consistent with that used at other AOC and non-AOC sites (e.g., Blazer et al., 2009[3]). The prevalence of orocutaneous tumours measured for brown bullhead at the KIH impacted site was higher than any of the sites compiled in the Blazer et al. 2009 review. Admittedly, the sample size for the KIH impacted site (n=14) is smaller than those from the other Great Lakes AOCs (n = 34 to 56). However, the area of the KIH impacted site is also much smaller than the area of the other Great Lakes AOCs, which limits the number of fish that can feasibly be collected.

With respect to assessing the causes of abnormalities in brown bullhead: see summary of literature in comment 20. Determination of the definitive causes for the brown bullhead abnormalities would require further ecotoxicological research studies that are beyond the scope of this project.

Section III.F Sources of Uncertainty

29. *Section III.F.1. page IV-56 – spatially weighted assessment.*

We don't feel that a spatially weighted assessment (SWA) is appropriate for the KIH for two reasons. First, the SWA assumes that a receptor is foraging equally throughout its home range; however, this assumption is likely false when preferred food items (such as cattail roots for the muskrat) are only found in concentrated patches. Use of the SWA in this case may under-estimate the potential risk through ingestion. Secondly, it should be noted that most ecological risk to upper trophic level receptors is due to consumption of fish, which are mobile – in this case, a SWA is not appropriate for a small site such as the KIH where the home range of the fish generally exceeds the site area.
The approach used in the KIH ERA was to include the contaminated site as a fraction of the home range of each receptor in order to estimate site use, which follows standard practice for risk assessment.

[3] Blazer et al., 2009. Assessment of the "fish tumors or other deformities" beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): I. Orocutaneous tumors. Journal of Great Lakes Research 35: 517-526.

December 24, 2013

Environmental
Sciences Group

Royal Military
College of
Canada

P.O. Box 17000
Stn. Forces

Kingston,
Ontario

K7K 7B4

Section III.G Ecological Risk Assessment

30. *Section III.G. page IV-59 – fish community productive capacity.*

    The link between morphological abnormalities in brown bullhead and potential impacts on the site's productive capacity or overall fish community is unknown. Establishing this link would require scientific research studies that are beyond the scope of this project.

We hope that our comments are useful and would be happy to participate in further discussion.

Sincerely,

Dr Ken Reimer

Viviane Paquin

Dr Astrid Michels

Dr Tamsin Laing

December 24, 2013

Response to Parks Canada Technical Review and Data Gap Assessment of Chapter IV of the RMC Report

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

Site: Kingston Inner Harbour (Parks Canada & Transport Canada)

Report Title: "***Application of the Canada-Ontario Decision Making Framework for Contaminated Sediments in the Kingston Inner Harbour, Chapter 4: Human Health and Ecological Risk Assessment***" prepared for Parks Canada by Environmental Sciences Group, April 2010.

Reviewed by: Hillary Knack, PCA
==

Thank you for reviewing our report summarizing the human health and ecological risk assessment for the Kingston Inner Harbour. We appreciate the time you have taken to review this report and provide feedback.

Please find our responses to the review comments listed below.

General Comments

1. *Page IV-iv, first paragraph – fish advisories*

   Addressed in text.

2. *Page 2, last page of introduction – proposed waterfront trail*

   The description of the proposed location for the waterfront trail was taken from Schedule 5: Pathways from the 2010 City of Kingston Official Plan. However, a recent private citizen initiative is proposing that the western side of the harbour be considered for a waterfront pathway from the Lasalle Causeway to Kingston Mills.

Specific Comments

Section 2 Human Health Risk Assessment

3. *Table IV-1 – lack of Hg data*

   The report has been updated with Hg values from the reference sites

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

4. *Table IV-2 – mean value of DDT used instead of maximum.*

   The 95UCL of measured contaminant concentrations was used for the risk assessment following standard practice.

5. *Page 5, potential hazards – DDT and PAHs.*

   Both DDT and PAHs are hydrophobic organic contaminants and so are generally found in trace levels in water samples.

6. *Page 7, potential hazards in harvested foods – wording change.*

   Text edited as suggested.

7. *Page 8, third paragraph – MOE guidelines for fish consumption.*

   Text has been updated and the MOE fish consumption guidelines have been included.

8. *Page 9, identification of receptors.*

   Contaminant concentrations in water samples from the KIH were screened against the available drinking water guidelines and the results are discussed in the revised HHERA report. None of the maximum concentrations for any of the contaminants exceed Ontario or Health Canada drinking water guidelines designated for the protection of human health. It is not known whether people living on moored boats in the harbour use water from the KIH as a drinking water source. However, intake of surface water is highly unlikely to pose a human health risk given that measured contaminant concentrations in KIH surface water samples are in compliance with drinking water standards.

9. *Table IV-8 – flooding as a possible pathway.*

   Flooding is an unlikely exposure pathway given that the water level in the harbour is regulated through the controls implemented for the St Lawrence Seaway.

10. *Table IV-11 – 80 years doesn't match the 60 years in Table 10.*

    Eighty years is the recommended lifetime for calculation of incremental cancer risks from potential carcinogens. Health Canada recommends using a composite receptor (*i.e.*, toddler + child + teen + adult) for carcinogenic effects – therefore the exposure duration for carcinogens for all receptors in Table 10 is added to get an overall value of 80 years.

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000 Stn. Forces

Kingston, Ontario

K7K 7B4

11. *Page 16 – add a "t" to relevant.*

    Text edited as suggested.

12. *Page 20, second paragraph – risk from lead from eating fish.*
    Text has been updated*.*

13. *Page 21, "certain species of fish...".*

    Text edited as suggested on page 29.

Section 3 Ecological Risk Assessment

14. *Page 28, last paragraph.*

    Text edited as suggested.

15. *Page 29, first paragraph.*

    It is possible that individuals from some fish species (e.g., northern pike) could travel between the impacted and the references site. However, the significantly higher PCB concentrations measured in northern pike from the impacted site compared with pike from the reference site (see Chapter 3 of the report) suggests that the fish populations at each site are largely distinct – otherwise, similar PCB concentrations should be observed. Similar patterns of elevated PCB concentrations in brown bullhead and yellow perch from the impacted site were observed, and it is unlikely that individuals of these species would be found at both the impacted and reference site due to their smaller home ranges.

16. *Page 31, muskrat.*

    Text edited as suggested.

17. *Page 34, reptile SARA designation.*

    The SARA designation has been added to the text and the wording edited as suggested.

18. *Page 39, second paragraph.*

    Text edited as suggested. At this date, the scientific knowledge does not exist for assessing the potential additive or synergistic effects of a complex mix of

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000
Stn. Forces

Kingston, Ontario

K7K 7B4

contaminants. In fact, the need for further research in this area has been clearly identified as an objective for future ecotoxicology studies by Health Canada. Current standard practice for risk assessment is to assess the risk of each Contaminant of Potential Concern individually – as was done for the KIH ERA.

19. *Page 43, first paragraph.*

Text edited as suggested. Mercury data is not available for cattails given budgetary and analytical limitations.

20. *Page 44, exposure points for fish consumption.*

For the ESG sampling program, Hg was not measured in fish tissue due to budgetary and analytical limitations. PCBs were measured for most samples and the text has been corrected to reflect this. Both Hg and PCB data on fish tissue concentrations were available through the MOE sport fish monitoring program and these data were used for the KIH ERA.

21. *Page 47, toxicity thresholds.*

The development of toxicity reference values for contaminants involves intensive laboratory and field research studies. Typically, toxicological information is only available for a few test species, and it is standard practice to apply these reference values to assess risk for similar organisms.

22. *Table IV-28 – risk to predators of muskrat and mink.*

Given the urbanized surroundings, the KIH is expected to provide minimal habitat for natural predators of muskrat and mink such as coyotes, wolves, foxes, and owls. Although it is possible that risk may be present to individuals consuming muskrat and mink, the contamination would be unlikely to affect predators at the population level given the lack of suitable habitat.

23. *Page 54 – significance of brown bullhead deformities at reference sites.*

The prevalence of brown bullhead skin anomalies in the KIH reference site is comparable to that measured in other reference sites throughout the Great Lakes (Blazer *et al.*, 2009[1]). With respect to the causes of fish tumors the fish health

---

[1] Blazer et al., 2009. Assessment of the "fish tumors or other deformities" beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): I. Orocutaneous tumors. Journal of Great Lakes Research 35: 517-526.

December 24, 2013

Environmental Sciences Group

Royal Military College of Canada

P.O. Box 17000
Stn. Forces

Kingston, Ontario

K7K 7B4

literature suggests that fish tumors are useful as an environmental indicator and there is evidence for higher rates of skin tumors in contaminated areas (Rafferty et al., 2009[2]). However, skin tumours may also be caused by viruses and parasites. It seems unlikely that the substantially higher rates of brown bullhead tumours noted at the impacted KIH site compared with the upstream reference site are not related to sedimentary contaminants. The prevalence of orocutaneous tumours measured for brown bullhead at the KIH impacted site compared with the upstream reference site was higher than any of the sites compiled in the Blazer et al. 2009 review.

24. *Page 56, red-winged blackbird diet.*

    We agree that high CoPC in benthic invertebrates and insects could affect amphibians also, but were unable to assess the risk to amphibians due to a lack of appropriate dose-based TRVs (toxicological reference values).

Section 4 Summary

25. *Page 58, summary – relationship of measurement endpoints to assessment endpoints.*

    The summary text has been edited to clarify the outcomes of the risk assessment regarding the assessment endpoints.

We hope that our comments are useful and would be happy to participate in further discussion.

Sincerely,

Dr Ken Reimer | Viviane Paquin

Dr Astrid Michels | Dr Tamsin Laing

[2] Rafferty et al., 2009. A historical perspective on the "fish tumors or other deformities" beneficial use impairment at Great Lakes Areas of Concern. Journal of Great Lakes Research 35: 496-506.

ESG response to comments on the
Kingston Inner Harbour Report, Chapter V:
An options analysis of management scenarios for the KIH

Table of Contents

Preface

The Kingston Inner Harbour (KIH), Kingston, Ontario, has been the subject of many scientific investigations over the past thirty years because of significant chemical contamination by historical industrial activities. The Environmental Sciences Group (ESG) of the Royal Military College of Canada in Kingston began investigating the river sediments of the KIH as a scientific project in 1999. ESG is an organization conducting applied and basic research on a not-for-profit basis, with expertise in aquatic and risk assessments. As contaminated site experts we have, for example, been commissioned by the FCSAP expert support departments to develop scientific guidance for achieving site closure at aquatic contaminated sites for Fisheries and Oceans Canada (DFO), and have developed science plans for both Environment Canada (EC) and DFO expert support. In addition, we have been contracted by Health Canada (HC) to support the advancement of risk assessment in Canada.

In 2006, ESG formed the Cataraqui River Stakeholder Group (CRSG) to address concerns about the potential adverse biological effects posed by the contamination in the KIH and to involve key stakeholders in the sediment assessment and remediation decision-making process. As the scientific lead on the project, ESG has devoted significant resources to the scientific studies within the KIH, as well as amalgamating the extensive data that has been collected and research that has been conducted by other institutions, such as the OMOE and the City of Kingston.

Throughout the assessment process, ESG has consulted with stakeholders and encouraged an open and ongoing dialogue between stakeholder members. For the past six years, ESG has coordinated semi-annual face-to-face meetings to present and discuss study results and invite input on proposed next steps that meet the requirements of the FCSAP process and COA frameworks for dealing with aquatic contaminated sites. The study results have been written up in a five-chapter report entitled "Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour." Each chapter has been extensively peer-reviewed by all three FCSAP expert support departments (EC, DFO and HC) as well as by third-party consultants contracted by the custodial departments Parks Canada and Transport Canada.

The scientific approach used to assess contamination in the KIH and develop remedial and risk management objectives follows established frameworks consistent with FCSAP guidance and current recommended scientific practice. As is typical for environmental investigations, an iterative process was used to assess sediment contamination, biological effects, and associated human health and ecological risks. Data gaps were identified at each stage, through scientific review and peer review from the FCSAP expert support departments as well as input from the CRSG. Additional information was collected throughout the project to address these gaps, decrease uncertainties, and provide realistic exposure scenarios for the KIH. The frameworks used to guide the process include:

- *Framework for addressing and managing aquatic contaminated sites under the FCSAP program*: A 10-step approach that provides overall guidance for addressing federal aquatic contaminated sites.

- *Canada-Ontario Assessment (COA) framework:* Guidance for Steps 2 to 6 of the FCSAP aquatic sites framework (sediment and biological assessment). The outcomes indicate that there is strong evidence for bioaccumulation and biomagnification of contaminants in the KIH aquatic food web and mixed evidence for benthic community impairments throughout the KIH.

- *Human Health and Ecological Risk Assessment (HHERA):* an appropriate assessment methodology was used to evaluate the risks to humans and upper trophic level receptors from contaminant bioaccumulation in the KIH aquatic food webs. The results indicate that some contaminants in the KIH pose unacceptable risks to human health and upper trophic level receptors. The current KIH human health risk assessment has been confirmed by HC to be a detailed quantitative HHRA; the KIH ecological risk assessment is consistent with standard practice in the field.

- *FCSAP Aquatic Sites Classification System (ASCS):* Information from the COA assessment and the HHERA were used to classify the site. Based on the comprehensive information from the COA assessment and the HHERA, the KIH was classified as Class I (Action required). The classification was reviewed by each of the FCSAP support departments (HC, DFO and EC), who all agreed that the KIH is a Class I site requiring management action.

As confirmed with the CRSG, the main risk management/remedial goal for the KIH is the protection of human health and ecological integrity. To this end, an HHERA was carried out, and the results were used to develop the sediment quality objectives (SeQOs) for the KIH presented in Chapter V of the KIH report. This approach is consistent with the FCSAP aquatic contaminated sites framework, which strongly recommends that site-specific numeric remediation objectives be developed to protect both human health and the environment, based on the outcomes of an HHERA.

The detailed scientific investigations conducted in the KIH to date have provided a large amount of data that may be used confidently by site managers to make a risk management decision. These include 947 sediment samples, 190 biological tissue samples comprising 15 species of biota, 34 toxicity samples, and 9 benthic community assemblage samples. The amalgamated data presented in the KIH report represent a considerable level of effort and expenditure that is comparable to and in some cases exceeds the information used at other aquatic sites to make remedial decisions. While ambiguities in benthic community responses are common in aquatic projects, they do not preclude making remedial decisions. In cases such as the KIH where contaminant bioaccumulation in the aquatic food web poses unacceptable risks to human and ecological receptors, the benthic community responses are of lesser importance.

It is ESG’s position that the scientific assessment of the KIH sediments is now complete and that it is necessary to proceed to an examination of risk management options.

As we have extensive experience with the peer review process, both for projects we have completed and as reviewers for other projects, we understand the time commitment associated with a strong review of a project, and we welcomed the volume of comments received. Many of the comments have been useful, particularly those from FCSAP expert support departments, and we thank you for the time taken to complete these reviews. We were surprised at the tone of some of the other comments received. Despite this, ESG has carefully reviewed and responded to every single peer review comment. This iterative process will be made transparent by including the comments and the responses to them in the appendices of the KIH report which, upon completion, will become a public document. At the meeting on February 23rd, 2012, ESG will present their responses to reviewer comments. The presentation will focus on those comments that have the greatest bearing on decisions concerning the development of remediation /risk management objectives for the KIH.

We look forward to bringing closure to the scientific assessment process for the KIH at the upcoming meeting. All of the original review comments and our responses are attached here for your reference.

K. J. Reimer
Professor, Chemistry & Chemical Engineering Department
Director, Environmental Sciences Group
The Royal Military College of Canada
Kingston, Ontario K7K 7B4 CANADA

Tel: 613-541-6000 x 6161
Fax: 613-541-6596
reimer-k@rmc.ca

ESG response to "Parks Canada's Comments on Chapter 5", revised September 16, 2011

PC comments: Parks Canada is one of the custodial departments of the Kingston Inner Harbour and is performing its due diligence in the review of this document.

Parks Canada makes reference to and incorporates comments of a gap analysis which is a report commissioned by Parks Canada during the winter of 2010–11. The report was provided to ESG under separate cover. The gap analysis indicates that more work is required in several areas in order to support/clarify some of the conclusions made in the Chapter 5 report. Parks Canada intends to complete the recommendations of the gap analysis report as quickly as staff and financial resources allow.

ESG response:

A response to comments made in the gap analysis commissioned by Parks Canada Review and Data Gap Assessment for Parks Canada Waterlot, Kingston Inner Harbour (Golder 2011a) is provided under separate cover. The Golder gap analysis document and ESG response will be included as an appendix in the final report

Principal Comments

1. **Upstream remote/non-point sources**

PC comment: The consideration of source control is paramount and assuming an integrated basin-wide approach should serve to ensure that remedial activities are not implemented while upstream inputs undo good work. This is particularly relevant with respect to the geographic location of the site at the mouth of the Cataraqui River. It is highly likely that remote/non-point upstream sources are contributing to natural transport and deposition of sediments at the site (substances are being transported downstream via suspension in water with deposition south of Belle Park).

ESG response:

We do not believe that upstream sources in the Cataraqui River are a significant ongoing source of contaminants to the Parks Canada water lot for the reasons outlined in the following paragraphs.

First of all, a historical review indicated that there was little industrial activity north of Belle Park. Potential upstream contaminant sources likely include nutrients and bacteria from septic systems, agricultural activities, and occasional combined sewer overflow events. It would be highly unlikely that these sources would contribute contaminants such as PCBs or Cr, which have been identified as main contaminants of concern in the southern KIH. As is typical for urban environments, urban runoff is also a likely source of contaminants to the northern KIH. However, water quality studies in the KIH have indicated that water quality is generally good with respect to provincial water quality objectives. Sediment quality studies are summarized below.

Secondly, the available evidence indicates that most of the water flow from the northern KIH occurs along the eastern shore and through the LaSalle Causeway, with very little flow along the western shore (City of Kingston and OMOE, 2005). This suggests that potential transport of contaminants from the northern KIH and deposition in the southwestern portion of the KIH would be limited.

Thirdly, a detailed comparison of contaminant concentrations in reference area sediment samples (collected north of Belle Park) compared with sediment samples from the southern KIH was presented in Chapter II of the KIH report. As is typical for urban environments, contaminant concentrations at many of the reference sites exceeded the CCME ISQG and, in a few cases, the CCME Probable effects level (PEL). However, mean sediment contaminant concentrations at southern KIH sites were identified as being significantly higher (in some cases, by several orders of magnitude) than those at northern KIH reference sites for the following list of contaminants: Cr, Pb, Cu, As, Hg, and PCBs. The available core data for the southern KIH indicates that inorganic contaminant concentrations in sediments deposited prior to the onset of industrial activities are comparable to surface sediment contaminant concentrations in upstream reference sites. This suggests that the reference site sediment contaminant concentrations are reflective of natural and urban background levels.

Taken together, these data indicate that contaminant concentrations in upstream sediments are low in comparison with the sediment contamination in the southern KIH that has accumulated as a legacy of historical industrial activities. The sediment quality remedial objectives determined for the southern KIH are generally at least an order of magnitude greater than mean sediment concentrations in the upstream reference area. Therefore, even if there was appreciable erosion and deposition of upstream sediments to the southern KIH (which appears unlikely given water flow patterns in the KIH), the resulting sediment concentrations would still be well below levels that would trigger management action.

We agree with the reviewer that source control is important to address for the KIH, and this is discussed in detail in Section II-B-b of the draft Chapter V report. Potential ongoing contaminant sources for the KIH have been investigated by the Ontario Ministry of the Environment (OMOE) and the City of Kingston (see response to comment 180 below). The City of Kingston, a member of the stakeholder group, has also reaffirmed that, if needed, the City will take the steps necessary to address any source issues related to sanitary/storm sewers (June 2010 remediation options workshop minutes).

2. **Chapter 5 as a recommendation**

PC comment: Parks Canada is recommending that Chapter 5 be regarded as a recommendation. There are elements in Chapter 5 that require coordination, additional work and further discussion. For example: Are the recommended institutional controls related to human health receptors practicable? Are the impacts of the project going to require replacement strategies and what will be the impacts of habitat alteration? In addition, the gap analysis identified additional work that needs to be completed.

ESG response:

The intent of Chapter 5 is to identify the area of the KIH that requires management action. Detailed remedial plan development, along with an environmental assessment and mitigation measures for remedial activities, will be identified as part of the remedial action plan.

Please note that the ESG response to comments made in the gap analysis commissioned by Parks Canada (Golder 2011a) is provided under separate cover. The Golder gap analysis document and ESG response will be included as an appendix in the final report.

3. **Separate ASCS classification for the Parks Canada and Transport Canada properties**

PC comment: Would it be appropriate to have a separate classification for the Parks Canada and Transport Canada areas of jurisdiction since they are currently listed separately on the Federal Contaminated Sites Inventory?

ESG response:

ESG would be happy to provide separate ASCS classification sheets for the Transport Canada and Parks Canada water lots if needed. However, in reviewing the ASCS classification worksheets and associated reports, Health Canada expert support recommended that Parks Canada and Transport Canada should compare their site conditions and determine whether conditions are sufficiently different to warrant separate sites, or whether they are sufficiently similar to warrant merging the sites into one FCSAP site (HC 2011). There are several factors that favour merging the sites into one FCSAP site, as follows:

a) Risks to higher trophic level receptors (e.g., humans, mammals, and birds) are driven in part by consumption of contaminated prey items that are mobile throughout the harbour. Completing separate risk assessments for the Transport Canada and Parks Canada water lots would not be scientifically sound, given that there is significant exposure of receptors to contaminants on adjacent water lots. Therefore, the KIH as a whole must be considered for receptor exposure.

b) As Environment Canada expert support has pointed out in their comments on Chapter V, “collaboration within the federal family is essential to achieve any operational and financial efficiency in the remedial process” (Summary, paragraph 5; EC 2011). This may warrant consideration of the KIH as one FCSAP site.

c) Due to the high potential for re-suspension and transport of KIH sediments (see Chapter V, Section III-B-a), it would be unwise to remediate the water lots separately, as there is potential for recontamination of the remediated area from the adjacent water lot property. Both water lots should be remediated at the same time to avoid this issue.

4. **Infilling of residual contamination on Rowing Club site**

PC comment: Work was done in the past to remove Hg from the site adjacent to the Rowing Club and over time the Hg has come back, presumably due to infilling by residual contamination. How would it be ensured that this same scenario would not happen again?

ESG response:

As clarification to the above, the focus of the OMOE dredging program was to remove PCB contamination (not Hg). The Rowing Club remediation was a very small targeted dredging action with removal of 780 m^3 of sediments. The dredged area is surrounded by contaminated sediment, and it is not surprising that some infilling of the dredged area has occurred with the surrounding contaminated sediment. Comparison of the sediment PCB concentrations measured in a follow-up sampling program with those measured immediately after dredging indicated that PCB concentrations had increased slightly, but were still below the sediment quality remediation objectives and well below pre-dredging concentrations (Benoit and Burniston 2010).

The proposed sediment remediation scenarios in Chapter V would require removal of a much larger area of sediments and have been selected to remove sediments that pose potential risks to human and ecological receptors. Some infilling with the surrounding sediments is inevitable, but under the proposed scenarios residual contamination would be much lower than in the targeted dredging action cited above. In this case, infilling would not be anticipated to result in widespread sediment concentrations that would pose unacceptable risk to receptors. It will be important to remediate both water lots at the same time to avoid subsequent infilling with contaminated sediments from adjacent water lots (see Comment 3 above).

5. **Scoring classification as residential development**

PC comment: The scoring classification refers to the federal land use for the site as "residential development." This may require a change as the federal government does not propose "residential development" as the federal government's future use of the site.

ESG response:

We recognize that the land use for the water lot is not residential development. However, residential development is proposed as the land use for the former Davis Tannery brownfield that borders the site. This would increase access to the Parks Canada water lot and would be likely to result in greater recreational use of this area of the harbour.

6. **Outcome of June 2010 meeting with regards to dredging**

PC comment: With regard to the June 2010 meeting, suggest replacing "was supported" by "was presented" as dredging as a remedial strategy was not clearly supported by all experts. Specialists in the field and the expert support departments can help to provide valuable advice and to ensure that the study is following federal guidelines; however, the management option ultimately will be chosen by the *custodial departments. This study should present advantages and disadvantages of the various management options to help this process.*

ESG response:

The FCSAP framework for addressing a contaminated site has adopted the guiding principles described in the US EPA contaminated sediment remediation guidance. The guidance strongly encourages the use of a technical team approach and the involvement of stakeholders in the sediment remediation process. A goal of the June 2010 remediation options workshop was to bring together appropriate expertise and stakeholders to get consensus on what constitutes the most feasible remediation approach for the KIH. To this end, ESG presented a sound scientific analysis of the pros and cons of different remediation options for the KIH for consideration by the group. The analysis showed that dredging is the most effective and technically feasible option, given the site-specific conditions. There was general agreement among workshop participants that dredging is an appropriate and reasonable remediation option for the KIH. However, while there was general agreement with the outcomes of the remediation options analysis, it is recognized that the remediation approach that is ultimately selected must balance the results of scientific investigations/analyses with environmental, social and economic considerations.

The various management options available for the Kingston Inner Harbour (i.e., no action, monitored natural recovery, capping, and dredging) are presented in Chapter V and evaluated as to their effectiveness and feasibility for addressing sediment contamination in the KIH. We do not believe it appropriate to select a management option that 1) will not be effective in decreasing environmental and human health risks from the sediment contamination, or 2) is not feasible as a remedial strategy for the KIH because of limiting conditions at the site.

Principal Comments

7. **Methodology**

PC comment: The methods used in developing the remedial options are sound and consistent with an understanding of current practice.

ESG response:

We appreciate confirmation of our approach.

8. **Weight of evidence approach**

PC comment: The report prudently employs a weight of evidence approach consistent with federal direction (and good science) thereby providing a strong basis for the argument that significant effects are occurring.

ESG response:

We appreciate confirmation of our assessment of the results for the KIH.

9. **Use of a risk-based approach**

PC comment: The development of the cleanup options is approached in a risk-based manner and thereby focuses on that part of the contamination that drives the risk, allowing the remedial plan to be designed to deal with what matters most while limiting environmental change.

<u>ESG response:</u>

We appreciate confirmation of our adoption of a risk-based approach to determine the area of the harbour that requires management. A goal of the June 2010 remediation options workshop was to have concurrence on how to determine what portion of the harbour is polluted and needs to be remediated. To facilitate this outcome, ESG presented case studies of different approaches used at other sediment contaminated sites to derive site-specific risk-based remediation objectives. The participants agreed that using a risk-based approach to derive cleanup objectives was appropriate for the KIH. Following much discussion, Dr. Ken Reimer confirmed with the group the risk-based approach to be used to develop the sediment quality objectives (SeQOs) presented in Chapter V.

10. **Add sections indicating short-term, mid-term, and long-term recommended actions**

PC comment: It is suggested that Chapter 5 include a section on "Immediate Recommended Actions" (e.g., put up signs, ban fishing) vs. "Mid-Term Actions" vs. "Long-Term Actions."

<u>ESG response</u>

These sections have been added into the revised report text.

11. **Health risks in the KIH**

PC comment: It would be beneficial to state that the potential health risk in the KIH is related to the area indicated on Map V-4; health risks in other areas are not as significant or not significant at all.

<u>ESG response:</u>

The human health risk assessment for the KIH assumed that receptors could be exposed to contaminants through the following pathways:

a. inadvertent ingestion of and dermal contact with sediment during wading, walking, playing activities;
b. ingestion and dermal contact with suspended sediments during swimming, rowing; and
c. ingestion of contaminated food stuffs (fish caught in the KIH).

Since fish are mobile and move throughout the KIH, it does not seem appropriate to assess human health risks for pathway c. (ingestion of contaminated fish) separately for different portions of the southern KIH. For contaminants of concern where the fish ingestion pathway is the main contributor to overall risk, such as PCBs and MeHg, human health risks would not vary significantly throughout the harbour. However, addressing sediments in the area for management indicated in Map V-4 would remove most of the PCB sediment contamination that is bioavailable to fish, resulting in eventual decreases in fish tissue PCB concentrations (and hence decreased human health risks due to fish consumption).

For other contaminants such as Hg, As, and Cr, dermal contact with sediments is the main exposure pathway contributing to overall risk. For these contaminants, Health Canada has recommended assessing human health risks for different microenvironments of the harbour to aid in making management decisions. ESG is incorporating this recommendation into the revised Chapter V report. This approach may be particularly useful in determining management decisions for the Rowing Club/Woollen Mill area, identified as an Area of Special Consideration in the management scenarios presented in Chapter V of the KIH report.

12. **Acronym list**

PC comment: It would be helpful to have an acronym list with all the acronyms used throughout the report.

<u>ESG response:</u>

Chapter V acronyms and abbreviations have been incorporated into the list of abbreviations for the entire KIH report, which defines abbreviations/acronyms presented in all five chapters.

13. **Standardize referencing to the area of interest SW of Belle Island**

PC comment: Please standardize the referencing to the area of interest SW of Belle Island as it is a small piece of the KIH. Suggest standardizing reference to the location as southwest of Belle Island, southwest portion of the KIH or something similar. (A list of page references for text revision follows.)

<u>ESG response:</u>

Text has been edited for clarification.

14. **Increased content for ongoing contaminant sources and volumes of sediment requiring remediation**

PC comment: Please increase the content of the following topics in order to meet the objectives outlined in the Parks Canada Implementation Agreement (IA) with ESG:

A. A summary of studies that assessed the potential for ongoing sources of contaminants to the Harbour (via groundwater, erosion, runoff, leaching, storm water, etc.) (section 3.1.1.2 of the IA)

Runoff as a potential source for contamination should be considered at the whole watershed level, not just the point sources. This is particularly important given the geographic distribution of the contaminated sediments for which priority action is recommended. The gap identified in the temporality of the contamination process (see Table V-2, Strength of evidence, page V-12) is in support of this observation. The contaminated sediment could have accumulated at the mouth *of the Cataraqui River through a very long-term process, involving both local point sources and remote non-point sources. In fact, contaminants were found upstream, but at lower concentrations, which do not preclude their transport through drainage/flow and deposition within the KIH. Dredging of area currently identified at high risk may not necessarily be effective as contamination will continue to build up in the KIH over time. Unless a whole watershed approach is taken, one may not necessarily identify all contributing sources.*

<u>ESG response:</u>

Please see the response to comment 1, which addresses the reviewer concerns with regard to potential upstream sources of contaminants and flow patterns in the KIH.

We would also like to clarify that the gap mentioned by the reviewer for the temporality of the contamination process is due to the fact that no samples were collected in the Cataraqui River before historical industrial discharge (i.e., pre-1890s) and does not support the argument for upstream sources of contaminants. In fact, the available core data shows that mean concentrations of inorganic contaminants at depth in sediments deposited prior to industrial discharge are similar to the mean concentrations in upstream surface sediments (see detailed discussion in Chapter II of the KIH report).

As discussed in Chapter II, the spatial distribution and depth profiles of contaminants in sediments for the southern KIH are consistent with historical discharge of these contaminants through industrial activities on adjacent lands. The sediment contamination in the southern KIH has accumulated as a legacy of historical activities and is not reflective of potential ongoing upstream sources.

Discussion of potential ongoing sources of contaminants to the KIH in Section II-B-b of the draft Chapter V report has been augmented with additional content. The outcomes of recent work by the OMOE and the City of Kingston to assess potential ongoing sources of contaminants have also been included.

B. *Provide estimates of the volume and distribution of contaminated sediments to be remediated among land tenures, based on the SeQOs, as well as associated costs (Section 3.1.1.7 of the IA)*

   It would be helpful if the volumetric and aerial distribution of contaminated sediments for which priority action is recommended could be broken along land tenures (or jurisdictions).

<u>ESG response:</u>

We have included a section in the report with a breakdown of which management areas fall under Parks Canada and Transport Canada ownership, along with the associated dredging volume and aerial estimates and order of magnitude cost estimate. A detailed estimation of costs would be provided as part of the Remedial Action Plan development.

15. **Custodian responsibilities for contaminated sites**

PC comment: At this point in the overall study, it is important for the report to stress the difference between being custodian to a contaminated site and being responsible for the contamination. Treasury

Board Secretariat (TBS) policy is that the party responsible for the contamination pays all necessary actions to properly address identified risks (i.e., the polluter pays). Custodial departments, on the other hand, have the ultimate management responsibility for the site. They must ensure proper action is taken by the party responsible for the contamination and must also report progress to the TBS via the annual update of the Federal Contaminated Sites Inventory.

<u>ESG response:</u>

Section 6.1.12 of Treasury Board policy on the management of real property (in effect since November 2006) states that custodial departments are responsible for ensuring that “known and suspected contaminated sites are assessed and classified and risk management principles are applied to determine the most appropriate and cost-effective course of action for each site. Priority must be given to sites posing the highest human health and ecological risks. Management activities (including remediation) must be undertaken to the extent required for current or intended federal use. These activities must be guided by standards endorsed by the Canadian Council of Ministers of the Environment (CCME) or similar standards or requirements that may be applicable abroad. The costs of managing contamination caused by others must be recovered, when this is economically feasible.”

ESG recognizes that PC should show that they have made reasonable attempts to contact the responsible third parties to initiate discussions regarding potential recovery of the third party’s share of remediation. However, in the case of the KIH, the source of Cr (the most pervasive contaminant in the KIH sediments) was the former Davis Tannery operations. The company is no longer in existence and the property was abandoned for decades before being taken over by a private developer. It would be impossible to recover funds from the party responsible for the Cr pollution in this case. The above TB policy statement clearly indicates that the custodial departments for the KIH river sediments are responsible for managing the contamination, including undertaking remediation to ensure the protection of human and ecological health even if the contamination was caused by others and remediation costs are unrecoverable.

We have edited the text to clarify Transport Canada’s and Parks Canada’s roles as custodians of contaminated sites.

16. **Consistent statement of Class I designation**

PC comment: Throughout the report, statements such as “Action is needed,” “Action is required,” or “Action is necessary” are made. These statements should be corrected to be consistent with the Class I designation as “High priority for Action.”

<u>ESG response:</u>

The FCSAP 10-step process for addressing aquatic contaminated sites uses the Canada-Ontario decision-making framework for the assessment stages of the FCSAP framework (Steps 2 to 6). The phrase “management actions required” is an outcome from the COA decision matrix and is quoted directly at some points of the report when referring to outcomes from the COA assessment.

We have edited the text for clarification to ensure that the remaining statements are consistent with the Class I designation as recommended above.

17. **No action option for management**

PC comment: The option for "No Action" has been ruled out on the basis of risk assessment indications/findings. This conclusion is inconsistent with the possibility that contamination in the KIH may have arisen from a combination of factors, including natural processes. It may be too early to reach this conclusion.

ESG response:

We strongly disagree with the statement that contamination in the KIH may have arisen from natural processes. The main contaminants of concern are PCBs and Cr. PCBs are man-made chemicals and laboratory synthesis of PCBs started in the late 1800s. This chemical is not present naturally in the environment. Chromium also does not occur naturally at the concentrations seen in the southern Kingston Inner Harbour. The presence of these chemicals in KIH sediments can be clearly linked with past industrial activities on lands adjacent to the southwestern portion of the KIH. An independent scientific review agreed with our conclusion that legacy contamination sources in the KIH sediments are the main source of contaminants in the harbour (Golder 2011b).

The "No Action" option has been ruled out based on the results of the assessment of biological effects from sediment contaminants and the quantitative human health and ecological risk assessment for the harbour. These studies identified that there are human health and ecological risks from sediment and biological contamination. The approach used to conclude that management action is necessary at the site is consistent with guiding documentation through the COA framework (EC & OMOE 2008), the aquatic sites classification system (Franz Environmental 2010) and the framework for addressing and managing aquatic contaminated sites under FCSAP (Chapman 2010). The outcome from all of these frameworks concludes that either risk management or remedial actions are necessary for the KIH. This conclusion regarding the need for management action has also been supported by independent review of the scientific findings by FCSAP Expert Support (DFO 2011; EC 2011; HC 2011).

18. **Dredging as a management option**

PC comment: There are some arguments in support for dredging, such as lack of long-term maintenance; however, the report mentions that residual contamination is likely following dredging (see page V-21), which is contradictory; therefore, there may be a requirement for long-term monitoring. Also, dredging as an option may not be the preferred action when balanced against the management of cultural resources and SARA considerations which are Parks Canada mandated responsibilities.

ESG response:

One of the main criteria used to evaluate the different management options for the KIH was feasibility — i.e., will the management option work given the specific constraints of KIH? Our scientific opinion is that dredging is the only feasible management strategy for the KIH given the nature of the contamination and the shallow water depths in the harbour. The site-specific limiting factors that preclude use of other typical aquatic remedies such as monitored natural recovery or capping are outlined in detail in the Chapter V report text under each management option.

With regards to dredging, a standard approach is to address residual contamination through a confirmatory sampling program, followed by appropriate management action as outlined in the remedial plan. Long-term monitoring for remedy performance is required for aquatic remedies that involve containment of contaminants on site, such as capping or monitored natural recovery. Since the contaminants are largely removed in dredging operations, this aspect of long-term monitoring is not required unless an engineered containment facility is constructed to sequester dredged sediments on site. Management of cultural resources and SARA considerations are considered as part of the environmental assessment (EA) process for aquatic remediation, with appropriate mitigation measures identified and undertaken during remedial activities to ensure protection of cultural resources and rare species.

19. **Guiding FCSAP principles — developing a management strategy through a collaborative approach**

PC comment: With regard to Section B "Guiding Principles for Remediation from FCSAP" (Page V-5, third row of table) and the following statements: "primary task to develop an environmental management strategy for KIH" and "the group is facilitating a collaborative approach to the assessment process and is working to achieve consensus on plans for the river sediments." Please note that there is no formal commitment on behalf of Parks Canada with respect to these 2 elements.

<u>ESG response:</u>

In 2006, all stakeholders with an interest in the environmental status of the KIH were invited to form the Cataraqui River Stakeholder Group (CRSG). Parks Canada attended this meeting and has participated in all subsequent meetings since 2006. Parks Canada is familiar with the aims of the CRSG. These aims were established early on in the formation of the group and are recapped at each meeting. The primary aims of the CRSG, which are essentially the key steps in the development of a sediment management strategy, are to:

I. Identify risks to human and ecological health.
II. Delineate areas of unacceptable risk.
III. Identify and contain all off-site sources of contaminants.
IV. Identify sustainable, risk-based remediation options.
V. Engage the community throughout the remediation process.

All stakeholders have important and necessary roles in the sediment remediation process, either as affected parties, as sources of essential information, as regulators or as future stewards of this natural resource. Furthermore, given that the KIH site is located within an urban area, the goals of the local government and community groups must be considered in the development of remediation plans for the river sediments.

The ultimate goal of the stakeholder process is to develop and implement a sediment management strategy that ensures the long-term protection of human and ecological health, maximizes sustainability of the remediation process and is acceptable to community and stakeholder members. Reaching this goal requires that custodial departments and stakeholders work collaboratively, openly discussing site goals and available alternatives and calling on appropriate expertise as needed. ESG understood Parks Canada's consistent participation in the CRSG as an implicit commitment to this goal.

20. **Visitor use patterns of the Parks Canada area**

PC comment: It is not likely that the Parks Canada portion of the Harbour is used regularly for boating, fishing and swimming; however, the visitor use patterns of the Parks Canada area south of Belle Island has never been studied. Parks Canada should study the use of the area in order to help the group understand which users are in the area and how the area is being used. The information gained could be used to inform the type of management which could include, but not be limited to, appropriate signage.

<u>ESG response:</u>

Visitor use patterns of the site could be investigated as part of the public consultation process. For example, anecdotal and observational evidence gathered by the City of Kingston has indicated that people currently fish in the area of concern, including from the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE (Cynthia Beach, personal communication). However, remedial strategies for the harbour take into account potential future recreational use. Proposed residential development of the southwestern shoreline, as well as construction of a waterfront trail, is anticipated to increase public access to this area. Current visitor use patterns may therefore not be representative of future use.

Discussion of administrative controls to restrict fish consumption from the site as a potential risk management scenario will be expanded in Chapter V. Public willingness to accept these administrative controls will need to be addressed as part of the public consultation process.

21. **Natural attenuation after dredging**

PC comment: Chapter 5 refers to how site conditions promote natural attenuation after dredging (Page V-21, bullets). Please explain how natural attenuation would be appropriate post-dredging but not as a management action.

<u>ESG response:</u>

Monitored natural recovery (MNR) depends on natural chemical, biological, and physical processes occurring at a site to either transform contaminants to a non-toxic form or sequester contaminants in isolation from contact with ecological and human receptors. These processes were examined for the KIH and are discussed in detail in Chapter V under the heading "Monitored Natural Recovery." In essence, a number of studies have indicated that contaminants such as PCBs are bioavailable in KIH sediments and will not degrade to non-toxic forms over time. The shallow water depths of the KIH favour re-suspension and mixing of the upper sediment layers, which does not allow for physical isolation of the contaminants through burial with clean material. These factors preclude the use of MNR as a remedial strategy.

However, once the contaminants are removed through dredging, re-suspension and mixing processes are no longer problematic since the underlying sediments are clean. The Cataraqui River and KIH are naturally eutrophic (i.e., productive), favouring infilling of the dredged area with sediment and subsequent recolonization of macrophytes and the benthic community.

22. **Children and toddlers as receptors in the risk assessment**

PC comment: Three statements are made in Section C "Summary of SeQOs for Individual COCs" (Page V-40) that seemingly contradict the inclusion of children and toddlers as legitimate receptors in a recreational scenario: first, they actually don't frequent the shoreline for this type of use; second, the water is deep and sediments are not exposed so playing in them seems not valid; and finally, the exposure time is apparently too long.

<u>ESG response:</u>

It should be noted that the above statements in the report relate only to the dermal contact exposure pathway, not to the human health risk assessment (HHRA) as a whole. The HHRA also assesses exposure through incidental sediment ingestion and fish consumption; children and toddlers are important receptors for these two exposure pathways.

ESG was asked to include the dermal contact exposure pathway for the KIH HHRA and was supplied with a suggested reference for exposure factors for children and toddlers (Shoaf et al. 2005a, 2005b) by the Health Canada expert support reviewer. The calculations for risk to children and toddlers through the dermal contact pathway presented in the Chapter IV HHRA were in accordance with the suggestions made in the Health Canada review.

While we are in agreement that dermal contact with sediments represents an important exposure pathway for children and toddlers through activities such as wading, we question the appropriateness of the exposure values suggested by the Health Canada reviewer for the KIH for the reasons discussed in detail on page V-40 of the draft report and paraphrased by Parks Canada above. Instead, we have proposed the use of dermal exposure values that are relevant to the site-specific conditions observed in the KIH. We have addressed this issue directly with Health Canada expert support, who confirmed that site-specific exposure factors may be used in the risk assessment if justification is provided. A discussion of the dermal contact exposure values used in the revised HHRA has been included in the text of Chapter IV.

23. **Re-visioning of Section D**

PC comment: Suggest re-visioning Section D, which could be a summary of the areas proposed for sediment removal. Suggest adding discussion on the historical dredging and the post-remedial status of the sediments, as well as the content of Page 44, last paragraph.

ESG response:

We have expanded the discussion in Section D (originally titled "Summary map displaying overlapped area of sediment for removal") to show areas requiring management in each of the KIH water lots. Discussion on historical dredging has been placed in an earlier section of the report.

24. **Residual risks and risk reduction**

PC comment: With regards to Section V-A "Residual Risks and Risk Reduction" (and in particular the first and second paragraphs of Page V-48): Please clarify and elaborate on the content of this section. Questions that arise when reading include: What does the content of these paragraphs mean in the context of site remediation? Will Cr effects still be present at the site after remediation? The activity of "playing in the sediment" is unlikely in the areas where Cr is high, so would remediation for contaminants other than Cr be sufficient?

ESG response:

The purpose of the "Residual Risks and Risk Reduction" section of the report is to examine the predicted reduction in human health and ecological risks following the proposed sediment remediation to ensure that risks will decrease to acceptable levels for all receptors (i.e., below an HQ of 1.0 for human receptors when including background exposure, and an HQ of 1.0 for ecological receptors). The estimation of risk reduction takes into consideration the potential for any residual contamination following implementation of site remediation activities

Please note that the SeQOs developed in Chapter V for Cr are based on reducing risk to ecological receptors (mallard duck), not human receptors. Cr exposure to humans has been re-evaluated in the revised HHRA and the more appropriate TRV for Cr (III) has been used in the determination of risk. The outcomes show that adverse effects are not expected to any human receptors as the species of Cr in the sediment is present as the less toxic Cr (III) form. Therefore, SeQOs for the protection of human health from Cr were not required for the KIH.

25. **Causality for brown bullhead deformities**

PC comment: The Parks Canada gap analysis indicates that more work should be done on morphological deformities of brown bullhead in order to conclusively link them with sediment contamination.

ESG response:

As a follow-up to the initial study, a literature review was completed by ESG with the following goals: 1) to review the available scientific information on brown bullhead deformities; 2) to compare the approach used for the KIH with fish health studies conducted at other Great Lakes AOCs; and 3) to assess the need for further work. The review identified that the approach used to describe orocutaneous deformities, erosion, lesions, and tumours (DELTS) for the KIH brown bullhead was consistent with that used at other AOC and non-AOC sites (e.g., Blazer et al. 2009). The causes of orocutaneous (skin) fish DELTs are not well established in the scientific literature, but higher rates are usually found in contaminated areas (Rafferty et al. 2009). Further, fish health studies to assess the prevalence of liver tumours in brown bullhead in the KIH were considered, as there is strong evidence to indicate that exposure to chemical carcinogens is a primary factor in liver tumours (Rafferty et al. 2009). However, the suggested sample size for liver tumour studies (n = at least 100 fish) is not feasible for the KIH given the small area of the contaminated site. The low prevalence of liver tumours generally found for Great Lakes fish (see Baumann 2010) means that the chances of detecting significant differences in liver tumour prevalence would decrease with lower sample size. Therefore, we concluded that liver tumour studies on KIH fish could involve a large cost and sampling effort with little ability to detect differences if present. Furthermore, there is sufficient other evidence for biological effects in the KIH that would lead to classification as a Class I FCSAP site without additional data on fish health.

With respect to understanding the cause of the brown bullhead DELTs; we agree that understanding causality would be important if the data were used to make decisions regarding sediment management at the site. Carrying out virology analyses on brown bullhead fish tissue may clarify whether the observed deformities are caused by pathogens. However, as Environment Canada pointed out in their review of Chapter V (EC 2011), it is possible that exposure to contaminant stressors may also result in increased fish susceptibility to hormonal imbalances and viral disease. If this is the case, then sediment contaminant concentrations could not be ruled out as a stressor even if virology analyses indicated the presence of pathogens.

It would also be very difficult and expensive to determine which chemical contaminant may be responsible for the observed DELTs — this would involve lab toxicology tests with brown bullhead. While there is a body of scientific literature documenting the link between fish exposure to PAHs and the subsequent development of DELTS and liver tumours, other chemicals have not been studied to the same extent (Rafferty et al. 2009). Although it is suspected that exposure to other contaminants (e.g., PCBs) also may result in fish deformities, defining the role these chemicals play would require extensive laboratory toxicology studies. The potential synergistic effects of the mixture of contaminants present in the KIH sediments would make the identification of causality for the observed deformities very challenging if not impossible. Because of these challenges, the KIH fish health data were not used to develop the sediment remediation SeQOs presented in Chapter V.

26. **Calculation of sediment volume**

PC comment: With regards to Section V-B-c "Calculation of Sediment Volume (Page V-51). The content of this section makes it appear that additional testing prior to remediation may be warranted. How confident are researchers that PCBs aren't deeper than the 50 cm depth for remediation? Does additional work need to be done to assess this?

ESG response:

Given that the total sediment accumulation above the native clay/peat layers is between 25 and 40 cm in most cores collected from the KIH, we are confident that PCBs (man-made chemicals) are not deeper than the 50 cm depth used to calculate sediment volumes for management. As this section of the report discusses, uncertainty in depth information can be addressed through either confirmatory sampling or additional depth sampling during development of the remedial action plan (RAP).

Editorial Comments

27. **V-vi, paragraph 1 and V-vii, paragraph 1**

PC comment: Refers to sediment remediation strategy but would suggest referencing the title — an options analysis of management scenarios. Especially as the context of the Chapter has not yet been introduced.

ESG response: Addressed in text.

28. **V-vii, paragraph 3, 7th line.**

PC comment: Check the spelling of "indicate."

ESG response: Addressed in text.

29. **V-vii, paragraph 3, 12th line.**

PC comment: Refers to "no significant inputs." Suggest including a guideline for what constitutes significant vs. non-significant input if one exists.

ESG response:

Definition of a significant vs. a non-significant input has been included in Chapter V in the section discussing ongoing sources of contamination (Section II-B-b).

30. **V-vii, paragraph 4**

PC comment: Suggest replacing "remedial" with "management" (this suggestion applies throughout the Chapter). Also "no action" is not mentioned here.

ESG response:

The suggested wording edits have been addressed in the text where appropriate. Discussion of the no action option has been included in this paragraph.

31. **V-iii, 1st paragraph**

PC comment: Please include information on the public consultation conducted in order to support the statement that there was a "general acceptance from the public"? Please provide dates and consultation process used.

ESG response:

Dredging is commonly more acceptable to the general public than other aquatic remedies because it involves the complete removal of contaminants from the site, rather than leaving the contaminants in place. This phrase is meant as a generality and does not state the outcomes of specific public consultation.

32. **V-viii, 3rd paragraph**

PC comment: Please spell out HHERA.

ESG response: Addressed in text.

33. **V-viii, 3rd paragraph**

PC comment: Please elaborate on the targets for "acceptable levels" referred. Please also include reference to relevant guidance for "acceptable levels."

ESG response:

"Acceptable levels" for human health and ecological risks are defined in standard guidance for human health risk assessments (HC 2009a and 2009b) and ecological risk assessments (CCME 1996). Following Health Canada guidance, human health risks are considered acceptable for a hazard quotient (HQ) less than 1 when background exposure is incorporated. Ecological risks are considered acceptable for an HQ less than 1.

34. **V-viii, 4th paragraph.**

PC comment: There is reference to an overestimation of risk for the dermal pathway. Could the risk be assessed more realistically? (Please see Health Canada's comments on Chapter 4 — they suggested using site-specific figures where possible.)

ESG response:

Please see response to comment 24.

35. **V-1, 1st paragraph**

PC comment: Suggest mentioning that past industrialization on the western shore was located SW of Belle Island.

ESG response: Addressed in text.

36. **V-1, 1st paragraph, 3rd line.**

PC comment: Could elaborate by stating that Chapter V examines both remediation and risk management options (management options analysis).

ESG response: Addressed in text.

37. **V-1, 1st paragraph.**

PC comment: Please add “Lasalle” before “causeway.”

ESG response: Addressed in text.

38. **V-1, 2nd paragraph, sentence that begins on line 8**

PC comment: The statement appears to contradict App. L ASCS Table, step 4 — Impacts to human health. Please review.

ESG response:

Human health risk assessment outcomes presented in the revised versions of the ASCS classification and Chapters VI and V are consistent with each other.

39. **V-1, 2nd paragraph, lines 9 and 10**

PC comment: Could add more detail to the discussion on the HHRA to include the pathways whereby receptor groups are at risk.

ESG response:

The pathways presenting human health risk differ according to each contaminant and are discussed in detail in Chapter IV. Since both chapters will be presented in the final report, we feel it is redundant to present this material again in Chapter V.

40. **V-1, 2nd paragraph, line 11**

PC comment: Check the sentence that begins with “Potential.” It may be incomplete. Also, please explain why the study is using a US standard instead of a Health Canada standard.

ESG response:

Addressed in text. Explanation for the use of the US EPA cancer toxicity value for PCBs is discussed in Section B-4 of Chapter IV.

41. **V-1, 2nd paragraph, last sentence**

PC comment: Suggest replacing “names” with “classifies.” Also, please consider outlining the various types of management actions that can be considered with a Class 1 site. For instance, in addition to remedial options, there is a “no action” option as well as a risk management option (i.e., find appropriate means to discourage contact of human receptors with the site and thus risk).

ESG response:

Text edited as suggested. Discussion of the various types of management actions that can be considered with a Class 1 site has been added into the introduction to Section III (options analysis of management actions).

42. **V-2, first paragraph**

PC comment: Previous chapters used the COA framework guidance; however, it does not appear to feature as prominently in Chapter 5 — were aspects of the framework used? (e.g., is it the COA weight-of-evidence approach?) If so, could it please be referred to more explicitly.

ESG response:

The COA framework is primarily used to guide the assessment stages for an aquatic contaminated site (i.e., Steps 2 to 5 of the FCSAP 10-step process for managing aquatic contaminated sites; Chapman 2010). The results of the COA assessment are used to classify the site in Step 6 of the FCSAP framework. Chapter V represents the first stages of Step 7 (development of a risk management strategy), and the COA framework is no longer applicable as guidance for this step. Principles outlined under Step 7 of the FCSAP framework for aquatic contaminated sites (Chapman 2010) and references cited therein were used as guidance for Chapter V.

43. **Page V-2, first paragraph, second sentence**

PC comment: Suggest replacing "common" with "relatively new."

ESG response:

The suggested edit would change the meaning of the sentence from its original intention (one common framework is used to address all FCSAP aquatic contaminated sites). We have omitted "common" from the sentence instead.

44. **Page V-2, third paragraph, sentence starting on line 1**

PC comment: The sentence appears incomplete — perhaps add "using" before "FCSAP funding."

ESG response: Text edited for clarification.

45. **Page V-2, fourth paragraph, first sentence**

PC comment: Change ACSC to ASCS. Also suggest changing "as" to "because."

ESG response: Addressed in text.

46. **Page V-3, first paragraph**

PC comment: The area of the KIH north of Belle Island (control sites) has elevated levels of contamination as well. Parks Canada has access to sediment quality data from this area that was collected as part of the third crossing project, which could be provided if this is of interest.

<u>ESG response:</u>

Reference sites for aquatic assessment programs are selected to cover the range of natural conditions at the test sites (e.g., similar sediment grain size, natural habitat features), but in areas that are minimally disturbed by human activities. For urban environments such as the KIH, it is unrealistic to expect that reference conditions will be near-pristine; rather, the reference sites represent “best available” or “least-disturbed” conditions. The area of the KIH north of Belle Island meets these criteria and is considered a good reference area for the southern KIH. Comparison of test sites to nearby “least-disturbed” reference areas rather than pristine areas is preferable as it accounts for background contamination levels typical of urban environments.

In regards to PC’s statement that the area of the KIH north of Belle Island has elevated levels of contamination as well, a detailed comparison of contaminant concentrations in reference area sediment samples compared with sediment samples from the southern KIH was presented in Chapter II of the KIH report. The approach outlined in the COA framework was used to identify contaminants of potential concern (CoPCs) for the impacted area (southern KIH) using the following criteria: (1) mean contaminant concentration at test sites greater than 20% higher than the mean at reference sites; and (2) mean contaminant concentration at test sites significantly different from the mean at reference sites. As is typical for urban environments, contaminant concentrations at many of the reference sites exceeded the CCME ISQG and, in a few cases, the CCME PEL. However, using the COA criteria outlined above, mean sediment contaminant concentrations at southern KIH sites were identified as being significantly higher (in some cases, by several magnitudes) than northern KIH reference sites for the following list of contaminants: Cr, Pb, Cu, As, Hg, and PCBs. Further details are presented in Chapter II.

ESG has reviewed the sediment quality data provided by Parks Canada. They do not change the main outcomes from Chapter II.

47. **Page V-3, first paragraph**

PC comment: States that sediment toxicity tests indicate toxic effects but early chapters indicated that the results for the benthic work were variable — some tests did not show evidence of toxic effects.

<u>ESG response:</u>

The text refers to the overall assessment of KIH toxicity results determined following the COA weight-of-evidence categorization for toxicity (see Table I-1 in Chapter I of the KIH report). The KIH toxicity results meet the following COA criteria for an assessment of potential overall toxicity: multiple tests exhibit minor toxicological effects (i.e., greater than a 20% reduction in two or more toxicological endpoints) and one text exhibits a major toxicological effect (i.e., greater than a 50% reduction in toxicological endpoints).

48. **Page V-3, second paragraph**

PC comment: PCDD/Fs — please spell out and add to an acronym list.

ESG response: Addressed in text.

49. **Page V-3, third paragraph**

PC comment: Species at Risk turtles are also using the site.

ESG response: Addressed in text.

50. **Page V-3, third paragraph, last sentence**

PC comment: Suggest shifting "have been documented" to before "quantified" (i.e., have been documented and quantified).

ESG response: Addressed in text.

51. **Page V-3, third paragraph, last sentence**

PC comment: Suggest adding "a potentially" before high exposure.

ESG response: Addressed in text.

52. **Page V-3, fourth paragraph, first sentence**

PC comment: Suggest adding "events" after "contamination." Also, please specify what "soil" is referring to — the marsh, the landfill?

ESG response:

The suggested edit would change the meaning of the sentence from its original intention (i.e., a list of contaminated media upgradient of the site). Details regarding potential upgradient sources are discussed in Section B-b (Control ongoing sources of contamination before taking remedial action involving physical work).

53. **Page V-3, fourth paragraph, second sentence**

PC comment: Regarding industrial inputs — the navigation channel and the eastern shoreline are relatively "clean" according to Chapters I-IV.

ESG response:

We agree. Upgradient inputs refer to historical sources of contamination to the KIH from former industrial properties located mostly on the southwestern shore of the KIH.

54. **Page V-3, fourth paragraph**

PC comment: Suggest adding "and depositional" after "erosional area."

ESG response: Text edited for clarification.

55. **Page V-4, Section A. Aquatic Classification for the KIH**

PC comment: Suggest removing the last paragraph "The ACSC worksheet for the KIH was reviewed by EC and DFO and the designation as class 1 was reaffirmed." Parks Canada has received comments on the classification score from EC, DFO, and HC. They agree that the classification score is likely a Class 1 but the scoring is not finalized until they receive feedback on their comments from ESG. Consequently, we cannot yet say the designation as a Class I was reaffirmed.

ESG response:

All comments from EC, DFO, and HC on the ASCS classification were addressed by ESG in September 2011. These responses and the revised ASCS worksheet for the KIH were sent directly to Parks Canada on September 23, 2011. The designation of the KIH as a Class I site has not changed and is now considered to be reaffirmed.

56. **Page V-4, first paragraph**

PC comments: Please specify what the source is for TSS — the storm drain, the marsh, Belle Park? Note that TSS is not listed in Table 7. Also, please change "ACSC" to "ASCS" (in the third paragraph also).

ESG response:

TSS refers to total suspended solids, which represents a physical impact or non-chemical disturbance (the focus of Table 7 of the ASCS worksheet). The source of the TSS is unknown, but likely to be re-suspension of the harbour sediments as well as surface water runoff from surrounding lands.

57. **Page V-4, fourth paragraph**

PC comments: Suggest replacing "will not affect" with "minimize impacts to."

ESG response: Addressed in text.

58. **Page V-4, fourth paragraph**

PC comments: Please specify which legislation is being referred to. Also, please specify why a US EPA reference being used — is there a Canadian version that would be an alternative?

ESG response:

Relevant legislation would include the Canadian Environmental Protection Act (CEPA), and sections 22, 32, 34, 35, and 37 of the Fisheries Act which deal with fish habitat protection and pollution prevention.

The Framework for Addressing and Managing Aquatic Contaminated Sites under the Federal Contaminated Sites Action Plan (FCSAP; Chapman 2010) adopts the 11 risk-management principles directly from the cited US EPA reference and refers the reader to US EPA guidance for further information.

59. **Page V-5, first row of table**

PC comment: The Parks Canada gap analysis indicates that additional work could be done in the area of potential sources.

<u>ESG response:</u>

A response to comments made in the gap analysis commissioned by Parks Canada (Golder 2011a) is provided under separate cover. The Golder gap analysis document and ESG responses will be provided as an appendix in the final document.

60. **Page V-5, second row of table**

PC comment: Please specify who the community is. Community meetings will be planned and implemented by Parks Canada, perhaps assisted by other partners and stakeholders.

<u>ESG response:</u>

The community refers to the residents of the City of Kingston who live and work near the contaminated sediments and who use the KIH for recreational activities including swimming, boating and fishing. Community meetings are needed to provide residents with correct information on potential risks, address community concerns about contaminated sediment, and make available opportunities for significant involvement in the sediment decision-making process. It is important that the message that reaches the community be scientifically correct, consistent, and easily understood. Hence, to be most effective, the development and implementation of a communication and outreach program should involve all stakeholder members. ESG therefore disagrees with the PC statement that “community meetings will be planned and implemented by Parks Canada and perhaps assisted by partners and stakeholders.”

61. **Page V-5, third row of table**

PC comment: Please change “CSRG” to “CRSG.”

<u>ESG response:</u> Addressed in text.

62. **Page V-5, third row of table**

PC comment: Please change “SEQO” to “SeQO.”

<u>ESG response:</u> Addressed in text.

63. **Page V-7, figure 1**

PC comment: For the top level of boxes please consider adding the Davis Tannery and the Lead Smelter. Also, if appropriate, please consider adding PAHs to the model as well as CoCs that result from urban or industrial inputs migrating downstream (see P. V-3, last paragraph).

ESG response:

The conceptual model has been revised for clarification since the draft report. Please note that the Davis Tannery was included as a potential source in the original figure.

We have not included PAHs as they were not identified as CoCs for the KIH (see Chapter II). Note also that a more appropriate wording of the above statement is "CoCs that result from urban or industrial inputs migrating downgradient" — i.e., from historical industrial sources located on lands adjacent to the southwestern KIH. These are addressed already in the conceptual model. See also Comment 1.

64. **Page V-8, second paragraph, first sentence**

PC comment: Suggest changing "Toxicity" to "Toxic effects." Also, please add a sentence explaining how toxicity testing is completed.

ESG response: Addressed in text. A detailed explanation of the toxicity testing is contained in Chapter III of the KIH report and the reader has been referred to this section for more details.

65. **Page V-8, second paragraph, second sentence**

PC comment: Consider changing the sentence to the following: "Toxicity was evaluated using the following criteria: one or more toxicity endpoints at test sites had more than a 20-percent difference from the reference sample and there was a statistically significant difference from the control versus the reference sample."

ESG response:

The suggested edit does not correctly state the criteria used to evaluate toxicity. The text has been edited for clarification.

66. **Page V-8, second paragraph**

PC comment: Please clarify whether the TIE test was completed or not. Are these standard tests?

ESG response:

TIE tests have not been completed for KIH sediments. TIE tests were originally developed for water or effluent toxicity tests. The application of TIE to whole sediments is still in the early experimental stages and procedures have not yet been developed for application on whole sediments (EC & MOE 2008). It would be very challenging to find a commercial lab experienced in using TIE tests on sediments.

67. **Page V-8, second paragraph**

PC comment: The paragraph refers to the conclusions of the sediment toxicity test that show toxic effects in only some test sites, which is a mixed result as opposed to a definitive one. Also, please clarify if the content of the last sentence is stating that it is currently not known which chemicals are impacting the benthic organisms?

<u>ESG response:</u>

Please see the response to comment 50 for the distinction between individual toxicity test results and the overall toxicity assessment for the KIH as defined by the COA framework criteria.

Regarding causation for the sediment toxicity results: this was addressed in ESG's response to comments made in the gap analysis commissioned by Parks Canada (Golder 2011b) and is provided under separate cover.

68. **Page V-8, second paragraph, 19^{th} line**

PC comment: "Potential toxicity to benthic organisms." Please elaborate how they are being affected (decreased biodiversity/survivorship etc.?).

<u>ESG response:</u>

Toxicity tests examined the endpoints of decreased survivorship, growth, and reproduction for multiple benthic invertebrate species. Details are outlined in Section C (Sediment Toxicity) of Chapter III.

69. **Page V-8, third paragraph, benthic community impairment**

PC comment: Could this section please be explained more clearly.

<u>ESG response:</u> Text has been edited for clarification.

70. **Page V-9, first paragraph, lines 4-8**

PC comment: The multivariate statistics should be able to separate out the different factors, so that there is an understanding of contamination impacts vs. other variables.

<u>ESG response:</u>

This is true, and the results of the multivariate analysis are stated in the proceeding sentences. Essentially, in addition to natural habitat variables, environmental parameters related to contamination are also important in explaining differences in benthic community structure between reference sites and test sites.

Causation for the benthic community impairments was addressed in ESG's response to comments made in the gap analysis commissioned by Parks Canada (Golder 2011a) and is provided under separate cover.

71. **Page V-9, second paragraph, line 9**

PC comment: Suggest replacing "KIH" with "Belle Park."

ESG response: Addressed in text.

72. **Page V-9, third paragraph, 4th line**

PC comment: "Trace levels of contaminants are present [north of Belle Park]." Parks Canada can provide sediment data from this area derived from the Kingston Third Crossing study, if this is of interest.

ESG response:

We thank Parks Canada for providing the Third Crossing sediment data. Please see the response to Comment 43 above.

73. **Page V-10, first paragraph, first line**

PC comment: Suggest adding "southwest portion of the" after "having deformities in the."

ESG response: Addressed in text.

74. **Page V-10, first paragraph**

PC comment: The term "substantially higher" does not meet the requirement for statistical significance, please clarify whether there is or is not a statistically significant effect.

ESG response:

The text in question has been edited in the revised Chapter V to address the above point.

75. **Page V-10, third paragraph**

PC comment: Consider re-phrasing "Risk characterization is another impairment."

ESG response: Addressed in text.

76. **Page V-10, fourth paragraph**

PC comment: Suggest adding "in that context" after "the results of the HHRA."

ESG response: We do not feel that the suggested edit adds clarification to the sentence and therefore have left it as is.

77. **Page V-11, first paragraph**

PC comment: Please add "human" to "all receptors."

ESG response: Addressed in text.

78. **Page V-11, last paragraph**

PC comment: Please spell out "COA" if it has not been already.

ESG response: It has already been defined and is included in the acronym list.

79. **Page V-11, last paragraph, last sentence**

PC comment: If additional information indicated less risk would it not potentially alter the classification?

ESG response:

This is possible but improbable, given the multiple lines of evidence indicating biological effects for the harbour.

80. **Page V-11, last paragraph**

PC comment: For the section starting with "However" (5th line), please consider moving this content to later in the Chapter as it prescribing action.

ESG response:

We disagree. The intent of this section is to summarize information indicating which contaminants are of concern in the harbour and the integrated assessment of biological effects considering all lines of evidence. This section is important for providing context for the prior sentences on causation.

81. **Page V-12, temporality row**

PC comment: Would information gleaned from the cores be applicable here?

ESG response:

Yes, the sediment core data can provide insights on background contamination levels in the harbour prior to historical industrial discharge. This information has been added into the table.

82. **Page V-12, consistency of association row**

PC comment: There has not been a discussion of plants yet within the Chapter, unless referring to cattails and macrophytes? If so perhaps use same language.

ESG response: Addressed in text.

83. **Page V-12, experiment row**

PC comment: The example given on estuarine fish may not apply since the KIH is not estuarine.

ESG response:

Ecotoxicological information is only available for a few species. It is common practice to extrapolate effects between species in the same group of organisms (i.e., fish) in the absence of species-specific information.

84. **Page V-12, plausibility row, middle column**

PC comment: Please check the spelling of "gradients."

ESG response: Addressed in text.

85. **Page V-13, analogy row**

PC comment: The example given on goldfish may not apply because of differences between species, including that goldfish have scales whereas bullheads do not.

ESG response: See comment 83.

86. **Page V-13, experiment row**

PC comment: Please add an "i" to "manipulation" in the first column.

ESG response: Addressed in text.

87. **Page V-13, consistency of evidence row, right column**

PC comment: According to past chapters, there have been mixed results (e.g., sediment toxicity tests, fish contaminant concentrations). Also, suggest replacing "receptors0" with "receptors."

ESG response:

The results from multiple lines of evidence (sediment toxicity, benthic community responses, and bioaccumulation/biomagnification of contaminants in aquatic biota) were assessed and discussed in detail according to the COA framework in Chapter III. Using the specific decision-making criteria outlined in the COA framework, potential adverse effects were found for all three lines of evidence.

Regarding the results of sediment toxicity tests, please see the response to comment 44 above. Fish tissue contaminant concentrations such as PCBs have been consistently elevated for fish sampled in the southwestern portion of the KIH compared with northern KIH sites in over 30 years of available fish monitoring data.

The text has been edited as suggested.

88. **Page V-13, second paragraph**

PC comment: The Kingscourt sewer is a combined sewer, not just a storm sewer. Please consider referring to it in this manner ("combined sewer" or simply "sewer"). Accordingly, the following areas of text may require some revision (original comments included a list of page numbers).

ESG response:

Addressed in text.

89. **Page V-13, second paragraph**

PC comment: Consider separating out the Orchard Street marsh and adding the lead smelter to the list of potential terrestrial sources.

ESG response:

The Orchard Street marsh received effluent directly from the Davis Tannery and we feel that both properties are best discussed together. Similarly, the lead smelter was also on the former Davis Tannery property. We have added the lead smelter to the list of potential sources in the Davis Tannery category.

90. **Page V-13-14, Emma Martin Park**

PC comment: The section on Emma Martin Park could include additional information. For instance: the source of Hg to the park, the previous cleanup of sediments, re-contamination of this area by inflow of residual sediments, etc.

ESG response:

Additional information has been added to this section as suggested.

91. **Page V-14, fourth paragraph**

PC comment: Heading could be "Sewer Systems." First sentence: suggest replacing "sewers" with "events".

ESG response: Addressed in text.

92. **Page V-14, third paragraph**

PC comment: Suggest adding "the upstream portion of the" before "Cataraqui River."

ESG response:

We have reworded the sentence for clarification.

93. **Page V-14-15, storm sewers**

PC comment: It has been mentioned in CRSG meeting that the City of Kingston plans on installing an end-of-pipe system at the combined sewer outfall.

ESG response:

The City of Kingston is operating under the assumption that a sediment remediation project within the Inner Harbour and Orchard Street marsh areas will provide the opportunity for effective end-of-pipe retention and treatment that will mitigate contaminants from the system normally associated with suspended sediment loads.

94. **Page V-15, Section c**

PC comment: "Remedial actions should not cause more environmental damage than the remedy": After the first sentence, the following could be added: "All federal projects have to comply with the Canadian Environmental Assessment Act (CEAA). The CEAA ensures that the environmental effects of projects are carefully reviewed before federal authorities take action in connection with them so that projects do not cause significant adverse environmental effects. CEAA promotes sustainable development which addresses environmental, economic and socio-political concerns. Among the concerns that will have to be addressed under the CEAA, there is species at risk and fish habitat."

ESG response:

ESG agrees that any remediation action must comply with the CEAA and also with the SARA and the Fisheries Act.

All EAs conducted under federal legislation must identify any species at risk listed under SARA, or critical habitat that is likely to be affected by the project. To facilitate the incorporation of SARA requirements into an EA under CEAA, the SARA-CEAA Guidance Working Group has developed a guidance document that shows how certain SARA requirements may be addressed at each step of an environmental assessment conducted under the CEAA (http://www.ec.gc.ca/Publications/0EA3B9D2-731B-4DC8-8BCF-30F9F8C203ED/AddressingSARAConsiderations.pdf).

With respect to fish habitat protection provisions of the Fisheries Act, a request to Fisheries and Oceans for a licence, permit, certificate or other regulatory authorization under sections 32 and/or subsections 22-1, 22-2, 22-3, 35-2, 37-2 of the Fisheries Act may trigger the requirement to complete a project-specific EA under the CEAA.

The text in Chapter V has been revised to include the above information.

95. **Page V-15, first paragraph**

PC comment: Consider creating a new paragraph starting with the sentence that begins with "Combined" in line 1. Also, please add "through the Kingscourt overflow" after "sewer outflows" on line 1.

<u>ESG response:</u>

The new paragraph has been created. There are locations other than the Kingscourt overflow in the KIH where sewer overflows occur, and therefore the suggested edit has not been made.

96. **Page V-15, first paragraph**

PC comment: Much is not yet known with respect to the proposed storm water retention pond. For example, how will it help with respect to combined sewage issues? Will the combined sewage flow still enter the PC portion of the wetland? How will storm water which captures and transports contaminants via overland flow be managed?

<u>ESG response:</u>

Answers to these questions will be formulated during the design phase of remedial plan development.

97. **Page V-15, second paragraph, line 1**

PC comment: Suggest removing "likely acted as a point source" and insert "was a source", as it is our understanding that evidence points to the landfill as the source.

<u>ESG response:</u>

There is no unequivocal evidence linking the Belle Park Landfill to the legacy PCB contamination in the KIH sediments so the suggested edit was not made.

98. **Page V-15, second paragraph, line 3**

PC comment: Please specify which types of barriers are being referred to.

<u>ESG response:</u>

These are steel sheet pile walls combined with extraction wells, which allow for the collection of groundwater and subsequent pumping for treatment. The text has been updated in this regard.

99. **Page V-15, second paragraph**

PC comment: Potential ongoing contaminant sources have been tracked down on the river. Which area of the river is being referred to?

<u>ESG response:</u>

This text refers to a PCB source trackdown project carried out by the OMOE in the Kingston Inner Harbour between 2001 and 2006. The study area focussed on identifying sources in the KIH between Highway 401 and the LaSalle Causeway (i.e., the whole of the Kingston Inner Harbour).

100. **Page V-15, last sentence**

PC comment: The Parks Canada gap analysis indicated that the Belle Island pathway remains operable at a low magnitude.

ESG response:

The Ministry of the Environment, Eastern Region Office has conducted an independent review of monitoring reports and historical data regarding the Belle Park closed landfill. These were their conclusions (OMOE 2011):

"The review of the Belle Park Closed Landfill Site Environmental Operations and Monitoring 2010 report dated May 26, 2011 and additional historic data provided by the City of Kingston was used to determine if the Belle Park Landfill is a continuing source of contaminants to the Kingston Inner Harbour. Monitoring conducted at the site indicates that PCB concentrations are considered to be very low and not likely representative of any significant ongoing source to the Kingston Inner Harbour.

As for other contaminants of concern (i.e., chromium, arsenic, mercury, and lead), historic data provided by the City of Kingston show only trace levels of these heavy metals in the groundwater monitoring wells and suggest that Belle Park is not an active source of these contaminants to the river. Surface water monitoring along the shore of the Cataraqui River also show levels of these metals consistently below the PWQOs".

101. **Page V-15, third paragraph**

PC comment: It is unclear whether this paragraph is stating that the report found more assessment work is needed in some locations to determine the magnitude of leaching or whether ongoing monitoring is recommended.

ESG response:

This paragraph is stating that the 2010 OMOE report recommended more assessment work to ensure that the Belle Park Landfill is not a significant source of PCB-contaminated groundwater to the KIH. The results from the OMOE follow-up study in 2011 are summarized under the response to comment 100 above. The report text has been clarified and updated with these findings.

102. **Page V-15, fourth paragraph**

PC comment: Suggest moving the paragraph to later in the Chapter as it is talking about a management strategy, not a source.

ESG response:

A new summary section has been added to this part of the report discussing potential ongoing sources of contaminants to the KIH (Section II-B-b of the draft report). The paragraph in question has been incorporated into the section summary.

103. **Page V-15-16, section c.**

PC comment: Suggest moving this section to the beginning of the "Options Analysis of Remediation Strategies" section, under the heading of the section (page V-18). Suggested re-phrasing as follows:

"Management options must be assessed for potential long-term and short-term benefits and impacts. Any management actions must comply with federal and/or provincial legislations and regulations as well as policies including but not limited to the Species at Risk Act and relevant sections of the Fisheries Act, the Department of Fisheries and Oceans long-term policy objective of achieving an overall net gain to the productive capacity of fish habitats (progress toward this objective can be achieved through the restoration of damaged fish habitats and the creation and enhancement of fish habitat), and the no net loss of wetland functions as per the federal government wetlands policy."

ESG response:

This section addresses the third guiding principle for remediation from FCSAP (Remedial actions should not cause more environmental damage than they remedy). Therefore, it is most appropriately discussed in the current section (titled "Guiding Principles for Remediation from FCSAP").

The suggested text, with additional highlights indicated above, has been added into the revised Chapter V.

104. **Page V-16, second paragraph**

PC comment: Instead of a focus on SAR habitat mitigation as part of remediation (as this belongs in an environmental assessment), the presence of SAR and their associated habitat should be discussed as a factor to consider in the decision of whether to remediate.

ESG response:

The presence of SAR is taken into consideration under the FCSAP Aquatic Sites Classification System as one of the factors when classifying the site as a low, medium, or high priority for action. However, the decision of whether to remediate is also based on the magnitude of potential risk to human and ecological receptors. SAR are addressed during the environmental assessment for the project, which will identify mitigation factors to protect SAR during remedial activities.

105. **Page V-16, table**

PC comment: The list does not include map turtle and snapping turtle, which Parks Canada has recorded for the site in 2009–2010. For milk snake and black tern species — the "species of" can be removed from the right-hand column. Also, instead of "COSEWIC Designation" please use "SARA listing" and "Endangered Species Act (ESA) designations" (on non-federal lands).

ESG response:

All of the species at risk identified for the KIH have a SARA designation and are at risk of extinction or extirpation nationally, with the exception of the black tern, which is listed under the ESA as a "species of special concern" provincially. The COSEWIC designation column has been changed to SARA listing as suggested. The list has also been updated to include the map turtle and snapping turtle and to incorporate the suggested edits for the milk snake and black tern species

106. **Page V-17, Section b. DFO fish habitat**

PC comment: In the first sentence "Remediation strategies under FCSAP also have to comply...", please remove "under FCSAP" as all projects have to comply with DFO. There is no relation between the funds sources and regulation compliance.

ESG response: Addressed in text.

107. **Page V-17, Section A, No Action**

PC comment: Please remove the sentence "This alternative cannot be selected for the KIH..." Suggest replacing by a sentence explaining that: "'No action' remedial alternative means the status quo. No improvement of the environment and human health is expected with the status quo. With this alternative, potential human health and ecological risks from sediment and biological contamination will remain." The study should present the scientific point of view with the environmental advantages and disadvantages of the different scenarios. Parks Canada managers will decide which alternative(s) will be selected.

ESG response:

We do not agree with the suggested edit. Please see the response to comment 17.

108. **Page 17, first paragraph**

PC comment: Please remove possible mitigations as they are better suited for the environmental assessment, which will come at a later date. Suggested re-working of the paragraph:

"SARA requires that when an environmental assessment (EA) is being carried out on a project that may affect a listed species or its critical habitat, the potential adverse effects be identified and, if the project is carried out, that measures are taken to avoid or lessen any impact. Measures must be consistent with any applicable recovery strategies and action plans for those particular species."

ESG response: Suggested edits have been addressed in the text.

109. **Page 17, first paragraph**

PC comment: The dredging activity may kill turtles because the dredging methods in water can be very intrusive. This activity would require a SARA authorization to kill individuals and/or impact habitat.

<u>ESG response:</u>

Under Section 73.1 of the SARA Act an agreement or permit is required to engage in an activity affecting a listed wildlife species, any part of its critical habitat or the residences of its individuals. Authorization of such an agreement or permit requires several pre-conditions to be met which would not preclude dredging from being carried out. The conditions are that: (a) all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted; (b) all feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of its individuals; and (c) the activity will not jeopardize the survival or recovery of the species.

110. **Page 17**

PC comment: Suggest adding additional sections: (b) Fisheries Act; and (d) Federal Wetland Policy. Also, consider how the following fit in: the provincial water quality standards, the provincial policy of combined sewer overflows and the provincial Endangered Species Act (pertaining to the Orchard Street Marsh).

<u>ESG response:</u> ESG will include an additional section to the report that identifies all of the standards and regulations that are relevant to the KIH project.

111. **Page V-17, second paragraph**

PC comment: Please remove the last two sentences as they appear contradictory.

<u>ESG response:</u>

The reviewer has misunderstood the text. The meaning is that the contaminants found in the KIH do not degrade quickly to non-toxic forms, meaning that organisms will continue to be exposed to the contaminants if no action is taken. This limits the feasibility of using Monitored Natural Recovery (which relies on natural processes such as the chemical transformation of contaminants to less toxic forms).

112. **Page V-17, third paragraph**

PC comment: Suggest replacing “remedial” with “management.”

<u>ESG response:</u> Addressed in text.

113. **Page V-17, last paragraph**

PC comment: Please consider adding a “Risk Management” scenario that would reduce the likelihood of exposure, that could include public communication regarding appropriate use of the area, erecting signage, increasing awareness of the fish eating advisories, or banning fishing (i.e., creating an exclusion zone for wildlife, fish in particular).

ESG response:

A risk management section discussing institutional controls to reduce potential human health risks has been added to the report. Note that the use of institutional controls would not alter the potential ecological risks due to KIH sediment contamination.

114. **Page V-18, second paragraph**

PC comment: Please add "The specific set of" before the sentence beginning with "Contaminants."

ESG response: Addressed in text.

115. **Page V-18, last paragraph, second-last sentence**

PC comment: It is not clear whether the former Davis Tannery and Kingscourt CSO were eliminated as sources.

ESG response:

The point of the sentence in question is to indicate that storm water flow from the Kingscourt sewer may contribute to sediment re-suspension in the harbour. Potential ongoing sources were discussed in Section II-B-b of the draft report.

116. **Page V-18, last paragraph, last sentence**

PC comment: What is the definition of "high precipitation" (2–5 yr, 10 yr, 50 yr or 100 yr storm)? Please specify because there are different outcomes/impacts depending on the rain event.

ESG response:

The sentence in question refers to a generality and follows on from the previous sentence addressed above under comment 115 — i.e., storm water flow may contribute to sediment re-suspension given the size of the Kingscourt sewer. The empirical relationship between the magnitude of the storm event and the amount of re-suspension has not been determined, and therefore this type of precipitation event definition cannot be specified.

117. **Page V-19, second paragraph**

PC comment: What would be the minimum depth of capping required? Would different capping depths be possible for different areas of the KIH based on contaminant load?

ESG response:

Caps are generally 60 cm to 160 cm thick, with the thinnest caps in the 50–60 cm range (SAIC 2005). Water depths less than 1 m above the cap are problematic as the cap can be easily damaged by wave action, ice scour, or propeller wash from boat traffic. This would be the case for much of the KIH and is considered a major limitation on the feasibility of capping.

118. **Page V-19, third paragraph, last sentence**

PC comment: Re-suspension should not be an issue as sediment curtains will be in place. The consultant would have to use sediment curtains to contain the sediment until things settle, and perhaps would have to add sediment bit by bit.

ESG response:

It is true that mitigation measures similar to those that would be used during dredging could be used to address re-suspension during the capping process. However, the main point of this paragraph is that the KIH has very soft organic sediments that are a geotechnical limitation on the feasibility for capping as they compromise cap integrity over time.

119. **Page V-19, fourth paragraph**

PC comment: Please specify which stream is being referred to (is it referenced in the table of Appendix L)? Also, ice scour, Lake Ontario storms and propeller wash may not be applicable to the Parks Canada portion of the harbour.

ESG response:

"Stream flow" is provided as a general example of an erosive process in the introductory sentence of this paragraph. It does not refer to a specific stream in the KIH. However, an analogous process for the KIH would be erosion associated with flow from the Kingscourt sewer.

Given the shallow water depths and proximity to Lake Ontario, ice scour and wave action from winter storms are almost certainly operating as erosive processes at the site.

120. **Page V-20, Section b, Capping**

PC comment: Suggest removing the sentence "Overall, capping is not considered a suitable remedial method for the KIH..." This study should present the advantages and disadvantages of each possible strategy. If a company has a suitable and affordable capping technique, it could be the best solution. Suggest replacing the sentence by explaining that "From an environmental and human health point of view, capping is a good alternative. However, capping remedial strategy will have to take into account the shallow water depth, potential erosive processes, soft sediments, and the potential for long-term maintenance issues."

ESG response:

We do not agree with the suggested edits. One of the main criteria for evaluating the different remediation options was feasibility — i.e., whether the remediation strategy will work successfully given the specific conditions of the KIH. Our technical review indicates that capping is not likely to be feasible for the KIH because of the shallow water depths and soft organic sediments. An independent review of Chapter V by Golder Associates (Golder 2011b) agreed that capping is not suitable for the KIH given these constraints. We feel that this is important to communicate to decision-makers.

121. **Page V-20, first paragraph**

PC comment: Discusses the outcome of public consultation — please specify when this was completed, by whom, and in what context.

<u>ESG response:</u> The following discussion of the public consultation process and the outcomes will be incorporated into the final report

The public consultation was completed in 2002 by the City of Kingston under the guidance of the Kingston Environmental Advisory Forum (KEAF), which is a committee made up of technical members from academic institutions and the Cataraqui Region Conservation Authority, members from the public, and several city councillors. The role of KEAF is to provide advice to the City of Kingston on environmental issues. Public consultation was carried out through two public workshops, as well as a consulting document published in "Kingston This Week" requesting public input.

The first public workshop was held on April 27, 2002, and communicated the main findings of a scientific review and gap analysis that summarized the available scientific knowledge for the Kingston Inner Harbour at that time. The second public workshop was a Waterfront Visioning Workshop held on May 23, 2002. The goal of the latter workshop and the consulting document was to receive input from the public regarding future uses of the KIH, which could then be incorporated by the City of Kingston into developing a strategic plan for the KIH. Both workshops attracted approximately 65 participants.

122. **Page V-20, first paragraph**

PC comment: Suggest removing the first and last sentences. Regarding "institutional controls" — Parks Canada does not require a certain depth in this area for navigation (Parks Canada only has to ensure a certain depth in the navigation channel). Capping this area could be explored as it would potentially create a larger wetland that could provide added fish and turtle habitat. This option would require consulting with Transport Canada's navigable waters group.

<u>ESG response:</u>

We disagree with the suggested edits for the same reasons outlined under the response to comment 120.

123. **Page V-20, first paragraph**

PC comment: Regarding the statement about public consultation (sentence that begins on line 10) — potential management actions will need to be considered in light of the custodial department's needs and/or projected uses for the site.

<u>ESG response:</u>

ESG agrees that a public consultation strategy that provides opportunities for community involvement in the remediation decision-making process will be very important going forward. This will ensure that the community's vision for the KIH and anticipated future use of the KIH are considered in the selection of a sediment management strategy.

124. **Page V-21, Option analysis of remediation strategies, conclusion of section B**

PC comment: Suggest adding that the chosen management option will have to comply with legislation, regulations, and policies. Furthermore, the chosen management option will need to incorporate concerns such as long-term issues, economic and public concerns. These concerns will be addressed within the Canadian Environmental Assessment process.

ESG response: Addressed in text.

125. **Page V-21, second paragraph, first sentence**

PC comment: Dredging will require long-term monitoring, and perhaps maintenance, if inflow of residual sediment occurs into the remediated area. It is anticipated that post-remediation monitoring will be required because of the characteristics of the bay with movement and re-mixing in a south to north fashion.

ESG response:

Evidence suggests that the water flows from the northern part of the KIH along the eastern shoreline and through the LaSalle Causeway, with very little flow occurring along the western shoreline (City of Kingston and OMOE 2005). However, the sediment transport patterns of the KIH have not been studied and are likely to be very complex. We agree that some long-term monitoring of surface sediment concentrations will probably be necessary following remedial actions. Infilling by residual sediments can be avoided to the greatest extent possible by remediating both water lots at the same time. Contaminant concentrations in surficial sediments outside the management area are generally below the SeQOs and therefore not anticipated to cause unacceptable risk to human and ecological receptors, even if they are redistributed into the remediated area. See also comment 4.

126. **Page V-21, bullets:**

PC comment: First and fifth bullet: Is there evidence that there is little or no debris, old piers, etc. (have side scan sonar imaging or other methods been used to assess)?

ESG response:

As indicated in the draft report text on page V-21, the extent of underwater debris is unknown. It is anticipated that the archaeological assessment would be likely to provide information regarding existing underwater structures.

PC comment: Second bullet: Has this factor been discussed in the report?

<u>ESG response:</u>

The vertical stratigraphy of sediments in the KIH is discussed in detail in Chapter II and summarized in Section III-C-a of the Chapter V report (page V-22).

PC comment: Third bullet: We don't have deep sediment information according to Appendix L.

<u>ESG response:</u>

Contamination depth profiles are discussed in detail in Chapter II and summarized in Section III-C-a of the Chapter V report (page V-22).

127. **Page V-21, last paragraph**

PC comment: Suggest ending the paragraph at "likely effectiveness" as it is currently difficult to say with certainty that there are no long-term maintenance issues and general acceptance by the public.

<u>ESG response:</u> Addressed in text.

128. **Page V-21**

PC comment: Suggest that the section on dredging also include a list of the negative aspects of dredging (e.g., disturbance of wildlife and SAR habitat, the cost to recreate habitat, the cost of sediment disposal etc.). This comment would apply to all management scenarios considered — the report should present an unbiased picture of the positives and negatives of each.

<u>ESG response:</u>

Increased discussion of the positive and negative aspects of each management scenario has been added to the report. In addition, the criteria used to evaluate each management scenario (e.g., feasibility given specific conditions in the KIH) have also been explained in the introduction to Section III.

129. **Page V-22, heading**

PC comment: Please remove "removal" from the heading.

<u>ESG response:</u> Replaced "removal" with "management."

130. **Page V-22, third paragraph**

PC comment: There does not appear to be a Map-II-3 in Appendix B.

<u>ESG response:</u>

The compiled KIH report (Chapters I to V) has all maps in Appendix B, including Map-II-3.

131. **Page V-23, first paragraph**

PC comment: Will the core PCB data be available soon?

ESG response:

Chapter II report text has been updated with the results from the 2010 PCB analyses on sediment cores from the KIH.

132. **Page V-23, third paragraph, last sentence**

PC comment: Should this sentence include the muskrat?

ESG response:

The sentence has been updated with the final results from the ERA.

133. **Page V-23, fourth paragraph**

PC comment: Suggest replacing the term "endorsed." This term implies a vote or some other method of affirming a direction.

ESG response:

As indicated in the response to comment 9, the risk-based approach described in the KIH report chapter V and used to develop site-specific SeQOs for the KIH was strongly supported by participants at the June 2010 remediation options workshop. There was full agreement that using a risk-based approach to derive cleanup objectives was appropriate for the KIH.

134. **Page V-23, fourth paragraph**

PC comment: Consider the following suggested changes to the last sentence: "These were used to delineate the horizontal area that is creating risk to human and ecological health."

ESG response:

We disagree with the suggested edits, as they do not incorporate the concept of managing sediment to decrease human health and ecological risks *to acceptable levels*. We suggest instead "These were used to delineate the horizontal extent of sediment management needed to decrease human health and ecological risks to acceptable levels."

135. **Page V-23, fifth paragraph, second sentence**

PC comment: Suggest altering the end of the sentence to read: "ultimately be accomplished."

ESG response:

The suggested edit would render the sentence grammatically incorrect.

136. **Page V-23-24, Sediment management goals section**

PC comment: Please consider removing the reference to remediation or cleanup since the goal of the Chapter is to present management options. For instance on page V-23: line 1 — "remedial action" and "general cleanup goals", line 2 — "the selected sediment remedy." On page V-24: line 1 — "remedial", #2 — "during remedial action" and "pre-remedy", #3 "remediation" and "sediment remediation activities" (could replace with "management actions"), last paragraph — "remedial."

<u>ESG response:</u> Addressed in text.

137. **Page V-24, third paragraph**

PC comment: After "developed", suggest adding "in" instead of "or."

<u>ESG response:</u> "or" replaced by "for" in text

138. **Page V-24, last paragraph**

PC comment: Please specify whether there is evidence that the public are interacting with the fish and sediments in the section of the KIH identified in Map V-4 as the area proposed to be remediated (excluding the Rowing Club area).

<u>ESG response:</u>

Anecdotal and observational evidence gathered by the City of Kingston has indicated that people currently fish in the area of concern, including from the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE (Cynthia Beach, personal communication). There is a walking trail along the shoreline of the former Davis Tannery property adjacent to the section of the KIH identified in Map V-4 that provides access to the adjacent harbour and is used by Kingston residents. The area of KIH for sediment management is also not far from the Kingston Rowing Club and is frequented by canoeists, kayakers, and other recreational boats. Proposed residential and trail development of the southwestern shoreline is also anticipated to increase public access to this area.

These details have been added to the report text.

139. **Page V-25, first paragraph**

PC comment: Suggest combining the first and second sentences. Weren't the receptor groups chosen to represent a guild — not because they are the most sensitive in all cases?

<u>ESG response:</u>

Receptor groups were chosen to represent a guild, with the most sensitive receptor in each guild selected where possible for the risk assessment. The text has been edited and clarified.

140. **Page V-25, second and third paragraphs**

PC comment: Refers to human health risk but this is within the ERA section.

<u>ESG response:</u>

The paragraphs have been moved to the human health risk assessment section.

141. **Page V-25, paragraph under the bullets**

PC comment: Please use the full term instead of abbreviation (Cr, As, Hg, PCBs).

<u>ESG response:</u>

It is standard convention to use the full term the first time an abbreviation is used (with the abbreviation defined in brackets), and then use the abbreviation throughout the report text. A list of abbreviations will also be provided with the final report.

142. **Page V-25, last paragraph**

PC comment: Suggest that the exposure pathways could be in bullets to match the HHRA section. Also, with reference to "for muskrat the ingestion of food poses potential risk as well" — please specify what the potential risks are attributed to?

<u>ESG response:</u>

Addressed in text. For the quoted phrase — this whole sentence refers to risks from Cr.

143. **Page V-26**

PC comment: Please specify whether the larger numbers related to muskrat and fish consumption, and red-winged blackbird and sediment ingestion, are indicative of higher risk.

<u>ESG response:</u>

Yes, larger numbers equate with greater potential risk and this has been addressed in the text.

144. **Page V-27, second paragraph**

PC comment: Please spell out the acronyms SAF and EDI if they have not already appeared.

<u>ESG response:</u> Addressed in text.

145. **Page V-27, last paragraph**

PC comment: It is unclear if the SeQOs were calculated for each pathway or each contaminant?

ESG response:

Both. SeQOs were calculated for each pathway and are contaminant-specific.

146. **Page V-29, last paragraph**

PC comment: The text refers to dermal exposure occurring via wading, walking, boating and other recreational activities — however, it is unlikely that these types of activities are taking place in the area identified in Map V-4 as the area proposed to be remediated, with the exception in front of the rowing club.

ESG response:

Please see the response to comment 138.

147. **Page V-29, first paragraph, 11th line**

PC comment: Please specify what the "E" in the equation represents.

ESG response:

These numbers are presented in scientific notation, which is a convention used when numbers are too large or too small to be easily presented as decimals. The "E" refers to the exponent. For example, 2.10E-05 can also be written as 0.0000021.

148. **Page V-31, figure**

PC comment: Please add a legend that explains what the "X" and the "O" points represent.

ESG response: Addressed in text.

149. **Page V-31, "special considerations"**

PC comment: Please specify if the SeQGs were only calculated for PCBs or for other biomagnifying substances as well.

ESG response:

PCBs were the only biomagnifying contaminant for which an SeQO was developed. The SeQOs will be modified based on the revisions to the HHERA and included in the revised Chapter V with a discussion on all biomagnifying substances (PCBs and MeHg).

150. **Page V-31**

PC comment: Please specify how this exposure assessment is related to the one in the ERA in Chapter 4? What was the rationale by which these receptors were chosen?

ESG response:

Similar receptors were chosen for the ERA in Chapter IV and a detailed rationale for receptor selection is presented there (Section C-2). The exposure assessment (fish ingestion by human and ecological receptors) and related exposure scenarios are the same in both chapters.

151. **Page V-32, first paragraph**

PC comment: Regarding species that are representative of trophic level 3 — consider adding birds to the list.

ESG response:

Birds are considered representative of trophic level 3 and are shown as such in Figure V-4.

152. **Page V-32-33, last sentence**

PC comment: Is this statement true for the whole KIH or just south of Belle Park? Perhaps there should be a stricter focus on the Belle Park area where concentrations are higher?

ESG response:

The OMOE Sport Fish Contaminant Monitoring program collects fish in the Belle Park vicinity as their sampling location. The sport fish consumption advisories are in place for the lower Cataraqui River (i.e., the whole of the KIH).

153. **Page V-33, third paragraph**

PC comment: Please specify the rationale used to choose the mink as the ecological receptor.

ESG response:

This rationale is outlined in detail in Chapter IV (Section C-2).

154. **Page V-34, figure**

PC comment: Please make sure that the photo of a brown bullhead is indeed a brown bullhead (bullheads do not have scales according to the description).

ESG response:

The figure has been revised in the report text.

155. **Page V-34, diagram**

PC comment: In the diagram at step 2 please make sure that the symbol is correct (+ vs. /).

ESG response:

The figure has been revised in the report text.

156. **Page V-37, first paragraph, line 4**

PC comment: Please specify what the 1 represents?

ESG response:

A biota sediment accumulation factor (BSAF) greater than 1 indicates that contaminants are accumulating to a higher degree in the biota than in the sediments (i.e., biomagnification). This has been clarified in the report text.

157. **Page V-37, second paragraph**

PC comment: Consider removing "he" from the first sentence

ESG response: Addressed in text.

158. **Page V-39, bottom paragraph, first line**

PC comment: The 750 ppm does not match the 775 ppm in the above table.

ESG response:

Text has been edited to ensure that the correct value is used throughout.

159. **Page V-39, table**

PC comment: Please spell out the term UCL if it has not been introduced.

ESG response:

UCL is an abbreviation for the "95% upper confidence limit of the mean." This definition has been added to the text.

160. **Page V-40**

PC comment: Please provide additional support for why mallards were selected over red-winged black birds. Choosing the mallard over the red-winged blackbird dramatically increases the acceptable level of chromium.

ESG response:

The rationale for selection of the mallard over the red-winged blackbird is outlined briefly in the second paragraph on Page V-40. The ERA presented in Chapter IV included the Orchard Marsh (the marsh north of the former Davis Tannery property). Receptors such as muskrat and red-winged blackbird were selected because of their potential exposure to contaminants in the Orchard Marsh. The elevated hazard quotients for these species are in part because Cr concentrations in the Orchard Marsh are very high. A separate remedial plan, including development of SeQOs, will be needed to address the Orchard Marsh but is beyond the scope of the current report.

The red-winged blackbird is not anticipated to have significant exposure to underwater sediments of the KIH. The mallard duck was deemed to have greater exposure to the KIH sediments and therefore was selected as the receptor for the development of SeQOs for the KIH.

161. **Page V-40, first paragraph**

PC comment: Please clarify if the suggestion to use ppm figures for ecological receptors is because the human ones are too conservative?

<u>ESG response:</u>

We feel that the exposure parameters used to calculate the risk from dermal contact with sediments are too conservative for children and toddlers. See the response to comment 162 below.

162. **Page V-40, first paragraph**

PC comment: Please specify the rationale for not using children and toddlers as the chief receptor for setting the human health target for Cr.

<u>ESG response:</u>

With regards to the dermal loading factors for toddlers and children (used to calculate risk from dermal contact with sediments), we feel that these are overly conservative and have high uncertainty associated with their use for the following reasons. First, there is very limited data describing sediment adherence factors to skin. Two studies were recommended by the Health Canada reviewer for the KIH human health risk assessment: one for adults digging clams in tide flats (Shoaf et al. 2005a), and the other for children playing on tide flats (Shoaf et al. 2005b). The dermal loading factors calculated in the latter study were based on measurements taken during one day of play for a very small sample size (nine children), and the study authors state that there is limited ability to generalize activity patterns and sediment adherence values for larger populations (Shoaf et al. 2005b). Secondly, as the reviewer mentions, both studies calculated sediment adherence factors based on activities in an exposed tidal flat of sediments. This scenario is not appropriate for the KIH, where sediments are typically confined underwater. Thirdly, the TRV developed by Health Canada for chromium is based on the toxicity of hexavalent chromium. Studies of sediment Cr, sediment pore water, and soils from adjacent sites indicate that Cr in the KIH is present as the less toxic, trivalent form (Cr (III)) (See Chapter II, ESG 2009). Using the more appropriate TRV for Cr decreases the risk associated with exposure to sediments to below acceptable levels as defined by Health Canada.

163. **Page V-40, first paragraph, sentences that begin on lines 8 and 9**

PC comment: The information in these sentences does not match that given on page V-28. Please clarify if adults are assumed to swim and "play in the sediments" in this area of the harbour?

ESG response:

The exposure factors presented on page V-28 were the recommended exposure pathways and parameters from Health Canada. Our concerns with the recommended exposure parameters for dermal contact with sediments are summarized under the response to comment 162. We have contacted Health Canada to express our concerns and resolve which exposure parameters should be used in both the risk assessment (Chapter IV) and the calculated SeQOs in Chapter V (see comment 22).

Adult receptors have been modelled with the assumption that they will use the harbour in a recreational fashion as explained on page V-28 and V-40. The reference to "playing in sediments" quoted in the reviewer's comment refers back to the explanation given on page V-28 that the dermal contact values used in the HHRA were accepted as being representative of this type of activity by the US EPA. The information on page V-40 speaks to the concerns expressed in the text of the report as to the appropriateness of these values for the KIH (please see comments 22 and 162).

164. **Page V-40, first paragraph, lines 11-22**

PC comments: Please clarify if this section is stating that human health effects are not expected to be found, therefore a decision will be based on ecological effects only?

ESG response:

In the previous version of the report, this section provided the rationale for not using predicted human health risks to toddlers and children using only the dermal contact exposure pathway to develop SeQO for the KIH, as the exposure parameters for this pathway seem overly conservative (see also the response to comment 162). The exposure parameters and assumptions used to calculate risks to human receptors through other exposure pathways (for example, fish consumption) are considered appropriate and have been validated through Health Canada review. This section has been rewritten as per the changes described in comment 22 and 162. SeQOs have been developed for all contaminants where acceptable risk thresholds have been exceeded for either human health or ecological health.

165. **Page V-40, second paragraph, first 2 sentences**

PC comments: Suggest that this content be presented earlier in the Chapter as it is a description of management action.

ESG response: This information has been discussed earlier in the report in a new risk management section (see response to comment 113).

166. **Page V-40, second paragraph**

PC comments: Please clarify why the mallard was chosen over other receptor species. Many of the ecological receptors identified in Table V-6 are associated with marshes.

ESG response:

Please see the response to comment 160.

167. **Page V-41, first paragraph**

PC comments: Please clarify where the 1220 ppm is derived. Perhaps it could be referenced?

ESG response:

The 1220 ppm is the current spatially weighted average concentration of Cr in the KIH surface sediments, calculated using geospatial modelling as outlined in Section IV-B-f of the preceding report section. This clarification was added to the text.

168. **Page V-41, first paragraph**

PC comments: Regarding the background Cr concentration of 61 ppm — please clarify how it was derived.

ESG response:

Derivation of the background sediment concentrations of contaminants of concern for the KIH is described in Section B-2 of Chapter IV.

169. **Page V-41, last paragraph**

PC comments: Check whether Table V-8 should read V-7?

ESG response: Addressed in text.

170. **Page V-41, second paragraph**

PC comments: The home range identified on Map V-2, Appendix B (114 ha) does not match the 153 ha stated here.

ESG response: Addressed in text.

171. **Page V-41, last paragraph**

PC comments: Suggest adding "of PCBs" after 332 and 985 ppm. Also, please clarify why there is a focus on mink in this section.

ESG response:

Edits addressed in text. There is a focus on mink in this section as they were the only ecological receptor that was found to be at potential risk from PCBs.

172. **Page V-42, Table title**

PC comments: Double-check the spelling of "equation." Also, suggest adding BSAF to a list of acronyms.

ESG response: Addressed in text.

173. **Page V-42, Table**

PC comment: Please remove the lines surrounding the four cells related to "mink" and create one cell.

ESG response: Addressed in text.

174. **Page V-42, first paragraph**

PC comment: Please add the term "95 UCL" to a list of acronyms.

ESG response: Addressed in text.

175. **Page V-44, second paragraph**

PC comments: Please clarify whether toddlers are used because they are a sensitive receptor? Also, check for an unfinished sentence starting with "The SWAC for..."

ESG response:

It is standard practice to calculate SeQOs based on the most sensitive human receptor, which is generally the toddler. The sentence in question is grammatically correct and not unfinished ("As" is the abbreviation for arsenic).

176. **Page V-45, Section D**

PC comment: Summary map displaying overlapped area of sediment for removal, as well as associated text: In the section title, suggest replacing "for removal" by "for remedial action" as removal may not be the chosen management option.

ESG response: Addressed in text.

177. **Page V-45, second paragraph**

PC comment: If appropriate, suggest creating a map to indicate the locations of different sediment depths that would potentially be remediated.

ESG response:

The suggested map has been created and added into the report text.

178. **Page V-45, residual risks and risk reduction**

PC comment: Please add “Map V-4” after both scenario 1 and 2.

ESG response: Reference to Map V-4 has been added into the text.

179. **Page V-46, second paragraph**

PC comment: Please clarify what is meant by the “original” HHRA being referred to.

ESG response:

The “original” HHRA refers to the risk assessment presented in Chapter IV. The text has been edited and clarified in the revised report.

180. **Page V-48, first paragraph**

PC comment: Suggest adding “for toddlers” after “playing in sediment activity.”

ESG response: Addressed in text.

181. **Page V-48, third paragraph**

PC comment: Please clarify how the percentage risk reduction translates into acceptable risk (and based on what?).

ESG response:

Remediation of the area in Scenario 1 is anticipated to decrease the risks to human and ecological receptors to acceptable levels (i.e., less than an HQ of 0.2 for human receptors and less than an HQ of 1 for ecological receptors).

The paragraph in question discusses the additional risk reduction that would be expected if the Rowing Club area (Scenario 2) was remediated in addition to the area identified for Scenario 1. The point of the paragraph is to examine if the additional level of effort associated with remediation of the Rowing Club area is warranted given the magnitude of additional risk reduction.

182. **Page V-51, second paragraph, last sentence**

PC comment: Please specify whether alternate removal/remediation scenarios were explored and evaluated or only those presented in this Chapter.

<u>ESG response:</u>

The removal/remediation scenarios presented in this Chapter targeted the areas of highest concentration, starting from the shoreline and moving outwards into the Inner Harbour in a contiguous pattern. This ensures that the areas of greatest concern (i.e., highest contaminant concentration) are addressed and takes into account practical considerations for remedial plan design. Alternate removal scenarios would result in a larger area of the harbour being targeted for remedial action, and would likely be less effective because hotspots of contamination would remain. Consequently, alternate remediation scenarios were not evaluated for this Chapter.

183. **Page V-52, second paragraph, line 6**

PC comment: Please add "potential submerged cultural resources" after "KIH."

<u>ESG response:</u> Addressed in text.

184. **Page V-52, Section VI Conclusions and Recommendations, second paragraph**

PC comment: Suggest removing/re-working the second sentence "No major potential ongoing sources of contaminants into the KIH were found." This sentence seems contradictory to the following one stating that the storm water is an active potential ongoing source.

<u>ESG response:</u>

The City of Kingston conducted re-sampling of Project Trackdown wells at Belle Park in December 2010 and obtained results consistent with earlier findings indicating that the Belle Park Landfill is not an ongoing source of PCB-contaminated groundwater to the Cataraqui River or sediments. The OMOE, Eastern Region Office has conducted an independent review of monitoring reports and historical data regarding potential ongoing sources of contaminants to the KIH. They have also concluded that the Belle Island Landfill is not a significant ongoing source of PCBs or inorganic elements to the harbour.

Regarding the Kingscourt sewer, it is very unlikely that the CSO effluent or storm water contain high levels of Cr and PCBs, which were identified as the main contaminants of concern for the KIH in the risk assessment. Furthermore, as pointed out in the latter part of the paragraph in question, there is general agreement amongst stakeholders that the Kingscourt storm sewer outfall will need to be addressed as part of remedial plans for the KIH. The City of Kingston has stated that it will take the steps necessary to address any source issues related to the sanitary/storm sewers if needed.

We have edited the paragraph to include the above information — i.e., that potential ongoing sources have been investigated and are being addressed by the OMOE and the City of Kingston.

185. **Page V-52, Section VI Conclusions and Recommendations**

PC comment: After the third paragraph, suggest adding a paragraph with content along the lines of the following: Capping is an acceptable remedial option from a human health and an ecological point of *view. This option would reduce or eliminate the risk to zero. However, technical limitations were discussed and will have to be taken into account if this solution is chosen.*

ESG response:

We disagree with the suggested edits for the reasons outlined under the response to comment 120. Also, it is inaccurate to say that the risk would be reduced to zero. No remedy is 100% effective and this would be particularly true for capping in the KIH, where site-specific considerations would certainly compromise cap integrity.

186. **Page V-52, Section VI Conclusions and Recommendations**

PC comment: Suggest adding a paragraph with content that discusses how natural capping is unlikely to occur.

ESG response:

More discussion of the limitations on the feasibility of remedial strategies other than dredging, including capping and monitored natural recovery, has been added to the Conclusions section.

187. **Page V-52, Section VI Conclusions and Recommendations**

PC comment: Suggest adding a paragraph on the "No action" management option, with content discussing how the "No action" management option could be acceptable from a human health point of view if management measures were applied, but will not address ecological risk.

ESG response:

More discussion of the potential use of institutional controls as a risk management strategy has been added to the Conclusions section.

References

Baumann, P.C. (Baumann 2010). Data analysis and fish tumor BUI assessment for the Lower Great Lakes and interconnecting waterways. Prepared for Environment Canada.

Benoit, N. and D. Burniston (Benoit and Burniston 2010). Cataraqui River Project Trackdown: Follow-up study on success of remediation efforts in the Cataraqui River 2006. Prepared for the Eastern Region of the Ontario Ministry of the Environment, April 2010.

Blazer, V.S., S.D. Rafferty, P.C. Baumann, S.C. Smith, and E.C. Obert (Blazer et al. 2009). "Assessment of the "fish tumors or other deformities" beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): I. Orocutaneous tumors." *Journal of Great Lakes Research* 35: 517–526.

Canadian Council of Ministers of the Environment (CCME 1996). A Framework for Ecological Risk Assessment: General Guidance. PN 1195. The Contaminated Sites Remediation Program, Winnipeg, MB.

Chapman, P.M. (Chapman 2010). Guidance Document: Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP). Final Report. Golder Associates Ltd., Burnaby, BC.

City of Kingston and Ontario Ministry of Environment (Kingston & OMOE 2005). Project Trackdown Cataraqui River, Kingston, Ontario. Assessment of PCBs in Nearshore Groundwater. Final Report, February 2005.

Environment Canada (EC 2011). FCSAP expert support peer review comments for "Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour" (ESG 2011 Chapter V). Revised July 4, 2011.

Environment Canada and Ontario Ministry of the Environment (EC & OMOE 2008). Ontario Decision-Making Framework for Assessment of Great Lakes Contaminated Sediments.

Environmental Sciences Group (ESG 2009). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour.

Environmental Sciences Group (ESG 2010). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter IV: Human health and ecological risk assessment.

Environmental Sciences Group (ESG 2011). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour. Revised July 4, 2011.

Fisheries and Oceans Canada (DFO 2011). Review of “Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour” (ESG 2011 Chapter V), June 14, 2011.

Franz Environmental Ltd. (Franz Environmental 2010). FCSAP Aquatic Sites Classification System (2009) version 1.0: Final detailed user guidance manual. Prepared for the Department of Fisheries and Oceans Canada, April 30, 2010.

Golder Associates (Golder 2011a). Final report on Review and Data Gap Assessment for Parks Canada Waterlot, Kingston Inner Harbour. Produced for Parks Canada, March 2011.

Golder Associates (Golder 2011b). Technical review of the Environmental Science Group-Royal Military College report entitled “Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour” dated March 2011. Produced for Public Works and Government Services Canada on behalf of Transport Canada, November 28, 2011.

Health Canada (HC 2009a). Federal Contaminated Site Risk Assessment in Canada Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0 DRAFT. Contaminated Sites Division, Safe Environments Programme, Health Canada.

Health Canada (HC 2009b). Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Complex Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRAchem), Version 1.0, February 2009. Prepared by the Contaminated Sites Division Safe Environments Programme.

Health Canada (HC 2011). Health Canada’s review of “Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour” (ESG Chapter V), June 22, 2011.

Ontario Ministry of the Environment (OMOE 2011). Kingston Inner Harbour Chapter V comments. Memorandum sent by e-mail from Roberto Sacilotto to Viviane Paquin on October 27, 2011.

Rafferty, S.D., V.S. Blazer, A.E. Pinkney, J.L. Grazio, E.C. Obert, and L. Boughton (Rafferty et al. 2009). “A historical perspective on the “fish tumors or other deformities” beneficial use impairment at Great Lakes Areas of Concern.” *Journal of Great Lakes Research* 35: 496–506.

Shoaf, M.B., J.H. Shirai, G. Kedan, J. Schaum, and J.C. Kissel (Shoaf et al. 2005a). “Child dermal sediment loads following play in a tide flat.” *Journal of Exposure Analysis and Environmental Epidemiology* 15: 407–412.

Shoaf, M.B., J.H. Shirai, G. Kedan, J. Schaum, and J.C. Kissel (Shoaf et al. 2005b). “Adult dermal sediment loads following clam digging in tide flats.” *Soil and Sediment Contamination* 14 (5): 463–470.

ESG response to "Environment Canada – FCSAP Expert Support Peer Review Comments for "Application of the Canada-Ontario Decision Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter 5: An Options Analysis of Management Scenarios for the Kingston Inner Harbour (ESG 2011 Chapter V)" revised July 4, 2011

The following document summarizes ESG responses to comments made by Environment Canada (EC) on Chapter V of the KIH report. Some of the EC comments were lengthy and have been paraphrased below to highlight main discussion points and questions. The complete version of original comments from EC will be included in an appendix in the final report.

Sections I and II – General Comments

1. **Page V-viii Executive Summary, 1st paragraph**

EC comment: EC does not recall collective agreement in the June 2010 workshop that dredging was selected as a remedial strategy for the KIH. Rather, the main outcome was consensus that the site assessment, data analyses and approach presented by ESG at that time was reasonable and appropriate for the KIH property, and a risk-based approach for developing remedial sediment quality objectives was endorsed.

ESG response:

ESG will change the wording in the summary to indicate that the remediation options analysis identified dredging as the most technically feasible option for the KIH given the site-specific conditions and that there was strong concurrence with the conclusions presented by ESG.

2. **Page V-vii Executive Summary, 3rd paragraph**

EC comment: EC recommends clarification of documented versus potential contaminant sources to better support the recommendation for storm water management and cleanup of the Orchard Marsh.

ESG response:

The text in question has been edited for clarification. Discussion of potential and documented contaminant sources has also been expanded in Chapter V to address this and other related comments.

3. **Aquatic site classification – Page V-3**

EC comment: There are inconsistencies in the ASCS classification presented in Appendix L and details referenced in the text.

ESG response:

Addressed in text.

4. **Deformities in Brown Bullhead – Page V-10**

EC comment: EC has a number of questions and comments regarding the higher incidence of deformities for brown bullhead collected from the KIH relative to the reference area. These questions and comments are summarized below.

- *Were contaminants measured in the bullheads other than Cr and PCBs significantly different between the two sites?*

ESG response:

In addition to Cr and PCBs, the ESG fish health study also tested fish tissue samples for Cu, Ni, Co, Cd, Pb, Zn, and As. All fish tissue samples had concentrations of Co, Cd, and As that were below the analytical limits of detection. Tissue concentrations of Cu, Ni, and Zn were not significantly different for fish sampled from the impacted area compared with the reference area. One bullhead from the impacted area had elevated Pb concentrations (5.3 ppm), while Pb tissue concentrations in all of the other fish were below the analytical limits of detection. These data are presented in Chapter III of the KIH report (ESG 2010a; Table D-3-5 in Appendix D).

- *Did ESG measure PAH concentrations in brown bullhead?*

ESG response:

PAHs are rapidly metabolized and excreted in fish, meaning that fish tissue analyses of PAH concentrations are not a reliable method of estimating past exposure to elevated PAHs (van der Oost et al. 2003). A better method of estimating PAH bioavailability to fish is through measuring the extent of ethoxyresorufin-O-deethylase (EROD – CYP1A) enzyme activity as a biomarker of previous PAH exposure. Hamilton (2002) assessed EROD activity of juvenile trout and chronic toxicity to larval trout after exposure to KIH sediments collected from the following locations: Anglin Bay; adjacent to the old Woollen Mill; adjacent to the former Davis Tannery site; along the south shore of Belle Island; in the channel to the east of Belle Island; and just west of the channel to the north of Belle Island. Her study found significantly elevated EROD activity for fish exposed to sediments from Anglin Bay and two Outer harbour sites, suggesting exposure to PAHs. EROD activity for fish exposed to sediments from all the other KIH sites was lower and not significantly different from control sites, indicating little exposure or effects due to PAHs.

- *Does the home range of bullhead known to have a higher incidence of tumours extend into the harbour in the vicinity of the Rowing Club?*

ESG response:

In habitats that are conducive to spawning, a study along the Anacostia River, Washington, DC, found that the average annual linear home range of brown bullhead was less than 1 km (Sakaris and Jesian 2005). The Rowing Club is within 1 km of the area where brown bullhead were sampled in the KIH (see

Appendix B, Map III-7 of the KIH report) and therefore assumed to be part of the home range of the affected fish.

However, it should be noted that a review of the PAH sediment data discovered a unit error in the report that presented data for sediments collected in the Woollen Mill and Rowing Club vicinity (Benoit and Dove 2006). The document erroneously reported PAH concentrations as ppm rather than ppb, meaning that reported concentrations were 1,000 times higher than those that were measured. This unit error was perpetuated into the draft version of Chapter II of the KIH report and the associated contaminant plume maps in which the Benoit and Dove (2006) data were used and which are cited in the EC review. Subsequent revisions have corrected the error (i.e., PAH concentrations of up to 37 ppm, not 36,650 ppm, have been reported from the Rowing Club area); the updated PAH data analyses and plume maps are presented in the final version of Chapter II. Although total PAH concentrations in sediments from the impacted area exceed the OMOE Lowest Effect Level (LEL) in many cases, concentrations in all samples were well below the OMOE Severe Effect Level (SEL) and are not expected to yield pronounced toxic responses. It seems unlikely that PAHs are responsible for the observed fish tumours, given the relatively low concentrations in the study area.

- *Were specific organs of the bullheads (liver, sexual organs) analysed for contaminants?*

ESG response:

Contaminant concentrations in fish tissue were primarily used in risk assessment equations to assess contaminant exposure to organisms at higher trophic levels (e.g., piscivorous mammals and birds). Because ecological receptors consume whole fish, contaminant analyses were performed on whole-body samples and not specific organs of the bullhead.

- *Where do the bullheads of KIH spawn?*

ESG response:

The spawning area for KIH bullheads has not been documented. However, habitats conducive to bullhead spawning include shallow water (from six inches to several feet deep), low flow, muddy or sandy substrate, and natural shelter such as logs and vegetation. All of these features are characteristic of the KIH, and it is likely that bullhead spawn throughout the harbour.

- *Was there evidence of seasonal fluctuations of tumour and lesion incidence at the SW Belle Island site?*

ESG response:

The fish health sampling program was completed during the late fall of 2009. Potential seasonal fluctuations in tumour and lesion incidence are unknown.

EC comments that although the causation for the bullhead abnormalities is not well understood with regard to sediment contaminants, the premise that a cause/effect relationship exists appears to be a reasonable conclusion because of the substantial differences in abnormalities between control and exposure locations. Also, the principal cause of abnormalities in KIH bullheads could be viral in nature, but their initiation and severity may have been triggered and/or abetted by contaminants in the sediments.

EC recommends conducting a comprehensive review of the issue and developing a systematic plan to determine the cause of abnormalities in bullhead within KIH, including virology and histopathology studies if necessary.

<u>ESG response:</u>

As a follow-up to the initial study, a literature review was completed by ESG with the following goals: 1) to review the available scientific information on brown bullhead deformities; 2) to compare the approach used for the KIH with fish health studies conducted at other Great Lakes AOCs; and 3) to assess the need for further work. The review identified that the approach used to describe orocutaneous deformities, erosion, lesions, and tumours (DELTS) for the KIH brown bullhead was consistent with that used at other AOC and non-AOC sites (e.g., Blazer et al. 2009). The causes of orocutaneous (skin) fish DELTs are not well established in the scientific literature, but higher rates are usually found in contaminated areas (Rafferty et al. 2009). Further, fish health studies to assess the prevalence of liver tumours in brown bullhead in the KIH were considered, as there is strong evidence to indicate that exposure to chemical carcinogens is a primary factor in liver tumours (Rafferty et al. 2009). However, the suggested sample size for liver tumour studies (n = at least 100 fish) is not feasible for the KIH given the small area of the contaminated site. The low prevalence of liver tumours generally found for Great Lakes fish (see Baumann 2010) means that the chances of detecting significant differences in liver tumour prevalence would decrease with lower sample size. Therefore, we concluded that liver tumour studies on KIH fish could potentially involve a large cost and sampling effort with little ability to detect differences if present. Furthermore, there is sufficient other evidence for biological effects in the KIH that would lead to classification as a Class I FCSAP site without additional data on fish health.

With respect to understanding the cause of the brown bullhead DELTs, we agree that understanding causality would be important if the data were used to make decisions regarding sediment management at the site. Carrying out virology analyses on brown bullhead fish tissue may clarify whether the observed deformities are caused by pathogens. However, we agree with Environment Canada that it is possible that exposure to contaminant stressors may also result in increased fish susceptibility to hormonal imbalances and viral disease. If this were the case, sediment contaminant concentrations could not be ruled out as a stressor even if virology analyses indicated the presence of pathogens.

It would also be very difficult and expensive to determine which chemical contaminant may be responsible for the observed DELTs — this would involve lab toxicology tests with brown bullhead.

While there is a body of scientific literature documenting the link between fish exposure to PAHs and the subsequent development of DELTS and liver tumours, other chemicals have not been studied to the same extent (Rafferty et al. 2009). Although it is suspected that exposure to other contaminants (e.g., PCBs) also may result in fish deformities, defining the role these chemicals play would require extensive laboratory toxicology studies. The potential synergistic effects of the mixture of contaminants present in the KIH sediments would make the identification of causality for the observed deformities very challenging if not impossible. Because of these challenges, the KIH fish health data were not used to develop the sediment remediation SeQOs presented in Chapter V.

5. **Additional chemical sampling and analyses**

EC comment: The significance of current contaminant inputs needs to be assessed relative to historical contamination in the area of concern, if not already done so. The relative input of contaminants may need to be assessed across water lot boundaries, including related inputs from all sources during different seasons and weather events, with results compiled into one comprehensive report. As an alternative, a consolidation of all current information may be appropriate if sufficient, relevant data is currently available.

ESG response:

Section II-B-b of Chapter V discusses potential ongoing sources of contaminants to the KIH. Following comments by EC and other reviewers, the discussion in this section has been augmented with additional content, including discussion on the significance of current inputs relative to historical contamination.

The OMOE and the City of Kingston are working together to address any ongoing sources of contamination to the KIH. The outcomes of recent work by the OMOE and the City of Kingston to assess potential ongoing sources of contaminants have also been included in Chapter V. The City of Kingston has also reaffirmed that, if needed, it will take the steps necessary to address any source issues related to sanitary/storm sewers (ESG 2010a).

6. **Other testing**

EC comment: A study of the combined sewer overflow (CSO) effluent in terms of bacteriological/virological/fungal contamination may be helpful to characterize biological effects. Sampling and analyses for mutagenic activity of all effluent discharges, major sources of runoff, and contaminated sediment may also be helpful to determine causality for the fish deformities.

ESG response:

Discussion of determining causality for the fish deformities is addressed under the response to Comment 4 above. Although characterization of the CSO effluent would be interesting from a scientific perspective, it would not be likely to give definitive answers regarding causality for the fish deformities. As mentioned by the reviewer in Comment 4 above, exposure to contaminant stressors may also result in increased fish susceptibility to hormonal imbalances and viral disease. In this case, sediment contaminant concentrations could not be ruled out as a stressor despite the presence of pathogens. The same would be true of conducting tests on the mutagenic activity for all the effluent discharges, major sources of runoff, and contaminated sediment. The considerable costs of conducting these tests may not be justified, given the likelihood of inconclusive results regarding causality for the fish deformities.

7. Effects versus impacts

EC comment: There is a need to separate effects on biota in terms of bioaccumulation/biomagnification from detrimental impacts on their survival, avoidance/tolerance (absence-habitat loss), potential reproductive impairment, and so on to assess the need for remediation. Detrimental impacts should be the overriding determinants in decision-making.

Another consideration may be to compare fish consumption advisories in KIH with other similar urban "reference" areas along the north shore of Lake Ontario where remediation measures for sediments or other contaminant courses are not contemplated prior to considering sediment removal from the KIH.

<u>ESG comment:</u>

We agree that management decisions should be made based on detrimental impacts to biota, rather than guideline exceedances or evidence of bioaccumulation in higher trophic level organisms. This is why the human health and ecological risk assessment was performed, as it evaluates whether biological uptake of contaminants poses risk to human and ecological receptors at the site.

The assessment endpoints used for the ecological risk assessment were the survival, fecundity, and growth of (1) fish, (2) herbivorous mammals, (3) piscivorous mammals, (4) non-piscivorous birds, and (5) piscivorous birds. These endpoints were measured through comparison of estimated dietary intake with professionally recognized toxicological reference values (through the calculation of hazard quotients) to assure protection of the most sensitive of the attributes of survival, fecundity, and growth.

The approach used to conclude that management action is necessary for the KIH is consistent with guiding documentation through the COA framework (EC & OMOE 2008), the aquatic sites classification system (Franz Environmental 2010) and the framework for addressing and managing aquatic contaminated sites under FCSAP (Chapman 2010). The outcome from all of these frameworks concludes that either risk management or remedial actions are necessary for the KIH. Furthermore, the FCSAP aquatic contaminated sites framework (Chapman 2010) strongly recommends developing site-specific remediation objectives that are based on risk assessment, as we have done for the KIH.

As suggested, the 2011/2012 OMOE fish consumption advisories for KIH were compared with other nearby reference areas as follows: 1) four Lake Ontario sites (NE Lake Ontario, NW Lake Ontario, the Lower Quinte, and Whitby Harbour); 2) three St. Lawrence River sites (Thousand Islands, Middle corridor, and Lake St. Lawrence); and one upstream reference site for KIH (Colonel By Lake). A similar suite of contaminants was tested in fish from all of these areas, ensuring good comparability.

The 2011/2012 OMOE sport fish consumption guide lists advisories for the KIH (Cataraqui River, Belle Island area) for five species of fish: brown bullhead, carp greater than 45 cm in length, largemouth bass greater than 35 cm in length, northern pike, and pumpkinseed. Complete restrictions on consumption (i.e., 0 meals per month) for sensitive populations (i.e., women of child-bearing age and children under 15) are advised for three species due to PCB concentrations: brown bullhead over 25 cm in length, carp over 55 cm in length, and northern pike over 30 cm in length. For brown bullhead, KIH fish consumption advisories were more stringent (i.e., fish contaminant levels were higher) compared with all of the other reference sites except Whitby Harbour. For northern pike, KIH fish consumption advisories were more stringent than for all of the other reference sites where northern pike were sampled (six locations). KIH fish consumption advisories for carp varied from site to site. However, this is not surprising given that carp migrate long distances compared with the other two species and therefore have limited exposure to the KIH sediments. For this reason, carp were not included in the KIH food web modelling that identified sediment quality objectives for PCBs based on target tissue concentrations in fish.

8. **The Precautionary Principle (PP)**

EC comment: The fish consumption exposure scenarios used in the original risk assessment appeared excessively conservative. The reviewer agrees with ESG's later adoption of the more realistic OMOE Great Lakes sport fish ingestion rate, but recommends that a creel survey may be useful to estimate actual ingestion of KIH contaminated fish.

EC agrees that toxicity thresholds for individual contaminants do not necessarily account for potential additive or synergistic effects, and that the use of fairly conservative toxicological reference values (TRVs) may be appropriate for dealing with multiple toxicants. However, the wording around potential underestimation of risk in this case appears inconsistent between different report sections.

<u>ESG response:</u>

As the reviewer mentions, the revised KIH HHRA uses the 2003 OMOE Great Lakes sport fish ingestion rate, which was recommended for use in the risk assessment by Health Canada. This is more realistic/less conservative than the fish consumption rates initially used in the HHRA. Uncertainty in fish ingestion rate parameters is discussed in the revised Chapter IV (HHERA).

Site-specific fish ingestion rates could be investigated through a creel survey of Kingston sport anglers as part of the public consultation process. Anecdotal and observational evidence gathered by the City of Kingston has indicated that people currently fish in the area of concern, including from the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE (Cynthia Beach, City of Kingston, personal communication). However, remedial strategies for the harbour must account for future recreational use. Proposed residential development of the southwestern shoreline is anticipated to increase public access to this area; fish ingestion rates from a creel survey of current sport fishers may therefore not be representative of future use.

Regarding the wording for potential underestimation of risk, the text has been edited and clarified to address inconsistencies.

9. **Fish tissue concentrations for animal consumers**

EC comment: Golder's suggestion of replacing maximum fish tissue concentrations with measures of central tendency for the risk assessment has merit. Alternatively, the method employed by OMOE/MNR in the Sport Fish program could be considered.

<u>ESG response:</u>

We note that Golder's comments were based in part from review of an earlier draft version of the risk assessment, which has been subsequently revised following comments from FCSAP expert support departments and Parks Canada. The updated version of the human health and ecological risk assessment (HHERA) used measures of central tendency (UCL95) for the fish tissue concentrations in all of the HHRA calculations and in the ERA calculations for PCBs and MeHg. The measure used (UCL95) is consistent with Health Canada and Environment Canada guidance for risk assessments.

10. **Human Consumption Limits**

EC comment: The statement that "the greatest potential risk to adult human consumers of KIH fish due to elevated PCB levels would limit fish consumption to no more than three meals of fish per year and no more than one meal per year for children" appears oversimplistic and inconsistent with OMOE fish consumption advisories.

<u>ESG response:</u>

This statement was removed from the revised Chapter V.

11. **Management Options**

EC comment: Any management options for remediation involving sediment removal from the PC water lot should be deferred until the CSOs in the city sewage collection system are separated and all related sanitary sewer waste is adequately treated before discharge. Once this has been accomplished, then a reassessment of brown bullhead health and some or all other appropriate drivers affecting decision-making for remediation could also be reassessed.

<u>ESG response:</u>

Scientific data for the KIH have been reviewed by the Cataraqui River Stakeholder Group (CRSG), which is overseeing management decisions for the harbour. One of the primary aims of the stakeholder group is to ensure that any significant ongoing sources are removed or contained. The group recognizes that there is a need to address potential contaminant transport from the Orchard Marsh and the Kingscourt storm sewer as part of the remedial strategy for KIH sediments. At the June 2010 remediation options workshop, stakeholders agreed that the Orchard Marsh should be cleaned up concurrently with the river and reengineered for end-of-pipe treatment of the Kingscourt storm sewer inflow. The City of Kingston, a member of the stakeholder group, also reaffirmed that, if needed, it will take the steps necessary to address any source issues related to sanitary/storm sewers (ESG 2010b).

We are in agreement that CSOs (and storm water discharge) from the Kingscourt storm sewer outfall will need to be addressed under remediation plans for the KIH; indeed, there has been general agreement amongst the stakeholders regarding this point. We feel that the designation of CSOs as a "significant" source of contamination to the KIH is premature, given the lack of information on contaminant concentrations in the CSO effluent. It is very unlikely that the CSO effluent contains high levels of Cr and PCBs, which were identified as the main contaminants of concern for the KIH in the risk assessment.

The City of Kingston has completed a number of recent upgrades to the sewer systems that will aid in addressing CSOs (Ch2MHill and XCG 2010). These include construction of a number of CSO holding tanks, including one located beneath Emma Martin Park in the southwestern KIH. The capacity of the River St. Pumping Station was also increased, and the sanitary sewer line that crosses underneath the KIH from the River St. Pumping Station to the Ravensview Water Pollution Control Plant was twinned. All of these improvements increase capacity within the sewer system and should aid in reducing the frequency and volume of CSOs to the KIH. Sewer separation is ongoing in the downtown core and in the catchment area for the Kingscourt sewer.

12. **Further Studies**

EC comment: The definitive causes of the tumours and lesions in bullheads are not known. A thorough review and systematic plan should be developed to determine the cause of abnormalities in KIH brown bullhead, including virology and histopathology assessment if necessary.

<u>ESG response:</u>

This comment is addressed above under Comment 4.

13. **Species at Risk (SAR) – Page V-17, 1st paragraph**

EC comment: Mitigation measures during dredging could also include the setting of TSS/correlated turbidity limits.

<u>ESG response:</u>

We agree. Specific mitigation measures will be identified as part of the EA process. The report text has been edited to include this example.

14. **DFO Fish Habitat – Page V-17, 2nd paragraph**

EC comment: DFO will likely have a "fish window" for the harbour where in-water work cannot take place without special authorization. Contact DFO for specific guidance and/or approvals on this matter.

<u>ESG response:</u>

We accept this recommendation and this will be done during the EA process.

Section III – Sediment Investigation Results

15. **Summary of Sediment Investigation Results – Page V-17f**

EC comment: The heading for this section does not accurately describe the contents, which deal with evaluating sediment remediation options and determining the vertical and horizontal extents of sediment that should be managed.

ESG response:

The section heading has been edited to reflect the section content.

16. **Options analysis of remediation strategies – Page V-18f**

EC comment: The preference for dredging is well argued, but the following statement requires additional explanation and support: "the likelihood of Cr(III) oxidizing to Cr(VI) during dredging practices is negligible."

ESG response:

Measurements of Cr(VI) in pore water samples have been performed for the KIH. The analyses indicated that pore water Cr(VI) was below the analytical detection limits at all sediment locations and depths (Burbridge 2010). Additionally, the chemical composition of pore waters in the sediments of the KIH favours the reduction of Cr(VI) to Cr(III).

The discussion in this section of the report has been augmented with the details above.

17. **Vertical extent of sediment removal – Page V-23, 2nd paragraph**

EC comment: The underlying peat and clay layer will need to be defined in terms of its location much more accurately in future work in order to accurately define the dredging prisms (the 3-D units used to describe what will be dredged). This helps to accurately estimate the quantity of material removed and the elevation to which the contractor dredges to. Well defined units also help to avoid future claims.

ESG response:

The underlying peat and clay layer provides a defined physical boundary for sediment removal that can be included in the contract for dredging. This offsets the need to remove sediment to a pre-defined elevation, as the presence of a physical boundary enables the contractor to assess the vertical extent of sediment removal required during operations. As outlined in Chapter V, the depth of sediment contamination extends almost to the peat and clay layer in the western KIH and therefore it is reasonable to use this layer as a limit for dredging.

We recognize that more depth information would aid in developing more accurate estimates of the quantity of material for removal. The available evidence suggests that the depth of the peat and clay layer is fairly uniform, but further depth sampling could be done within the management areas as part of the Remedial Action Plan (RAP) development.

Section IV – Sediment Management Goals

18. **Page V-24, 1st paragraph below the numbered list**

EC comment: May wish to add that the generic sediment quality guidelines are usually not considered practical for defining remediation goals.

ESG response:

Text edited as suggested.

19. **Ecological Risk Assessment – Page V-25**

EC comment: Several statements in this section relate specifically to human health risk and are more appropriately placed in the previous section on "Human health risk assessment."

ESG response:

Text edited as suggested.

20. **Editorial – Page V-27**

EC comment: Some acryonyms presented here appear to have not been defined.

ESG response:

Addressed in text.

21. **Editorial – Page V-28, Equation V-1**

EC comment: Several terms defined below the equation are not in the equation. There is a unit error for the HHSedQO and SAF should be defined as the site allocation factor.

ESG response:

Addressed in text.

22. **Editorial – Pages V-30 and V-33**

EC comment: Give units for terms of Equation V-2 and Equation V-4.

ESG response:

Addressed in text.

23. **Editorial – Page V-36, Equation V-6**

EC comment: For a BSAF, the terms should be Cb = contaminant concentration in biota (lipid-normalized) and Cs = contaminant concentration in sediment (organic-carbon normalized).

ESG response:

Addressed in text.

24. **Hazard Quotients**

EC comment: There are inconsistencies between hazard quotients (HQs) for chromium (III) for ecological receptors presented in Chapter IV and Chapter V of the KIH report. Also, the relative contribution of each exposure pathway to the overall HQ for muskrat is unclear. What loadings of sediment are ingested by muskrats relative to levels of food in terms of overall daily ingestion rates?

It would be of value to understand the potential critical effects upon which the elevated ecological risks for muskrat (due to chromium III) and mink (for PCBs) are based.

ESG response:

The ERA presented in the draft Chapter IV report has subsequently been revised following comments from expert support review, and this accounts for the inconsistencies in HQs presented in the draft versions of Chapter IV and Chapter V. The inconsistencies will be resolved in the final draft of the KIH report.

The TRV for muskrat was taken from the US EPA ECO-SSL documents which examined 33 studies of effects in mammalian species from trivalent chromium exposure. The TRV chosen by the US EPA and used in the KIH report (2.40 mg/kg) is the geometric mean of the no adverse effects level (NOAEL) values from the effects on the reproduction, growth or survival of mammalian species. Effects to behaviour, physiology, pathology or biochemical changes were observed over a range of values from 0.22 mg/kg-d to 1,770 mg/kg-d. The US EPA value was chosen through a rigorous literature search and evaluation of appropriate toxicological values as described Chapter IV of the KIH report.

Regarding the relative contribution of sediment ingestion by muskrats compared with food ingestion: following results observed in Beyer et al. (1994) for mammals that feed on roots and tubers, it was estimated that muskrats ingest sediment at a rate of 3 percent of their total food intake rate. The sediments of the Orchard Marsh contain levels of chromium that are several orders of magnitude higher than those found in the cattail roots, and this explains why the greatest proportion of the hazard quotient for the muskrat is due to sediment ingestion. Details of the exposure calculations for muskrat and the rationale for the values used are explained in Chapter IV.

Reproductive toxicity in mink is known to be one of the most sensitive endpoints of PCB toxicity in mammals and was therefore selected as an ecologically relevant response. Fuschman et al. (2007) compiled published results from more than 50 studies of reproductive effects in mink from exposure to

PCBs (in the form of technical mixtures or as accumulated in prey). The value chosen for use as the toxicological reference value (0.053 mg/kg-d; Brunström et al. 2001 in Fuschman et al. 2007) was based on a no effects level (i.e., no effect on the survival rate of mink kits, on mated female minks or on individual mink kit weights (a less sensitive endpoint) in comparison to a control set referenced in Fuschman et al. (2007)).

25. **Fish consumption pathway calculations**

EC comment: The results of lab tests with fathead minnows exposed to KIH sediment were used in the biomagnification model (KIH Ch V, Fig. V-5) to measure the uptake of PCBs specific to fish in contact withKIH sediments (page V-35). However, the body burden of PCBs in bullheads used as part of the model would be a result of both sediment and food ingestion. Therefore, how does the model deal with the ingestion of PCBs by fish from both food and sediments in the overall SeQO determination?

While we do not necessarily question the appropriateness of ESG's methods for this derivation, a greater explanation of the methodology for those not familiar with this component of the evaluation would add greater comfort to our acceptance and understanding of the SeQO estimations from this method, as described in Figure V-5 (pg. V-34).

ESG response:

The diet of fathead minnows and brown bullhead is comparable: both species ingest algae, detritus, and sediments as well as invertebrates. For this reason, the BSAFs developed in the KIH fathead minnow lab uptake studies were considered appropriate as a proxy for brown bullhead PCB uptake. For comparison, PCB concentrations in the KIH food web were also modeled using a literature-based sediment to invertebrate uptake equation for PCBs (Diep and Boyd 2007). Validation of the calculations using KIH data showed that the BSAF approach best approximated measured uptake. Therefore, the BSAF approach was used to develop remediation criteria.

This approach has been used in other studies to develop risk-based sediment quality remediation objectives for PCBs. Similar methods were used for Hamilton Harbour, Ontario (Labencki 2008); Sheboygan Harbour, Wisconsin (USEPA 2000); and Peninsula Harbour, Lake Superior (Environ 2007).

Greater explanation of the rationale and methodology for the food web modelling and SeQO estimation has been added into this section of the report.

Sections V – Residual Risk

26. **Calculation of areas warranting management – Page V-51, Part d.**

EC comment: Since the plan is to remove only enough contaminated sediment to bring the risk within an acceptable level, care must be taken to prevent further contamination of adjacent non-remediated polygons during dredging operations. This may require more than just silt curtains.

ESG response:

Agreed. Mitigation measures will be addressed as part of the EA process and will subsequently be incorporated into remedial plan design.

27. **Residuals**

EC comment: This report touches on residuals in a number of locations and that is good, because they are always an issue when dredging is selected as a remediation method. As the authors of the report are aware, the polygons that were converted to "background" concentrations in order to calculate the removal area where the SWAC concentrations are below the risk-derived objectives will not actually end up as background concentrations after dredging. Rather, they will contain residual contamination with a range of concentrations, and with levels being quite high in some areas. Additional dredging passes can be specified; however, experience has shown a record of diminishing returns with this strategy and therefore its use alone will not likely solve the issue. Thin layer capping, where residuals are essentially diluted, is a common solution. The implications at this site would be that the thin layer cap would have to be designed (modeled) so that the cap would dilute any residuals to a level less than the background concentrations (used in the derivation of the risk-derived objective). Otherwise, the risk-derived objective would be invalidated (i.e., if polygons exist after dredging which exceed background concentrations, more polygons would require dredging than what you originally estimated in order to meet the objectives based on SWAC).

ESG response:

Residual contamination was incorporated into the polygon estimates presented in Chapter V in the following way (summarized on page V-51 of the draft report). Generated residuals from dredging have been estimated to contain 2 to 9% of the contaminant mass originally targeted for removal (Palermo et al. 2008). To investigate this scenario in the KIH, residual risks for PCBs were calculated using residuals of 9% and compared to residual risks calculated assuming that dredging was 100% effective. The difference in residual risks between the two scenarios was 0.3%, which is negligible compared to the overall reduction in risk from sediment removal.

Remedial plans for dredging typically involve confirmatory sampling to ensure that the dredging targets have been met. As the reviewer mentions, additional dredging passes or thin layer capping can be used as follow up methods in cases where significant residual contamination remains. These strategies would be considered as part of the remedial plan development for the harbour.

General Comments – Chapter V: Remedial Options Analysis

28. **Editorial**

EC comment: Headings and subheadings should be reviewed for consistency in numbering and relevance in their contents.

<u>ESG response:</u>

Addressed in text.

29. **Editorial**

EC comment: It would be good to have a list of acronyms and abbreviations.

<u>ESG response:</u>

Chapter V acronyms and abbreviations have been incorporated into the list of abbreviations for the entire KIH report, which defines abbreviations/acronyms presented in all five chapters.

30. **General comment**

EC comment: The Chapter V document, which recaps the results of the sediment investigation and human and ecological assessments for Kingston Inner Harbour, applies the FCSAP aquatic site classification, evaluates sediment remediation options, and determines post-remediation sediment quality objectives (SeQOs), is convincingly argued and well-written. In principal, we agree with the reasoning for selecting dredging as remedial option over managed natural recovery and capping, as well as the procedures used to estimate candidate areas and volumes for sediment removal. Use of a risk-based approach for setting SeQOs is supported by leading sediment management practices.

<u>ESG response:</u>

We appreciate confirmation of the approach used in the report to identify remedial options.

31. **Measuring success**

EC comment: Since this remediation is based on a reduction of risk to an acceptable level by partial remediation, it is going to be important to demonstrate the effectiveness of the cleanup. It appears that many studies of the various biota have occurred in the past (baseline). Consideration needs to be made to ensure the project baseline is adequate and what will be required as follow-up (post-remediation) to evaluate the effectiveness of the remediation.

<u>ESG response:</u>

This would be addressed largely in the RAP, as monitoring the effectiveness of the cleanup is directly related to the remedial plan design. However, a brief section has been added to Chapter V summarizing the current project baseline and any recommendations for additional data.

32. **Editorial – Appendix L, page 5, cell 6 - Rationale**

EC comment: should it be "($p<0.05$)" rather than "($p<0.5$)"?

<u>ESG response:</u>

Text edited as suggested.

33. **Map V-4: approximate boundaries of the management areas in KIH**

EC comment: We note that the boundaries of management areas in Map V-4 appear to extend beyond the boundaries of the Parks Canada property. On page V-45, there is a further breakdown of "the area requiring management actions for Cr and PCBs." Please clarify if the dredging estimates include any areas outside of federal jurisdiction — specifically, the portions extending north into Belle Island, and to the northeast extending in the Orchard Marsh (i.e., at the outfall of the Kingscourt storm sewer). Also, it would be useful to have a further breakdown delineating what areas fall under Parks Canada and Transport Canada ownership, and the associated dredging volume estimates.

ESG response:

The final report will provide clarification on the boundaries of federal jurisdiction and will delineate the TC and PC boundaries. The final report will also provide an estimate of the dredging volumes associated with the TC and PC boundaries. Dredging volumes presented in the draft Chapter V will be recalculated using the revised SeQOs.

Summary

EC comments: ESG has listed the three prerequisites to remedial planning as: 1) Determine causation for biological effects; 2) control ongoing sources; and 3) ensure that remedial actions do not cause more environmental damage than they remedy (page V-6). On balance, it appears that prerequisites 1) and 3) will have been adequately covered once our comments herein are addressed. On page V-13f of the KIH Chapter V draft document, ESG provides some details as to how the four identified "potential continuing contaminant sources" could be addressed. However, addressing these ongoing, third-party, off-site sources remains a key element in determining the ultimate success of this remediation. FCSAP guidance recommends that any likely and active source of contamination should be completed at the site prior to the initiation of any risk management or remedial alternative, in order to prevent site recontamination. This is noted on page V-13, 1st paragraph.

ESG response:

The Cataraqui River Stakeholders Group has agreed to ensure that any significant remaining ongoing contaminant sources are removed or contained. Specific comments related to source control are addressed under Comments 5, 6, and 11 above.

EC comments: Since other contaminated federal properties (that is Transport Canada) are adjacent to the Parks Canada site, collaboration within the federal family is essential to achieve any operational and financial efficiencies in the remediation process.

ESG response:

We agree.

EC comments: When contamination on federal sites is caused by a third party (non-federal), the "Polluter-pays" principle must be applied, and the federal contribution to remediation costs must be proportional to share of responsibility for contamination. For this project, the federal property has been 100% contaminated by a third party. As per TB policy, when submitting such a property for FCSAP funding, custodians must take appropriate measures to ensure remediation costs are paid for by the party responsible for contamination. Please refer them to Section 6.1.12 of TB policy on Management of Real Property — for third-party contamination. For this project, Parks Canada should show that they have made reasonable attempts to contact the responsible third parties to initiate discussions regarding potential recovery of the third party's share of remediation. If successful, FCSAP must be reimbursed for that share.

ESG response:

Section 6.1.12 of Treasury Board policy on the management of real property (in effect since November 2006) states that custodial departments are responsible for ensuring that "known and suspected contaminated sites are assessed and classified and risk management principles are applied to determine the most appropriate and cost-effective course of action for each site. Priority must be given to sites posing the highest human health and ecological risks. Management activities (including remediation) must be undertaken to the extent required for current or intended federal use. These activities must be guided by standards endorsed by the Canadian Council of Ministers of the Environment (CCME) or similar standards or requirements that may be applicable abroad. The costs of managing contamination caused by others must be recovered, when this is economically feasible."

ESG is aware that Parks Canada is required under Treasury Board policy to show that they have made reasonable attempts to contact the responsible third parties to initiate discussions regarding potential recovery of the third party's share of remediation. However, in the case of the KIH, the extensive Cr contamination in the sediment on the Parks Canada property is almost certainly from the former Davis Tannery. The company is no longer in existence and the property was orphaned before being taken over by a private developer. It would be impossible to retrieve funds from the "polluter" in this case. The above policy statement clearly indicates that the custodial departments are responsible for managing the contamination, including undertaking remediation to ensure the protection of human and ecological health, even when the contamination was caused by others and remediation costs are not recoverable.

References

Baumann, P.C. (Baumann 2010). Data analysis and fish tumor BUI assessment for the Lower Great Lakes and interconnecting waterways. Report prepared for Environment Canada.

Benoit, N. and A. Dove (Benoit and Dove 2006). Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 monitoring programs. Technical report prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Beyer, W.N., E.E. Connor, and S. Gerould (Beyer et al. 1994). "Estimates of soil ingestion by wildlife." *Journal of Wildlife Management* 58 (2): 375–382.

Blazer V.S., S.D. Rafferty, P.C. Baumann, S.C. Smith, and E.C. Obert (Blazer et al. 2009). "Assessment of the "fish tumors or other deformities" beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): I. Orocutaneous tumors." *Journal of Great Lakes Research* 35: 517–526.

Brunström, B., B.-O. Lund, A. Bergman, L. Asplund, I. Athanassiadis, A. Athanasiadou, S. Jensen, and Örberg J. (Brunström et al. 2001). "Reproductive toxicity in mink (*Mustella vision*) chronically exposed to environmentally relevant polychlorinated biphenyl concentrations." *Environonmental Toxicology and Chemistry* 20 (10): 2318–2327.

Burbridge, D.J. (Burbridge 2010). "Contaminated sediments in the Kingston Inner Harbour: Assessing ecological effects, evaluating and minimizing remediation impacts." Master's of Science thesis, Royal Military College of Canada, Kingston, ON.

Ch2MHill and XCG (Ch2MHill and XCG 2010). Pollution control plan update for the City of Kingston. Final Report. Prepared for Utilities Kingston, July 2010.

Chapman, P.M. (Chapman 2010). Guidance Document: Framework for Addressing and Managing Aquatic Contaminated Sites Under the Federal Contaminated Sites Action Plan (FCSAP). Final Report. Golder Associates Ltd., Burnaby, BC.

Diep N. and D. Boyd (Diep and Boyd 2007). "Muddy Creek, Wheatley Harbour AOC contaminant exposure pathway study: 2004-2007 sediment and young-of-the-year fish results." Toronto (ON): Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment.

Environ (Environ 2007). Environmental Risk Assessment for Peninsula Harbour, Lake Superior. Prepared for Environment Canada.

Environment Canada and Ontario Ministry of the Environment (EC & OMOE 2008). Ontario Decision-Making Framework for Assessment of Great Lakes Contaminated Sediments.

Environmental Sciences Group (ESG 2010a). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter III: Ecological effects: Evaluation of bioaccumulation of contaminants in biota, sediment toxicity, and benthic community structure.

Environmental Sciences Group (ESG 2010b). Minutes from the June 28, 2010 Kingston Inner Harbour remediation options analysis workshop, Kingston, ON.

Franz Environmental Ltd. (Franz Environmental 2010). FCSAP Aquatic Sites Classification System (2009) version 1.0: Final detailed user guidance manual. Prepared for the Department of Fisheries and Oceans Canada, April 30, 2010.

Fuschman P., T. Barber, and M. Bock (Fuschman et al. 2007). “Effectiveness of various exposure metrics in defining dose-response relationships for mink (*Mustela vison*) exposed to polychlorinated biphenyls.” *Archives of Environmental Contamination and Toxicology* 54: 13–144.

Hamilton, T. (Hamilton 2002). “Are Kingston sediments toxic to fish? Effects of PAHs and PCBs from Kingston Inner Harbour sediments on rainbow trout.” Honours Bachelor of Science thesis, Department of Biology, Queen’s University, Kingston, ON.

Labencki, T. (Labencki 2008). An assessment of polychlorinated biphenyls (PCBs) in the Hamilton Harbour Area of Concern (AOC) in support of the beneficial use impairment (BUI): Restrictions on fish and wildlife consumption. Ontario Ministry of the Environment, Environmental Monitoring and Reporting Branch.

Palermo, M., P. Schroeder, T. Estes, and N. Francingues (Palermo et al. 2008). "Technical Guidelines for Environmental Dredging of Contaminated Sediments," ERDC/EL TR-08-29, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Rafferty, S.D., V.S. Blazer, A.E. Pinkney, J.L. Grazio, E.C. Obert, and L. Boughton (Rafferty et al. 2009). “A historical perspective on the “fish tumors or other deformities” beneficial use impairment at Great Lakes Areas of Concern.” *Journal of Great Lakes Research* 35: 496–506.

Sakaris, P.C., R.V. Jesian, and A.E. Pinkney (Sakaris et al. 2005). “Brown bullhead as an indicator species: Seasonal movement patterns and home ranges within the Anacostia River, Washington, DC.” *Transactions of the American Fisheries Society* 134: 1262–1270.

United States Protection Agency (US EPA 2000). U.S. EPA Superfund Record of Decision Sheboygan River and Harbor, Sheboygan, Wisconsin.

Van der Oost, R., J. Beyer, and N.P.E. Vermeulen (van der Oost et al. 2003). “Fish bioaccumulation and biomarkers in environmental risk assessment: A review.” *Environmental Toxicology and Pharmacology* 13: 57–149.

ESG response to "Health Canada review of ASCS classification worksheets and associated reports for the Parks Canada Kingston Inner Harbour project" reviewed by Heather Jones-Otazo, dated February 21, 2011

The following general comments were provided by Health Canada related to work at the site:

1. **Site jurisdiction and ASCS scores**

HC comment: Presently, the provisional Parks Canada ASCS score and the ESG (2010) human health risk assessment are reflective of conditions in the entire Kingston Inner Harbour site. However, the Kingston Inner Harbour site is divided into two separate contaminated sites, one of which is under the jurisdiction of Parks Canada, and the other under Transport Canada. If they have not already done so, Parks Canada and Transport Canada should compare their site conditions and determine whether conditions are sufficiently different to warrant separate sites, or whether they are sufficiently similar to warrant merging the sites into one FCSAP site. If they are sufficiently different and separate sites are required, the Parks Canada ASCS score should be revisited to be reflective of only the specific portion of the site under Parks Canada jurisdiction. Notably, data in the ASCS "5. Contaminant Characteristics" worksheet should be specific to the Parks Canada-owned portion of the contaminated site.

<u>ESG response:</u> We would be happy to provide separate ASCS classification sheets for the Transport Canada and Parks Canada water lots if needed.

2. **Human health risks for different portions of the KIH**

HC comment: It is assumed that a harbour-wide site management plan will be jointly developed by Parks Canada and Transport Canada. It may be helpful to assess human health risks separately for different portions of the Kingston Inner Harbour, as human exposures to sediment during recreational activities may be variable. Further, this information could be of assistance in developing a targeted site management plan for the Kingston Inner Harbour site. Depending on the data available, use of maximum concentrations could be required to assess sub-portions of the site.

<u>ESG response:</u>

The human health risk assessment for the KIH assumed that receptors could be exposed to contaminants through the following pathways:

a. inadvertent ingestion of and dermal contact with sediment during wading, walking, playing activities;
b. ingestion and dermal contact with suspended sediments during swimming or rowing; and
c. ingestion of contaminated food stuffs (fish caught in the KIH).

Since fish are mobile and move throughout the KIH, it does not seem appropriate to assess human health risks for pathway c. (ingestion of contaminated fish) separately for different portions of the southern KIH. For contaminants of concern where the fish ingestion pathway is the main contributor to overall risk, such as PCBs and MeHg, human health risks would not vary significantly throughout the harbour.

For other contaminants such as Hg, As, Cr and Pb, contact with sediments is the main exposure pathway contributing to overall risk. We agree that the separate assessment of human health risks for different portions of the harbour for these contaminants has merit, as potential human health risks due to sediment exposure are anticipated to vary across the KIH. This may be particularly useful in determining management decisions for the Rowing Club/Woollen Mill area, identified as an Area of Special Consideration in the management scenarios presented in Chapter V of the KIH report. The revised Chapter V examines human health risks for micro-environments of the KIH to aid in risk management decisions.

3. **OMOE sport fish consumption advisory**

HC comment: The Ontario Ministry of the Environment (MOE, 2009) provides a sport fish consumption advisory for fish in the Cataraqui River in the Belle Island area. The advisory is fish species- and fish length-specific, and is based on the most sensitive measured chemical in fish. Specific advisories are in place in the area for consumption of northern pike, largemouth bass, yellow perch, black crappie, pumpkinseed, bluegill, brown bullhead, and carp of specific lengths. The proposed fish consumption restrictions calculated by ESG (2010) are not fish species- or fish length-specific, nor were they calculated according to the accepted OMOE Sport Fish Contaminant Monitoring Program protocol. If it is determined that there is sufficient data to support the development or update of a sport fish consumption advisory for the Cataraqui River in the Belle Island area, then Parks Canada should work together with the OMOE Sport Fish Contaminant Monitoring Program to do so according to the accepted OMOE protocol.

<u>ESG response:</u>

Much of the data used for the KIH human health risk assessment was taken from the OMOE Sport Fish contaminant monitoring program. ESG did analyze fish tissue samples for some contaminants not assessed in the OMOE program (e.g., As, Cr). However, human health risks from fish consumption for these contaminants were generally small because of the relatively low concentrations measured in fish tissue. Overall, there is probably not sufficient extra data to warrant calculation of a revised sport fish consumption advisory. Rather, our risk assessment supports the need for a sport fish consumption advisory as is currently in place through OMOE.

4. **Sports fish consumption advisory for Parks Canada property**

HC comment: Sufficient rationale or justification should be provided by Parks Canada that demonstrates that their portion of Kingston Inner Harbour is the direct cause of (or significantly contributes to) the Sport Fish Consumption advisory for that area, if such fish consumption advisories are going to be the basis for FCSAP funding and any site management and/or mitigation measures proposed on site. Further, OMOE (2009) sport fish consumption advisories are considered to be an effective tool for managing the human health risks from sport fish consumption in Ontario. Parks Canada should work with the OMOE Sport Fish Contaminant Monitoring Program should there be a need to update any consumption advisory at any Ontario aquatic site.

<u>ESG response:</u>

The OMOE Sport Fish consumption advisories are primarily in response to elevated PCB concentrations in fish tissue. There is consistent evidence to indicate that (1) PCB concentrations in sediment are generally elevated throughout the Parks Canada water lot and the maximum concentrations for the harbour are found here; (2) PCBs in the sediments are bioavailable for uptake by fish and other aquatic organisms; and (3) fish caught near Belle Island in the vicinity of the Parks Canada water lot have significantly elevated PCB concentrations in comparison with fish caught in upstream reference areas and locations in the Great Lakes and St. Lawrence River. Below, we expand on the evidence for each of these three points.

(1) PCB concentrations in surface sediments of the KIH are shown in Map II-12 in Chapter II of the KIH report (ESG 2009). PCB concentrations exceed the CCME probable effect level (PEL) of 277 ppb for much of the Parks Canada water lot and are greater than 554 ppb (2x the PEL) for most of the northern portion. The maximum PCB sediment concentrations for the KIH (4,400 ppb) were measured here.

(2) A number of scientific studies investigating invertebrates and fish collected in and adjacent to the Parks Canada water lot have noted that these organisms are accumulating higher levels of PCBs compared with upstream references sites. The most likely explanation is that contaminants in the sediments are bioavailable and are accumulating in the food chain through ingestion of incidental sediment and aquatic prey items. Fathead minnow sediment uptake laboratory bioassays with KIH sediments support this conclusion: minnows exposed to contaminated sediments from the Parks Canada water lot and adjacent areas accumulated Pb and PCBs in their tissue to a much greater extent than do minnows exposed to upstream reference sediments (Watson-Leung 2004). Studies assessing the possibility of existing terrestrial or groundwater sources of PCB contamination to the impacted area of the KIH have not located a present source to date.

(3) The OMOE has over 30 years of fish monitoring data from the KIH on PCB concentrations in young-of-the-year fish (Derry et al. 2003). Young-of-the-year fish have small home ranges and therefore are thought to be good indicators of exposure to local contamination. These data show consistent evidence for elevated PCB concentrations in fish collected south of Belle Park compared with reference sites in the northern KIH.

Most sport fish collected near Belle Island also show elevated PCB concentrations in comparison with fish from other areas. The 2011/2012 OMOE fish consumption advisories for the Cataraqui River at Belle Island were compared with other nearby reference areas as follows: (1) four Lake Ontario sites (NE Lake Ontario, NW Lake Ontario, the Lower Quinte, and Whitby Harbour); (2) three St. Lawrence River sites (Thousand Islands, Middle corridor, and Lake St. Lawrence); and (3) one upstream reference site for KIH (Colonel By Lake). A similar suite of contaminants was tested in fish from all of these areas, ensuring good comparability.

Complete restrictions on consumption (i.e., 0 meals per month) for sensitive populations (i.e., women of child-bearing age and children under 15) are advised for three species in the KIH (Cataraqui River, Belle Island) due to PCB concentrations: brown bullhead over 25 cm in length; carp over 55 cm in length; and northern pike over 30 cm in length. For brown bullhead, KIH fish consumption advisories were more stringent (i.e., fish contaminant levels were higher) compared with all of the other reference sites except Whitby Harbour. For northern pike, KIH fish consumption advisories were more stringent compared with all of the other reference sites where northern pike were sampled (six locations). KIH fish consumption advisories for carp varied from site to site. However, this is not surprising, given that carp migrate long distances compared with the other two species and therefore spend a much smaller fraction of time in the KIH. For this reason, carp were not included in the KIH food web modeling that identified sediment quality objectives for PCBs based on target tissue concentrations in fish.

We also question the effectiveness of the OMOE fish consumption restrictions in limiting sport fish consumption from the site. Anecdotal and observational evidence gathered by the City of Kingston has indicated that people currently fish in the area of concern, including from the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE (Cynthia Beach, City of Kingston, personal communication).

Discussion of administrative controls to restrict fish consumption from the site as a potential risk management scenario will be expanded in Chapter V. Public willingness to accept these administrative controls will need to be addressed as part of the public consultation process.

References

Derry, A., A. Dove, R. Fletcher, and N. Benoit (Derry et al. 2003). PCB Source Trackdown in the Cataraqui River: 2001 Findings — Technical Memorandum. Prepared for the Ontario Ministry of the Environment, Eastern Region.

Environmental Sciences Group (ESG 2009). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour.

Hamilton, T. (Hamilton 2002). “Are Kingston sediments toxic to fish? Effects of PAHs and PCBs from Kingston Inner Harbour sediments on rainbow trout.” Honours Bachelor of Science thesis, Department of Biology, Queen’s University, Kingston, ON.

Van der Oost, R., J. Beyer, and N.P.E. Vermeulen (Van der Oost et al. 2003). “Fish bioaccumulation and biomarkers in environmental risk assessment: A review.” *Environmental Toxicology and Pharmacology* 13: 57–149.

Watson-Leung, T. (Watson-Leung 2004). Laboratory Sediment Toxicity and Bioaccumulation Tests: Report on Cataraqui River Sediments 2002 — Technical Memorandum. Appendix J to: Derry, A., A. Dove, R. Fletcher, and N. Benoit (Derry et al. 2003). PCB Source Trackdown in the Cataraqui River: 2001 Findings — Technical Memorandum. Prepared for the Ontario Ministry of the Environment, Eastern Region.

ESG response to "Health Canada's review of Application of the Canada-Ontario Decision Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter V: An Options Analysis of Management Scenarios for the Kingston Inner Harbour (ESG Chapter V)" reviewed by Christine McEwan, dated June 22, 2011

1. **Potential human health risks with remedial activities**

HC comment: As the KIH area supports recreational activities and commercial space is located immediately south of the Rowing Club (historic Woollen Mill), a detailed remedial action and source control plan should address the potential human health risks associated with the KIH dredging and additional remedial activities to occur along the western shore of the KIH. Human health concerns related to dredging involve the re-suspension and release of sediments; management of water and suspended sediment drained from dredged material; and accidents/malfunctions. Human health concerns identified in the remedial action and source control plan should include appropriate mitigation and/or monitoring control measures. This human health component could also be included in ESG 2011 Chapter V in the section on page V-15 titled "Remedial actions should not cause more environmental damage than they remedy."

ESG response:

We agree that these are important considerations that should be included as part of the Remedial Action Plan (RAP). As part of the RAP development, potential human health risks will be identified and mitigation/monitoring measures implemented where appropriate. The RAP outlines the detailed design for the remedial program and is therefore a more appropriate stage to address this information than in Chapter V.

2. **Fish consumption scenarios**

HC comment: Revised fish consumption values have been used for the development of sediment quality objectives (SeQOs) based on HC's peer review comments for Chapter IV (HHERA). Specifically, it is stated that the SeQOs have been developed based on an adult consuming 39 meals of fish per year (236 g). Please provide adequate references for these values in Chapter V, and please clarify if the 236 g refers to 236 g/meal as an average meal size. Please note HC has not been provided with the revised Chapter IV (HHERA) for review.

ESG response:

The SeQOS were developed based on the revised HHERA presented in Chapter IV of the KIH report. This chapter outlines in detail all of the exposure scenario assumptions, as well as the rationale and references for the values chosen. Since the two chapters will be presented together in the same report, we feel it is appropriate to summarize the HHERA briefly in Chapter V and leave the details in Chapter IV.

The revised KIH HHRA uses the 2003 OMOE Great Lakes sport fish consumption fish ingestion rate, which was recommended for use in the risk assessment by Health Canada (OMOE 2006). Based on responses from Great Lakes sport anglers regarding fish consumption habits, adults in the KIH HHERA are assumed to consume 39 meals of fish per year. As clarification, the 236 g does refer to 236 g/meal as an average meal size for an adult receptor.

We would be happy to provide a copy of the revised Chapter IV (HHERA) for HC review.

3. **Equations and input parameters for the calculation of KIH SeQOs**

HC comment: Additional information regarding the calculation of the SeQOs for the KIH would be useful in order to verify the methodology. SeQOs were calculated for the dermal and ingestion sediment exposure pathways and for the fish consumption pathway. The equation used to calculate the SeQOs for the sediment ingestion was not provided. Additionally, the calculation of the SeQO for the fish consumption pathway was not clearly displayed. Many of the input parameters (i.e., body weight, surface area, ingestion rates, TDIs (tolerable daily intakes), EDIs (estimated daily intakes), etc.) were not provided and there is no reference to previous reports (i.e., Chapter IV HHERA) if the same parameters were used. Please provide all equations and input parameters used to derive the SeQOs so that Health Canada can verify the approach. Include all assumptions and justifications as appropriate. Worked examples would be useful.

<u>ESG response:</u>

Additional information regarding the SeQO calculations for the KIH has been added into Chapter V to address the concerns outlined by HC above. Specifically, the SeQO equations for the sediment ingestion pathway and the fish consumption pathway have been provided and clearly displayed. The input parameters are the same as those summarized in detail in Chapter IV of the KIH report, and reference to these tables has been provided in the Chapter V text. Any additional assumptions and justifications have been documented in detail in the text as appropriate. Worked examples of the SeQO calculations have been included in an appendix of the final KIH report.

4. **Arsenic SeQO**

HC comment: For arsenic, what is the SeQO based on (threshold or non-threshold effects)? Both HQ and ILCR calculated in the HHRA warranted risk management.

<u>ESG response:</u>

SeQOs will be developed for both threshold and non-threshold effects. Risk management options will consider the more protective value.

5. **Site allocation factor (SAF)**

HC comment: A site allocation factor (SAF) of 0.6 was used in the calculation of the SeQOs based on the assumption that COPCs are not expected to be found in air or water (not detected in air or groundwater and PCBs unlikely to be in surface water — please provide references to this data). The use of an SAF of 0.6 that does not include reference to background EDIs is not consistent with HC guidance nor is it *justified as representative for the general population. An SAF of 0.2 is instead recommended for this site, unless background EDIs are incorporated on a chemical-specific basis. Any alterations to a default of 0.2 should be made on a chemical-specific basis with full justification rather than globally for all COPCs.*

ESG response:

Following consultation with Health Canada, in the revised chapter V an SAF of 0.2 will be used in the calculation of risk and SeQOs unless sufficient data has been presented to justify the development of chemical-specific background EDIs. Where SeQOs in the revised Chapter V are calculated incorporating both on-site and background exposures, a value of 1.0 will be used as the SAF, as recommended by HC.

6. **HQs for human health exposure pathways**

HC comment: Additionally, on page V-27, it is indicated that SeQOs were calculated for human health pathways which resulted in an HQ > 0.2 and an HQ > 0.6. Please note that a default HQ of 0.2 is recommended by HC, unless background exposures are incorporated. An HQ ≤ 1.0 should be deemed to represent an acceptable or negligible risk if both on-site and background exposures are combined (i.e., total exposure is being assessed) (HC DQRA 2010). This is also applicable to the interpretation of Table V-9 and Table 5-M-3.

ESG response:

See the response to Comment 5.

7. **Dermal contact pathway for Cr**

HC comment: The calculated human health based SeQOs for Cr were: toddler (32 ppm), children (40 ppm), teens (440 ppm) and adults (775 ppm). The values for toddlers and children were ultimately rejected as being overly conservative because the dermal loading factors (Shoaf et al. 2005b) were based on activities along a tidal flat where sediments are not confined underwater (this scenario does not exist at the KIH) and were not used to set remedial targets. A Cr SeQO of 650 ppm is recommended by ESG based on an ecological receptor—– the mallard duck.

Given that the Cr SeQO is significantly greater than the CCME residential/parkland human health soil quality guideline (SQG) for total chromium (64 ppm) and the CCME PEL is 90 ppm,. please provide further support which addresses the over-conservatism with respect to the dermal pathway and demonstrates the Cr SeQO of 650 ppm is likely protective of human health for all age groups.

Also, it is indicated that the mallard duck is not the most sensitive ecological receptor. Please provide justification for this receptor selection and advise if there is potential human health risks associated with not using the most sensitive receptor to set the SeQO — i.e., impact to food chain/human consumption of biota from the site.

ESG response:

The CCME SQG of 64 ppm for total chromium is an environmental SQG and is derived based on toxicity studies to plants and invertebrates (CCME 1997). A nutrient and energy cycling check is also calculated as an additional protective measure. For Cr, 64 ppm is the geometric mean of the preliminary soil contact value and the nutrient and energy cycling check for residential/parkland land use (CCME 1997). For sediments, the CCME PEL of 90 ppm for total chromium is derived from studies of biological effects to benthic organisms (i.e., those living in or on sediment) (CCME 1999).

Neither the environmental SQG or the CCME PEL for sediments are appropriate for assessing potential human health risks, as they are based on toxicity to invertebrates and other organisms. No CCME human health guidelines are currently available for sediments. However, a human health SQG of 220 ppm for residential/parkland use has been derived based on incidental soil ingestion (CCME 1997). Derivation of the human health SQG is based on highly conservative risk assessment calculations that assume that the most sensitive receptor (i.e., a toddler) is ingesting soil from a site 24 hours a day, 365 days a year. Furthermore, the calculations assume that the ingested Cr is 100% bioavailable to the toddler ingesting the soil. Recent studies indicate that chromium bioaccessibility is substantially less than 100% (Koch et al. in press, and references therein), meaning that the human health SQGs are likely to be very conservative.

With regards to the dermal loading factors for toddlers and children, we feel that these are overly conservative and have high uncertainty associated with their use for the following reasons. First, there is very limited data describing sediment adherence factors to skin. Two studies were recommended by the HC reviewer for the original KIH HHERA: one for adults digging clams in tide flats (Shoaf et al. 2005a), and the other for children playing on tide flats (Shoaf et al. 2005b). The dermal loading factors calculated in the latter study were based on measurements taken during one day of play for a very small sample size (nine children), and the study authors state that there is limited ability to generalize activity patterns and sediment adherence values for larger populations (Shoaf et al. 2005b). Secondly, as the reviewer mentions, both studies calculated sediment adherence factors based on activities in an exposed tidal flat of sediments. This scenario is not appropriate for the KIH, where sediments are typically confined underwater. Thirdly, the TRV developed by HC for chromium is based on the toxicity of hexavalent chromium. Studies of sediment Cr, sediment pore water, and soils from adjacent sites indicate that Cr in the KIH is present as the less toxic, trivalent form (Cr (III)) (see Chapter II, ESG 2009). Based on the scientific evidence provided, the risk calculations have been revised using the more appropriate TRV (based on Cr(III) toxicity) which has been adopted by the US EPA as well as the OMOE. A TRV for Cr(III) specific exposure is not provided by HC as it is seen as an essential nutrient. The revised risk calculations show that adverse health impacts to any of the modelled human receptors are not expected from exposure to Cr (III). Therefore, only ecological receptors have been modelled in the development of SeQOs.

Calculated ecological risks due to Cr were higher for muskrat and red-winged blackbird receptors compared with the mallard duck. However, this is because muskrat and red-winged blackbirds were assumed in the risk assessment to obtain most of their food (i.e., cattail roots and cattail seeds) from

Orchard Marsh, where there are very high chromium sediment concentrations. Exposure to the KIH river sediments for these two receptors would probably be restricted only to shoreline areas where cattails are present. In contrast, the mallard duck is found throughout the KIH and would be exposed to KIH sediments through incidental sediment ingestion and ingestion of invertebrate prey. Therefore, the mallard duck is a more appropriate receptor to use for the calculation of SeQOs for the KIH.

Remediation of the Orchard Marsh will need to occur in conjunction with the KIH, but will be addressed in a separate document from the present report.

8. **Inconsistencies in chromium SeQOs for adults**

HC comment: There is inconsistency for the chromium SeQO for adults (750 ppm in text on page V-39 and in Table 5-M-1; 775 ppm in Table V-6; 7,000 ppm on page V-40). Please clarify the correct value.

ESG response:

SeQOs for Cr (III) have not been developed for adults in the revised Chapter V. The text and tables have been edited to address this.

9. **Spatially weighted average concentrations (SWACs)**

HC comment: It is Health Canada's understanding based on the information provided that spatially weighted average concentrations (SWACs) (using Thiessen polygons based on sampling points) were used to determine the impacted area requiring management (i.e., dredging). The areas requiring management were determined first by defining the relevant area (Cr: smallest home range for mallard duck for Cr; all other COPCS: the entire impacted area of the KIH). Concentrations in each polygon (starting with most heavily impacted) were replaced with background concentrations for the COPC until SeQO was reached for the relevant area identified. A number of comments relating to this method are provided below:

A. It is not clear if the SWAC statistical approach is conservative and protective of human health risk since there is no supporting scientific rationale referenced. Please provide scientific defensible rationale demonstrating its protectiveness.

ESG response:

Use of SWACs as the exposure point concentration is considered appropriate when environmental data may be biased through collecting more samples in contaminated locations than uncontaminated locations, providing sufficient spatial coverage. Surface sediment environmental data for the Kingston Inner Harbour fulfills both of these conditions, and therefore the SWAC was deemed to be a more accurate measure of environmental exposure for calculating sediment quality objectives. The use of SWACs has been used in a number of studies to develop risk-based sediment quality guidelines that are protective of human health (e.g., Sheboygan River and Harbor, Wisconsin — US EPA 2000; Peninsula Harbour, Ontario — Environ 2007).

The use of SWACs in the human health risk assessment for the KIH was discussed with HC expert support in our conference call on December 19, 2011. According to HC expert support, the use of SWACs is acceptable in Chapter V to define areas of management provided that: (1) the text in Chapter V clearly identifies the differences in the approach used compared to the KIH human health risk assessment presented in Chapter IV; and (2) the risk management scenarios in Chapter V consider both a harbour-wide approach as well as specific microenvironments. This is the approach we have taken in the revised report.

B. Please provide rationale and references (i.e., previous investigations) for background concentrations (i.e., 61 ppm for Cr) used to define the areas requiring management. Also, please indicate if these background concentrations are from the reference location or the concentration in the sediment below the depth to be dredged.

ESG response:

Detailed discussion of the spatial distribution of contaminants of concern is provided in Chapter II of the KIH report (ESG 2009). This includes comparisons of mean surface sediment comparisons in the impacted area (defined as the southern portion of the KIH between Belle Island and the LaSalle Causeway) and the reference area (defined as the northern portion of the KIH between the 401 and the north shore of Belle Island), as well as contaminant plume maps showing the spatial distribution of surface sediment contaminant concentrations for CoPCs throughout the KIH. The data are also presented in Table IV-1 in Chapter IV (ESG 2010) and Tables D-4-1 to D-4-4 in Appendix D of the KIH report.

For the SWAC calculations, background concentrations represent the mean surface sediment concentration in the upstream reference area. Some data is available on Cr concentrations at depth in the sediments underlying the area for management in the KIH. These concentrations range from <20 ppm to 110 ppm, with an average Cr concentration of 53 ppm (Table D-2-3 in Appendix D of the KIH report; ESG 2009). These values are very similar to those obtained from upstream reference area sediments.

Statements explaining the rationale and references for the background concentrations have been added to the text of Chapter V.

C. For Hg and Pb, the report (Page V-44) indicates that the SeQOs were lower than the SWAC and no remedial activities are warranted. Please clarify if this sentence is correct; based on this, it appears that management options would need to be considered.

ESG response:

The statement should have read "For Hg and Pb, the report (Page V-44) indicates that the SeQOs were **higher** than the SWAC and no remedial activities are warranted." The text has been revised within the revised Chapter V.

10. **UCL definition and relevance**

HC comment: SeQOs provided in Table V-6 and Table 5-M-1 indicate SeQOs for Cr (fish consumption pathway), Pb, Hg, and MeHg to be less than the UCL. Please define what "UCL" refers to for these COPCs, how they were determined and the relevance.

ESG response:

UCL is an abbreviation for the "upper confidence limit." For the COPCs in the KIH, the UCLs were calculated as the 95th percentile of the mean. The individual sample results and derivation of the UCL for all contaminated media are described in detail in Chapter IV (HHERA; ESG 2010). The 95 UCL was used in the risk assessment as an appropriate statistical estimate of the average exposure concentrations in media sampled from the KIH (e.g., sediments, water, fish tissue). The report text has been updated in the revised Ch. V.

11. **Residual HQs above 0.2**

HC comment: Residual HQ values (predicted risk post-dredging to SeQOs) shown in Table V-9 and Table 5-M-3 are elevated above 0.2 for Cr, As, and PCBs for a number of age groups. These HQ values are based on SWACs rather than exposure point concentration used in the HHERA. Please justify the HQ values exceeding 0.2 based on predicted residual contamination in a discussion section of the report.

ESG response:

Following HC's recommendations, we have recalculated the SeQOS as outlined in the response to comment 5 above. All residual HQ values have been presented and justified.

12. **Health Canada's comments concerning the Golder 2011 Data Gap Assessment**

HC comments: The 2011 Data Gap Assessment (Golder 2011) suggests that the implementation of remedial measures is premature. That is, the results of the assessment completed to date warrant further investigation prior to making site management decisions. Health Canada's comments concerning the items identified by Golder that are specifically relevant to human health are listed below:

A. Bioavailability of metals not assessed. Additional information regarding metals bioavailability may be of use, specifically to address elevated Cr concentrations, and SeQO for Cr which is 10x the CCME SQG_{HH}.

ESG response:

Note that the CCME SQG_{HH} is 220 ppm for residential/parkland use and not 64 ppm (see comment 7 above). Also please note that SeQOs for Cr (III) have not been developed in the revised Ch. V.

While we have some concerns with Golder's suggested methodology for assessing bioavailability (Golder 2011), we agree with HC that measures of Cr bioavailability are important. Specifically, these measures would provide a more accurate exposure estimate for the ERA and could alter the associated risk-based sediment quality objectives (SeQOs). In the current ERA, Cr poses risk to several ecological receptors largely due to incidental sediment ingestion. Having a more accurate assessment of Cr bioavailability would likely decrease the risk from sediment ingestion.

We recommend that analyses of Cr bioavailability, using a surrogate bioaccessibility test, be undertaken on sediments from the KIH to provide a better estimate of exposure for use in the risk assessment calculations. ESG has been developing bioaccessibility testing methods for over 10 years and also has experience with conditions that model gastrointestinal conditions in ecological receptors (Kaufmann et al. 2007; Ollson et al. 2009), as well as with chromium (Koch et al. in press). No bioaccessibility tests have been validated against animal models for chromium, but our studies (and those of other researchers, using similar or dissimilar tests) indicate that chromium bioaccessibility is substantially less than 100% (Koch et al. in press, and references therein). For the present application and recommended tests, ESG recommends the use of an avian (specifically, mallard duck) bioaccessibility model.

B. *Uncertainty in fish tissue concentrations — HC concurs that the use of an estimate of central tendency is preferred in a detailed quantitative risk assessment, and it is understood that the revised Chapter IV uses estimates of central tendency to estimate fish concentrations instead of the maximum (cannot be verified until Health Canada is provided with a copy of the revised Chapter IV). Species-specific tissue concentrations may be useful in refining site management objectives; however, the outcome of incorporating this information with respect to site management cannot likely be predicted.*

<u>ESG response:</u>

The updated version of the human health and ecological risk assessment (HHERA) used measures of central tendency (UCL95) for the fish tissue concentrations in all of the HHRA calculations and in the ERA calculations for PCBs and MeHg. The measure used (UCL95) is consistent with Health Canada and Environment Canada guidance for risk assessments. We would be happy to provide a copy of the revised Chapter IV (HHERA) for HC review.

We agree with HC that incorporating species-specific tissue concentrations into the risk assessment with respect to site management would be challenging. However, we did incorporate different fish species into the development of remedial SeQOs for PCBs in Chapter V through the food web model. This was to account for the fact that PCBs biomagnify in aquatic food webs, and it is therefore important to have representation from species at different trophic levels. The detailed methodology used to calculate sediment SeQOs is outlined in Section IV of Chapter V.

C. *Local fish ingestion rates uncertain — This issue may have been partly addressed in the revised HHERA completed by ESG based on HC comments made related to Chapter IV — HHERA. Health Canada recommended consideration of a provincial fish ingestion rate, and it is understood that the revised Chapter IV has adopted this (cannot be verified until Health Canada is provided with a copy of the revised Chapter IV). However, consideration of local species-specific ingestion rates (obtained from local conservation authority or the Ontario Sport Fish Contaminant Monitoring*

Program or obtained via local sampling methods such as a creel census as mentioned by Environment Canada) may result in a more accurate human health risk characterization and may impact PCB management options. Local data should include estimates of meals/year and grams/meal to be consistent with the risk assessment. This should include fish caught but preserved for later consumption (i.e., frozen or pickled).

<u>ESG response:</u>

The revised KIH HHRA uses the 2003 OMOE Great Lakes sport fish consumption fish ingestion rate, which was recommended for use in the risk assessment by Health Canada. This is a more recent source than the Kearney (1995) study mentioned by Golder and is more realistic/less conservative than the fish consumption rates initially used in the HHRA. Uncertainty in fish ingestion rate parameters is discussed in the revised Chapter IV (HHERA). We would be happy to provide a copy of the revised Chapter IV (HHERA) for HC review.

Site-specific fish ingestion rates could be investigated through a creel survey of Kingston sport anglers as part of the public consultation process. Anecdotal and observational evidence gathered by the City of Kingston has indicated that people currently fish in the area of concern, including from the former Davis Tannery property, despite the fish consumption restrictions currently in place through OMOE (Cynthia Beach,City of Kingston, personal communication). However, remedial strategies for the harbour must account for future recreational use. Proposed residential development of the southwestern shoreline is anticipated to increase public access to this area; fish ingestion rates from a creel survey of current sport fishers may therefore not be representative of ingestion rates with increased future use.

References

Canadian Council of Ministers of the Environment (CCME 1997). Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health: Chromium. In: Canadian Environmental Quality Guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB.

Canadian Council of Ministers of the Environment (CCME 1999). Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Chromium. In: Canadian Environmental Quality Guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, MB.

Environ (Environ 2007). Environmental Risk Assessment for Peninsula Harbour, Lake Superior. Report prepared for Environment Canada**.**

Environmental Sciences Group (ESG 2009). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour.

Environmental Sciences Group (ESG 2010). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter IV: Human health and ecological risk assessment.

Golder Associates (Golder 2011). Final report on review and data gap assessment for Parks Canada water lot, Kingston Inner Harbour. Report produced for Parks Canada, March 2011.

Hamilton, T. (Hamilton 2002). "Are Kingston sediments toxic to fish? Effects of PAHs and PCBs from Kingston Inner Harbour sediments on rainbow trout." Honours Bachelor of Sciences thesis, Department of Biology, Queen's University, Kingston, ON.

Kaufmann, C.A., J.R. Bennet, I. Koch, and K.J. Reimer (Kaufmann et al. 2007). "Lead bioaccessibility in food web intermediates and the influence on ecological risk assessment." *Environmental Science and Technology* 41: 5902–7.

Kearney, J., D.C. Cole, and D. Haines (Kearney et al. 1995). Report on the Great Lakes angler pilot exposure assessment study. Great Lakes Health Effects Program, Health Canada, Ottawa, ON.

Koch I., M. Moriarty, J. Sui, B. Gibson, and K.J. Reimer (Koch et al. in press). "Insolubility of Cr_2O_3 in bioaccessibility tests points to requirement for a new human oral reference dose for trivalent chromium." *Human and Ecological Risk Assessment*, in press (accepted September 2011).

Ministry of the Environment (OMOE 2006). Results of the 2003 Guide to Eating Ontario Sport Fish Questionnaire.

Ollson, C., I. Koch, P. Smith, L.D. Knopper, and K.J. Reimer (Ollson et al. 2009). "Addressing arsenic bioaccessibility in ecological risk assessment: A novel approach to avoid overestimating risk." *Environmental Toxicology and Chemistry* 28 (3): 668–675.

Shoaf, M.B., J.H. Shirai, G. Kedan, J. Schaum, and J.C. Kissel (Shoaf et al. 2005a). "Child dermal sediment loads following play in a tide flat." *Journal of Exposure Analysis and Environmental Epidemiology* 15: 407–412.

Shoaf, M.B., J.H. Shirai, G. Kedan, J. Schaum, and J.C. Kissel (Shoaf et at. 2005b). "Adult dermal sediment loads following clam digging in tide flats." *Soil and Sediment Contamination* 14 (5): 463–470.

United States Environmental Protection Agency (US EPA 2000). EPA Superfund Record of Decision: Sheboygan River and Harbor, Sheboygan, Wisconsin.

Van der Oost, R., J. Beyer, and N.P.E. Vermeulen (Van der Oost et al. 2003). "Fish bioaccumulation and biomarkers in environmental risk assessment: A review." *Environmental Toxicology and Pharmacology* 13: 57–149.

Watson-Leung, T. (Watson-Leung 2004). Laboratory Sediment Toxicity and Bioaccumulation Tests: Report on Cataraqui River Sediments 2002— Technical Memorandum. Appendix J to: Derry, A., A. Dove, R. Fletcher, and N. Benoit (Derry et al. 2003). PCB Source Trackdown in the Cataraqui River: 2001 Findings — Technical Memorandum. Prepared for the Ontario Ministry of Environment, Eastern Region.

ESG responses to "Fisheries and Oceans Canada - Review of 'Application of the Canada-Ontario Decision-making Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter 5: An Options Analysis of Management Scenarios for the Kingston Inner Harbour (ESG 2011 Chapter V)'"

1. Page V-10 **Deformities in Brown Bullhead**

DFO comment: The Golder Gap Analysis "Review and Data Gap Assessment for Parks Canada Waterlot, Kingston Inner Harbour. March 2011" has identified several factors which could influence the presence of tumours found in brown bullhead, specifically indicating that PAHs may be a significant contributor. Has there been any data collected or analyses performed on fish and/or fish tissue samples regarding PAHs?

<u>ESG response:</u>

It should be noted that a review of the PAH sediment data discovered a unit error in the report that presented data for sediments collected in the Woollen Mill and Rowing Club vicinity (Benoit and Dove 2006). The document erroneously reported PAH concentrations as ppm rather than ppb, meaning that reported concentrations were 1,000 times higher than those that were measured. This unit error was perpetuated into the draft version of Chapter II of the KIH report and the associated contaminant plume maps where the Benoit and Dove (2006) data were used. Subsequent revisions have corrected the error and the updated PAH data analyses and plume maps are presented in the final version of Chapter II (ESG 2009). Although total PAH concentrations in sediments from the impacted area exceed the OMOE Lowest Effect Level (LEL) in many cases, concentrations in all samples were well below the OMOE Severe Effect Level (SEL) and are not expected to yield pronounced toxic responses. It seems unlikely that PAHs are responsible for the observed fish tumours, given the relatively low concentrations in the study area.

PAHs are rapidly metabolized and excreted in fish, meaning that fish tissue analyses of PAH concentrations are not a reliable method of estimating past exposure to elevated PAHs (van der Oost et al. 2003). A better method of estimating PAH bioavailability to fish is through measuring the extent of ethoxyreorufin-o-deethylase (EROD – CYP1A) enzyme activity as a biomarker of previous PAH exposure. Hamilton (2002) assessed EROD activity of juvenile trout and chronic toxicity to larval trout after exposure to KIH sediments collected from the following locations: Anglin Bay; adjacent to the old Woollen Mill; adjacent to the former Davis Tannery site; along the south shore of Belle Island; in the channel to the east of Belle Island; and just west of the channel to the north of Belle Island. Her study found significantly elevated EROD activity for fish exposed to sediments from Anglin Bay and two outer harbour sites, suggesting exposure to PAHs. EROD activity for fish exposed to sediments from all the other KIH sites was lower and not significantly different from control sites, indicating little exposure or effects due to PAHs.

2. **Page V-21 Dredging**

DFO comment: DFO would encourage that, if dredging is the accepted remediation strategy, the effectiveness of this method in removing the contaminants of concern (CoCs) at the site be evaluated through a monitoring program. This program can be developed in conjunction with input from habitat biologists at DFO in order to determine and minimize the potential impacts to fish and fish habitat at this site.

ESG response:

ESG agrees that the KIH remedial action plan (RAP) should be developed with input from DFO expert support to minimize potential impacts to fish and fish habitat at the site during and following remediation.

References

Benoit, N. and A. Dove (Benoit and Dove 2006). Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 monitoring programs. Technical report prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Environmental Sciences Group (ESG 2009). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour.

Hamilton, T. (Hamilton 2002). “Are Kingston sediments toxic to fish? Effects of PAHs and PCBs from Kingston Inner Harbour sediments on rainbow trout.” Honours Bachelor of Science thesis, Department of Biology, Queen’s University, Kingston, ON.

Van der Oost, R., J. Beyer, and N.P.E. Vermeulen (van der Oost et al. 2003). “Fish bioaccumulation and biomarkers in environmental risk assessment: A review.” *Environmental Toxicology and Pharmacology* 13: 57–149.

ESG responses to "Fisheries and Oceans Canada - Review of the Aquatic Sites Classification System Scoring submitted in the 'Application of the Canada-Ontario Decision Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter 5: An Options Analysis of Management Scenarios for the Kingston Inner Harbour (ESG 2011 Chapter V)'"

1. **Worksheet 4, Question 3.**

DFO comment: Based on HC comments should be "No." Additional justification required if answer will be "Yes."

ESG response:

ESG has taken DFO's suggestion under consideration and provided additional justification for a "yes" response.

2. **Worksheet 5**

DFO comment: Many of the comments and questions from ESDs have not been addressed here. First data point entry "Surface Water/ PCBs & PCDD/Fs" has an error in calculation as identified in March 2011 comments - Score A should be zero.

ESG response:

ESG has taken DFOs suggestion under consideration and adjusted scoring accordingly.

3. **Worksheet 6, Question 2d**

DFO comment: Provide rationale for change of score from "Highly Sensitive" to "Less Sensitive."

ESG response:

ESG has provided a rationale for the revised scoring.

4. **Worksheet 6, Question 3**

DFO comment: Skip questions 3b through 3h if you answered "A," "B" or "C" to question 3a (above). Questions 3b through 3h need only be scored if you answered "D"("Do Not Know") to question 3a.

ESG response:

ESG has taken DFOs suggestion under consideration and adjusted scoring accordingly.

5. **Worksheet 6, Question 4**

DFO comment: Skip questions 4b through 4e if you answered "A," "B" or "C" to question 4a (above). Questions 4b through 4e need only be scored if you answered "D" ("Do Not Know") to question 4a.

ESG response:

ESG has taken DFOs suggestion under consideration and adjusted scoring accordingly.

6. **Worksheet 7, Question 1g**

DFO comment: As per previous comments from EC/DFO, re-score as "No."

ESG response:

ESG has taken DFOs suggestion under consideration and adjusted scoring accordingly.

ESG response to the City of Kingston's comments on "Application of the Canada-Ontario Decision-making Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter 5: An Options Analysis of Management Scenarios for the Kingston Inner Harbour (ESG 2011 Chapter V)" sent by e-mail April 28, 2011

1. **Page V-2 and others**

CoK comment: The acronym for Aquatic Sites Classification System is referred to as ASCS and ACSC in various locations.

ESG response: The text has been edited throughout to cite the correct acronym (ASCS).

2. **Page V-3: 3rd paragraph**

CoK comment: First sentence is not clearly worded.

ESG response: Text edited for clarification.

3. **Page V-3: 3rd paragraph, 3rd sentence**

CoK comment: Not clear if "endangered or threatened" refers to classification under the Species at Risk Act (SARA) or if it refers to potential impact from contaminants present.

ESG response: "Endangered or threatened" refers to classification under SARA. The text has been edited for clarification.

4. **Page V-4: last paragraph**

CoK comment: Contaminated Sediment Remediation Guidance should have consistent capitalization style applied.

ESG response: Text has been edited as suggested.

5. **Page V-7**

CoK comment: The discussion of potential causes may be misleading to some readers. It does not provide qualification of potential sources as being historic, ongoing, or both. It also ignores urban runoff via storm sewers or overland flow as a potential source as well as deliberate dumping or spills (especially important for PCBs) and agricultural or septic runoff from upstream sources. The text and diagram also create confusion between potential causes (Stressors) and potential sources (Sources).

ESG response: Following the above comment and others from external reviewers, we have expanded and clarified the text in the report section on potential ongoing sources of contamination to the Kingston Inner Harbour. Specifically, we have included separate sections on storm sewer runoff and the combined sewer overflows and included many details for each potential source that were not summarized in the draft version. Figure V-1 (conceptual model for potential causes of ecological impairment) has also been modified for clarification. The new report text summarizes the available information for each potential source, identifies important data gaps, and outlines the significance (if known) of this source compared with historical sources leading to the contaminated KIH sediments.

Scientific data for the KIH has been reviewed by the Cataraqui River Stakeholder Group (CRSG), which is overseeing management decisions for the harbour. One of the primary aims of the stakeholder group is to ensure that any significant ongoing sources are removed or contained. The Ontario Ministry of the Environment (OMOE) has been working with the City of Kingston to ensure that potential ongoing sources are addressed.

6. **Page V-13**

CoK comment: There is potential for confusion between the Kingscourt storm sewer (Page V-13) and the Combined Sewer Overflow (Fig V-1) terms that are used to describe potential ongoing sources.

ESG response: Discussion of the storm water runoff from the Kingscourt storm sewer and Combined Sewer Overflows has been expanded and placed in two different sections in the report to avoid confusion.

7. **Page V-15, 1st paragraph**

CoK comment: I would suggest changing "with raw sewage" to "with untreated sanitary sewage that is combined with runoff." And also "to control impact from the Kingscourt sewer" to "to control potential impacts from the Kingscourt sewer system."

ESG response: Text edited as suggested.

8. **Page V-15, Section d. Belle Park**

CoK comment: Add a sentence stating that the City of Kingston conducted re-sampling of Project Trackdown wells at Belle Park in December 2010 and obtained results consistent with earlier findings indicating that the Belle Park Landfill is not an ongoing source of PCB-contaminated groundwater to the Cataraqui River or sediments.

ESG response: The OMOE has reviewed the 2010 data as well as additional historic data provided by the City of Kingston. The goal of the OMOE review was to assess whether the Belle Park Landfill is a continuing source of contaminants to the Kingston Inner Harbour. They concluded that the Belle Park Landfill is not a significant ongoing source of PCBs to the KIH (Castro 2011). The report text has been edited to reflect the suggested edits above and the confirmation of results by OMOE.

9. **Page V-20**

CoK comment: It would be worthwhile to include a sentence about the requirement to assess for underwater archaeology and the localized restrictions or mitigations that the preservation of significant artifacts (if any) may impose on a dredging program.

ESG response: Discussion of the requirement for an archaeological assessment and the potential resulting restrictions or mitigations has been added into this section of the report.

10. **Page V-24: Last paragraph before Section A**

CoK comment: "...exposure scenarios developed or the HHERA" should read "…developed for the..."

ESG response: Text edited as suggested.

11. **Page V-34**

CoK comment: The picture at the top appears to be a carp but is captioned as a brown bullhead.

ESG response: The graphic has been replaced with a picture of a brown bullhead.

References

Castro, V. (Castro 2011). Memorandum regarding Belle Park Landfill (Closed), Environmental Operations and Monitoring 2010. Sent to Craig Dobiech, Senior Environmental Officer, Kingston District Office, Ontario Ministry of the Environment, Eastern Region, on October 12, 2011.

ESG response to Golder Associates' "Technical review of the Environmental Sciences Group – Royal Military College (ESG-RMC) report entitled 'Application of the Canada-Ontario Decision-making Framework for Contaminated Sediments in the Kingston Inner Harbour – Chapter V: An Options Analysis of Management Scenarios for the Kingston Inner Harbour,'" dated November 28, 2011

The following document summarizes ESG responses to comments made by Golder Associates in their review of Chapter V of the KIH report, which was commissioned by Public Works and Government Services Canada on behalf of Transport Canada. Some of the Golder comments were lengthy and have been paraphrased below to highlight main discussion points and questions. The complete version of original comments from Golder may be found in an appendix of the KIH report.

General Comments

1. **Interpretation of data and uncertainties**

Golder comment: The report appears to emphasize stations and measurement endpoints that suggest adverse responses, whereas endpoints and stations that indicate either lack of response or ambiguous information appear to be de-emphasized. Accordingly, some narrative statements in the report that are generalized, appear to overstate risk potential, and do not convey uncertainties appropriately. For example, the comment on page V-2 regarding "direct and significant evidence of impacts to ecological receptors" would benefit from a more balanced interpretation of the results of previous investigations. Based on the available data, it appears that the majority of stations did not exhibit significant toxicity following the Framework decision rules for sediment quality, the minority of stations showing toxicity do not provide "direct" but rather indirect evidence of potential harm, and the benthic community assessments indicate, at most, weak evidence of adverse alterations. Also, the wildlife risks appear highly uncertain and do not provide direct and significant evidence.

<u>ESG response:</u>

We believe that the issue comes down to what will be the basis for remediation: effects to benthic organisms or effects to the higher trophic levels (risk-based). We have chosen to emphasize the latter and use a risk-based approach to determining remediation objectives. This is consistent with FCSAP guidance and is also supported by the COA framework (see sections 4 to 6).

Multiple lines of evidence indicate that the sediments are the main source of bioavailable contaminants. For example, lab bioassays with contaminated sediments from the KIH investigating contaminant uptake into test invertebrates and fathead minnows indicate significant bioaccumulation of Cr and Pb and biomagnification of PCBs (ESG 2009; Benoit and Dove 2006). The risk assessment identifies these as the main contaminants of concern that pose potential risk to humans and ecological receptors in the KIH. The need for management action is also clearly shown by the FCSAP aquatic sites classification system (ASCS) scoring, which is used to prioritize sites for future risk management/remedial action based on contaminant characteristics, receptors and exposure, and physical and other disturbances. The FCSAP

ASCS scoring identified the KIH as a Class I site requiring action; this score for the KIH has been reviewed and substantiated by FCSAP expert support departments (HC, EC, and DFO).

Identifying areas for remediation based on toxicity to benthic organisms is one approach that can be used to design a sediment remediation program. However, it is not the only approach. We have delineated a remediation zone for the KIH based on calculated risk to ecological receptors — i.e., mallard ducks consuming invertebrate prey items from Cr-contaminated sediments, and humans — i.e., sport fish consumers. This approach has also been used to determine remediation sediment quality objectives (SeQOs) in other contaminated sediment projects such as Peninsula Harbour, Lake Superior (Environ 2007) and the St. Clair River, Ontario/Michigan (Environ 2009). The uncertainties associated with the benthic assessment and wildlife risks are consistent with other similar projects and do not preclude making remedial decisions.

2. Spatial boundaries of the impacted KIH site

Golder comment: The report references "the impacted KIH site" but would benefit from a clear definition of the spatial boundaries of this site, particularly in terms of the southern limit. Many of the discussions in the document focus on contamination pathways near the former tannery operations and landfill, with relatively little attention given to sediment quality south of Emma Martin Park. For example, the sediment polygons identified for remediation are focussed on the area between the former tannery site and Belle Island, in spite of indications of overall risk in other portions of KIH that are similar (or higher for some endpoints and COPCs). As such, the need for (and potential effectiveness of) remediation in a portion of the KIH should also consider data from other areas. Recently collected information from Transport Canada water lot areas that were previously poorly characterized have not been incorporated in this report; the latter studies provide important information for assessing relative risks and overall effectiveness of the proposed remedy.

<u>ESG response:</u>

The area around the Rowing Club/Woollen Mill (on Transport Canada's water lot) is also identified as an area of special concern for management. The revised report has completed a human health risk assessment for this area and other microenvironments of spatial contaminant patterns and receptor exposure to aid in management decisions.

The information from the Transport Canada water lot referred to by Golder was not available when the draft Chapter V report was released. We will incorporate this data in the revised version of the report.

3. Process by which the report was commissioned

Golder comment: The report does not provide an indication of the impetus for preparing this deliverable at this time, given the ongoing status of sediment delineation and assessment. For transparency, it would be beneficial if the report provided additional details regarding the process by which the report was commissioned (if this information can be disclosed), including:

a. *Who commissioned the report (was it requested by specific agencies or stakeholders, or was it prepared independently?);*

b. *The source of funding used to prepare this deliverable is not disclosed (we note that the acknowledgements on page V-vi make no mention of funding); and,*

ESG response:

We are unable to see the relevance of these comments.

c. *How the decision was made to proceed to Step 6 of the Framework. Investigations are currently underway to reduce uncertainty in previous assessments, and both Parks Canada and Transport Canada have expressed concerns about the uncertainty in the understanding of risk.*

ESG response:

ESG has hosted meetings of the CRSG on a regular basis over the past six years to present and discuss results and get input on proposed next steps. An outline of KIH report chapter V was proposed to the CRSG for consideration in advance of researching and writing the document, as was done for all of the chapters in the KIH report.

1.1 Framework Application

4. Stakeholder peer review

Golder comment: The report provides a number of "professional judgement" determinations. In cases where professional judgement is invoked, it is recommended that a process of peer review be undertaken prior to endorsement of rendered conclusions (if this has not been completed to date). To this end, consideration should be given to engaging the major stakeholders in the Federal Contaminated Sites Action Plan (FCSAP) in review of the conclusions, including the FCSAP secretariat, Federal "Expert Support," and Public Works and Government Services Canada (PWGSC).

ESG response:

Please note that Federal Expert Support (Environment Canada, Health Canada, and Fisheries and Oceans Canada) have reviewed all of the chapters of the Kingston Inner Harbour report to date, including Chapter V. The final report text has been revised to address their comments. Copies of their peer review comments and the ESG responses will be found in an appendix of the final KIH report.

Members of the FCSAP secretariat have been briefed. We fail to see the need for PWGSC involvement at this time.

5. ASCS classification system

Golder comment: We agree that reclassification of a site is required at Step 6 "to update the ranking after obtaining results from detailed investigations." However, such detailed investigation has not been *completed, in terms of providing either full spatial characterization or sufficient level of certainty for the assessment of human or ecological health risks.*

ESG response:

We disagree.

Golder has not seen the revised HHRA which, after consultation with Health Canada, has confirmed that the KIH HHRA now meets the requirements of a detailed quantitative risk assessment. The ERA has been conducted according to standard practice. Uncertainties are standard for this type of risk assessment and very little could be done to generate meaningful improvements to these.

Incorporation of the Golder information for the Transport Canada water lot will complete the spatial characterization for the harbour. The basis for remediation is protection of upper trophic level receptors and humans. Information is sufficient to determine remedial goals in this case.

6. Sediment toxicity results and the ASCS score

Golder comment: The assignment of a "Class 1 designation" to the KIH site based on sediment toxicity results assumes that the entire site should be classified on the basis of toxicity observed in a minority of samples. By treating the site as a single unit, and not considering the different responses observed in different spatial units, this decision point is biased toward assigning a Class 1 designation. The approach applied would allow for such designation of any parcel of sediment, irrespective of size, if any sample exhibited toxicity. This is important because page V-1 argues that the reclassification stage (Step 6) "indicates that management actions are needed." Linking the need for active management to toxic responses observed in a subset of samples appears inconsistent with Framework principles (including the directive to use a weight-of-evidence decision framework, and the need to consider field responses as an important line of evidence).

ESG response:

The Golder text is based on an incorrect premise. The ASCS Class I designation to the KIH site was not assigned purely on the basis of the toxicity results. Toxicity results for the KIH are one line of evidence that was taken into account when scoring Section 4a (Current/past exposure of ecological receptors) on worksheet 6, which may contribute a maximum of 18 points to the total overall site score (maximum 100). Along with the toxicity results, four other lines of evidence were examined: the degree of benthic community impairment; the prevalence of deformities, eroded fins, lesions, and tumours (DELTS) on brown bullhead at the site; the significantly higher biological uptake of contaminants at the site compared with reference areas; and the potential ecological risks to upper trophic level receptors identified in an ecological risk assessment. For KIH, this category was assigned a score of 8 out of a possible 18 (i.e., strongly suspected ecological effects). This has been reviewed and confirmed by FCSAP expert support.

7. Contaminant characteristics portion of the ASCS

Golder comment: The Contaminant Characteristics portion of the ASCS tends to overstate potential for harm associated with bulk sediment concentrations of COPCs.

ESG response:

The KIH ASCS was completed in accord with the ASCS guidance and was reviewed by all Expert Support departments. It should be noted that concentrations of some contaminants in the KIH (e.g., chromium) are unusually elevated compared with most other aquatic contaminated sites.

We agree with Golder that using guidelines to assess bulk sediment contaminant concentrations is a highly conservative approach and not appropriate for making remedial decisions. In fact, this has been a main guiding principle in determining remedial objectives for the KIH — only the area of the harbour that shows biological effects (i.e., poses risk to upper trophic level receptors and humans) should be remediated. We have assessed bioavailability of the contaminants through the following lines of evidence: (1) pore water studies; (2) speciation studies where appropriate (e.g., chromium); (3) sediment bioassays to assess biological uptake of sedimentary contaminants into invertebrates and fathead minnows; (4) field studies of biological uptake into caged test organisms and resident organisms; and (5) bioaccessibility of sedimentary contaminants to ecological receptors (proposed work).

8. Receptors and Exposure component of the ASCS

Golder comment: In the Receptors and Exposure component of the ASCS, the "adverse impacts" listed in the bullets on page V-3 in several cases appear overstated, and do not acknowledge the conservatism in the risk derivations. For example, sediment toxicity testing does not indicate "toxic effects in the benthic community" but rather indicates toxicity to sensitive indicator organisms in a laboratory environment. This is an example of where it is claimed that direct evidence exists where evidence is indirect (and in some cases inconsistent). The authors have interpreted the HHERA results in a "worst-case" manner, without consideration of the need to refine conservative screening assumptions or to balance contradictory lines of evidence. As such, this portion of the ASCS fails to provide appropriate context for the site-specific biological investigations.

ESG response:

We disagree. The HHERA has been reviewed by FCSAP expert support and follows guidance provided by Health Canada and Environment Canada regarding the exposure assumptions and scenarios. It is certainly not a "worst-case" assessment. Perceived conservative exposure scenarios have been addressed in the revised version of the HHERA and are addressed specifically in the peer review comments in an appendix in the final KIH report.

Please see the response to Comment 6 for a detailed review of this component of the ASCS classification, particularly with respect to sediment toxicity.

9. Collaboration with regulatory stakeholders

Golder comment: Concerning the principle of collaboration with regulatory stakeholders, it is stated that the Cataraqui River Stakeholder Group (CRSG) is conducting a "collaborative approach to the assessment process and is working to achieve consensus on plans for the river sediments." It is unclear whether a consensus has been achieved, and two principal regulatory stakeholders (Transport Canada and Parks Canada) have commented on their concerns that the need for, and scale of, the proposed remediation effort has not been justified. Nevertheless, ESG-RMC (2011), states that broad agreement exists. Although ESG-RMC (2011) claims that "stakeholders' viewpoints are considered in the remedy selection process," Chapter 5 does not appear to convey the viewpoints of those parties that provide differing opinions.

ESG response:

For the past six years ESG has coordinated regular face-to-face meetings on a semi-annual basis to present and discuss study results and invite input on proposed next steps that meet the requirements of the FCSAP process and COA frameworks for dealing with aquatic contaminated sites.

Each chapter of the KIH report has been extensively peer-reviewed by all three FCSAP expert support departments (EC, DFO and HC) as well as a third-party consultant contracted by the custodial departments themselves. ESG has carefully reviewed and responded to every single peer review comment.

ESGs recommendation for a remediation strategy is based on sound science and careful consideration of stakeholder viewpoints. This iterative process will be made transparent by including the comments and responses to them in the appendices of the KIH report which, upon completion, will become a public document.

10. Level of investigation

Golder comment: Concerning the principle of iterative investigation, we disagree that a detailed level (DQRA) investigation has been used to support the conclusions of Chapter 5 for all pathways. For sediment-associated organisms, additional investigations have been recently completed or are underway to refine the initial assessments conducted by ESG-RMC. For wildlife and human receptors, we believe that the ESG-RMC analysis reflects a preliminary quantitative risk assessment (PQRA) but not a detailed quantitative risk assessment (DQRA) level of analysis. In our opinion the ESG-RMC investigation, while a very important contribution to the site investigation, does not provide the level of certainty required to proceed to the remedial planning stage of the Framework.

ESG response:

See comment 5.

11. Assumptions and uncertainties

Golder comment: Concerning the principle of considering assumptions and uncertainties carefully, our opinion is that the ESG-RMC analysis is highly conservative in the assessment of potential harm under current sediment exposure scenarios. In addition, the effectiveness of the remedy recommended by the authors is highly sensitive to numerous uncertain assumptions (such as model bioaccumulation factors); these uncertainties are large relative to the comparatively small surface area weighted concentration (SWAC) reductions predicted even under a large sediment removal action.

ESG response:

This sensitivity analysis will be addressed as a part of the revised Chapter V.

12. Monitored natural recovery

Golder comment: Concerning the principle of minimizing short-term risks, the ESG-RMC analysis has eliminated further consideration of monitored natural recovery, despite the advantages of this option for minimizing short-term risks.

ESG response:

We do not believe that the use of MNR will minimize short-term risks. The use of MNR to remedy long-term risks has been addressed as part of Chapter V.

1.2.1: Determination of causation

13. Contaminant profiles

Golder comment: The main COPCs in KIH exhibit different spatial profiles. If the chemical "fingerprint" were homogenous across KIH, the situation would be different, as addressing one substance would simultaneously address others. However, in KIH there are some substances that show a strong pattern of decrease with distance from the Orchard Street Marsh (particularly chromium), whereas other substances exhibit maximum concentrations farther to the south, reflecting different historical contamination sources. Others exhibit a relatively flat profile across much of the southwest quadrant of KIH. Because the spatial profile of contamination differs among COPCs, identification of individual substances or contaminant groups linked to observed responses is recommended. Otherwise, remediation efforts may target contaminant groups falsely, leading to limited long-term risk reduction but with short-term damage and cost.

ESG response:

SeQOs have been developed for each contaminant that poses a risk to ecological and human receptors. The management area for each contaminant focuses on areas where concentrations were highest and therefore account for spatial variations in contamination. The revised risk management scenarios in Chapter V also examine different microenvironments throughout the KIH, which were chosen based on contaminant spatial profiles and specific receptor exposure.

The variation in spatial distribution of contaminants is most important for dermal exposure and incidental ingestion pathways. Fish are mobile throughout the harbour (the home range of most species except perhaps brown bullhead should encompass the whole of the KIH) sand therefore the risks due to fish consumption should not vary spatially given the relatively small area of the KIH.

14. Ambiguous responses

Golder comment: The pattern of responses over much of KIH is complex. Although sediment quality in the eastern half of KIH can safely be deemed to pose insignificant risk using a weight-of-evidence framework (Golder 2011b), there is more variation in sediment quality in the southwestern quadrant of KIH. In the latter area, there are mixed indications of effects to resident benthic communities, both within stations and among stations. Because observed responses are not definitive, variability creates uncertainty in the assessment of both overall risk and the benefit of intrusive remediation. More thorough assessment of potential causal linkages is recommended to help discriminate endpoint responses that are coincidental versus those that reflect an actual influence of specific sediment contaminants on biological resources.

ESG response:

Addressed in comment 1.

15. The assessment by ESG-RMC has emphasized a subset of the KIH sediments

Golder comment: The assessment by ESG-RMC has emphasized a subset of the KIH rather than the full spatial domain of the sediments influenced by anthropogenic contaminants. Whereas the Parks Canada water lot has been considered, the Transport Canada property has been evaluated mainly in the context of the Rowing Club/Emma Martin Park area....

ESG response:

The Golder data will be incorporated into the revised Chapter V. Because we have based our sediment quality objectives on risks to higher trophic organisms which are mobile throughout the harbour, the spatial coverage of benthic community data is of less importance.

16. The evidence used by ESG-RMC to assess causation...

Golder comment: The evidence used by ESG-RMC to assess causation is assessed in a conceptual manner. The discussion on pages V-7 through V-13 does not evaluate direct evidence of causation, and often concludes that causal relationships are challenging without exploring what information could be collected to resolve the uncertainty. For example, the text states that "the presence of multiple contaminants in the sediments complicates the definition of causal relationships in the KIH." We agree with this statement, but this fact simply underscores the benefit of carefully considering multiple tools (including mechanistic tools such as TIE and empirical tools such as concentration-response analysis) rather than relying on an informal assessment

ESG response:

In cases where there are multiple contaminants it will always be difficult to determine causality. We have used standard practice and have multiple lines of evidence to complete the aquatic assessment. We do not believe that this is an "informal approach." It is known that the sediments are the source of the contaminants to the aquatic food web in the KIH.

Because we have based our sediment quality objectives on risks to higher trophic organisms, the causality of the benthic invertebrate impacts becomes less important. The main contaminants that pose risk to human and ecological receptors through bioaccumulation and biomagnification in the aquatic food web were identified in the risk assessment.

17. **The comments made with respect to lack of correlation between toxicity endpoints and sediment chemistry...**

Golder comment: These weak relationships actually increase the importance of conducting a robust causal assessment, because these observations underscore how chemical contamination does not necessarily translate into overt biological responses. The difficulty in finding a simple correlation between COPC and response highlights the need to resolve uncertainty regarding potential causes.

ESG response:

The Golder text is based on a mistaken premise, as it implies that there is no relationship between measured concentrations of a suite of contaminants in the sediments used for toxicity tests and the toxicity test results. Only Cr concentrations are available from toxicity test sediments because of resource constraints. It is true that there is no relationship between the observed toxicity responses in test invertebrates and measured Cr concentrations. However, it is possible that other contaminant concentrations or synergistic effects from a mixture of contaminants could be related to sediment toxicity results. Establishing causality for observed toxicity is very challenging and expensive, especially when mixtures of contaminants are present.

ESG disagrees with Golder's assessment that the cause of toxicity must be known prior to making remedial decisions. Identifying areas for remediation based on toxicity to benthic organisms is one approach that can be used to design a sediment remediation program. However, it is not the only approach. We have delineated a remediation zone for the KIH based on calculated risk to ecological receptors — i.e., mallard ducks consuming invertebrate prey items from Cr-contaminated sediments and humans — i.e., sport fish consumers. This approach has also been used to determine remediation SeQOs in other contaminated sediment projects such as Peninsula Harbour, Lake Superior (Environ 2007) and the St. Clair River, Ontario/Michigan (Environ 2009), where ambiguous effects on benthic communities were also noted.

As stated in the text of Chapter V: "The objective of determining the causes is to identify the factors that can be regulated or remediated to improve the ecological condition. While the methods for determining impairments are relatively well developed, methods for inferring the causes of impairment are often largely informal. Suter et al. (2002) have developed a methodology for causal evaluation of observed impairments in aquatic ecosystems by showing the evidence and logic that formed the basis of their conclusion about the cause. The evaluation includes i) the definition of impairments; ii) the identification of possible causes; and iii) an analysis of evidence and a characterization of the cause." We have applied this approach, which goes well beyond "informal."

18. The discussion of benthic community analyses is again described...

Golder comment: The discussion of benthic community analyses is again described as being "difficult" and "challenging to explain." The informal assessment of causation on pages V-8 and V-9 places a high level of weighting on the interpretation of multidimensional scaling results. Other approaches, such as major taxa abundances, richness, and diversity measures are not discussed, and the overall weak response to benthic communities relative to reference (as communicated in Golder 2011) is not conveyed. There is lack of clarity in the assignment of evidence causation to empirical association statistics (which are not really indicators of causation).

<u>ESG response:</u>

Golder has summarized benthic community information for the KIH using univariate indices (e.g., diversity, abundance). While this is a commonly used approach in benthic studies, multivariate methods are generally considered more sensitive at detecting differences between test and reference sites (e.g., Norris and Georges 1993; Grapentine 2009). This may explain why the ESG study detected differences while Golder did not. The use of multivariate approaches also allows for better determination of causality for the observed effects: many environmental variables can be evaluated for determining which ones are most important in explaining the benthic community structure. Consequently, the COA framework strongly recommends the use of a multivariate approach, as ESG used for the KIH study.

We agree that the limited number of appropriate reference sites is a constraint on KIH benthic community studies. In the past, we have investigated reference areas closer to the 401, but these are not suitable because of the influence of the Great Cataraqui Marsh. We note that the Golder study also collected a single reference location (Station 9) from the same reference area that we used for our study (Stations BC9 and ERA 10) and consequently their data interpretations are also limited. To address this limitation, our study examined benthic community differences using a number of approaches. This included comparison of test sites with large sets of regional reference sites as recommended under the Canadian Aquatic Biomonitoring Network protocols (CABIN). As discussed below, using a multivariate approach also allows for the separation of effects due to natural habitat variables that influence benthic community structure (e.g., TOC (total organic carbon), grain size) from those due to site contamination.

In their gap analysis, Golder (2011a) points out that there are differences in TOC and grain size at the KIH reference sites compared with the test sites, and that these may limit the ability to detect benthic community impairment if present. These variables may also influence Golder's univariate indice results to an unknown degree. However, the use of multivariate analyses allows the influence of these variables to be determined and controlled for using variance partitioning techniques. The multivariate analyses of benthic community data and environmental variables for the ESG sites indicate that contaminants (represented by Cr) explain a significant portion of the benthic community differences between reference and test sites, independent of the influence of TOC and grain size.

Overall, while further benthic community analyses would probably improve scientific understanding of the magnitude of benthic impairment for the KIH, they would not alter the need for management action or the remediation SeQOs presented in Chapter V for the reasons discussed above. Namely:

- KIH is classified as a Class I site requiring management action under the FCSAP site classification.
- Remediation objectives were developed based on risk to higher trophic level organisms (e.g., bird and mammal receptors, humans).s

19. The discussion of bioaccumulation is not really evidence of causation

Golder comment: The discussion of bioaccumulation is not really evidence of causation. Although this endpoint can assess bioavailability (a necessary condition for effect), bioaccumulation is a measure of exposure, not biological effect. Furthermore, the discussion emphasizes a control-impact comparison in which tissue concentrations from "the impacted area of the KIH" are assessed relative to the reference condition north of Belle Island. Given the variety of potential sources of PCBs, we believe the study would benefit from an evaluation of different areas south of Belle Park in order to make inferences regarding causation.

<u>ESG response:</u>

The significance of biota bioaccumulation has been assessed through the HHERA, which documents potential risks to higher trophic level receptors and humans from contaminant uptake into the aquatic food web.

Most of the unacceptable human health and ecological risks related to ingestion of contaminated biota are due to fish consumption. There is a large dataset on fish tissue contaminant concentrations in the KIH, including forage fish, young-of-the-year fish, benthivores, and several species of sport fish. For mobile organisms such as fish, evaluating spatial differences in tissue bioaccumulation throughout the southern KIH does not make sense, as the home range of most fish species encompasses the entire southern KIH.

20. Bullhead deformities do not provide information regarding causation...

Golder comment: In our opinion, the discussion of bullhead deformities does not provide information regarding causation, apart from the documented difference between exposed and reference conditions. Reference is made to the Housatonic River study, in which goldfish from PCB-contaminated water bodies were observed to exhibit external lesions. We have concern regarding the linkage made to PCBs as a causative agent — note that the fish tissue concentrations of PCBs are more than two orders of magnitude higher at the Housatonic River site than in the exposed area of KIH, and numerous other *agents (including PAHs, other chemicals, and non-chemical factors) may be responsible for the observed lesions in KIH fish. Tools are available to investigate the cause of these malformations, and should be considered.*

<u>ESG response:</u>

As a follow-up to the initial study, a literature review was completed by ESG with the following goals: 1) to review the available scientific information on brown bullhead deformities; 2) to compare the approach used for the KIH with fish health studies conducted at other Great Lakes AOCs; and 3) to assess the need for further work. The review identified that the approach used to describe orocutaneous (skin) deformities, erosion, lesions, and tumours (DELTS) for the KIH brown bullhead was consistent with that used at other AOC and non-AOC sites (e.g., Blazer et al. 2009). The causes of orocutaneous fish DELTs are not well established in the scientific literature, but higher rates are usually found in contaminated areas (Rafferty et al. 2009). Further, fish health studies were considered to assess the prevalence of liver tumours in brown bullhead in the KIH, as there is strong evidence to indicate that exposure to chemical carcinogens is a primary factor in liver tumours (Rafferty et al. 2009). However, the suggested sample size for liver tumour studies (n = at least 100 fish) is not feasible for the KIH given the small area of the contaminated site. The low prevalence of liver tumours generally found for Great Lakes fish (see Baumann 2010) means that the chances of detecting significant differences in liver tumour prevalence would decrease with lower sample size. Therefore, we concluded that liver tumour studies on KIH fish could potentially involve a large cost and sampling effort with little ability to detect differences if present. Furthermore, there is sufficient other evidence for biological effects in the KIH that would lead to classification as a Class I FCSAP site without additional data on fish health.

Carrying out virology analyses on brown bullhead fish tissue may clarify whether the observed deformities are caused by pathogens. However, as Environment Canada has stated in their expert support review of the KIH data, it is possible that exposure to contaminant stressors may also result in increased fish susceptibility to hormonal imbalances and viral disease. If this were the case, then sediment contaminant concentrations could not be ruled out as a stressor even if virology analyses indicated the presence of pathogens.

While there is a body of scientific literature documenting the link between fish exposure to PAHs and the subsequent development of DELTS and liver tumours, other chemicals have not been studied to the same extent (Rafferty et al. 2009). Although it is suspected that exposure to other contaminants (e.g., PCBs) also may result in fish deformities, defining the role these chemicals play would require extensive laboratory toxicology studies. The potential synergistic effects of the mixture of contaminants present in the KIH sediments would make the identification of causality for the observed deformities very challenging if not impossible. Because of these challenges, the KIH fish health data were not used to develop the sediment remediation SeQOs presented in Chapter V.

21. Human and wildlife risk is based on minor adjustments to a screening level assessment

Golder comment: The discussion of human and wildlife risks is based on minor adjustments to a screening level assessment. There is considerable discussion in this section of Chapter V, but very little in terms of actual assessment of causal evidence. In spite of this, it is concluded that a variety of contaminants are "clearly...associated with potential adverse health effects." We believe that a fair degree of uncertainty remains and the study would benefit from a more detailed evaluation to potentially avoid excessive conservatism.

<u>ESG response:</u>

We strongly disagree that the KIH HHERA is based on minor adjustments to a screening level assessment. Consultation with Health Canada has confirmed that the KIH HHRA now meets the requirements of a detailed quantitative risk assessment. The ERA has been done according to standard practice. Uncertainties are standard for this type of risk assessment and very little could be done to make meaningful improvements on these.

22. Strength-of-evidence analysis

Golder comment: We have identified some issues with the strength-of-evidence analysis (Table V-2). Under "co-occurrence," the table entry focuses on control-impact comparisons of chemistry, which reveal little about causes of effects. Under "consistency of association," the text again discusses control-impact comparisons of chemistry, rather than assessing whether observed effects have been consistently observed in monitoring events. In our opinion, this summary does not provide sufficient evidence that there is a linkage between sources and types of contamination to actual observed effects. Without this linkage, there cannot be confidence that the proposed remediation design is addressing the contaminants of greatest concern in the remedy. The phrase "clearly demonstrate the need for sediment management" is used in spite of the evidence being mixed and uncertain, especially in terms of causation.

<u>ESG response:</u>

The text and tables are being revised.

23. The conceptual model of impairment

Golder comment: The conceptual model of impairment (Figure V-1, Table V-2) lacks consideration of PAHs, an important COPC in KIH.

<u>ESG response:</u>

The conceptual model is being revised based on comments from other reviewers. PAHs will be considered for inclusion in this model once we have had a chance to review and incorporate the data from Golder's 2011 assessment.

24. The discussion of toxicity identification evaluation (TIE)

Golder comment: The discussion of toxicity identification evaluation (TIE) on page V-8 discusses perceived drawbacks of this method without a corresponding discussion of strengths. For example, TIEs are dismissed as "complex and labour-intensive" and uncertainties highlighted.

ESG response:

While TIE has been used on effluent, its use on sediments is relatively new and under development. Furthermore, as recommended in FCSAP guidance, risk management and remedial scenarios for the KIH have been developed to address unacceptable risks to human health and upper trophic level ecological receptors (birds, mammals) due to bioaccumulation of contaminants in the KIH aquatic food web. Improved understanding of which contaminants may be causing toxicity to benthic invertebrates is relatively unimportant in this case as it would not alter management decisions.

1.2.2: Control of contaminant sources

Note that Golder agrees with our report conclusion that the legacy contamination sources in Cataraqui River sediments are the dominant source of contaminants.

25. Principle of controlling sources early

Golder comment: On page V-5, concerning the principle of controlling sources early, it should be recognized that KIH contains concentrations of numerous COPCs in sediments well above screening guidelines, even beyond the area contemplated for remediation by ESG-RMC. Furthermore, not all of these elevations are for COPCs that have maximum concentrations near the Orchard Street Marsh. For example, arsenic and mercury, as well as PCBs and PAHs, are found above the PEL in large portions of the Transport Canada property to the south. If sediments are mobile, as they appear to be based on contaminant distributions, recontamination of any dredged area could occur for numerous COPCs.

ESG response:

With regards to possible redistribution of contaminated sediments, evidence suggests that the water flows from the northern part of the KIH along the eastern shoreline and through the LaSalle Causeway, with very little flow occurring along the western shoreline (City of Kingston and OMOE 2005). However, the sediment transport patterns of the KIH have not been studied and are likely to be very complex. Infilling of the remediated area by residual sediments can be avoided to the greatest extent possible by remediating both water lots at the same time. Contaminant concentrations in surficial sediments outside the management area are generally below the site-specific SeQOs developed for the KIH and therefore not anticipated to cause unacceptable risk to human and ecological receptors, even if they are redistributed into the remediated area.

We agree with the reviewer that source control is important to address for the KIH, and this is discussed in detail in Section II-B-b of the draft Chapter V report. Potential ongoing sources for the KIH have been investigated and are being addressed by the OMOE and the City of Kingston. For example, a recent

OMOE review of Belle Park 2010 monitoring data and additional historic data has concluded that the Belle Park Landfill is not a significant ongoing source of PCBs to the KIH (Castro 2011). The City of Kingston, a member of the stakeholder group, has also reaffirmed that, if needed, the City will take the steps necessary to address any source issues related to the sanitary/storm sewers (ESG 2010).

1.2.3: Net Environmental Benefit

26. On the first point (science)...

Golder comment: On the first point (science), it is good that the report distinguishes the short-term and long-term trade-offs, as time scale is quite important in a remedial scenario evaluation. However, there is no discussion of the magnitude of effects under various temporal scenarios. For example, the remediation of such a large sediment area would entail substantial disturbance and temporary elimination of the entire benthic invertebrate community over the dredging zone. To justify dredging, this short-term negative response should be outweighed by the longer-term benefit associated with post-remediation conditions. There is limited evidence that the benthic community would be substantially improved through removal of contaminated sediments. As shown in Table 18 of Golder (2011c), the majority of sediment samples collected in the zone of proposed remediation have overall community condition (as indicated by multiple benthic metrics) similar to the reference condition. Although some sediment samples exhibit impaired community condition relative to reference, these samples are a minority of the stations, do not reflect major alterations, and are not consistently linked to a clear spatial or contamination gradient.

ESG response:

Golder's focus is on net benefit to resident benthic invertebrates, while we focus on net benefit to human and upper trophic level ecological receptors.

27. On the third point

Golder comment: On the third point, ESG-RMC claims that there was "general acceptance by the public" that dredging is the preferred environmental management option, as "supported by sediment remediation experts at a workshop on remedial options for the KIH held in June 2010." Although it is true that the presenters (from RMC/ESG) concluded that remediation was warranted and that the best option for remediation was dredging (as opposed to capping), this is their opinion and does not reflect the views of all stakeholders. Parks Canada has already suggested replacing "supported" by "presented" and has noted that dredging as a remedial strategy was not clearly supported or endorsed by all experts. The Transport Canada representative at the workshop has also indicated that there was not consensus that remediation was required, and certainly no consensus conclusion as to the extent if it was conducted.

ESG response:

The FCSAP framework for addressing a contaminated site has adopted the guiding principles described in the US EPA contaminated sediment remediation guidance. The guidance strongly encourages the use of a technical team approach and the involvement of stakeholders in the sediment remediation process.

A goal of the June 2010 remediation options workshop was to bring together appropriate expertise and stakeholders to get consensus on what constitutes the most feasible remediation approach for the KIH. To this end, ESG presented a sound scientific analysis of the pros and cons of different remediation options for the KIH for consideration by the group. The various management options available for the Kingston Inner Harbour (i.e., no action, monitored natural recovery, capping, and dredging) are presented in Chapter V along with an evaluation as to their effectiveness and feasibility for addressing sediment contamination in the KIH.

The analysis showed that dredging is the most effective and technically feasible option given the limiting conditions at the site for decreasing environmental and human health risks from the sediment contamination. There was strong agreement among workshop participants that dredging is an appropriate and reasonable remediation option for the KIH.

A second goal of the workshop was to decide the approach for determining risk based SeQOs for the KIH. The approach decided on at the workshop was then used to develop the SeQOs and management areas presented in Chapter V.

1.3: Summary of sediment investigation results

28. The statement of limitations mentions...

Golder comment: The statement of limitations mentions that the report content is "based on information collected during our [ESG-RMC] analysis" and current up to March 31, 2011. These studies would not have included the results of Golder (2011c) because the latter was issued on March 31, 2011 and therefore not available in time for incorporation in this document. This is an important consideration because Golder (2011c) provided significant additional data collection in Kingston Inner Harbour, including ten stations with full sediment quality Triad characterization (sediment chemistry, chronic toxicity testing, benthic community structure). In addition, studies are currently underway to fill residual data gaps and address uncertainties in the characterization of sediment quality within the Transport Canada water lot.

<u>ESG response:</u>

We have since received a copy of the Golder report (2011c) and plan to incorporate the findings into the revised version of Chapter V.

1.3.1: Non-intrusive options

29. The "no action" and "monitored natural recovery" (MNR) alternatives are dismissed from further consideration

Golder comment: The "no action" and "monitored natural recovery" (MNR) alternatives are dismissed from further consideration. It is stated that such a dismissal requires that the site does not pose any current or potential threat to human health or the environment. Based on the principle of net environmental benefit, a threat may be deemed acceptable if the magnitude and/or probability of harm *are sufficiently low; the risk does not need to be zero. Based on the magnitude of potential human health and ecological risks under the current condition (which importantly can only be characterized as potential, not actual), we do not believe that these alternatives warrant automatic dismissal in the remedy selection process. The potential risks can be refined and uncertainties reduced, and risk management trade-offs made following reassessment of these preliminary risks. Considerable uncertainty remains regarding that actual level of risks under existing conditions. Recent investigations have provided new information since Chapter V was authored, and studies (including TIE) are underway to refine uncertainties in the previous assessment. Although it is unlikely that no action alternative would be considered at a broad scale in the absence of any monitoring, it is possible that non-intrusive management would be preferred where incremental risks are not zero. ESG-RMC has eliminated MNR (i.e., "not suitable for this site") on the basis of environmental persistence, but does not acknowledge the net environmental benefit argument that was identified as one of the three FCSAP prerequisites to risk management.*

<u>ESG response:</u>

The first part of the paragraph stating that such a dismissal requires that the site does not pose ANY current or potential threat to human health or the environment is misleading. This was not what was intended in the report text — more the concept of addressing unacceptable risk.

MNR was eliminated as the primary remediation strategy because sediment re-suspension and mixing in the upper sediment layers leads to very slow isolation of contaminants from contact with biological receptors. There are over 30 years of fish monitoring data that indicate that PCB concentrations are elevated for the southern KIH. The rate of recovery would not be sufficient to reduce human health and ecological risks from PCBs appreciably.

MNR will be employed in some areas where net environmental risks are sufficiently low.

1.3.2: Intrusive options

30. Capping and dredging considerations

Golder agrees with our conclusion that capping is not feasible for the KIH. Their comments regarding dredging appear valid and these will be addressed as part of the remedial action plan.

1.4: Sediment management goals

We note that Golder’s comments are based in part on a review of an earlier draft version of the human and ecological risk assessment, which has been subsequently revised following comments from FCSAP expert support departments and Parks Canada.

31. Preliminary versus detailed quantitative risk assessment

Golder comment: Chapter V claims that a detailed risk assessment framework was applied to identify potential risks. The level of analysis conducted to date appears to represent a hybrid between *preliminary and detailed level analyses. There are several areas for which conservative assumptions have been made that, while minimizing the chance of a false negative, have a high probability of a false positive…*

ESG response:

The HHRA has been revised and is now considered by Health Canada to be a detailed quantitative risk assessment. It incorporates all of the recommendations from Health Canada expert support including recommendations regarding the SAF approach for the KIH.

32. Invertebrate based bioaccumulation model

Golder comment: The mathematical relationship used to relate invertebrate tissue chromium to sediment chromium (Figure V-3) is highly uncertain….there is some uncertainty in the use of an invertebrate-based bioaccumulation model to estimate the concentrations in fish.

ESG response:

We agree with Golder's critiques of the invertebrate tissue chromium to sediment chromium regression equation. We have reviewed alternative approaches to this; either they are not feasible or are not available in the literature, or they would require assumptions which would introduce more uncertainties. It is difficult to develop field uptake regressions for the KIH because of the fine-grained sediments, the impoverishment of the benthic communities (which are dominated largely by small chironomid species), and the need to have a large-enough sample mass for contaminant analyses. It would be difficult to collect enough invertebrates from each location of the same family to develop reliable invertebrate bioaccumulation models.

33. Wildlife TRVs are a source of uncertainty

Golder comment: There are a number of uncertainties associated with the target tissue concentrations back-calculated from the modelling procedure. The direction and magnitude of uncertainty are difficult to define for many of the exposure parameters. However, the effects measures (TRVs) for wildlife are a particular source of uncertainty that could be resolved through more detailed derivations. The TRVs could be based on a more thorough evaluation of the effects data for relevant bird and mammal studies, and the range of benchmarks should be considered across the continuum of potential doses, rather than as a point estimate.

ESG response:

The toxicological reference values (TRVs) used in the ecological risk assessment (ERA) came from frequently used industry standard sources. The majority of TRVs were taken from the US EPA ECO-SSL documents for each contaminant, which are based on an extensive literature review of toxicological studies. The PCB TRV used in the revised ERA was a peer-reviewed publication of reproductive toxicity in mink from PCB exposure (Brunström et al. 2001). The TRV for mercury was taken from a dated but still frequently used source (Sample et al. 1996); however, in the revised ERA, mercury was found to be within the acceptable risk quotient and therefore performing a more detailed risk assessment for this contaminant is not necessary.

In the most recent version of the KIH ERA, three contaminants exceeded the quotient threshold of 1.0 for ecological risks: Cr, Pb, and PCBs. The hazard quotients (HQs) for Cr exposure in muskrat, red-winged blackbird, mallard duck and great blue heron were exceeded, as well as the HQ of PCB exposure in mink and the HQ of Pb exposure in the blackbird. The exposure to Cr is largely due to the incidental ingestion of sediment which has very high concentrations of the least toxic form of chromium (Cr III), driving the average daily dose equation. The exposure to Pb is also due to the incidental ingestion of sediment. A better measurement of the risk posed to Cr and Pb would be to refine the sediment ingestion rate for these animals. However, the available literature has already been referenced and limited data is available for all of the above species. Additional laboratory studies to measure sediment ingestion rates would be very expensive and challenging to complete, as few laboratories are capable of doing this work. The assumptions made for each animal and their incidental sediment ingestion rates have been described and are still considered valid and appropriate.

Sediment ingestion is not the main driver of risk from Cr for the mallard duck. The TRV for Cr was taken from the US EPA ECO-SSL documents which examined 28 studies of effects in avian species from Cr III exposure. The TRV chosen by the US EPA and used in the KIH report (2.66 mg/kg) is the geometric mean of the no observed adverse effects level (NOAEL) values from effects on the reproduction, growth or survival of avian species. The US EPA value was chosen through a rigorous literature search and evaluation of appropriate toxicological values as described in section C-4 of Chapter IV of the KIH report. This TRV is considered valid and appropriate for use in this risk assessment.

Regarding the TRV used to assess PCB exposure in mink: as suggested by Golder, a review of multiple studies of varying endpoints was undertaken to determine the toxicity value to be used for PCBs. Reproductive toxicity in mink is known to be one of the most sensitive endpoints of PCB toxicity in mammals and was therefore selected as an ecologically relevant response. Fuschman et al. (2007) compiled published results from more than 50 studies of reproductive effects in mink from exposure to PCBs (in the form of technical mixtures or as accumulated in prey). The value used as the TRV in the KIH report was based upon this review and is discussed below.

The value chosen for use as the TRV (0.053 mg/kg-d; Brunstrom et al. 2001 in Fuschman et al. 2007) was based on a no observed adverse effects level (NOAEL) (i.e., no effect on the survival rate of mink kits or mated female minks or on individual mink kit weights (a less sensitive endpoint) in comparison to a control set) referenced in Fuschman et al. 2007. It is based on an NOAEL which (as the reviewer has suggested) is a conservative toxicity value. However, if the Allard et al. (2009) approach (an effect-size-based method) as suggested by Golder is used, the values associated with a 30% decrease in the chosen endpoint (reproductive success) would range from 0.059 to 0.063mg/kg-d, which is very close to the value of the NOAEL used in the KIH ERA. Therefore, if either of these TRVs was used in the current risk assessment as an effect-size-based method following Allard et al. (2009), the magnitude of hazard quotients predicted for the KIH would not be altered and there would be no effect on the risk management outcomes.

The ERA has been conducted in accordance with a standard level of effort and is consistent with the approach used in other cases where risk-based SeQOs have been derived (see references in comment 1).

34. The SWAC modeling procedure

Golder comment: The SWAC modeling procedure invokes a number of uncertain assumptions in the calculation procedure

ESG response:

A sensitivity analysis of the approach used to develop the areas requiring remediation will be included in the revised Chapter V of the KIH report.

The approach for areas of special consideration has changed after consultation with Health Canada. Risk management options will be discussed for micro-environments based on contaminant spatial patterns and receptor exposure.

1.5: Residual risk and uncertainty analysis

35. Food web bioaccumulation model...

Golder comment: Given the range in outcomes that occur from changing the BSAF assumptions alone, not to mention other uncertainties for other parameters, the effectiveness of the proposed remediation appears to highly sensitive to uncertain choices of parameters. The BSAF parameter is described to have "acceptable accuracy" even though there is no robust comparison of the predicted tissue concentrations to a validation data set of appropriate sample size. Moreover, the precision of the estimates are of unknown acceptability because a sensitivity analysis was not conducted using alternate BSAFs that fall with the range of values considered by ESG-RMC.

ESG response:

A sensitivity analysis with the BSAFs in the original set of remediation criteria calculations (min, max, average BSAFs) was conducted. The models were validated through comparison of mean measured sediment data for the KIH with mean measured fish tissue concentrations. A similar approach will be used in the revised Chapter V.

36. Remedy effectiveness

Golder comment: Under remedy effectiveness, the potential effect of dredge residuals is discussed. The nature of the loose fine-grained material in KIH sediments is such that dredging may result in replacement of a thick contaminated layer with a thinner but equally contaminated (or nearly so) *sediment layer. This would not achieve the target environmental benefits because the bioaccumulation pathway would be driven by concentrations of contaminants at the surface where most organisms reside.*

ESG response:

These residuals would be addressed as part of the confirmatory sampling program. Follow-up remedial strategies would be developed as part of the RAP to address unacceptable residual contamination.

1.6: Conclusions

37. Approach assumes chromium is the driver

Golder comment: The authors have presented, in the attached maps, a limited range of remedial options that emphasize sediment removals in the region closest to the Orchard Street Marsh. This approach presumes that chromium is the driver for the remediation effort, because all of the remedial options presented entail preferential removal of the highest chromium contamination…

ESG response:

We disagree with Golder's conclusion that the approach presumes that chromium is the driver for the remediation effort — SeQOs were developed for Cr and PCBs. Although PCBs are elevated across the harbour, the highest concentrations are found along the southern shore of Belle Park, and this is why the area of PCB management focuses on this area.

38. Recommendations on two data analysis steps

Golder comment: Once all the available data (including the Transport Canada 2010 and 2011 data) are incorporated, it is recommended that two important data analysis steps be conducted.

ESG response:

The smoothing of surface concentrations of COPCs that drive the risk estimates has already been completed in our concentration plume maps presented in Chapter 2 of the KIH report. These maps will be updated with Golder's data.

We agree that cumulative plots that depict the decrease in surface weighted area concentrations that would be achieved across a range of sediment removal area scenarios would be useful. We will include this in the revised report.

2.0: Specific comments

Page V-13: Table V-2 will be revised in the revised Chapter V to address these comments.

Page V-41: See response to section 1.4. We agree that analyses of Cr bioavailability, using a surrogate bioaccessibility test for avian models, could be undertaken on sediments from the KIH to provide a better estimate of exposure for use in the risk assessment calculations. ESG has been developing bioaccessibility testing methods for over 10 years and also has experience with conditions that model gastrointestinal conditions in ecological receptors (Kaufmann et al. 2007; Ollson et al. 2009), as well as with chromium (Koch et al. in press). No bioaccessibility tests have been validated against animal models for Cr, but our studies (and those of other researchers, using similar or dissimilar tests) indicate that Cr bioaccessibility is substantially less than 100% (Koch et al. in press, and references therein). For the present application and recommended tests, ESG recommends the use of an avian (specifically, mallard duck) bioaccessibility model.

Page V-42: Will be addressed in text.

Page V-42 and V-43: Will be addressed in text.

Page V-49: A sensitivity analysis was done in the original remediation criteria calculations but will be re-done for the updated calculations.

Page V-50: Golder's data will be reviewed and incorporated into the revised Chapter V.

Page V-52: Our remediation sediment quality objectives have been developed based on risk to upper trophic levels, and therefore the ambiguity associated with the benthic community impairments are relatively unimportant. A sensitivity analysis will be used to examine the parameters influencing the remedy effectiveness.

Page V-52: A very large data set has been used to develop the risk outcomes for the KIH contaminants. The risk assessment follows a detailed quantitative risk assessment with respect to the level of effort and receptor characteristics and exposure scenarios. There are limited additional studies that could be conducted to increase the confidence in the outcomes.

Page V-52: Following consultations with Health Canada, this will be addressed through inclusion of risk management scenarios for micro-environments of the KIH based on spatial contaminant patterns and receptor exposure.

References

Allard P., A. Fairbrother, B.K. Hope, R.N. Hull, M.S. Johnson, L. Kapustka, G. Mann, B. McDonald, and B.E. Sample (Allard et al. 2009). "Recommendations for the development and application of wildlife toxicity reference values." *Integrated Environmental Assessment and Management* 6: 28–37.

Baumann, P.C. (Baumann 2010). Data analysis and fish tumor BUI assessment for the Lower Great Lakes and interconnecting waterways. Prepared for Environment Canada.

Benoit, N. and A. Dove (Benoit and Dove 2006). Polychlorinated Biphenyl Source Trackdown in the Cataraqui River: Results of the 2002 and 2003 monitoring programs. Technical report prepared for the Ontario Ministry of the Environment, Eastern Region, Kingston, ON.

Blazer, V.S., S.D. Rafferty, P.C. Baumann, S.C. Smith, and E.C. Obert (Blazer et al. 2009). "Assessment of the "fish tumors or other deformities" beneficial use impairment in brown bullhead (*Ameiurus nebulosus*): I. Orocutaneous tumors." *Journal of Great Lakes Research* 35: 517–526.

Brunström, B., B.-O. Lund, A. Bergman, L. Asplund, I. Athanassiadis, A. Athanasiadou, S. Jensen, and Örberg J. (Brunström et al. 2001). "Reproductive toxicity in mink (*Mustella vision*) chronically exposed to environmentally relevant polychlorinated biphenyl concentrations." *Environonmental Toxicology and Chemistry* 20 (10): 2318–2327.

Castro, V. (Castro 2011). Memorandum regarding Belle Park Landfill (Closed), Environmental Operations and Monitoring 2010. Sent to Craig Dobiech, Senior Environmental Officer, Kingston District Office, Ontario Ministry of the Environment, Eastern Region, on October 12, 2011.

City of Kingston and Ontario Ministry of Environment (Kingston & OMOE 2005). Project Trackdown Cataraqui River, Kingston, Ontario. Assessment of PCBs in Nearshore Groundwater. Final Report, February 2005.

Environ (Environ 2007). Environmental Risk Assessment for Peninsula Harbour, Lake Superior. Report prepared for Environment Canada**.**

Environ (Environ 2009). Final project report for applying the COA framework to the St. Clair River Area of Concern. Prepared for St. Clair Region Conservation Authority.

Environmental Sciences Group (ESG 2009). Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter II: Spatial distribution of contaminants in sediments of the Kingston Inner Harbour.

Environmental Sciences Group (ESG 2010). Minutes from the June 28, 2010 Kingston Inner Harbour remediation options analysis workshop, Kingston, ON.

Fuschman P., T. Barber, and M. Bock (Fuschman et al. 2007). "Effectiveness of various exposure metrics in defining dose-response relationships for mink (*Mustela vison*) exposed to polychlorinated biphenyls." *Archives of Environmental Contamination and Toxicology* 54: 13–144.

Golder Associates (Golder 2011a). Final report on Review and Data Gap Assessment for Parks Canada Waterlot, Kingston Inner Harbour. Produced for Parks Canada, March 2011.

Golder Associates (Golder 2011b). Technical review of the Environmental Science Group-Royal Military College report entitled "Application of the Canada-Ontario decision-making framework for contaminated sediments in the Kingston Inner Harbour, Chapter V: An options analysis of management scenarios for the Kingston Inner Harbour" dated March 2011. Produced for Public Works and Government Services Canada on behalf of Transport Canada.

Golder Associates (Golder 2011c). Implementation of the Canada Ontario decision-making framework for assessment of Great Lakes contaminated sediment Kingston Inner Harbour: Framework Steps 4 and 5 (PQRA) dated March 31, 2011. Produced for Public Works and Government Services Canada on behalf of Transport Canada.

Grapentine, L.C. (Grapentine 2009). "Determining degradation and restoration of benthic conditions for Great Lakes Areas of Concern". *Journal of Great Lakes Research* 35: 36–44.

Kaufmann, C.A., J.R. Bennet, I. Koch, and K.J. Reimer (Kaufmann et al. 2007). "Lead bioaccessibility in food web intermediates and the influence on ecological risk assessment." *Environmental Science and Technology* 41: 5902–7.

Koch I., M. Moriarty, J. Sui, B. Gibson, and K.J. Reimer (Koch et al. in press.) "Insolubility of Cr_2O_3 in Bioaccessibility Tests Points to Requirement for a New Human Oral Reference Dose for Trivalent Chromium." *Human and Ecological Risk Assessment*, in press (accepted September 2011).

Norris, R.H. and A. Georges (Norris and Georges 1993). "Analysis and interpretation of benthic macroinvertebrate surveys." Pp. 234–286 in Rosenberg, D.M. and V.H. Resh, eds. *Freshwater Biomonitoring and Benthic Macroinvertebrates*. New York: Chapman and Hall.

Ollson, C., I. Koch, P. Smith, L.D. Knopper, and K.J. Reimer (Ollson et al. 2009). "Addressing arsenic bioaccessibility in ecological risk assessment: A novel approach to avoid overestimating risk." *Environmental Toxicology and Chemistry* 28 (3): 668–675.

Rafferty, S.D., V.S. Blazer, A.E. Pinkney, J.L. Grazio, E.C. Obert, and L. Boughton (Rafferty et al. 2009). "A historical perspective on the "fish tumors or other deformities" beneficial use impairment at Great Lakes Areas of Concern." *Journal of Great Lakes Research* 35: 496–506.

Sample B.E., D.M. Ospreko, and G.W. Suter (Sample et al. 1996). Toxicological benchmarks for wildlife: 1996 revision. Risk Assessment Program, Health Sciences Research Division, Oak Ridge, Tennessee. ES/Er/TM-86/R3.

Suter G.W., S.B. Norton, and S.M. Cormier (Suter et al. 2002). “A methodology for inferring the causes of observed impairments in aquatic ecosystems.” *Environmental Toxicology and Chemistry* 21 (6): 1011–1111.

ESG responses to "The Ministry of the Environment's Eastern Region Office has reviewed the draft of Chapter V of the Kingston Inner Harbour report titled 'An Options Analysis of Management Scenarios for the Kingston Inner Harbour'" dated October 27, 2011.

Note: The main focus of the Ministry's review was to confirm that there were no ongoing sources of contamination to the Kingston Inner Harbour from adjacent lands

1. **Emma Martin Park**

OMOE comment: In July 2011, the Ministry of the Environment conducted a hydrogeological assessment of the Emma Martin Park/Rowing Club as part of the review of the draft Chapter V report. Results of the assessment show that the Emma Martin Park/Rowing Club is a continuing source of arsenic to the Kingston Inner Harbour with groundwater discharge as the primary pathway. The Ministry of the Environment's Kingston District Office has since met with the City of Kingston and will continue to work with the City to ensure this issue is addressed appropriately.

<u>ESG response:</u>

ESG will update the KIH report Chapter V with the results of the OMOE hydrogeological assessment of the Emma Martin Park/Rowing Club. The report will also describe the work that will be undertaken by the OMOE Kingston District Office and the City of Kingston to ensure this issue is addressed appropriately prior to remediation of the contaminated sediments.

2. **Belle Park Landfill**

OMOE comment: The Ministry of the Environment, Eastern Region Office recently completed a review of the Belle Park Closed Landfill Site Environmental Operations and Monitoring 2010 report dated May 26, 2011. The review of the 2010 report and additional historic data provided by the City of Kingston was used to determine if the Belle Park Landfill is a continuing source of contaminants to the Kingston Inner Harbour. Monitoring conducted at the site indicate that PCB concentrations are considered to be very low and not likely representative of any significant ongoing source to the Kingston Inner Harbour. As for other contaminants of concern (i.e., chromium, arsenic, mercury, and lead), historic data provided by the City of Kingston show only trace levels of these heavy metals in the groundwater monitoring wells and suggest that Belle Park is not an active source of these contaminants to the river. Surface water monitoring along the shore of the Cataraqui River also shows levels of these metals consistently below the PWQOs.

<u>ESG response:</u>

ESG will update the KIH report Chapter V with the OMOE review of the Belle Park landfill environmental operations and monitoring data and their assessment that Belle Park is not a significant source of PCBs or other contaminants of concern to the Kingston Inner Harbour.