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REPORT ON

NIAGARA RIVER AREA OF CONCERN CONTAMINATED SEDIMENT SITE ASSESSMENT PHASE I AND PHASE II

Submitted to:

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EXECUTIVE SUMMARY

In support of the Niagara River RAP, a review of sediment conditions in 12 sites within the Area of Concern was undertaken as a move towards de-listing the area. The focus of the study was to determine whether additional investigation was needed at any of the sites with a view towards identifying those areas where remediation may be required. Since the areas included in the list represented diverse contaminant conditions, an additional aim was to identify those sites where contaminant concerns were not identified and additional investigation was not warranted. Those areas could then be removed from further consideration.

The sites had been prioritised into Level 1, 2 and 3 sites by the Niagara River RAP. Level 1 sites were those where a contaminant concern had been identified, usually through significant exceedance of one or more guideline values such as the MOE SEL. Level 2 sites were those where a potential concern existed due to exceedance of guidelines such as the MOE LEL, while Level 3 sites were those where a marginal exceedance of LEL guidelines and/or a lack of recent information indicated that a concern may exist.

The concerns at each of the sites were assessed through a review of the contaminant history of the site, a review of the processes and operations at the site, the potential contaminants of concern (COCs) produced, and the history of monitoring at the sites. The information was summarized and was used to derive a list of potential COCs for each of the sites. This list formed the basis for developing a monitoring plan for sediments adjacent to and downstream of the site that focussed on the COCs. At some sites, recent studies had been undertaken and there was no identified need to undertake additional investigations.

The sites included in the assessment, and the potential contaminant concerns identified at each of the sites, were:

Location	Potential COCs
Level 1 Sites	
Lyons Creek, west of the Welland Canal By-Pass	PCBs
Welland River, Port Robinson to Chippawa Power Canal	Metals (Cr, Cu, Ni), PAHs, PCBs
Level 2 Sites	
Sir Adam Beck Reservoir	Metals
Thompson's Creek	Metals
Frenchman's Creek	Metals, dioxins/furans
Level 3 Sites	
Welland River at Oxy Vinyl (Geon)	Metals, dioxins/furans
Black Creek Mouth	Metals (arsenic)
Pell Creek Mouth	Metals, PAHs, PCBs
Chippawa Creek	Metals, PAHs, PCBs

Chippawa Power Canal	Metals
Niagara River at Queenston	Metals, dioxins/furans
Niagara River at Niagara-on-the-Lake	Metals, dioxins/furans

A sediment sampling program to address the COCs at each of the sites was carried out during the 1st week of November, 2003.

A two-step screening process was developed to identify potential concerns at each of the sites. The MOE has developed a process for evaluating sediment quality and determining when additional investigations would be warranted. The Provincial Sediment Quality Guidelines (PSQGs) are the first step in this process and are used to initially screen sediment concentrations.

Where concentrations of a compound of concern exceed the LEL, additional investigation is recommended to assess the biological significance of the exceedance. Where an SEL is exceeded, additional investigation to assess biological effects and determine the need for remedial action is typically required. Comparison with the MOE guidelines was conducted through a risk quotient approach:

- the maximum concentration of each parameter was considered relative to the MOE LEL and a risk quotient (RQL) was calculated for each parameter. This level indicated negligible risk to biota.
- Where the RQL > 1, concentrations were evaluated relative to the SEL. Where the RQs > 1, potential risks to biota were identified, and the site was considered a candidate for detailed assessment under Phase III.

Bioaccumulative substances, such as PCBs, dioxins and furans, and mercury were considered as special cases. For these compounds, the calculation of Risk Quotients based on MOE PSQGs or on toxicological testing may not be protective against the effects of bioaccumulation and biomagnification, and the following approach was used:

- the maximum concentration of each parameter was considered relative to the MOE LEL and a risk quotient (RQ_L) was calculated for each parameter. This level indicated negligible risk to biota.
- Where the $RQ_L > 1$, or, in the case of dioxins and furans, $RQ_{PEL} > 1$ (MOE guidelines were not available for these compounds and the CCME PEL was used as the benchmark) the existing concentrations were evaluated relative to a screening level risk assessment. Where risks were identified, the site was considered a candidate for detailed assessment under Phase III.

Level 1 Sites:

Lyon's Creek West

Contaminant concerns at Lyon's Creek west have historically centred around PCB contamination. Previous sampling at the site has revealed that the highest PCB contamination occurred in the northern section of the site, where elevated concentrations typically occurred down to depths of 30 cm (and up to 3 m in some disturbed areas). In the southern section of the site, PCBs were detected at much lower concentrations, and only in the surficial sediments.

Additional sampling for PCBs and metals indicated that potential risks exist for both humans and non-human biota on the northern section of the site due to PCBs, and that additional investigation would be warranted, particularly since the risk assessment was undertaken using conservative assumptions. Exceedance of the SELs for arsenic and zinc also indicated the need for additional investigation of these COCs due to potential risks to biota.

Welland River - Pt Robinson to Chippawa Power Canal

Historical studies on the Welland River have identified metals and PAH compounds as the potential contaminants of concern. In particular, chromium, copper and nickel were elevated in sediments in previous studies. Both chromium and nickel appear to originate from sources upstream of this area while elevated copper concentrations appeared to be due to local sources.

Sampling results indicated that these three metals continued to be present at levels above MOE SEL guidelines and that additional assessment is warranted under Phase III. Localized occurrences of PCBs, mercury and PAH above guidelines were also noted. Exceedance of the LEL guidelines for PCBs and mercury prompted additional evaluation with respect to potential bioaccumulation. Risks to water column organisms such as fish were predicted to be low due to the low concentrations and the small areas affected.

Level 2 Sites

Sir Adam Beck Reservoir

The original investigation of the Reservoir was undertaken in 1983 and identified minor exceedances of the MOE Lowest Effect Levels (LELs) for some of the metals. The sites were revisited by Environment Canada in 1998. Consequently, additional sampling was not undertaken as part of this study.

Based on the process for evaluation described above, no risks to biota were identified in reservoir sediments and as a result, additional investigation of this site was not considered warranted.

Thompson's Creek

The Niagara River RAP identified the concerns in Thompson's Creek to be primarily due to concentrations of some metals in excess of the MOE LELs. The available information was typically more than 10 years old, and consequently additional sampling was undertaken at this site.

The results indicated that some of the metals, notably copper, chromium, and nickel exceeded the MOE guidelines and additional investigation would be warranted under Phase III. Of the metals that exceeded the SEL only copper appeared to originate from local sources.

Frenchman's Creek

Industries along Frenchman's Creek have been associated with elevated levels of metals (mainly chromium and lead) and dioxins and furans. As a result, additional sampling focused on these parameters, but also included both PCBs and PAHs.

Sampling results indicated that both chromium and cadmium were elevated at some locations. Concentrations of both of these metals were in excess of the MOE SEL guidelines, and would warrant additional investigation under Phase III. Elevated levels of dioxins and furans in excess of the CCME PELs indicated a potential risk to biota. Given the high uncertainty surrounding the results, this site was recommended for additional assessment under Phase III.

Level 3 Sites

Welland River at Geon (Oxy Vinyl)

The review of historical data indicated that the occurrence of mouthpart deformities in chironomids was the basis of the listing of this site as a potential concern. Therefore, since no specific COCs had been identified in previous studies, testing at this site included a number of compounds, based on the compounds used and produced on the site.

Both chromium and nickel exceeded the SELs and indicate a potential concern. As well, PAHs exceeded the LEL at one site. While PAH concentrations did not exceed the SEL, concentrations in sediment were sufficiently above the LEL that potential adverse effects to biota could be present. Consequently, additional investigation is considered necessary under Phase III.

Black Creek Mouth

This site was originally listed as a site requiring further evaluation based on a single occurrence of arsenic at the mouth. Sediment sampling of Black Creek was undertaken by Environment

Canada and the MOE in 2002, and consequently, additional sampling was not performed as part of this study.

The 2002 results indicated that concentrations of all contaminants were low and there were no identified risks to biota due to sediment concentrations of contaminants. Additional investigation of this site under Phase III was not warranted.

Pell Creek Mouth

A number of industrial facilities along Pell Creek were reviewed, and on the basis of the raw materials used, and the products produced, metals, PCBs and PAHs were included in the list of potential contaminants of concern.

Sediment analysis indicated that none of the contaminants of concern exceeded screening values, and suggested that risks to biota were negligible. As a result, additional investigations at this site were not included in the recommendations.

Chippawa Creek

The review of direct industrial sources to Chippawa Creek, as well as tributaries such as Pell Creek, indicated that metals, PCBs and PAHs could be considered as potential contaminants of concern.

The results of the sampling program were consistent with previous studies in Chippawa Creek and indicated that concentrations of all COCs were below MOE guidelines and presented a negligible risk to biota. Additional sampling under Phase III was not considered necessary.

Chippawa Power Canal

Due to very high flow velocities in the upper canal, only the lower section of the canal was considered as having potential to accumulate contaminated sediments. Since both the Welland River and Chippawa Creek flow to the Power Canal, the list of potential contaminants of concern included those identified in these watersheds.

Concentrations of all COCs were low in the canal, and posed no identified risks to biota. Elevated levels occurred in some of the ditches to the canal, but due to significant dilution, would not be expected to result in sediment contaminant concerns in the canal. Consequently, additional investigation of the canal was not included in the recommendations.

Niagara River at Queenston

Previously identified concerns in this section of the Niagara River focussed on concentrations of some metals that exceeded the MOE LELs. Review of potential upstream sources on both the Canadian and U.S. sides of the river indicated that a broader range of potential contaminants should be included in additional sampling. As a result, sediment samples were analysed for metals, PCBs and dioxins and furans.

No risks were identified due to metals or PCBs. Dioxins and furans exceeded the CCME Probable Effects Levels (PELs) at a few locations and present a potential concern through both toxicity and bioaccumulation. A screening risk assessment identified no potential risks to sensitive receptors, and additional assessment was not considered to be warranted at this site.

Niagara River at Niagara-on-the-Lake

Originally identified in the early 1980's as a potential concern due to mercury concentrations above the MOE LEL, additional sampling in 1993 by the MOE identified one area with elevated levels of dioxins and furans. Consequently, additional investigation included metals, PCBs and dioxins and furans as potential COCs.

With the exception of dioxins and furans, all COC concentrations in sediments were low, and were associated with only negligible risks to biota. Dioxins and furans exceeded the CCME PEL and suggest potential risks to biota may be present. Additional assessment indicated risks were low and effects on biota were unlikely.

Based on the outcome of the initial investigation, three areas were identified where risks to biota indicated the need for more detailed assessment under Phase III:

- Lyon's Creek West, for investigation of potential effects due to PCBs, arsenic and zinc;
- Welland River, for investigation of potential effects due to chromium, copper and nickel, and at one site, PAHs; and
- Frenchman's Creek, for investigation of potential effects due to dioxins and furans in the southeast tributary, and cadmium and chromium in the southwest tributary.

A detailed study plan has been developed for these sites.

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1.0 INTRODUCTION

In 1972, in order to provide a co-ordinated approach to addressing environmental concerns in the Great Lakes, the Canadian and U.S. governments signed the Great Lakes Water Quality Agreement. The original Agreement focused on phosphorus and associated problems regarding eutrophication. In 1978, the Agreement was revised to focus on toxic compounds, and promoted an ecosystem approach to addressing water quality concerns. The 1978 Great Lakes Water Quality Agreement was amended by Protocol signed in November 1987, and contained a number of additional provisions, including Annex 14, which committed both parties to undertake action to remedy areas of contaminated sediments.

In 1985, based on recommendations by the states and provinces, the Water Quality Board of the International Joint Commission (IJC) identified 44 areas in the Great Lakes where contaminant concerns existed. These Areas of Concern formed the priorities for environmental actions. The original listing of areas as Areas of Concern was based on a list of 14 designated beneficial use impairments. While these noted the major area of environmental impairment in each of the Areas of Concern, these also identified the issues that would need to be addressed for the area to be de-listed as an Area of Concern. In many of these areas, contaminated sediments were identified as a primary cause of the use impairments.

In their 1985 report, the IJC’s Water Quality Board identified a number of use impairments in the Niagara River that formed the basis of the listing of the River as an Area of Concern in the Great Lakes. The Stage 1 RAP Report Update (Niagara River RAP 1995) has identified the following use impairments as directly related to contaminated sediments:

- Degradation of benthos; and
- Restrictions on dredging.

In addition, contaminated sediments can also contribute to other beneficial use impairments identified in the Niagara River Area of Concern, including:

- Restrictions on fish and wildlife consumption;
- Degraded fish populations; and
- Bird or animal deformities or reproductive problems.

In order to address the use impairments, the sources of the problems need be addressed. Studies undertaken since the 1980's have identified a number of areas in the Niagara River watershed where sediment contaminant concentrations could result in impairments. As well, a number of biological assessments have indicated that sediments in some areas of the watershed could result in adverse effects on biota, or in accumulation of contaminants in biota to unacceptable levels. The Welland River in the area of the Atlas Specialty Steels discharge was identified as a significant source of contaminants to the Welland River on the Canadian side. Process changes at the site had resulted in a significant reduction in discharges of contaminants to the Welland River. However, deposits of "mill scale", an metal-oxide material, still remained in the Welland River downstream of the Atlas discharge. These had formed two reefs within the river and remediation of this section of the Welland River through removal of the "reefs" was undertaken in 1995.

With remediation of one of the more contaminated areas of the river, attention turned to other sites within the Niagara River watershed where potential contaminated sediment concerns may exist. Many of these sites had initially been investigated in the late 1970's and early 1980's as part of the Niagara River Toxics Committee investigation. In 1996, the Niagara River RAP, in it's Stage 1 Update, identified 12 locations within the watershed where additional investigation was warranted based on previously identified concerns. These are the focus of the current study. An additional area, the portion of Lyon's Creek that lies to the east of the Welland Canal, while included in the list of areas, is the subject of a separate investigation and is not included in the current study.

The impetus for the study is provided by both international agreements between Canada and the United States, and federal-provincial agreements between Canada and Ontario. The federal government, as a signatory to the 1978 Great Lakes Agreement with the U.S., is committed to undertake efforts to remediate Areas of Concern. As well, the 2002 Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, commits both the federal and provincial governments to cleanup of a number of Areas of Concern. The Lake Ontario Lakewide Management Plan (LaMP) also contains commitments for both countries to reduce the loading of toxic substances to the lake. A significant part of the management plan calls for remediation of areas of concern. The Binational Toxics Management Strategy that has evolved out of the commitments contained within the 1978 Great Lakes Water Quality Agreement also calls for Canada and the United States to work towards virtual elimination of toxic substances. Included in the list of substances are PCBs and a number of PAH compounds.

The Niagara River sediment assessment project has been designed as a means to address the contaminated sediment concerns in the Niagara River Area of Concern, thereby satisfying Canada's commitments under the 1978 Great Lakes Water Quality Agreement. The project will also serve as a step towards de-listing the Niagara River as an Area of Concern through identification of those areas within the Canadian side of the watershed where toxic sediments exist and additional remediation would be warranted.

1.1 Background

The contaminants identified in the Niagara River watershed on the Canadian side include heavy metals, PCBs, PAHs, and at one site, dioxins and furans. In addition, a number of contaminants that are related to agricultural use, namely pesticides such as DDT compounds and chlordane compounds, have also been detected at low concentrations in sediments. Many of the studies upon which the determination of beneficial use impairments was based were undertaken in the 1980's and current conditions in these areas are, therefore, largely unknown. The current study is designed to address the Recommendations in the RAP Stage 2 Report (*The Cleanup Connection*), which were:

> Recommendation 16: *The lower Welland River (downstream of the Welland Airport) be the priority focus of any sediment assessment.* This recommendation has been partially addressed through the Welland River cleanup. However, additional downstream areas in the Welland River have not been addressed and will still require further assessment to satisfy this recommendation.
>
> Recommendation 17: *Potentially contaminated locations be prioritized for review, assessment and remediation.* The remaining sites have been prioritized into Level 1, 2 and 3 sites by the RAP, based on existing information regarding levels of contamination. However, these now require further assessment. Where concerns are identified, remediation options will need to be considered, though these will be addressed in Phase III of the current study.
>
> Recommendation 18: *Test potentially contaminated sediment sites to confirm absence/presence of contamination.* This forms the basis of Phases I and II of the study. The RAP Stage 2 Report noted that this recommendation is applicable to both the Niagara River and it's tributaries, including the Welland River.

The RAP Stage 1 Update identified 13 areas on the Canadian side of the Niagara River that should be investigated in addition to the Welland River at Atlas Steel. (The general study area is shown on Figure 1, while the locations of the individual sites are shown on Figure 2). These were prioritised as Level 1, Level 2 and Level 3 sites based on existing understanding of sediment conditions. The sites include:

Level 1 Sites

Those sites where existing contaminant concentrations are sufficiently elevated to result in potential adverse effects to biota were identified as Level 1 sites. Four locations were identified in the RAP Stage 1 Update as Level 1 sites:

- Welland River at Atlas Steel
- Lyons Creek West
- Lyons Creek East
- Welland River from Port Robinson to Power Canal

Level 2 Sites:

Those sites where contaminant concentrations were elevated over background levels, but did not exceed the MOE Severe Effect Level (SEL) guideline were identified as Level 2 sites and included:

- Sir Adam Beck Reservoir
- Thompson's Creek
- Frenchman's Creek

Level 3 Sites:

Those sites where minor exceedances of available guidelines have been noted, and/or where recent data is lacking have been identified as Level Three sites. These include:

- Welland River at Geon (Oxy Vinyl)
- Black Creek Mouth
- Pell Creek Mouth
- Chippawa Creek
- Chippawa Power Canal
- Niagara River at Queenston
- Niagara River at Niagara -on-the-Lake

In 1995, based on a number of studies, a sediment cleanup of the Welland River was undertaken adjacent to the Atlas Specialty Steels site. Follow-up monitoring was conducted by the MOE in 2000 (Jaagumagi 2003) and additional monitoring for this site was not considered necessary for this study. Therefore, the current study focuses on 12 of these sites, since the Lyon's Creek East site is the focus of a separate investigation.

2.0 STUDY APPROACH

The evaluation of the sites has been conducted under a step-wise process. These are listed below:

1. The history of contaminant use at each identified site was reviewed to determine whether potential contaminants of concern have been used at the site. The sites included industrial facilities, municipal discharges, such as waste water treatment plants, and passive discharges, such as landfills. The review also included a description of the wastewater treatment and management process used on the site in order to determine whether there is or has been a possible route of discharge. Discharges included both process water and cooling water. In some cases, processes have been altered (closed-looped at some sites) such that currently there is no active discharge of process water. In these cases, the previous discharges were reviewed, since sediment contamination is often related to historical discharges.
2. The potential contaminants of concern were identified based on the types of products or processes used, or in the case of landfills, the types of wastes disposed of at the site.
3. The previous monitoring results were reviewed and the need for additional data was determined. Where recent data were available, site evaluation proceeded on the basis of this information, and additional data collection was not considered necessary. Where only historical data were available (more than 5 years old), additional sampling was considered necessary in order to properly characterize existing conditions.
4. The existing levels of contamination were compared to the MOE PSQGs and the CCME CSQGs where PSQGs were not available. The assessment proceeded through a Risk Quotient evaluation, defined by the equation RQ = [at site]/ screening level criterion. Since the screening criteria used were based on biological effects, where the RQ > 1, therefore, by definition, a potential for an adverse effect on biota is present, with the risk increasing with higher RQ values. Since the MOE criteria have two levels of effect, an RQ was calculated for the Lowest Effect Level (LEL) (i.e., the more conservative value) first. If this resulted in a $RQ_L > 1$, then the concentrations in sediments were evaluated with respect to the Severe Effect Level (SEL). Where the RQ_s exceed a value of one with respect to the SEL, the MOE protocol (Persaud *et al* 1993) requires that additional biological assessment be undertaken to determine the extent and severity of the effect, since the requirement for remedial actions is based upon biological effects, rather than simple exceedance of guidelines.
5. Where a potential risk was identified, the physical conditions in the waterbody were considered. In particular, this focused on whether there was a risk that contaminants could be re-suspended during significant flow events, and thereby could be distributed over a broader area. As well, the availability of contaminants to biota can be enhanced through disturbance of sediments, and therefore, potential risk to biota can be increased under these conditions. The evaluation also considered the possibility of exposure of more contaminated layers in the subsurface sediments through review of existing contaminant concentrations with depth.
6. Where potential risks to biota were identified through the screening approach (i.e., [COC] > SEL), these sites were targeted for detailed assessment under Phase III. This is expected to involve additional biological testing, using community structure and toxicity measurements, and in general is consistent with the MOE Approach, and the CCME Detailed Comprehensive Risk Assessment. In some cases it may be necessary to assess risks to human health.
7. At those sites where significant effects have been determined under the Phase III assessment, remedial measures will be evaluated, and cleanup options developed.

The Phase I site assessment considers the existing conditions at each of the sites, based on a review of site history and previous studies, and also recommends focused sampling in those areas where potential risks are identified, or where there is a substantial lack of data upon which to make an assessment. These address Steps 1 to 3, above. The evaluation of existing conditions, with respect to risks to biota, are the subject of the Phase II component and address Steps 4 and 5. Phase III studies will address Steps 6 and 7 for those sites where Steps 1 though 5 identify risks to biota.

3.0 REGIONAL BACKGROUND

3.1 Geology

The regional hydrogeology of the study area can be subdivided into three broad areas; the Lake Ontario plain situated below and north of the Niagara Escarpment, the Halminande plain extending south of the Niagara Escarpment, to and including part of the Onondaga Escarpment which borders Lake Erie and the area south of the Onondaga Escarpment to Lake Erie. These areas are characterised by Pleistocene fine grained glacial deposits dominated by glaciolacustrine silts overlying Devonian, Silurian and Ordovician aged bedrock. Bedrock and surficial (quaternary) geology for the area are presented on Figures 3 and 4 respectively.

The principal groundwater bearing horizons occur within the bedrock. The area is hydrogeologically bound to the east and west by the Niagara River and the Welland Canal, respectively. These features, in many areas, cut though the surficial deposits to the bedrock thereby creating groundwater discharge boundaries. Similarly, Lake Ontario and Lake Erie form groundwater discharge boundaries to the north and south. In addition, the Queenston Chippawa Power Canal through Niagara Falls also forms a discharge zone.

The area north of the Niagara Escarpment beneath the Lake Ontario Plain is underlain by low permeability shale bedrock of the Queenston Formation and fine grained, low permeability soil predominately comprised of glacial tills and glaciolacustrine clay deposits. Groundwater locally occurs within sandy lenses of limited lateral extent. Groundwater flow is typically shallow and reflects the patterns of surface drainage.

The area above the Niagara Escarpment extending south to the Onondaga Escarpment is underlain by dolostone bedrock of the Lockport and Salina Formations. These formations are groundwater bearing, largely associated with bedding horizons in the Lockport Formation while in the Salina Formation, the water bearing horizons are typically associated with zones of gypsum erosion near the bedrock surface. The aquifers associated with these water bearing zones are laterally continuous and directly influenced by the Canals and Niagara River which are discharge zones. The face of the Niagara Escarpment is also a discharge zone for the Lockport Formation.

Fluctuations in the surface water levels of the Welland Canal, the Queenston - Chippawa Power Canal, Lake Gibson and the Sir Adam Beck power reservoir can also locally affect bedrock groundwater recharge conditions.

The Halminande Plain consists of extensive clay deposits which can be as thick as 30 m and forms a low permeability blanket or aquitard over much of the bedrock. This blanket limits the rate of surface recharge to the bedrock aquifer thereby protecting it from surface activity but at the same time maintains very hard and sulphurous groundwater quality conditions within the bedrock. Directions of groundwater flow in this area are strongly influenced by the patterns of surface drainage.

The area south of the Onondaga Escarpment to Lake Erie is underlain by dolostone and cherty limestone of the Bertie and Bois Blanc Formations. These formations are permeable and locally exposed at surface forming areas of groundwater recharge. Groundwater quality within these horizons tend to have fresher water quality than that of the underlying Salina Formation due to the greater degree of groundwater recharge associated with the areas of thin overburden and exposed bedrock.

3.2 Hydrology

The drainage pattern of the Niagara Peninsula is shown of Figure 2, and is dominated by the Niagara River and it’s largest tributary, the Welland River. The drainage pattern is determined by the Niagara escarpment, which runs close to the northern edge of the Peninsula near the southern edge of Lake Ontario. The result is that most of the larger watercourses, such as the Welland River, drain from west to east, rather than north to Lake Ontario, discharging to the Niagara River upstream of the current location of the Falls. The Welland River is the largest tributary to the Niagara River, and the drainage area includes approximately 30% of the land area of the Niagara Peninsula. A number of smaller tributaries drain to the Niagara River south of the Welland River. To the north of the Welland River watershed, watercourses drain directly to Lake Ontario.

Due in part to the needs of hydro-electric power generation and the needs of water-borne commerce, the hydrology of the Niagara River drainage on the Canadian side of the river has been altered significantly from it's pre-colonial state. The need to provide a route by which ships could by-pass the Niagara River, and in particular, the Falls, resulted in the construction of the first Welland Canal, which was opened in 1829. The canal in it's original configuration made extensive use of existing watercourses. Since that time, the canal has been re-built a number of times, most recently in the 1970's. During the construction of the various canals, a number of new channels were excavated, such that parts of the Welland Canal cross the Welland River at two locations. In order to maintain the existing flow of the Welland River, siphons were constructed to carry the Welland River under the Welland Canal. The current canal is actually the fourth Welland Canal which was completed in 1972, and included a by-pass east of the City of Welland.

In the 1940's, construction began on the Sir Adam Beck Power Stations to augment the hydroelectric generating capacity of the area. Since regulations prohibit both Canada and the US from unrestricted diversion of the Niagara River, and require both countries to maintain a minimum flow of 100,000 m^3 daily during the hours of 7 am to 11 p.m. during the tourist season from May to November, it is necessary to store water during the night in order to maintain generation capacity during the day, when electrical needs are highest. Consequently, a reservoir was created at Queenston to contain Niagara River flows diverted from above the Falls. The Adam Beck Reservoir therefore, is filled nightly through diversion of water from the Niagara

River, which provides a daily store of water for power generation during peak periods. This augments the base flow that is obtained from the Niagara River and Welland River.

The Sir Adam Beck Reservoir is fed by both surface and subsurface channels from the Niagara River. These channels divert water from above the Falls to the powerhouses at Queenston. The major surface route for water is the Chippawa Power Canal.

The Power Canal was constructed such that it utilised the lower reaches of the Welland River. Approximately 4 km west of the Town of Chippawa, the Power Canal was constructed due north from the Welland River along what was then the western edge of the City of Niagara Falls. As a result, the lower section of the Welland River typically flows west, away from it's historic mouth, to the Power Canal. Similarly, water from the Welland River that historically flowed to the Niagara River at Chippawa is now diverted north along the Power Canal and is either used directly for power generation, or is stored in the reservoir. Only occasionally, when power generation needs are low, or during servicing or maintenance, does water flow east along the lower Welland River, now known locally as Chippawa Creek, to the Niagara River. Flows in Chippawa Creek are in the order of 0.6 m/s, and consequently there is little deposition of fine-grained material, except along the banks of the channel. Due to the large volume of water moving down the channel, the sides of the channel are steep, and the river drops to an average depth of approximately 10 m within 5 m of the shore. The upper section of Chippawa Creek in the Town of Chippawa is slightly narrower than the lower section, with the result that flows are stronger, and there are no bankside depositional areas due to channelization of the river.

The complex hydrology of the region typically defines potential contaminant transport from either water-borne contaminants or sediment adsorbed contaminants. Most of the contaminated sediment load from the Welland River would be expected to be transported down the Chippawa Power Canal to the Niagara River. Similarly, any contaminant load from Chippawa Creek would predominantly move west to the Power Canal, rather than east to the Niagara River. Flows in the Power Canal are typically in the order of 1 m/s, while depths are in the range of 10-15m. Consequently, there is significant scour in this section, and there is little deposition of sediments. As a result, sediments transported down the Power Canal are either deposited in Sir Adam Beck Reservoir, or are discharged directly to the Niagara River through the power house.

The lack of substantial topographical relief translates into most of the rivers in the area being relatively slow-flowing streams. Flow data collected by the NPCA indicates that peak flows in the Welland River occur during the spring (Figure 5) with a secondary peak in September-October. Water level fluctuation is in the range of 20 cm, which, assuming an average depth of 2 m, represents approximately a 10% increase over summer base flows. Typically the lowest flows occur during the summer and winter months. Therefore, it is likely that much of the suspendable bed load of the river is transported during the peak flow periods. Studies have indicated that in most rivers, bedload is transported during peak flow periods by a process of saltation whereby particulates are carried stepwise down the water course over a number of high flow periods. This results, over time, in a distribution downstream of any contaminated materials, and while this serves to dilute some of the material, it increases the area of potential impact.

The Welland River begins well to the west, south of the Town of Grimsby. There are no major urban centres on the river upstream of the City of Welland. In Welland, the River crosses both the Old Welland Canal and the new Welland Canal, also known as the Welland By-Pass. To avoid mixing water from the Welland River and Lake Erie, the Welland River has been diverted to flow under the canals through inverted siphons. In the section of the river between the two canals, the river has received inflows from the Atlas Specialty Steel mill. Historically, discharges from the mill resulted in accumulation of mill scale (primarily insoluble metal oxides) at the mouths of the discharges. In 1995, these areas were the focus of a sediment remediation project undertaken jointly by Environment Canada, the Ontario Ministry of the Environment, the City of Welland, and Atlas Specialty Steel. During the course of the project, the mill scale deposits were removed down to the existing bed of the river.

Below the Welland Canal By-Pass, the river flows through primarily rural areas. With the exception of a few industries, there is no development in this section of the river. The river meanders broadly through agricultural areas and is typically lined with cattail marshes on the inside curves of the meanders, where currents are slower. The middle of the channel is typically scoured, and substrates are mainly clay. Along the sides of the channel, substrates are variable. Where the cattail marshes occur, sediments are mainly silts and organic detritus in various stages of decomposition. In other less protected areas, sediments consist of a mix of silt and sand. In the lower sections, near the entrance to the Power Canal, the clay substrates are present under thin surface silty layers. As such, the substrates are indicative of a river that sees a substantial flow in the middle of the channel, preventing deposition of materials. These appear to be deposited along the sides, where currents are slower, at least during periods of low flow. These areas also appear to be scoured during high flows, given the narrow band of depositional areas along the banks of the river.

In addition to changes to the Welland River, construction of the new Welland Canal in the early 1970's resulted in changes to Lyon's Creek, a tributary of the Welland River. Prior to construction of the by-pass, Lyon's Creek originated at the southern end of the City of Welland, and flowed east to join the Welland River west of the Town of Chippawa. In the early 1970's the construction of the Canal by-pass and highway underpass resulted in the severing of the upper reaches of the Creek. However, unlike the Welland River, the integrity of the flow in Lyon's Creek was not maintained. As a result, Lyon's Creek west, as the upper reaches are known, currently drains to the Welland Canal, from where any contaminants would be transported down the Canal. Flow to the upper reaches of the east section of Lyon's Creek is maintained through pumping of water from the Welland Canal.

While drainage from the southeast section of the City of Welland originally entered the creek in the wetland area, in 1992, the City re-routed the drainage ditch around the wetland. Currently the ditch joins Lyon's Creek just above the outlet to the Welland Canal. The remnant of the original creek in the wetland area, therefore, is currently mostly dry creek bed, except during snow melt and high rainfall events.

A number of smaller rivers within the Niagara Peninsula, south of the Welland River, drain directly to the Niagara River. Of these, only Frenchman's Creek and Black Creek are included in this study. Frenchman's Creek is a small stream that begins west of the City of Fort Erie and flows east through the western section of the City before turning north to join the Niagara River. The creek is alternately slow-flowing pools, and rapidly flowing over rocks and gravel. The section of the creek upstream of the rail yards has recently been dammed by beavers, with resultant flooding of some areas. The drainage area is predominantly rural in the headwaters, and grades to industrial in the lower sections where it passes through the western end of the City of Fort Erie. There is little surface relief throughout the drainage course, and the hydrology is driven primarily by rainfall events and spring snowmelt.

Black Creek begins southeast of the City of Welland and runs mainly due east, before also turning north to the Niagara River. The drainage area, and therefore the width of the channel, and flows are larger than in Frenchman's Creek. The creek drains a predominantly rural area with little commercial or industrial development. Consequently, conditions in this watershed are considered the most typical of the historical rural activities in the area, and are considered throughout this study as the ambient control.

All of the creeks and river that are the subject of this study ultimately flow to the Niagara River. Due to the high flows in the river, scour is substantial, and few depositional areas exist along the river. In the lower river, below the Niagara Gorge, the river is very deep (>30m) with highly turbulent flow, but currents slow as the river broadens out. Along the sides of the channel, areas of deposition occur below each of the points of land, where backeddies can form. These areas typically have slower currents, are shallow (<1 m), compared to the main river channel, and are characterised by silty-sand deposits, and submerged vegetation. The size of the areas varies with the size of the point of land: an extensive area of deposition was found below the large point of land approximately midway between Queenston and Niagara -on-the-Lake, while much smaller areas were located below the smaller points of land. The shorelines leading to the points of land (i.e., the upstream side) are scoured, since this is where the river current sweeps close to the shore resulting in hard (rocky) substrates.

The backeddy areas are likely to have a mix of contaminants that reflect the various inputs from both the Canadian and U.S. sides. Substantial mixing occurs in the Niagara Gorge, and it is expected that no segregated areas of flow will exist. Downstream, as the river broadens, there is less turbulent flow, and therefore likely less cross-channel mixing.

The mouth of the Niagara River is also characterised by rocky substrates, as both the river current and lake wave action interact to create a dynamic environment. Depositional areas occur only behind protective areas such as docks and breakwalls. Areas near shore are characterised by accumulations of sand that are likely temporary in nature. Consequently, the major depositional areas of the Niagara River lie off-shore in the deeper waters of Lake Ontario. The lake-wide circulation pattern results in much of the suspended sediment load from the Niagara River being deposited in a broad fan to the east of the river. Studies have shown elevated levels of a number of COCs associated with the Niagara River extending east as far as Rochester, N.Y.

As noted above, flows in the Niagara River are also variable, and depend on hydro-electric power generation needs on both the Canadian and U.S. sides.

3.3 Land Use

The industrialisation of the Niagara region occurred earlier than in other areas of the province due to the proximity of first, hydraulic power, and later, hydro-electric power. As a result of the proximity of hydro-electric power, many industries that had heavy electrical power requirements located in the area, and their history in the region coincides with the development of electric power. In particular, those industries that made use of electric arc furnaces, such as the abrasives industries in Chippawa and Niagara Falls, and the steel manufacturing in Welland, were among the heavy industries to settle in the region.

Consequently, the region is a mix of heavy industries and agricultural use. The industrial uses would have contributed contaminants that, in many cases, were particular to the types of processes used and the effluent discharged. Agricultural usage would have resulted in nutrient inputs and agricultural chemicals, particularly herbicides and pesticides. These would include both the organic chemicals, such as DDTs, Lindane, and chlordanes, as well as the older, arsenic-based pesticides.

Currently, the uses in the area include: industrial sites; urban regions of the Cities of Welland, Niagara Falls, and Fort Erie, as well as a number of smaller urban centres; commercial development; and rural areas. A major transportation corridor, comprised of the QEW and railways, crosses most of the watercourses draining to the Niagara River. Therefore, the potential impacts on watercourses include not only industrial sites and agricultural runoff, but also wastewater treatment facilities, urban runoff, highway runoff and rail activities.

Runoff from urban areas has been implicated in increased concentrations of PAH compounds, which originate from leaching of asphalt, tire compounds, as well as combustion products from internal combustion engines (Umlauf and Bierl 1987). A number of metals have also been associated with urban runoff, with the primary ones being copper and lead. Both have been measured at higher concentrations in sediments in urban areas, such as the Toronto waterfront (Boyd et al 2001).

Land use, as noted earlier, can have significant impacts on water quality as well as stream flow, affecting local hydrology (i.e., increased runoff, where this is likely), as well as the types of contaminants contributed from non-point sources (i.e., agricultural).

4.0 INDIVIDUAL SITE ASSESSMENT

The sites considered in this study have been previously identified by the Niagara River RAP as potentially contaminated areas. All have been identified as needing additional evaluation before a management decision can be made on whether some type of active intervention is required. The sites were categorised by the RAP in it's Stage 1 Update into Level 1, 2 or 3 sites, based on existing knowledge of contaminant concentrations in sediments. The classification adopted by the RAP is followed in this report. It should be noted that a number of the sites occur on the same watercourse, such as the Cytec, Oxy Vinyl (Geon) and Ford Glass sites on the Welland River. While these sites are discussed individually, they are also considered within the discussions on the particular watershed, since each site contributes to the cumulative impacts on these waterbodies.

4.1 Level One Sites

Level One sites are those sites where existing information indicates that concentrations of contaminants are sufficiently elevated that potential risks exist, and there is a possibility of adverse biological effects. Based on previous studies, only two sites were considered to be potentially contaminated to levels where adverse effects could be likely; Lyon's Creek West, and the Welland River from Port Robinson to the Chippawa Power Canal.

4.1.1 Lyon's Creek West

Lyon's Creek West is the small remnant watershed that resulted from the construction of the new Welland Canal in the 1970's. The canal cut across the upper reaches of Lyon's Creek, with the result that the watershed area to the west of the canal was severed and was subsequently routed to discharge into the Welland Canal (Figure 6). The existing watershed is contained between the Old Welland Canal to the west, and the new Welland Canal to the east. Flows to the east portion of Lyon's Creek were maintained through pumping of water from the Welland Canal.

The watershed drains the south-eastern section of the City of Welland, and within the drainage area are included an Ontario Hydro (Hydro One) transformer substation (Crowland Transformer Station) at Humberstone Rd., the StelPipe Page Hersey Works tube works, and urban storm drainage from the south-eastern section of the City of Welland.

A summary of potential sources and contaminants is provided in Table 4.1.1. Chemical analysis results for previous studies in Lyon's Creek West are provided in Appendix A (Table A-14). Sampling locations from previous studies have been included in Figure 7 (for those studies where figures showing sampling locations were available). It should be noted that the locations of the previous sampling locations are considered approximate, due to the lack of accurate mapping and geo-referenced data.

Contamination of soils and sediments in Lyons' Creek came to light in 1991, when, as part of site characterization by MTO during Hwy 406 construction, PCBs were detected in the wetland area adjacent to the Welland Canal. The majority of the wetland area is within the St Lawrence Seaway Authority (SLSA) property, though Hydro One and the City of Welland also own parts of the site. Both the SLSA and MOE conducted soil/sediment sampling for PCBs (Table A-14, Appendix A). (Sampling locations are shown on Figure 7). Subsequently, PCBs were also detected in the stormwater ditch from the south-eastern section of the City (identified as the north branch on Figure 7). The ditch sediments were removed by the City in 1991.

A number of potential sources were identified as contributors of PCBs to the wetland. A transformer leak at the [then] Ontario Hydro Crowland Transformer Station on Humberstone Rd in 1990 resulted in a spill of PCB contaminated fluids to the ditch draining to the wetland from the south (identified as the south branch on Figure 7). Concentrations up to 8 ppm of PCBs were detected in this ditch/tributary. A cleanup of the area of the spill was subsequently undertaken by Ontario Hydro. Additional remediation was undertaken in selected areas both on the Ontario Hydro property, and off-site in Lyon's Creek.

Additional sampling in the north branch also yielded elevated levels of PCBs. This ditch drains local residential areas of the City and also the StelPipe Page Hersey Works, located in the south-eastern section of the City. Previous monitoring has shown detectable levels of PCBs in discharges from this site, and therefore, this facility was identified as a potential contributor of PCBs to the wetland. Sampling in the ditch yielded PCB concentrations up to 42 ppm, prior to cleanup of the ditch (R. Slattery, Pers. Comm. 1991).

Studies undertaken in 1992 (ESL 1992) included additional sampling data, as well as a summary of existing data on PCB contamination within the wetland and Lyon’s Creek. The study found elevated levels of PCBs within the wetland and the ditches draining to the wetland from the city as well as the Crowland station. PCBs were also found in sediments in the ditch draining the wetland to the Welland Canal. Analysis of the PCBs from the wetland indicated that Aroclors other than those used in the transformers were present in wetland soils and sediments, and indicated that other sources had likely contributed PCBs to the wetland.

The review concluded that the PCBs were confined to the upper 1 m of soil/sediment in the wetland area. Similarly, PCB contamination in the ditches was also confined to the upper sections, generally less than 1m. In a few areas, contamination extended to deeper sections (up to 3 m depth), where soils had been previously disturbed due to construction activities associated with the Canal and underpass.

In general, the highest PCB concentrations occurred in the upper 20 cm of soil/sediment, and ranged up to 87 ppm. However, subsurface concentrations at one location adjacent to the ditch draining the southeast section of the City ranged up to 648 ppm in the 18-36 cm section.

Concentrations in the ditches ranged up to a high of 65 ppm. Re-sampling in the City ditch after the cleanup undertaken in 1991 revealed most areas to be below 5 ppm, though one sample yielded 515 ppm, and two other samples had concentrations ranging from 67 ppm to 76 ppm, indicating that hotspots persisted after the cleanup.

Activities at the site have been complicated by the number of property owners in the area. Currently, the City and Hydro One (as Ontario Hydro) have undertaken cleanups on their properties.

In 1994, the City re-routed the Lyon's Creek Storm Drainage Channel (the northwest tributary) around the contaminated area (shown on Figure 7). A plug was left in place at the upper end of the re-routed section until 1995, when the plug was removed, a berm was constructed to prevent flows into the existing channel and storm water was diverted into the new by-pass channel.

However, aside from the cleanup undertaken by Ontario Hydro at the southwest end of the site, there is no record of additional remediation on the site. It was therefore assumed that no further actions were undertaken to remove contaminated soils or sediments from the wetland area, or the former drainage channel. Based on the above review, the COCs identified at the site were restricted to PCBs, which were known to occur at high concentrations in a number of areas on the site.

4.1.2 Welland River - Port Robinson to Chippawa Power Canal

The Welland River downstream of the Welland Canal By-Pass has been identified in the RAP Stage 1 Update as an area requiring additional investigation. However, due to upstream sources of contaminants, this area cannot be considered in isolation. The RAP Stage 1 Report (1996), identified the Atlas Specialty Steel site in the City of Welland (Figure 8) as one of the largest single sources of contaminants to the river. River sediments below this site were found to be contaminated with high concentrations of chromium and nickel, as well as elevated levels of PAH compounds (Acres 1990; Jaagumagi and Bedard 1991, 1995) and elevated levels of these COCs were also noted downstream of the Canal By-Pass in studies conducted by the MOE and Environment Canada (MOE 1993a; MOE-EC 1996). In 1995, a cleanup project was initiated that resulted in the removal of the most contaminated areas, but elevated levels of both chromium and nickel remained adjacent to, and downstream of, the remediated areas.

The lower section of the river, from the Canal By-Pass to the Chippawa Power Canal also includes a number of industrial sources, even though much of this area is rural/agricultural (the locations of the major industrial sources are shown on Figure 9). These include the Oxy Vinyl LP site (formerly Geon, and before that, B.F. Goodrich), the Cytec (formerly Cyanamid) Welland Plant, and the former Ford Glass Plant. Both the Oxy Vinyl and Cytec sites are discussed separately in Sections 4.3.2 and 4.2.2. respectively. The potential sources of COCs, as well as previous monitoring results are summarized in Table 4.1.2.

The RAP Stage 1 Update identifies the major concern in this section of the river to be due to the presence of oil and grease below the former Ford Glass plant. As well, a number of metals, such as nickel, chromium, copper and silver were also identified in sediments. However, since these metals have not been recorded in effluents from the Ford Glass plant, it is likely that other sources in the area or upstream have contributed contaminants to the system.

Table 4.1.2, lists the potential sources to the Welland River in the section from Port Robinson to the Chippawa Power Canal. In addition to local sources within this stretch, upstream sources have likely contributed to contaminated sediment issues and these need to be considered within the overall context of the Welland River.

Located at Port Robinson are sewage lagoons that discharge to the Welland River below where the river crosses the Welland Canal. The site commenced operation in 1990, and monitoring after start-up indicates that trace levels of arsenic, as well as variable levels of lead were detected in the effluent (MOE 1993c). However, the MOE-EC study of 1996 does not show an increase in either lead or arsenic in sediments below the Lagoons (Appendix A, Table A-11).

Approximately 3 km downstream of the Welland Canal, the former B.F. Goodrich site is located on the north bank of the Welland River. The site was operated as Geon Canada from 1993 to 1999, at which time the site changed ownership. Currently the site is operated as Oxy Vinyls LP. The site is discussed in more detail in Section 4.3.1.

East of, and adjacent to the Oxy Vinyl (Geon) site is the Cytec Welland, formerly Cyanamid Welland, site. Approx. 1.5 km downstream of Cytec, Thompson Creek flows into the Welland River. The Cytec Canada facility is located along the north bank of the Welland River, between the river and Thompson's Creek, to the north, with most of the discharge routed to Thompson's Creek. The Cytec site and Thompson's Creek are discussed in Section 4.2.2. However, since Thompson's Creek discharges to the Welland River, the effects are also considered in this section. A review of historical discharges, as well as studies conducted in the site, indicate that the contribution of this site to contaminant concerns in the Welland River is minor. While the study by Hart (1986) in 1983 indicated elevated levels of copper and nickel in Welland River sediments at the mouth of Thompson's Creek, subsequent studies on the Welland River by EC and MOE in 1996 (Appendix Table A-11 and A-12) indicate that these metals are elevated at a number of sampling locations upstream of Thompson's Creek.

Furthest downstream was the Ford Glass Plant, which was located on the south side of the river approximately 0.5 km upstream from the Chippawa Power Canal (Figure 9). The plant was decommissioned in 1994 and as part of the site decommissioning, Beak undertook a study of the site (Beak 1994). The study noted that while both chromium and nickel were elevated in sediments adjacent to the site, concentrations of these metals were higher at upstream locations as well. Prior to construction of the plant, the area had been agricultural land.

The Beak 1994 study also noted elevated levels of oil and grease in sediments below the site. The MOE-EC 1996 study did not include analysis for oil and grease or polycyclic aromatic hydrocarbons (PAHs) below this site, but sampling upstream, below the confluence of Thompson’s Creek, indicated low concentrations (<LEL) of total PAH in river sediments (Appendix A, Table A-13).

In 1993 Tarandus conducted a sediment and benthic survey of the lower Welland River for the MOE, from upstream of the City of Welland to Chippawa Creek (MOE 1993a). The study found elevated levels of chromium and nickel below the Atlas Steel site and at a number of locations downstream of the Canal By-Pass (Appendix A, Table A-10).

In 1996, a study of the Welland River was initiated by the MOE and Environment Canada. The intent of the study was to identify additional contaminated sediment areas within the river, and as part of this study a number of core samples were collected in the section of the river between Port Robinson and the Power Canal. The results of these analysis are presented in Appendix A, Tables A-11 to A-13.

Five locations sampled between Port Robinson and the Chippawa Power Canal were analysed as part of this project and are identified as stations C3, C4, C10, C11 and C13 in Table A-11 (Appendix A) and on Figure 9. At both sites, three metals were present in sediments at concentrations in excess of the MOE PSQG SEL: nickel, chromium, and iron.

Based on these reviews, the primary compounds of concern in the Welland River appear to be the metals, mainly chromium and nickel, though a number of other metals exceed the MOE LEL guidelines. Other potential compounds of concern include PCBs, which are present at concentrations above the LEL at all sampling sites in the MOE-EC study (Appendix A, Table A-12), as well as PAH compounds (Appendix A, Table A-13). While PAH compounds have been identified as potential concerns below the Ford Glass site, the MOE-EC study did not include a sample below this site. The use of phenolic compounds at upstream sites, such as the Oxy Vinyl (Geon) site, suggest that dioxins and furans (PCDD/PCDF) compounds could also be of concern in Welland River sediments. However, it does not appear that any monitoring has been undertaken for these compounds. Therefore, while relatively recent sediment sampling has been undertaken in the Welland River, the coverage is incomplete, and a number of potential contaminants of concern have not been measured recently.

In summary, a number of industrial facilities have discharged to the Welland River, and could have contributed contaminants to the system. However, a review of the most recent sediment data for the Welland River indicates that most of the exceedances of screening criteria, and therefore, most of the concern, is centred around contaminants that are known to have been discharged from upstream sources in the City of Welland. While nickel and chromium have been identified as the contaminants that most consistently exceed PSQG SELs, concentrations of both these metals are higher upstream of the Welland Canal (Jaagumagi and Bedard 1991; Jaagumagi and Bedard 1994). The pattern of nickel and chromium distribution in sediments suggests that transport of contaminated sediments, likely during high flow events, has moved some of the contaminated sediments downstream, and could account for the pattern of attenuation with distance downstream. Nonetheless, there are indications that the industrial sources east of the Welland Canal have contributed contaminants, since both nickel and chromium have been identified with discharges from the Cytec sites (see discussion in Section 4.2.2).

4.2 Level Two Sites

The sites in this category in general have lower measured levels of contaminants of concern. At many of the sites reviewed the concentrations are typically below the SEL screening level. However, since many of the sites were last sampled in the early 1980’s, there is no recent information upon which management decisions can be based.

4.2.1 Sir Adam Beck Reservoir

The Sir Adam Beck Reservoir was created in the 1940's as part of the expansion of hydro-electric generating capacity in the Niagara Falls area. The Reservoir was constructed with a clay liner, and is fed by a canal system that diverts water from the Welland River, and the Niagara River, by way of Chippawa Creek (as the lower section of the Welland River, below the Power Canal has come to be known). The hydrology of the system is complex, and has been discussed in detail in Section 3.2.

Since flows to the Reservoir are comprised of combined flows from the Welland River and Chippawa Creek, the potential contaminants entering the reservoir include those identified in these watercourses. As well, the Cyanamid (Niagara Falls) plant, which operated from 1907 until it was mothballed in 1992, discharged cooling water and partially treated process waters to the Power Canal (see discussion under Section 4.3.4). A landfill site associated with the Cyanamid operation also drained, via groundwater, to the Power Canal. Finally, the Niagara Falls WPCP discharged to the Power Canal downstream of the inlet to the Reservoir. It should be noted that since only part of the flow from the Power Canal enters the Reservoir, with the rest discharged directly to the Niagara River through the powerhouse, the full contaminant load transported by the Power Canal is not likely to settle out in the Reservoir. A summary of historical sources and monitoring studies is provided in Table 4.2.1.

In 1983, the MOE conducted a study of sediments within the reservoir (Kauss and Post 1987). Figure 11 shows the locations of sampling stations for the 1983 and 1998 (discussed below) sampling programs. The 1983 study found no exceedances of the SEL for any of the compounds, though a large number of metals exceeded the LEL (Appendix A, Table A-3).

In 1998, Environment Canada (Williams *et al.* 2003) conducted a sediment investigation of the Reservoir, re-sampling the locations sampled in 1993. Despite differences in analytical methods (the Environment Canada samples were analysed by a combined extraction with hydrofluoric acid and aqua-regia), concentrations of metals did not differ substantially. While a number of metals exceeded the LEL, no exceedances of the SEL were noted.

4.2.2 Thompson Creek

Cytec Canada operates a plant along the north side of the Welland River, between the Welland Canal and the Chippawa Power Canal. The plant is situated between the Welland River and Thompson's Creek to the north, with discharges from the plant directed to Thompson's Creek. Until 1993, the facility was operated as the Cyanamid Canada Welland Plant, and produced inorganic chemicals, primarily inorganic nitrogen and phosphorus products such as ammonia and dicyanimide (Beak 1994). Records indicate that the plant has been at the present site since 1907. The facility is currently owned by Cytec, which operates the plant as Cytec Specialty Chemicals. The plant produces phosphine compounds and derivatives for use as solvent extraction reagents, chemical and catalyst intermediates, flame retardants, reagents in mineral ore recovery and in pharmaceutical, agricultural and electronics manufacturing.

According to Beak (1994), in 1994 process and cooling water from the plant were discharged to a product recovery system, after which the discharge was routed to settling ponds before being discharged to Thompson's Creek. Given the current and historical uses of chemicals at this site, primary concern would focus on nitrogenous compounds (including ammonia) and cyanide. While both would be expected to have significant water quality concerns if released, these compounds would have substantially less effect in sediment. Nitrogen compounds would be expected to result in an increase in ammonia generation in sediments, as well as promoting organic enrichment, while cyanide undergoes rapid photo-decay and would not be expected to accumulate in sediments. A summary of historical discharges and monitoring activities at this site is included in Table 4.1.2.

Anderson *et al* (1991), in samples collected in 1987, found low concentrations of PAHs in sediments at the mouth of Thompson's Creek (Appendix A, Table A-5). No results were presented for PCBs, organochlorine pesticides or chlorophenols.

Richman (1992) collected a single sediment sample at the mouth of Thompson's Creek in 1989 for analysis of metals, PCBs and organochlorine pesticides, chlorinated benzenes, and PAHs. Only nickel exceeded the SEL (130 μg/g). PCBs were relatively low (285 ng/g), though levels did exceed the LEL (70 ng/g) (Appendix A, Table A-6). PAH compounds, as total PAH, was 2.26

μg/g, which is below the LEL of 4 μg/g. Richman also placed caged mussels at the mouth of the creek in 1989, and only trace levels of the pesticide gamma-BHC were detected in mussel tissues (Appendix A, Table A-8).

A review of water quality data indicates that up until 1991, nickel and chromium were included in Cytec's Certificate of Approval, but were subsequently removed since these were no longer used at the site. Previous concerns at the site have included ammonia toxicity, but in the Beak (1994) study, it was noted that no toxicity was noted in tests for a number of years previously.

Beak (1994) undertook sediment, benthic community and toxicity testing on the site in 1994. Sediment analysis showed that nickel and manganese exceeded the SEL, but only in the deeper sediments (Appendix A, Table A-9). Nickel, chromium and manganese concentrations were higher in the upstream reference than in the surficial sediment layers in the on-site pond, with nickel exceeding the SEL at the upstream reference site. Benthic community analysis found that the benthic community was dominated by chironomids, and the benthic community was typical of relatively slow-flowing fine-grained sediment areas. Beak noted that the benthic community was impaired, based on the low BIOMAP value. However, the presence of a diverse fauna suggests that the benthic community reflects the physical characteristics of the watercourse, and organisms typically considered indicative of unimpaired conditions, such as mayflies and stoneflies, would not be present due to lack of suitable habitat.

The Beak study also found acute toxicity in both reference (control) sediments and the experimentals, suggesting that difficulties with the test procedure could have occurred. Consequently, this data is not considered suitable and is not considered in the overall site evaluation.

Sediment concentrations of chromium and nickel in the deeper sediments in the MOE/EC 1996 survey at C13 could reflect these historic discharges (Appendix A, Table A-11). However, since nickel and chromium in sediments were both lower downstream of Thompson's Creek than upstream, this suggests that the Cytec operation has not been a significant source of these metals to the system. Sampling at the mouth of the creek indicates that while nickel levels were above SEL values, concentrations were lower than in Welland River sediments both upstream and downstream of Thompson's Creek. The relatively low concentrations in Thompson's Creek, compared to existing levels in the Welland River, suggest that elevated levels could be due to upstream identified sources. The primary likely source of these metals is the Atlas Specialty Steel site, where very high levels of both chromium and nickel were present in sediments prior to the 1995 cleanup.

4.2.3 Frenchman's Creek

The Fleet Manufacturing facility in Fort Erie was identified as a potential source of metals to the Niagara River by the Niagara River Toxics Committee (NRTC 1984). In 1996, Fleet became a division of Magellan Aerospace, though the site continued to manufacture aircraft components. In early 2003, Magellan announced a decision to close the operation and transfer production to other facilities, though the facility continued to operate at the time of this study.

Subsequent studies by the MOE have identified additional potential sources in this area, including Canadian Oxy Chemical - Durez Division and Gould National Battery. Both sites are located on a tributary to Frenchman’s Creek, and have in the past discharged to the creek. Figure 12 shows the locations of the major industrial sources, as well as previous monitoring locations. A summary of historical sources and monitoring activities is provided in Table 4.2.2.

Fleet Aerospace produces aircraft components, including wing assemblies, as well as electronic components such as sonar and radar assemblies. The processes include washing of components, degreasing and painting. Bonding agents are commonly used in the assembly process. While the site currently discharges to the municipal sewer, wash water, cooling water, and overspill effluents have, in the past, been discharged to Frenchman’s Creek via a culvert, and water quality monitoring downstream has indicated periodic occurrences of chromium, arsenic, mercury and lead in the effluents. However, there is no record of sediment samples collected below the site. Samples were collected at the mouth of the Creek in 1983 and 1987 (Appendix A, Tables A-1, A-2 and A-5) (NRTC 1984, Hart 1983, Anderson et al 1991), and indicate elevated levels of chromium on one occasion, as well as exceedances of the LEL for a number of metals, including cadmium, copper and nickel.

Therefore, potential contaminants of concern associated with this site would include metals, as well as a range of solvents. The latter are typically soluble compounds, and do not accumulate or persist in sediments. Unlike soils, where spills of solvents can infiltrate the soil and remain on site for extended periods, spills or releases of soluble components to water will not result in contact with sediments, since the spilled materials will solubilize in water and will ultimately volatilise before any contact with sediment can occur. Since direct discharges to Frenchman's Creek were eliminated some years ago, there is little justification for concern regarding persistence of volatile solvents.

Canadian Oxy Chemical - Durez Division operates a facility in Fort Erie (Figure 12) that produces phenol-formaldehyde resins, moulding compounds, furfuryl alcohol-formaldehyde resins and furan resins for use in the automotive industry, among others. The major water use has been for cooling water. Cooling water from the phenol-formaldehyde resin area was recycled through cooling towers, while the distillates from the recycling were stored on-site. These were shipped off-site for disposal or recovery. Non-contact cooling water from other areas of the facility were, in the past, discharged without treatment to Frenchman’s Creek. In 1993 the entire process was closed looped, and there is no further discharge to Frenchman’s Creek.

Sampling by the MOE in 1987 (Anderson et al 1991) (Appendix A, Table A-5) indicated low concentrations of dioxins and furans (as total TEQs) in creek sediments below the CanOxy site that could be related to use of furan resins on the site. Sampling included a single site in Frenchman's Creek and a second sample at the mouth of the creek in the Niagara River. Mussel biomonitoring as part of the same study detected low concentrations of PAHs and some pesticides below the CanOxy site. However, dioxin/furan compounds do not appear to have been analysed for in Frenchman’s Creek since 1987. It is also not known how far downstream dioxin/furan accumulation in the sediments extends. In 1989, the MOE (Richman 1992) found low concentrations of PCBs (285 ng/g) in creek sediments at a single sampling site below the Durez site, but no detectable levels were found in mussels. Mussels at this location accumulated only low concentrations of DDE and some of the PAH compounds (Appendix A, Table A-8). A similar study conducted in 1993 (Richman 1994) again found only low concentrations of DDT metabolites (DDD and DDE) in mussel tissues (samples do not appear to have been analysed for dioxins and furans) (Appendix A, Table A-8).

Gould National Battery is located further upstream on the same tributary as CanOxy (Figure 12), and while the site is removed from the creek, it has in the past discharged to the creek via a ditch. The facility produces lead-acid batteries using lead, antimony, lead oxide and sulphuric acid as raw materials. Process water was used for battery washing, washing of castings and in battery charging areas. The system was closed looped in 1993, but discharged to the creek until 1987 after which the discharge was routed to the WPCP. Currently there are no discharges from this site (MOE 1993b). In 1993, Gould undertook a cleanup of the creek bed to remove lead-contaminated sediments, but there does not appear to have been follow-up monitoring at this site. The extent of possible downstream contamination is also not known However, the past discharges to the creek indicate that metals, specifically lead, would be of primary concern at this site.

Given the number of discharges to the creek, a number of potential contaminants of concern exit. These include metals, such as lead, chromium, and arsenic, as well as organic compounds such as PCBs, PAHs and dioxins and furans. While a number of solvents and degreasers appear to have been used at some of the sites, these typically are soluble compounds and do not persist in sediments, and therefore, residues of these compounds are unlikely to be present in sediments. Since little direct assessment of the creek has been undertaken, the current condition of the sediments in the creek is largely known.

4.3 Level Three Sites

Sites categorised as level three sites, in general, are considered to have relatively low environmental concerns. In many cases, this is based on a lack of direct information on sediment contaminants, though biological monitoring has indicated there may be a concern.

4.3.1 Welland River at Geon

The available data for the Welland River at Geon (currently Oxy Vinyl LP), indicates that sediment contaminant concerns were based on an increase in chironomid mouthpart deformities adjacent to the Geon site, as reported in a study undertaken by Dickman in 1991 (RAP Stage 1 Update). The study was unable to identify whether contaminated sediments, or water quality, was the cause of the increased deformity rate. In subsequent studies, only iron has exceeded the SEL. The Niagara River Toxics Committee, in their 1984 report (NRTC 1984) noted that the Geon plant (identified as the B.F. Goodrich plant), was considered a minor source since pollutants of interest had not been detected in the discharge above cut-off values. A summary of historical sources and monitoring activities at this site is included in Table 4.1.2.

The Oxy Vinyl site (formerly the Geon Canada site and, before that, B.F. Goodrich) is located along the north bank of the Welland River on Thorold Townline Rd., immediately upstream of the Cytec Canada site. The facility produces polyvinyl chloride (PVC) and PCV resins, which are used in the manufacture of automotive trim, piping, wire insulation, window frames and siding for houses.

Water needs are met by pumping from the Welland River (MOE 1993b). The intake of fresh cooling water is reduced through the use of cooling water towers to recycle water. Blowdown is routed through a biological treatment plant, and is re-circulated. Effluent discharge, as of 1993 was 2,500 m3 per day (MOE 1993c).

Prior to 1988, two distinct process were used at the site: an emulsion/polymerization process, and a suspension process. The emulsion process was discontinued in 1991, and the emulsion plant was decommissioned in November of 1991 (MOE 1993b). Due to the age and the process employed, the emulsion plant was identified by the MOE (MOE 1993b) as a greater source of contamination of water. The waste water from the process was steam stripped in three tanks prior to biological treatment. The treated effluent was subsequently sent to an aeration pond and finally to a polishing pond, from which it was discharged to the Welland River. Prior to 1991, wastewater from the suspension process was treated in a distillation column to recover the vinyl chloride monomer after which it was discharged to the aeration pond and polishing lagoon. In 1991, the wastewater system was upgraded. The stabilisation ponds were removed and a second activated sludge unit and a secondary clarifier were added. A gravity sand filter comprised the tertiary treatment system. Sludges generated by the primary and secondary clarifiers were vacuum filtered, with the supernatant routed back to the treatment system, while the filtered cake was disposed on off-site.

Monitoring in 1990 revealed trace levels of arsenic and mercury (well below PWQOs) as well as lead (also below PWQOs) (MOE 1993c). The lead was thought to be due to use of stabilization compounds containing trace amounts of lead in the polymerization unit. Recent monitoring data indicates that lead concentrations have been reduced to acceptable limits.

The primary raw material used on the site is vinyl chloride. Due to the low octanol-water partition coefficient ($\log K_{ow}<2$), most vinyl chloride discharged to the aquatic environment will remain in the water column, where it can be toxic to aquatic life (CCME 1999). Consequently, the primary fate of vinyl chloride in water is volatilization and vinyl chloride is not known to accumulate in sediments.

Sediment samples collected in the Welland River in 1996, downstream of the Geon Canada site showed no increase in either lead or mercury compared to upstream sites (chemical data are presented in Appendix A, Table A-11, while sampling locations are shown on Figure 9). Sediment arsenic concentrations were higher at one site (C10) than at upstream or downstream locations, though levels were still below the MOE SEL (all sites in the Welland River, including sites upstream of the Welland, exceeded the LEL for arsenic). However, since the core sample collected at this site extended to 15 cm, the current surficial concentration may be lower.

4.3.2 Black Creek Mouth

The Black Creek mouth has been included primarily due to slightly elevated levels of arsenic in Niagara River sediments at the mouth of Black Creek in 1983 (Creese 1987). A review of potential sources within the watershed indicated that there were no known industrial discharges to the creek, and the land use within the watershed is primarily agricultural.

Black Creek was recently sampled by the MOE and EC at two locations (D. Milani, Pers Comm, 2003; R. Fletcher, Pers. Comm, 2003) (Appendix A, Table A-15; Figure 13). Arsenic concentrations at both locations in the creek were below detection limits, though the limits were relatively high (5 µg/g). Concentrations of all other parameters were low, though a number of elements exceeded the PSQG LEL. The significance of chromium and copper concentrations in excess of the MOE LEL guidelines is discussed in more detail in Section 6.2.

4.3.3 Pell Creek Mouth

Pell Creek was included in the list of sites for additional consideration on the basis of a sediment sample collected at the mouth of the creek in 1983 (Hart 1986). Copper exceeded the SEL of 110 µg/g, while arsenic, chromium, lead and zinc exceeded the LEL. Solvent extractables (oil and grease) were also well above the MOE criterion of 1500 µg/g in the June 1983 sample.

Pell Creek is a small tributary of Chippawa Creek (Welland River) that joins the creek along the north bank of the river, west of the St Gobain (Norton Ceramics) site. Pell Creek has received discharges from both the Norton Ceramics and Washington Mills Electro Mineral sites, the locations of which are shown on Figure 14. Both sites were reviewed by the MOE (MOE 1993b). A summary of historical sources and monitoring activities in Pell Creek is included in Table 4.3.3.

The Norton Advanced Abrasives facility along the north bank of the Welland River-Chippawa Creek is currently owned by Saint Gobain Ceramics. The plant manufactures a variety of abrasives, including aluminum oxide, dark aluminum oxide, and alumina-zirconia (MOE 1993b). As of 1993, chromic oxide was produced on an infrequent basis. The raw materials used at the site include bauxite, coke, and iron borings. Electric arc furnaces are used to fuse the raw materials and the resulting solid material is then crushed and ground into a granular product. Dark aluminum oxide consists of bauxite, coke and iron borings, while light aluminum oxide has sulphur added during the reduction process, resulting in a higher grade product. Following the crushing stage, the grains are acid slaked and washed with water to remove iron impurities (MOE 1993b).

Cooling water is used for furnace shells, power transformers and for the cooling of moulds. Prior to 1991, contact cooling water, as well as untreated storm water from the northeast border of the site, were treated in a settling basin prior to discharge. These systems were closed looped in 1991, with no subsequent discharge to the Niagara River. As of 1991, (MOE 1993b) only lead was found in the discharge.

Also discharging to Pell Creek is the Washington Mills Electro Minerals plant at the north end of Pell Creek. The plant manufactures abrasive metallic rods including brown and pink alumina, alumina bubbles, ferro-silicon, fused magnesium-chrome and ferro-carbo briquettes from raw materials which include bauxite, coke, iron borings, white alumina, chromic oxide, ferro-silicon, magnesite and chrome ore. The raw materials are fused in electric arc furnaces, and are poured into moulds for cooling. Wastewater consists mainly of contaminated cooling water from the furnace heads and power transformers, which is sent to one of two lagoons for solids reduction and oil and grease removal. Water from the main lagoon is partially re-circulated, while the remaining water is discharged to Pell Creek. The other lagoon receives wastewater from the left side of the plant and discharges to the Stanley Ave CSO (MOE 1993b). Lead is the only compound of concern that has been detected in the effluent.

The above review indicates that a limited number of metals, as well as oil and grease, have been of potential concern at these sites. The abrasives products produced (primarily metal oxides) are typically of very low solubility, and are unlikely to result in toxicological effects on organisms.

In 1989 dredging was undertaken in Chippawa Creek to remove a deposit of coal tar adjacent to the Kane Dock. While the exact source of the deposit is not known, the issue came to light during construction of the Chippawa Power Canal. Prior to remediation, Dickman had noted a higher incidence of mouthpart deformities in chironomid larvae from the site (in Niagara River RAP

1996). Studies after cleanup noted that the incidence of deformities was similar to other, non-contaminated sites.

4.3.4 Chippawa Creek

Chippawa Creek refers to the section of the Welland River from the Power Canal east to the Niagara River. As noted above, a number of industries discharge, either directly or indirectly to Chippawa Creek, including Saint-Gobain Ceramics (formerly Norton Advanced Abrasives), Washington Mills Electro Minerals (WMEM), and Washington Mills (formerly Canada Carborundum).

The inclusion of this site is based primarily on the work of Dickman (in Niagara River RAP 1996), who found an increase in the rate of chironomid deformities in the area of the coal tar contamination. The coal tar site was located adjacent to the Kane dock and was remediated in 1989.

A number of potential sources to Chippawa Creek have previously been discussed under Section 4.3.3 (Pell Creek). In addition to the sources to Pell Creek, which ultimately discharge to Chippawa Creek, the Washington Mills site along the north bank of the creek, as well as part of the Norton and WMEM sites discharge to Chippawa Creek either directly or via storm sewers (mainly the Stanley Ave CSO) (Figure 14). A summary of historical sources and monitoring activities in Chippawa Creek is provided in Table 4.3.3

The potential contaminants from the Norton and WMEM sites have already been noted. The Washington Mills site produces similar products (aluminum oxide and ferro-silicon abrasives), and the discharges would also be similar. As with the other sites, water is used primarily for cooling the furnace shell and melt pots. As of 1991, part of the cooling water was discharged, with the remainder re-circulated. The cooling water discharges to the Stanley Ave CS, from where it drained to Chippawa Creek.

There has been relatively little sampling conducted in Chippawa Creek. In 1993, the MOE commissioned a study (MOE 1993a) on the Welland River that included two locations at the western end of Chippawa Creek. The results are presented in Table A-10 (Appendix A) and show relatively low concentrations of all metals, with no exceedances of the LEL except for a minor exceedance of the cadmium guideline. Benthic community sampling was conducted as part of this study, and while the fauna was dominated by chironomids and oligochaetes, diversity was relatively high. The physical characteristics of this habitat (i.e., very high flows) would favour the presence of burrowing organisms, such as chironomids and oligochaetes, that would reek refuge in the sediments and would not be considered indicative of impaired conditions due to the presence of contaminants.

In summary, while a number of industrial sources have discharged to the Creek, little assessment has been undertaken with respect to sediments in the Creek. The sampling that has been conducted has shown low concentrations of all COCs, and these are likely related to the high flows in the river, which could preclude deposition of particulates, and attached contaminants.

4.3.5 Chippawa Power Canal

The Chippawa Power Canal has been included in the list of potentially contaminated sites as a result of a single sample collected in 1983 (Hart 1986) in which cadmium exceeded the LEL by a minor amount (0.8 μg/g as compared to the LEL of 0.6 μg/g).

The Power Canal exists as two very different segments (Figure 14). The lower section is broad and is similar in width to the Welland River. Approximately 2 km from the start of the Canal at the Welland River, the Canal narrows to a straight, concrete lined channel that flows through the west side of the City of Niagara Falls before turning northeast towards the Sir Adam Beck Reservoir (Figure 11). The Canal flows to the Sir Adam Beck generating stations, but with a connection to the Reservoir. The hydrology of the Welland River-Chippawa Creek-Chippawa Power Canal system is described in more detail in Section 3.2. Flows in the upper section of the canal are high (approximately 14 ft/s or 4.25 m/s (T. van Oostum, Pers. Comm.)), and would preclude the settling of materials in the bottom of the canal. Therefore, only the lower section of the canal would need to be considered with respect to potential for accumulation of contaminated sediments. However, even in this section, flows are in the order of 1 m/s, and would preclude settling of fine-grained materials.

There are no direct discharges to the lower section of the Power Canal, and flows in this section are from combined flows in the Welland River and Chippawa Creek. No landfill sites have been identified in this area and as a result, the only potential sources of contaminants in this section of the Canal would be from suspended sediments and dissolved contaminants transported from sources upstream on the Welland River and Chippawa Creek and from the limited number of storm water ditches that drain to the Canal. These sources have been discussed in Sections 4.1.2 and 4.3.4.

Within the City of Niagara Falls a number of potential sources to the Power Canal have been identified. These include the Cyanamid Niagara Falls plant, which was shut down in 1992, and associated landfill sites, and the Niagara Falls WPCP. Since this section of the canal is channelized, with strong flows that preclude the deposition of materials, contaminants released to the Canal, or transported from upstream sources will be carried to either the Adam Beck Reservoir, or to the Niagara River. A summary of historical sources and monitoring activities in the Power Canal is provided in Table 4.3.2.

The Cyanamid (Niagara Falls) plant is located in the City of Niagara Falls, to the east of the Power Canal (the site is bounded to the west by the Power Canal) (Figure 11). The plant manufactured calcium carbide, calcium cyanide, calcium cyanamide and desulphurization polymers that are used in metallurgical processes. Calcium carbide is used for desulphurizing steel, while calcium cyanide is used in the extraction of gold from gold-bearing ores. Electric arc furnaces were used in the production process, and most of the water use on site was to provide cooling for the furnaces and transformer cables. Contamination of cooling water was primarily due to spills of raw materials and product into storm drains, which drained directly to cooling water channels (MOE 1993b). The MOE review (MOE 1993b) notes that approximately half of all cooling water was discharged directly to the Power Canal, while the remainder was discharged to a cooling pond for re-use within the plant. Overflow from the pond discharges to Whitty's Creek, which drains east to the Niagara River. Monitoring in the 1980's indicates that a number of metals, such as arsenic and lead were detected in the discharges, but did not typically exceed the PWQO. Losses of other materials would primarily be raw materials or products, which, with the exception of cyanide, would be expected to be relatively non-toxic. Calcium carbide, for example, consists simply of Ca and C (created by reacting coke with lime in an electric arc furnace at high temperature), while calcium cyanamide is formed from the reaction of calcium carbide with nitrogen and small quantities of fluorospar. The by-products of these reactions typically include carbon monoxide, oxygen, calcium and carbonate sludge. Of these, only the sludges present potential concerns due to the presence of trace impurities, such as metals. The Cyanamid Niagara Falls plant closed in 1992.

Cyanamid also operated a landfill site in the City of Niagara Falls. The site is located on the east side of the Canal, just to the north of the plant site, and was used for the disposal of cyanide-bearing wastes during construction of the Power Canal in the 1940's. In 1979, the wastes disposed of at most of the sites were removed to ground level (MOE 1991), though subsequent investigation revealed that some wastes had been left on site (approximately 75,000 m3 of process wastes and wasted raw materials).

The site has been relatively well monitored, and the MOE 1991 study indicated that approximately 20 kg/day of cyanide residues were being transported to the Power Canal via groundwater, while a further 5.8 kg/day was being carried to the Niagara River (estimates ranged from a low of 0.4 kg/d to a high of 107.9 kg/day to the Power Canal).

North of the Cyanamid site, on the opposite side of the Power Canal is the Niagara Falls WPCP. Recent monitoring data suggests that the primary compounds of concern were conventional parameters, such as BOD.

Very little sediment or biological sampling has been undertaken in the Chippawa Power Canal, likely due to the high flows that occur in this channel. In 1982, as part of studies in support of the Niagara River Toxics study, two locations at the south end of the Canal were sampled for sediments (Appendix A, Table A-1). The results, which included only metals, were very low for all metals of concern, and indicated only a minor exceedance of the LEL at one location for cadmium (0.8 μg/g compared to the LEL of 0.6 μg/g). In 1983 (Hart 1986) a single sediment station was sampled on two occasions at the base of the Power Canal (i.e., at Chippawa Creek) (Appendix A, Table A-4). The results indicated that again, only cadmium exceeded the LEL by a small amount on one of the sampling occasions. In 1987, the MOE (Anderson *et al* 1991) included a station at the entrance to the Power Canal among the sediment and mussel biomonitoring locations sampled (Appendix A, Table A-5). The sediments were analysed only for PAH compounds, which were below the LEL of the PSQGs.

Sampling by the MOE in 1993 (Richman 1994) yielded trace levels of pp-DDE (3 ppb) in mussels at the mouth of the Welland River (Appendix A, Table A-8). No other organic compounds were detected and no sediment samples were collected as part of the survey.

While the paucity of data for the Chippawa Power Canal indicates that additional sampling of this site would be warranted, the high flows through this area would suggest that there is little opportunity for contaminated materials to accumulate in the Power Canal. The major concerns would relate to discharges to the Canal, which could add to contaminant loads transported to the Reservoir and the Niagara River. The sampling undertaken in the 1980's indicates that sediments are not contaminated, and that the minor exceedance of the LEL for cadmium would not likely result in any adverse effects on biota. Sampling undertaken in the Welland River in 1996 indicates that similar cadmium levels are present in sediments upstream of Welland, and suggests that the trace levels present may be due to natural origins.

The major potential sources to the Power Canal indicate that metals and oil and grease (PAHs) would be the contaminants of primary concern. The manufacture of cyanide compounds within the drainage area does not present a concern regarding sediment contamination, since cyanide is rapidly degraded in sunlight, and would not be expected to persist in sediments. The use of electrical transformer units at some of the facilities suggests that PCB use may also have been an issue in the past. Nonetheless, only very low concentrations were detected in sediments in the Adam Beck Reservoir in 1983 (Kauss & Post 1987).

4.3.6 Niagara River at Queenston

Major sources to the Niagara River at Queenston are those that contribute to the Power Canal, and upstream sources on both the Canadian and U.S. side of the Niagara River.

Upstream sources on the Power Canal include a number of historical sources such as the Cyanamid (Niagara Falls) plant, the Niagara Falls WPCP, a number of landfill sites (Cyanamid Landfill) as well as direct sources to the Niagara River (e.g., CN Landfill) (Figure 11).

The dynamic nature of the Niagara River at Queenston precludes the long-term deposition of sediments except in protected areas. Within the main channel of the river, the sediments that accumulate will typically be transient, and most materials are ultimately carried to Lake Ontario. Therefore, existing contaminant levels in sediments of the Niagara River will reflect current loadings, rather than historical deposition. However, the depositional areas along the banks of the river could accumulate and retain sediments for extended periods of time. The presence of accumulated materials below points of land, and the development of submergent vegetation in these areas suggests that these areas are relatively stable and would be the most likely areas for contaminants to accumulate.

The Welland River is the largest tributary to the system on the Canadian side, and, through the Welland River-Chippawa Creek-Chippawa Power Canal system, can potentially contribute contaminants to the system. Current sources along the Welland River-Chippawa Creek-Chippawa Power Canal system include historically contaminated sediments that are periodically eroded and transported down the Power Canal during high flow events (i.e., when flows have sufficient energy to erode, and transport, contaminated sediments from within the system), and current discharges, such as industrial discharges, storm sewers, and waste water treatment plants.

Historical sediment sampling at Queenston indicates that a small number of parameters exceeded the MOE LEL guidelines. Sampling conducted by the NRTC in the early 1980's, and by the MOE in 1983 (Creese 1987), shows that of the metals, only nickel, cadmium, zinc, iron and mercury exceeded the LELs. (analytical data are provided in Appendix A, Tables A-1, A-2 and A-4; locations of sampling points are shown on Figures 15 and 16). For all of these metals, the exceedances were only marginally above the LEL. A small number of organic parameters also exceeded the LEL of the PSQGs, and included PCBs, mirex and hexachlorobenzene (HCB). Both mirex and HCB likely originate along the U.S. side since there are no documented sources along the watersheds studied as part of this project.

Potential upstream historical sources in the Welland River system include the metals nickel, chromium and mercury. A review of toxic chemical loadings to the Welland River (MOE 1993) indicates that a number of sites have significantly reduced their loads of these metals. For example, Geon, by 1991, has reduced it's loading of mercury by 96.7 %. A recent study conducted for Environment Canada indicates that mercury loading to the Niagara River have decreased significantly since 1986 (Holland 1996).

Sources on the Canadian side include those within the City of Niagara Falls. The CNR site has been identified as a potential discharge to the Niagara River. The site has been used since the late 1960's for the disposal of car cleaning wastes, including scrap metal and wood, foundry magnets, paper, lube pads, and some domestic wastes (MOE 1991). The organic materials were apparently burned on a regular basis, such that only inorganic wastes remained. The site was covered with a 1m clay cap in 1981.

Groundwater monitoring at the site indicates that groundwater flow is eastwards to the Niagara River. Due to limited data, only a single estimate of loadings was calculated, which indicated that approximately 0.9 kg/day of trace metals was being transported to the Niagara River. The metals concerned were not identified (MOE 1991).

In summary, the potential contaminants of concern within the Niagara River include a number of metals, PCBs, and PAHs.

4.3.7 Niagara River at Niagara-on-the-Lake

The potential for sediments to accumulate at the mouth of the Niagara River is determined by two factors: the flow of the river, which at this point broadens out to flow across a rocky shelf, and the action of waves from Lake Ontario, that will continually re-distribute materials. As such, there are very limited areas where sediments could accumulate, and contaminant issues could exist. These are primarily adjacent to structures built into the river, such as docks and piers, that intercept river flow and create quiescent areas.

The Niagara River at Niagara-on-the-Lake was identified as a potential concern due to the detection of mercury in sediments above the LEL in 1983 (Creese 1987). At two of the locations sampled, mercury was marginally above the LEL of 0.2 μg/g (Appendix A, Table A-2). A review of the data indicates that levels of HCB and PCBs were also in excess of the LEL.

No direct discharges to the Niagara River occur at Niagara-on-the-Lake. Rather, contaminated sediments appear to be deposited in this area from upstream sources, and occur primarily where backeddies favour the deposition of materials. As noted earlier, a number of potential sources occur within the Niagara River watershed. For example, Richman (1992) detected elevated levels of HCB in mussels at the Pettit Flume and Bloody Run Creek, while PCBs were detected in mussels at Pettit Flume.

In addition to the compounds identified in the NRTC study, a survey by MOE in 1993 (Richman 1994) found high levels of dioxins and furans in sediments at the mouth of the Niagara River (Appendix A, Table A-7). Total TEQs were 14.8 pg/g, and, while lower than the CCME PEL guideline of 21.5 pg/g TEQ for sediment, may represent a potential concern.

5.0 PHASE II STUDIES

Based on the review of exiting conditions at the identified sites undertaken in Section 4, a study plan to update the information was developed and implemented in November, 2003. The rationale for the studies at each of the sites is described in this section. The need for additional information was based on the historical and current concerns at each of the sites with respect to the types of compounds used and produced at each site, the types of discharges, and the amount of existing information on sediment contaminants. It also considered the existing physical conditions, including flow velocity.

A summary of the sampling sites and the analyses conducted under this Phase are presented in Table 5.1.1. Sampling locations are shown on the individual site maps and are referred to in the appropriate discussion. Analytical results are presented in Table 5.1.2 (metals, nutrients and PCBs), Table 5.1.3 (PAH compounds) and Table 5.1.4 (dioxins and furans). In many cases, the sampling sites selected for this study were not the same as those sampled in previous studies. The selection of sampling sites for the individual study areas was based on the review of discharges, and the likely areas where sediments could accumulate, given the flow patterns in the waterbodies. This resulted in the identification of discharge points that had not been sampled previously, as well as likely sediment accumulation areas that in many cases were modified from the original plan once actual conditions could be assessed in the field.

Since all of the field work was conducted in a single trip, samples were kept in coolers until the field work was completed. Samples were submitted to Philip Services Inc. in Mississauga within one working day of completion of the field work.

5.1 Level One Sites

5.1.1 Lyon's Creek West

Previous studies in Lyon's Creek have indicated the presence of PCBs in soils and sediments at concentrations that in some cases exceed the MOE hazardous waste criterion of 50 ppm. Therefore, additional sampling in Lyon's Creek West and the wetland area was focussed on PCBs. A total of 15 sampling stations were sampled and the locations of these are shown on Figure 7. A description of the sites, the types of samples collected, and the chemical analyses conducted are provided in Table 5.1.1. Since analysis for metals does not appear to have been included in previous studies, the current sampling program included analysis for a suite of metals at a selected number of locations.

Most of the sites selected were those where, in previous studies, the highest concentrations of PCBs were noted and sampling stations were distributed relative to the potential sources. Sediment and soil sampling was focused on addressing surficial contamination and therefore, sampling depth was restricted to the top 5 cm since this is the sediment layer to which most organisms would be expected to be exposed. However, the penetration of the deeper soil horizons by wetland plant roots, and uptake of PCBs by vegetation could be a potential concern, and therefore, at two of the sites cores were collected. These were sectioned into 5 cm sections to a depth of 15 cm (0-5 cm, 5-10 cm, 10-15 cm), and each section was analysed separately for PCBs. The results provide an indication of the distribution of PCBs across the site and will assist in the evaluation of exposure of plants and animals to potentially adverse levels of PCBs.

Samples were taken from surficial sediments within a 0.5m by 0.5m square area of substrate. Samples were collected by stainless steel spoon into a stainless steel mixing bowl and were mixed (homogenized) until a consistent colour was obtained. A subsample of the homogenate was collected into containers for submission to Philip Services Inc., in Mississauga. Core samples were collected as single cores with a Benthos Gravity-type corer fitted with a 5 cm diameter Plexiglas tube. Samples were sectioned into 5 cm sections, homogenised, and placed in sample containers for analysis. Samples were collected on November 7, 2003 for PCBs at all sites, and metals at stations LC-6 and LC-8. Additional samples for metals analysis were collected at stations LC-1, LC-2, LC-9, LC-10, LC-12 and LC-13 on November 25, 2003 since the results of the initial sediment samples indicted elevated levels of some metals, and identified the need for additional characterization of the area for metals distribution.

While the toxicity of PCBs depends on the presence of toxic congeners (those that structurally resemble dioxins typically are considered the most toxic), the current round of sampling for the Phase II assessment focused on the distribution of PCBs in the creek and wetland as total PCBs. Additional sampling in Phase III will likely include congener-specific analysis.

5.1.2 Welland River from Pt Robinson to the Chippawa Power Canal

The review of existing sediment conditions in the Welland River downstream of the new Welland Canal conducted in Section 4.1.2 was based primarily on data collected by Environment Canada and MOE in a joint study undertaken in 1996. The study noted that both nickel and chromium exceeded the SEL at all sites sampled between the Welland Canal and the Chippawa Power Canal.

The RAP Stage 1 Update identifies the major concerns within this section of the Welland River as relating to the operation of the Ford Glass plant, located near the junction of the Power Canal. However, a review of the issues related to this site indicate that some of the metals of concern may be associated with upstream sources. Similar issues exist around the other sites identified in this stretch of the river, particularly with respect to the Oxy Vinyl (Geon) and Cytec sites. Therefore, the sampling plan developed for the Welland River was designed to provide additional background data for each of these sites, such that the effects of the plants, and the need for additional assessment, could be assessed in the context of the entire river, including upstream effects.

The MOE PSQGs note that where sediment concentrations of a contaminant exceed the SEL, there is a potential for adverse effects on benthic organisms. These are likely to be the most sensitive organisms, since they are in direct contact with the contaminated sediments. Given the small number of locations sampled, better characterization of the sediments in this stretch of the Welland River was considered to be warranted. The MOE-EC study conducted in 1996 included only three locations in the river: Moyers Rd bridge, adjacent to Cytec Canada, and at Thompson's Creek. It is also not clear from the data precisely where in the river the samples were collected. Therefore, additional sampling was conducted at 11 stations within the river in November 2003. It should be noted that these locations also address three of the other sites of concern on the Welland River: the Geon Canada (currently Oxy Vinyl) site, the Cytec Canada site and the Ford Glass site. Of the proposed 11 sampling locations, 10 are in the Welland River, while one is located at the mouth of Thompson’s Creek. Details on the sampling sites are provided in Table 5.1.1.

Since the accumulation of contaminants in sediments depends on the accumulation of fine-grained sediments, the selection of sampling sites needed to address the variations in deposition of sediments that are typical of large, relatively slow flowing rivers. The main channels of most larger watercourses have little sediment deposition due to scour by erosive flows. Most fine-grained materials are deposited in shallower, slower-flowing areas at the margins of these rivers. In particular, protected areas, such as those on the inside curves of river meanders, and areas within embayments, tend to accumulate sediments, at least on a temporary basis and are the most likely areas where contaminated sediments could accumulate. Previous studies conducted by the MOE in the Otonabee River (Jaagumagi *et al* 1997) and the Porcupine River (Jaagumagi and Bedard 2001) found much higher contaminant concentrations in sediments at the margins of large watercourses, than in sediments in the main channel. Therefore, each of the sampling sites in the Welland River, with the exception of the sample in Thompson's Creek, consisted of a transect perpendicular to the river, with three sampling points on the transect:

- Near the north or west bank (identified with the suffix N in the figures and tables);
- The approximate middle of the river (identified with the suffix M in the figures and tables); and
- Near the south or east bank of the river (identified with the suffix S in the figures and tables).

This permitted assessment of contaminant distribution in depositional areas along both banks of the river as well as comparison with concentrations in the scoured main channel. The locations of the sites are shown on Figure 9. Composite sediment samples were collected with a Petit Ponar at all locations and consisted of three separate grabs at each location. The top 5 cm from each grab was combined to provide a single composite sample with care being taken to ensure that an equal volume of material was removed from each of the replicates. The sample was homogenised until a consistent colour was obtained, and subsamples were collected into each container for laboratory analysis. The number of containers varied depending on the types of analyses required at each location. Samples were collected on November 3rd and 4th, 2003, and kept cold in coolers until submitted to Philip Services Inc in Mississauga on November 10th, 2003.

The review of previous sampling data indicated that the primary contaminants of concern along this stretch were the heavy metals. Therefore, analysis included a full suite of metals, as well as nutrients such as TOC and TKN. Since levels of PCBs have exceeded the LEL in previous studies, PCBs were also included in the suite of analyses. The relative paucity of data relating to PAH contamination indicated that a number of sampling sites should also include analysis for PAH compounds and therefore, at 6 of the locations (Table 5.1.1), sediment samples were also collected for PAH analysis, including stations immediately downstream of the current and historical industrial sources. Additional parameters related to specific industrial sites along this stretch of the river (e.g., Geon, Cytec) are addressed in those sections.

The use of phenolic compounds at the Oxy Vinyl (Geon) site, and possibly other sites as well, indicated that dioxin and furan compounds could be of concern in sediments. Since these have not been investigated in previous studies, analysis for these compounds was included at a total of 5 sites in the Welland River. The locations sampled are presented in Table 5.1.1.

5.2 Level Two Sites

5.2.1 Sir Adam Beck Reservoir

Given the relatively low levels of most contaminants in reservoir sediments in previous studies, and the recent data collected by Environment Canada, additional sampling was not undertaken in the Reservoir. The assessment of current sediment conditions undertaken in Section 6 is based on existing information.

5.2.2 Thompson's Creek

Sampling in the Welland River, adjacent to and downstream of, the Cytec Canada site has been described in Section 5.1.2. In addition to the sampling sites proposed in the Welland River, a single sampling site was located at the mouth of Thompson's Creek. Previous sampling on the site by Beak (1994) has indicated that there are minor concerns with some of the heavy metals, which have exceeded the LELs on site. Therefore, the sample was analysed for a suite of metals as well as nutrients. Sampling by the MOE in 1989 indicated low concentrations of PAH compounds in sediments at the mouth of Thompson's Creek (Richman 1992), and additional analysis for PAH compounds therefore did not appear to be warranted. However, since the MOE samples indicated the presence of PCBs at levels above the LEL, analysis for PCBs was included.

The single sample at the mouth of Thompson's Creek was collected using a Petit Ponar. Three separate grab samples were collected and a subsample of the top 5cm was removed from each sample. These were combined in a stainless steel mixing bowl, and homogenised until uniform colour was achieved. Subsamples were collected into appropriate containers for analysis by Philip Services Inc., in Mississauga. Samples were collected on November 4th and kept in coolers until submitted to the lab on November 10, 2003.

5.2.3 Frenchman's Creek

The results of previous studies in Frenchman's Creek are relatively sparse. Previous sampling was been focused at the mouth of the Creek in the Niagara River, and therefore the results are more indicative of conditions in the Niagara River than Frenchman's Creek.

A total of 8 locations (including an upstream control) within the Frenchman's Creek watershed were sampled and are shown on Figure 12. Details on sampling sites are presented in Table 5.1.1. The selected sites included the mouth of the Creek as well as an upstream location to serve as an ambient background location for the creek (below the QEW). A number of industrial sites have been identified along the creek that could be of potential concern, and include the Fleet Aerospace site, the CanOxy Thermoset Division, and the Gould Manufacturing site. In addition, a downstream site below the CN Rail yards was also sampled.

The history of the Fleet Aerospace site indicates that there is a potential for use of solvents on site, such as degreasers, chemical cleaning agents, and paint compounds. Past monitoring has also indicated the presence of some heavy metals, such as arsenic, mercury and lead. Previous monitoring by the MOE (Anderson *et al* 1991) indicated the presence of dioxin and furan compounds below the Thermoset site. As well, the use of phenol-formaldehyde resins on site and the production of furan resins, indicates that this group of compounds should be included in the analyses. The history of operations at the Gould site indicates that lead has historically been a concern. While the area below the site did undergo remediation, there does not appear to have been any verification studies since cleanup was undertaken.

Therefore, sampling in Frenchman's Creek included:

- Heavy metals at all sites
- Dioxins and furans at selected sites,
- PCBs at all sites.

Since little previous sampling has been undertaken in the creek, the sampling plan included three locations where core samples would be collected. However, the substrates in the creek precluded collection of cores except at one site near the mouth, where cores up to 25cm were obtained. The cores were collected with a modified Benthos Gravity Corer. Samples at the other sites were collected either by hand or with a Petit Ponar. In the upper sections of the creek, gravel substrates precluded use of the Ponar, and samples were collected by hand from areas where fine-grained material had accumulated. Sampling was contained within a 1m by 1m area, and samples were collected to a maximum depth of 5 cm. Ponar samples and cores were collected as three replicates that were subsampled to form a single composite sample. In the case of the core samples, similar sections were combined to create a composite. The composite samples were homogenised and subsamples of the homogenate were placed in sample containers. Samples were collected on November 6, 2003, and maintained in coolers until submitted to Philip Services Inc., on November 10, 2003.

5.3 Level Three Sites

5.3.1 Welland River at Oxy Vinyl (Geon)

The sampling plan undertaken for this site is included in the sampling plan for the Welland River (Section 5.1.2). Additional details that relate specifically to the Oxy Vinyl site are provided below.

The use of chlorinated ethanes for the production of vinyl chloride is not expected to result in residues of organic compounds in sediments due to the low persistence of these compounds, and volatilization is the typical environmental fate in the aqueous environment. These compounds are not known to persist in sediments, and therefore, were not included in the sampling program. The previously identified issues at this site include arsenic and lead, and sediment sampling at and below the Geon site therefore included a suite of metals, as well as PCBs (as noted earlier in Section 5.1.2) and PAHs. Samples were collected as part of the Welland River component, and methods for sample collection are described in Section 5.1.1. Sampling locations are shown on Figure 9.

5.3.2 Black Creek Mouth

Black Creek has been included in the list of potential sites primarily on the basis of a single sample collected at the mouth of the creek in 1983. This sample appears to have been collected in the Niagara River, and not in the creek itself. A review of potential sources in this watershed indicated that most of the land use was agricultural, and no specific industrial sources have been identified. Recent sampling of the creek by MOE and Environment Canada has indicated that concentrations of metals and organic compounds are low. As a result of the recent sampling, additional sampling was not undertaken in Black Creek.

5.3.3 Pell Creek Mouth

The single sample collected at the mouth of Pell Creek in 1983 showed copper present at levels above the SEL. A review of the industries within the Pell Creek watershed indicates that both the St Gobain (Norton) and Washington Mills Electro Minerals sites have, in the past, discharged to Pell Creek, and suggests that a number of metals as well as PAHs could be of concern in creek sediments. Since there is no record of samples collected from within Pell Creek, 2 locations were sampled within the creek. The upper portion of the creek has been recently modified, and the channel now runs underground until the Saint-Gobain property boundary and as a result, sampling commenced below this point and extended to near the mouth of the creek. (The sample locations are shown on Figure 14). Concerns at this site centred around potential erosion, and subsequent transport to Chippawa Creek, of any contaminated sediments within this small watershed.

Samples were collected by hand using a stainless steel spoon and consisted of small areas of fine-grained sediments within the rocky substrate of the stream. Sample depth was restricted to the top 5 cm, and consisted of a number of scoops that were combined in a stainless steel mixing bowl until sufficient volume of material was obtained. The sample was homogenised, and the homogenate collected into sample containers for analysis. Samples were collected on November 4, 2003, and maintained in coolers until submitted to Philip Services Inc., on November 10, 2003.

The types of industries present within the watershed indicates that metals and nutrients, PAHs and also PCBs (due to potential use in high temperature fluids) were the most suitable parameters to include in the analysis.

5.3.4 Chippawa Creek

The location of a number of industries at the south end of the City of Niagara Falls that could have contributed to contamination of sediments in the Chippawa Creek section of the Welland River indicated that additional sampling in the Creek would be warranted. As well, the previous coal tar cleanup indicated a need to assess current conditions with respect to sediment PAH concentrations.

The operation of the abrasives plants located along the north bank of the creek indicated that metals and PAH compounds would be the primary concern in sediments along this section of the creek. Previous sampling has not included PCB compounds, but these were often components of high temperature fluids (transformers, hydraulic equipment) prior to the banning of PCBs, and therefore residues may persist in these sediments.

A total of 6 locations were proposed for sediment sampling in Chippawa Creek and like the sampling program proposed in the Welland River upstream of the Power Canal, each sampling location consisted of a transect, with three sampling locations along the transect: near the north bank, in the middle of the channel, and near the south bank. However, of the 6 locations proposed, samples could not be obtained at a number of locations since high flows precluded the deposition of sediments in these areas. (The locations where hard substrates precluded collection of samples are noted on Table 5.1.1). The sampling locations where samples were obtained included the mouth of Pell Creek and the Stanley CSO (both Washington Mills and WM Electro Minerals have discharged part to the Stanley CSO) and are shown on Figure 14.

Samples were collected using a Petit Ponar grab, and consisted of three replicates at each location that were combined to form a single composite sample. At each location a subsample of the top 5 cm of each grab was collected into a stainless steel mixing bowl. The sample was homogenised until a uniform colour was obtained and a subsample of the homogenate was collected into sample container and kept in coolers until submitted to the laboratory for analysis.

Analysis included a suite of metals and nutrients, PAHs and PCBs. There was no indication that other organic compounds would be a concern, due to the nature of the industries located along this section of the river.

5.3.5 Chippawa Power Canal

The historical data for the Power Canal consists of two sediment samples collected in 1981 as part of the NRTC study. The sediment samples indicate that there were no concerns due to exceedance of SELs, and there were only minor exceedances of LELs for a few compounds. As well, the high flows through the Canal would preclude deposition of sediments in the main channel.

While there are no identified industrial sources to the Power Canal in the lower section of the Canal, a number of ditches and storm sewers discharge to the canal. Therefore, the most likely influences are current storm sewers and ditches, and transport of contaminated materials from upstream sources. The data for the Welland River indicates that chromium and nickel for example have been transported significant distances from their presumed sources, and in all likelihood, some of this material will have been transported to the Power Canal. It is recognised that most of this material is unlikely to settle in the canal, due to the significant flow velocities. Consequently, 3 locations where storm water ditches enter the Canal, and could transport contaminants to the Canal were sampled, and these are shown on Figure 14. Analysis included metals, nutrients, PCBs and PAH compounds.

Samples were collected by hand using a stainless steel spoon from depositional areas either in the drainage ditches leading to the canal or at the margins of the canal. Samples consisted of a number of scoops using a stainless steel spoon which were then homogenised in a stainless steel bowl. A subsample of the homogenate was collected into sample containers. Samples were collected on November 5, 2003, and were kept in cooler until submitted to Philip Service Inc., on November 10, 2003.

A number of potential sources, many of them historical, exist at the upper end of the Power Canal, near the north end of the City of Niagara Falls. These include the Cyanamid Niagara Falls plant and associated landfill, and the Niagara Fall WPCP. However, due to the narrow width of the Power Canal in this section and the strong flows (>4 m/s), deposition of materials was considered unlikely, and any discharges to the Power Canal would end up either deposited in the Sir Adam Beck reservoir, or carried to the Niagara River. As a result, there was no identified benefit to sampling in the upper section of the Power Canal. Any contaminants from local industries should appear as elevated concentrations in Sir Adam Beck Reservoir while materials that are carried to the Niagara River would be carried with the high flows in the river to Lake Ontario, and would be deposited in the lake. Materials in the Niagara River that are deposited near shore would be assessed as part of the sampling program on the Lower Niagara River (Section 5.3.6).

5.3.6 Niagara River at Queenston

As noted above, a number of potential sources, most of them historical, have been identified along the Power Canal. These have potential to affect sediment quality in the Niagara River and more likely, Lake Ontario. Direct sources to the Niagara River have also been noted, such as landfill sites in the City of Niagara Falls, where groundwater flow is likely to transport any leachable contaminants east to the Niagara River. As well, there are a number of identified sources of contaminants on the New York side, that, due to highly turbulent flows, could be distributed across the river, and be deposited in quiescent areas on the Canadian side.

Previous studies in the river have noted the lack of deposited materials in the river except for protected areas near shore. The river scour is likely to prevent deposition of materials throughout the lower river, and previous sampling has indicated that only in protected areas, such as in embayments, would materials collect. These are also likely to be temporary in nature and could be flushed during unusually high flows.

The low concentrations of most potential contaminants recorded in the NRTC studies and that of Creese (1983) indicate that minor exceedances of some of the metals have occurred in this section of the River.

Therefore, an additional 4 sampling locations, near the Canadian shore of the river, from Queenston to Niagara-on-the-Lake were sampled (Figure 15). Sampling included analysis for metals, PCBs (since these exceeded the LEL in 1979 and 1983 samples) and dioxins and furans (see discussion below in Section 5.3.7).

Samples were collected using a Petit Ponar grab, and consisted of three replicate samples. A subsample of the top 5 cm was removed from each replicate with a stainless steel spoon, and these were combined in a stainless steel mixing bowl. Care was taken to ensure that equal volumes of material were subsampled from each replicate. The composite samples were homogenised until a uniform colour and consistency were obtained, and subsamples of the homogenate were collected into sample containers for analysis. Samples were collected on November 5, 2003, and maintained in coolers until submitted to Philip Services Inc., on November 10, 2003.

5.3.7 Niagara River at Niagara-on-the-Lake

Previous sampling at Niagara-on-the-Lake has indicated that localized, depositional areas near the mouth of the Niagara River have on occasion accumulated elevated levels of some compounds. In particular, the samples collected by the MOE in 1993 (Richman 1993) indicated moderately elevated levels of dioxins and furans, with total TEQ of 14.8 ppt.

Sampling in the early 1980's (Creese 1987) indicates that a number of metals exceeded the LEL, while mercury exceeded the SEL at one location on one sampling occasion. A number of organic compounds, primarily pesticide residues as well as HCB, also exceeded the LEL on at least one sampling location. The variability in results for the same sampling locations indicates that much of the material exists either in small isolated pockets where flows are sufficiently quiescent during at least part of the year to permit deposition of sediments or that the areas where deposition occur are also periodically scoured. Most likely it is a combination of the two forces. Nonetheless, given the previous sampling results, and the lack of more recent data for this area, additional sampling was undertaken on the Canadian side of the river at the Town of Niagara-on-the-Lake.

A total of 2 locations yielded sediments, and only one of these was retained for analysis (the other sample consisted entirely of sand). The analytical parameters included metals and nutrients, PCBs, and dioxins and furans (Figure 16). Details are provided in Table 5.1.1. Samples were collected as part of the sampling in the Niagara River and follow the methods described in Section 5.3.6.

6.0 PHASE II SITE ASSESSMENTS

The results of the additional sampling at the sites, as noted in Section 5, are described in this section and the COCs are identified, or in many cases, confirmed, and the potential effects evaluated. A detailed list of the locations sampled is provided in Table 5.1.1.

6.1 Compounds of Concern

Several chemicals of concern (COCs) have been identified at the sites contained within the Niagara River Area of Concern. While several of the inorganic contaminants are necessary at trace concentrations for adequate biological function, exposure to elevated concentrations of essential and non-essential elements may be toxic. Other COCs, such as persistent organic contaminants, are anthropogenic in origin and have no inherent biological value. As a result, the potential toxicological impacts to aquatic biota from direct exposure to inorganic (arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn)) and organic COCs (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs)) were considered in order to assess the potential risks to the environment, and where appropriate, to human health.

6.1.1 Mechanisms of Toxicity

In order for a contaminant to be toxic to biota there needs to be a pathway by which the organism is exposed to the contaminant. Typically, this is considered as simple exposure through residence in a pathway. However, there are a number of mechanisms that control availability of contaminants in aqueous media that can limit exposure. For metals, the most important appears to be the presence of free ions, since these have usually been considered as the most biologically reactive forms (Rand and Petrocelli, 1985). However, even in the aqueous environment, there are factors such as pH and the presence of other ligands that can control the amount of free ions (Stumm and Morgan 1981). The latter includes dissolved substances in the water column that can form complexes with metal ions, thereby reducing the availability of the metal. These are comprised mainly of organic molecules, such as dissolved organic carbon (DOC) as well as humic and fulvic acids (Martino *et al.* 2003; Rand and Petrocelli, 1985). Therefore, the concentration of a metal in water cannot be considered as the actual amount of metal that will be available to biota, with the result that criteria based on water concentrations of compounds can be overly conservative, particularly in those cases where significant quantities of these ligands may be present in the water column.

Since it has been shown by a number of authors (e.g., Campbell *et al.* 1988; Luoma 1983) that metal availability to biota depends on the free ionic form, the factors that control the presence or release of free metal ions in effect control the bioavailability and hence toxicity of metals (i.e., the metals have to be available in order to be toxic). As a result, metals bound to sediments are typically much less bioavailable (Tessier and Campbell 1987). A number of constituents in sediments have been identified as controlling availability, with the primary ones including organic carbon, sulphides, iron and manganese hydroxides, and carbonates (Tessier *et al.* 1984). The importance of these factors depends, in turn, on other environmental conditions, with pH and redox typically the most important (Mok and Wai 1990).

The behaviour of metals, and their complexation with ligands, in large measure explains the apparent anomaly in many of the studies reviewed in this section: the presence of high concentrations of metals, often well in excess of available criteria, and the concurrent lack of biological effects. Thus, while potential pathways of exposure may exist for aquatic organisms (and terrestrial organisms that feed upon them) there are factors that limit the availability from sediments. As such, the bulk sediment concentration of a metal is not a particularly useful guide to the potential biological effects and often, the effects levels are much higher than predicted on the basis of conservative criteria (Hart and Andrews 1991). As such, the development of criteria to protect against adverse biological effects due to contaminants in sediments should be based on measured biological impacts, rather than bulk sediment concentrations that may be unreflective of the actual availability of the metals.

Under oxic conditions, most of the metals of concern within the present study area, such as chromium, copper, nickel, zinc and cadmium, as well as the metalloid arsenic, are bound to iron and manganese complexes (hydroxides and oxides). The ability of iron and manganese hydroxides to scavenge other metals and effectively bind them within the hydroxide shell of the molecule has been shown in many instances (e.g., Forstner and Witmann 1981; Forstner 1990). In most surficial sediments, the zone of oxygen penetration of the sediment is confined to the top 2 or 3 cm, and it is within this zone that the solubility of metals is controlled primarily by Fe and Mn hydroxides.

Below this level, oxygen concentrations in sediment decrease rapidly, a reducing environment develops within a few centimetres of the sediment surface and under reducing (anoxic) conditions, the iron and manganese hydroxides undergo reductive dissolution. As a result, the iron, manganese and other bound metals are released to the pore water as the oxygen is consumed. In sulphide-rich sediments, these metals are usually quickly bound up in metal sulphide complexes which, in undisturbed conditions, are very stable.

Under reducing conditions, most metals such as copper, nickel and zinc tend to form insoluble complexes with sulphide. While arsenic does as well, Messcheleyn *et al.* (1991) found that up to 51% of total arsenic was still soluble, and noted that, in general, arsenic solubility increased substantially upon reduction. They further note that upon reduction the arsenic changes from arsenate (As (V)), which is the predominant form under oxic conditions, to arsenite (As (III)). The latter has been shown to be the more toxic form of arsenic (since arsenic is similar chemically to phosphorus and sulphur, it can replace these elements in essential metabolic processes). Left undisturbed, these are very stable complexes and little metal is cycled back into the environment. The result is that little free metal ion is available in these environments, relative to the bulk sediment concentration of metals.

Therefore, under stable redox conditions, the solubility of most metals, and hence the biological availability, appears to be low and is controlled primarily by the Fe/Mn hydroxides under oxic conditions, and by sulphide under anoxic conditions. The major releases of metals appear to occur with changes in redox, i.e., when conditions change from oxidised to reducing or vice versa. Since toxicity is determined by the availability of free metal ions, it is those changes, such as alteration of redox conditions, that result in release of free ions into the pore water that appear to have the most significant biological consequences. It is also for this reason that bioassay tests can be considered as worst-case simulations, since the preparation of the sediment for testing results in alteration of existing redox conditions with subsequent release of metals before new complexes form.

The other major environmental factor controlling metal binding is pH (Stumm and Morgan 1981). Different metal-ligand complexes are favoured under different pH conditions. With most metals, the presence of the free ionic form increases under low pH, with the result that changes in pH can result in the dissolution of some metal-ligand complexes and the formation of new ones. This has important implications for organisms, both in the amount of free ion available in the water column, and in the ability of organisms to extract metals through ingestion. Since the gut pH of most invertebrates has been shown to be between pH 6 and 7 (Luoma 1983), metals ingested as part of a metal-ligand complex would not likely be present in the gut in the free ion form.

Thus, for most organisms the major exposure pathway for metals would be the solubilized (free ionic) form, which, as noted above, is controlled by the presence of other complexing ligands. Ingestion, while important in some cases, typically appears to be a minor pathway, again due mainly to the strength of binding to sediment organic and mineral constituents.

The behaviour of organic compounds in sediments is often much simpler than metal behaviour (Knezovitch *et al.* 1987). Most organic compounds will dissociate in water to form ionic compounds. Only those compounds that exist as non-polar (i.e., lacking a charge) are stable enough to persist in aquatic environments without undergoing dissolution. However, even non-polar compounds typically have weak charges (van der Waals forces), and through this type of electrostatic bonding (partitioning) will form complexes with sediment constituents (Smith *et al* 1988). As a result, most persistent organic compounds are also sparingly soluble in water, but will solubilize in organic solvents, typically through the formation of the electrostatic bonding noted above. Thus, usually very little is available as a free form and most of the compounds will be present complexed to organic constituents (mainly organic carbon). This is the major factor that limits the availability of these compounds in aquatic environments and accounts for the very low concentrations typically encountered in surface waters relative to sediment.

Due to this chemical binding or partitioning, these compounds also exhibit a strong preference for other sources of organic carbon, such as organism tissue, particularly lipids (Smith *et al.* 1988) and most accumulation in organisms is into lipids. Since the water solubility of these compounds is very low and concentrations in water are negligible compared to sediments, for most organisms, the major exposure pathways would be through ingestion. This also accounts for the ability of these compounds to biomagnify through the food chain.

Natural levels of trace elements are present due to biogeochemical cycling, but may occur at elevated levels due to anthropogenic activity. Concern for the potential biological effects of essential and non-essential elements to aquatic flora and fauna has resulted in a large body of research on the subject. Brief synopses of the relevant toxicological information for the identified COCs are provided below.

Arsenic

Arsenic occurs in the aquatic environment primarily in two oxidation states; arsenite (trivalent, III) and arsenate (pentavalent, V). Arsenic is a hazardous element and toxicity may appear even when biota are exposed to trace concentrations via ingestion or direct uptake across membranes (e.g. gill surfaces). The toxic effects are mediated through the trivalent (arsenite) form. Pentavalent arsenic (arsenate) forms are believed to be reduced to trivalent forms in vivo (Thomas et al., 2001). The main mode of arsenic toxicity is inhibition of enzyme activity by binding to the sulfhydryl groups (-SH) which inhibit succinic dehydrogenase activity and thereby uncoupling oxidative phosphorylation (Ellenhorn and Barceloux 1988; Goyer 1996). Arsenic is also substituted for phosphorus in the oxidative phosphorylation chain, further increasing the loss of production of high-energy phosphate bonds in ATP, which causes widespread multisystem effects (Thomas et al., 2001).

Chromium

Chromium concentrations in the analytical data for this report were assessed as total chromium, which contains a combination of trivalent (Cr(III)) and hexavalent chromium (Cr(VI)). Trivalent chromium is considered to be a nutritionally essential trace element in the human diet (Goyer 1996), and likely other organisms as well. Though trivalent chromium is the predominant form in soils and sediments, it is not readily bioavailable. Hexavalent chromium primarily exists in aerobic media such as surface waters, and is more bioavailable than the trivalent species (Health Canada 1994). Hexavalent chromium can be converted to chromium (III) by a variety of reducing agents such as S^{2-}, Fe(II), fulvic acid, low molecular weight organic compounds, and proteins. In the aquatic environment, the effectiveness of these reducing agents is dependent on pH, redox conditions, and the total concentrations of chromium (Nriagu et al. 1993).

In general, Cr(VI) is considered to be of greatest concern due to its potentially toxic and carcinogenic properties (Rowbotham et al., 2000). Reports suggest this action is likely to be due to uptake of Cr(VI) via the sulphate anion channel, and then reduction of Cr(VI) to Cr(II), which can then bind to DNA, leading eventually to DNA damage and mutation (Standeven and Wetterhahn, 1989). In contract, Cr(III) is consider relatively non-toxic due, in part, to the fact there is little or no cellular uptake of this chromium species.

Copper

Copper is a nutritionally essential element and is naturally found in the earth's crust; thus, naturally high levels may be found in soil and sediment. There are four oxidation states of copper: Cu (0), Cu (I), Cu (II), and Cu (III) (ATSDR, 2002). Sediment is a common reservoir of copper, as copper is largely found bound to organic matter (ATSDR, 2002). Copper also tends to remain immobile in soil; one study indicated that appreciable mobilisation of copper was only found at a soil pH of 2.8 (Tyler 1978). Leaching into groundwater and liberation into air do not appear to be significant as copper is frequently tightly bound to organic matter in soil and sediment (ATSDR, 2002).

Copper is generally well-absorbed in the gastrointestinal tract, with small doses in rats being absorbed to upwards of 50%. Once absorbed, copper is mainly bound to proteins, most of which are enzymes. It is also bound to a low-molecular weight protein similar to metallothionein, forming ceruloplasmin which is used for copper transport as well as enzymatic action as an oxidase. Copper is mainly stored in the liver, brain, heart, kidney and muscles, with approximately 10% being in the liver (Aaseth and Norseth, 1986).

Short-term copper deficiencies or excess may be regulated by a variety of organisms thus minimising its potential toxic effects. Chronic administration results in the deposition of copper in the liver, kidney and other organs. One study reported that as copper accumulated in the liver of the rainbow trout, the number of lysosomes increased, and mitochondrial swelling and contraction as well as some mitochondrial degeneration, interruptions in the plasma membrane and an increased number of necrotic cells occurred (Leland and Kuwabara, 1985).

Nickel

Nickel is a relatively common metal used in a variety of manufacturing processes. Some organic nickel derivatives, particularly nickel carbonyl, are highly toxic to humans and various ecological receptors (Goyer, 1996). However, orally ingested nickel has a very low toxicity since it is sparsely absorbed from the gastrointestinal tract. It is transported in the plasma bound to serum albumin and multiple small organic ligands, amino acids, or polypeptides. In mammals, excretion in the urine is nearly complete in 4 to 5 days (Goyer, 1996).

While recent literature suggests that nickel is a nutritionally essential trace metal, increased exposure may lead to toxicosis via multiple effect pathways. The administration of nickel to rats resulted in enhanced lipid peroxidation, decrease glutathione peroxidase activity, and increased tissue iron levels (Stohs and Bagchi, 1995). Nickel is not considered to be a carcinogen, and has reported oral and dermal reference doses for non-cancer toxicity.

While element nickel is not a significant human health concern, exposure to aquatic biota may have significant adverse biological effects. This is important due to the ubiquitous nature of nickel in the biosphere and is a common component of natural freshwater waters due to erosion, weathering, and anthropogenic sources. There are many examples of Ni toxicity to aquatic biota in the scientific literature. Recently, Pane et al. (2003) found that in moderately hard water and at elevated concentrations (i.e. 7-16 mg Ni/L), Ni acts as a respiratory toxicant to rainbow trout and causes sufficient gill damage to critically impair gas exchange leading to eventual suffocation

Zinc

Zinc is an essential element for humans and animals and is required for the proper function of a variety of metalloenzymes (alcohol dehydrogenase, alkaline phosphatase, carbonic anhydrase, leucine aminopeptidase, super-oxide dismutase, and DNA and RNA polymerases). Zinc is required for normal nucleic acid, protein and membrane function and metabolism, as well as proper gene structure (zinc finger phenomenon), and zinc deficiency is associated with a variety of pathologies (ATSDR, 1994).

Zinc is a naturally-occurring metal in the earth’s crust, and it can be released by both natural and anthropogenic sources. It does not readily volatilise, but rather adsorbs to soil and sediment, as well as particulates in groundwater. Leaching is not common, though has been at sites of contamination. Zinc may bioconcentrate in organisms, particularly aquatic organisms such as higher crustaceans and bivalve species, but not particularly in fish and other vertebrates as body content is modulated by homeostatic mechanisms that act principally on absorption and liver levels (ATSDR, 1994).

Excessive exposure to zinc may cause toxic effects. Symptoms of zinc toxicosis include hypotension, diarrhoea, vomiting, pulmonary oedema, jaundice, hyperamylasemia, oliguria, anaemia, and thrombocytopenia (Ellenhorn et al. 1997). Testicular tumours have been produced by direct intratesticular injection in rats and chickens. However, this effect is probably related to the concentration of Zn normally found in the gonads and may be hormonally dependent (Goyer, 1996). Zinc is classified as a class D carcinogen, or not classifiable with respect to human carcinogenicity, based on inadequate data (U.S. EPA 2003a).

Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) are a class of synthetic chlorinated organic compounds with a biphenyl as the basic structural unit. In general, the industrial production of PCBs was not highly specific and resulted in the formation of complex mixture of congeners. Its empirical formula

$C_{12}H_{10-n}Cl_n$ (n=1 to 10) allows for 209 structurally different congeners; however, it is unlikely that all will be formed during the technical chlorinated process of the biphenyl moiety.

Due to their high chemical stability, relative low volatility, and high dielectric contract, PCBs became an increasingly valuable commercial product for numerous industries and applications, such as electric transformer and capacitor oils, heat exchange fluids, and various oils and paints. Subsequently, the commercial value of PCBs gave rise to a series of technical mixtures under various trade names, which are comprised of congeners with different degrees of chlorination. For example, the Aroclor series were characterised by a four-digit number, where the first two digits defined the type of molecular structure (e.g. 12 denoted a biphenyl), and the latter two digits gave the approximate estimate of the percentage of chlorine (by weight) present in the mixture (Safe 1994) (the exception being 1016, which is actually 41.5% chorine by weight).

It has been estimated that 1.3 million metric tons of PCBs were produced globally, with an unknown proportion discharged (either directly or indirectly) in the environment. While open use of PCBs is currently banned in North America, a large amount is still permitted for restricted closed-use applications such as electrical transformers. Following their initial detection in water and soil in 1966, PCBs have been identified in nearly every component of the biosphere. The hydrophobicity and environmental recalcitrance of this class of persistent organochlorine contaminants facilitates the bioaccumulation of PCBs in biota and its subsequent biomagnification from prey to predator (de Wit et al. 2003; Giesy and Kannan 1998; Safe 1994).

The toxicity of PCBs is complex and dependent upon the degree and orientation of PCB chlorination and the target species. In general, PCB-induced toxicosis is caused by induction of cytochrome P-450 (CYP) isozymes (particularly CYP1A, CYP2B, and (or) CYP3A), likely mediated from binding to the aryl hydrocarbon (AhR) or the constitutively activated receptors (CAR) (Giesy and Kannan 1998; Ueba et al. 2002).

In humans and wildlife, exposure to PCBs is associated with gastrointestinal symptoms such as abdominal pain, nausea, vomiting, anorexia, and others; in severe cases, coma and death may occur. Neurological symptoms such as dizziness, headache, depression and nervousness are also associated with PCB exposure. In addition, pregnancy problems such as toxaemia, abortions, stillbirths, and underweight births have been associated with exposure to PCBs (International Labour Office 1983; WHO 1993). Exposure to PCBs may also cause dermal toxicity such as erythematous eruptions with pruritis, eczema associated with contact dermatitis, chloracne, oedema and other irritation of the mucous membranes, hyperpigmentation, and thickening of skin and fingernails (International Labour Office 1983; WHO 1993). Increased liver weights and enlarged livers are common consequences of PCB exposure (WHO 1993), along with immunosupression, reproductive impairment, and endocrine disruption (Safe 1994). IARC (International Agency for Research on Cancer) classifies PCBs as group 2A carcinogens, or probable human carcinogens; this is based on limited evidence in humans and sufficient evidence in animals (IARC 1987). The United States Environmental Protection Agency (EPA) classifies PCBs as group 2B carcinogens, or probable human carcinogens; this is based on inadequate human data and sufficient animal data (US EPA 2003b).

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs) are routinely detected as complex mixtures of isomers and congeners in almost every component of the global ecosystem. PCDD/Fs are comprised of two series of tricyclic aromatic compounds with a possible number of 75 positional isomers of PCDDs and 135 isomers of PCDFs. These compounds are not intentionally produced since they have no identified uses, but are formed as by-products of numerous industrial processes, including the synthesis of diverse chlorinated aromatics (particularly the chlorinated phenols and derived products), production and smelting of metallic ores, pulp and paper production, and the combustion of municipal and industrial wastes (Safe 1994). Despite the complex composition of many PCDD/Fs-containing wastes, the most toxic congeners are the laterally 2,3,7,8-Cl substituted congeners (Geyer et al. 2002).

Risk assessment of PCDD/F is typically focused on one congener, TCDD, which is referred to as one of “the most toxic man-made compounds” (Huwe 2002). Based on structure-activity relationships, toxic equivalencies of other PCDD/F isomers and congeners were developed (Dyke and Stratford 2002). Like PCBs, toxicological response resulting from PCDD and PCDF exposure is highly dependent upon the nature of the chemical composition (i.e. congener distribution) and the target organism. However, it is generally accepted that most of the toxic responses elicited by PCDD/Fs are mediated thought the AhR and subsequent P-4501A-like isozyme induction (Safe 1994). In addition, these compounds are sufficiently lipophilic and recalcitrant that biomagnification in food chains is possible and may have significant implications to higher trophic level biota.

The toxic and biological effects resulting from exposure to 2,3,7,8-TCDD are dependent on a number of factors, which include the species, strain, age, and sex of the animals used. The toxic responses observed in several animal species include body weight loss, hepatotoxicity, porphyria, dermal toxicity, gastric lesions, thymus atrophy and immunotoxicity, teratogenicity, reproductive effects, endocrine disruption (including reproductive impairment and estrogenic activity and carcinogenicity. TCDD induces a wide spectrum of biological effects including enzyme induction and vitamin A depletion. Not all of these effects are observed in any single animal species. The most characteristic toxic effects observed in all laboratory animals are body weight loss, thymus atrophy, and immunotoxicity. Chloracne and related dermal lesions are the most frequently noted signs of 2,3,7,8-TCDD toxicosis in humans; dermal lesions are also observed in rhesus monkeys, hairless mice, and rabbits. In contrast, most rodents do not develop chloracne and related dermal toxic lesions after exposure to 2,3,7,8-TCDD. Many of the toxic lesions are noted primarily in epithelial tissues (WHO 1987).

TCDD does not appear to have mutagenic properties, and is therefore not likely to be genotoxic. Thus, it is assumed to be carcinogenic through an indirect mechanism. IARC classifies TCDD as group 1 carcinogens, or a likely human carcinogens (IARC 1987). The U.S. EPA (2003b) classifies TCDD as group 2B carcinogens, or probable human carcinogens; based on inadequate human data and sufficient animal testing. All other PCDD/Fs are classified as group 3 carcinogens due to paucity of sufficient data to evaluate the potential carcinogenicity to humans and wildlife.

6.2 Assessment Criteria

As noted in Section 2, the assessment of the sites proceeds through a step-wise process, where existing concentrations of contaminants in sediments are compared to benchmark values.

A number of jurisdictions have developed sediment criteria, including the MOE (Persaud *et al.* 1993), and the CCME (CCME 1999). Most of the available guidelines are based on co-occurrence studies that evaluate the effects of contaminants in sediments on benthic organisms in-situ at the level of populations of individual species. Few are based on actual toxicological studies. The method of derivation of most guidelines, therefore, results in conservative values that are designed to be protective in all conditions. Recognising this, the MOE has noted that the guidelines do not constitute cleanup levels, but rather, where guideline levels are exceeded, a potential contaminant concern may exist and additional investigation is required. The MOE has developed an approach to assess the site-specific impacts of contaminated sediments, and determine the need for remediation (Jaagumagi and Persaud 1996).

Under the MOE process, two guideline levels have been established: a Lowest Effect Level (LEL) that is operationally defined as the concentration of a contaminant that will not result in adverse effects to 95% of the species present, and; a Severe Effect Level (SEL) that represents the concentration of a contaminant that could result in adverse effects to 95% of the organisms present (Persaud *et al.* 1993). Given the conservative manner in which the guidelines have been derived, the LEL provides a suitable initial screening level for sediments. In this study, those locations where sediment concentrations are below the LEL can be considered as areas with negligible risk to sediment-dwelling biota, based on the understanding that those organisms that live in the sediment, and are in most direct contact with sediment bound contaminants would most likely be at risk. At those sites where sediment concentrations exceed the LEL, a progressive screening or evaluation is undertaken by the calculation of a simple risk quotient (RQ), which is simply the ratio of the sediment concentration to the LEL. Where the coefficient is marginally in excess of 1, the risks are very low, due to the conservative means by which the guidelines are calculated. The potential risks increase based on the degree of exceedance of the LEL such that where risks exceed the SEL, there is a greater potential for adverse effects.

The screening level criteria, such as the PSQG LELs and SELs, provide a means by which the effects of bioaccumulative compounds such as PCBs are assessed only with respect to potential toxicity to organisms. Therefore, the above approach may not be protective for these compounds, since organic compounds such as PCBs present additional concerns regarding bioaccumulation and biomagnification. Therefore, potential effects of PCBs are additionally assessed through a screening level risk assessment. Where relevant, the risk assessment considers exposure of both human and non-human biota to conditions on the site.

A review of previous studies conducted by the MOE (described in Section 6.3) indicates that for metals, levels in sediments are typically above the MOE SEL before adverse effects become apparent on biota. In large measure, this has to do with the behaviour of these elements in sediments, and in particular their binding to ligands, as discussed in Section 6.1. Therefore, based on the review in Section 6.3, for metals, the LEL is considered a very conservative value, with adverse effects considered highly unlikely. Concern regarding sediment concentrations for most metals, therefore, would be warranted only where concentrations exceed the SEL. Since the bioassay tests upon which this conclusion is based simulate a worst-case condition for most metals, the effects *in situ* are likely to be less, and provides assurance that for most metals, concentrations in sediments could exceed the SELs before adverse effects occur.

A similar review conducted for organic compounds (Section 6.3) suggests that no effect concentrations are above current LELs, and that therefore, the LEL guidelines offer suitable protection for aquatic organisms. However, the results indicate that for both PCBs and the PAH compounds, adverse effects, including mortality, could occur at concentrations well below the SEL, and that the SEL does in fact represent the concentration that could potentially be detrimental to the majority of benthic organisms. Therefore, in evaluating these compounds, exceedance of the LEL should be considered as resulting in potential adverse effects, and the compounds should, wherever concentrations in sediment exceed the LEL, be assessed through biological studies.

The review of potential effects, therefore, shows that different approaches are needed to assess the different classes of COCs. For metals, where the adverse effects have typically been reported at concentrations higher than the MOE SELs, the following approach has been used:

- the maximum concentration of each potential contaminant is considered relative to MOE LEL and a risk quotient (RQ_L) is calculated for each parameter. This level indicates negligible risk to biota.
- Where the RQ_L is > 1, the existing concentrations are evaluated relative to the MOE SELs, denoted in this report as RQ_S.
- Where the RQ_S > 1, there is potential risk to sensitive organisms, and additional assessment would be warranted.

For assessment of PAH compounds, where the review of relevant studies conducted by the MOE indicates adverse effects could occur at concentrations below the MOE SEL, the following approach was used:

- the maximum concentration of each potential contaminant is considered relative to MOE LEL and a risk quotient (RQ_L) is calculated for each parameter. This level indicates negligible risk to biota.
- Where the RQ_L > 1, there is potential risk to sensitive organisms, and additional assessment would be warranted.
- Where the RQ_S > 1, the sediment concentrations were compared to the MOE SELs. Where an RQ_S > 1 was calculated, an adverse effect was considered likely, and additional assessment would be necessary.

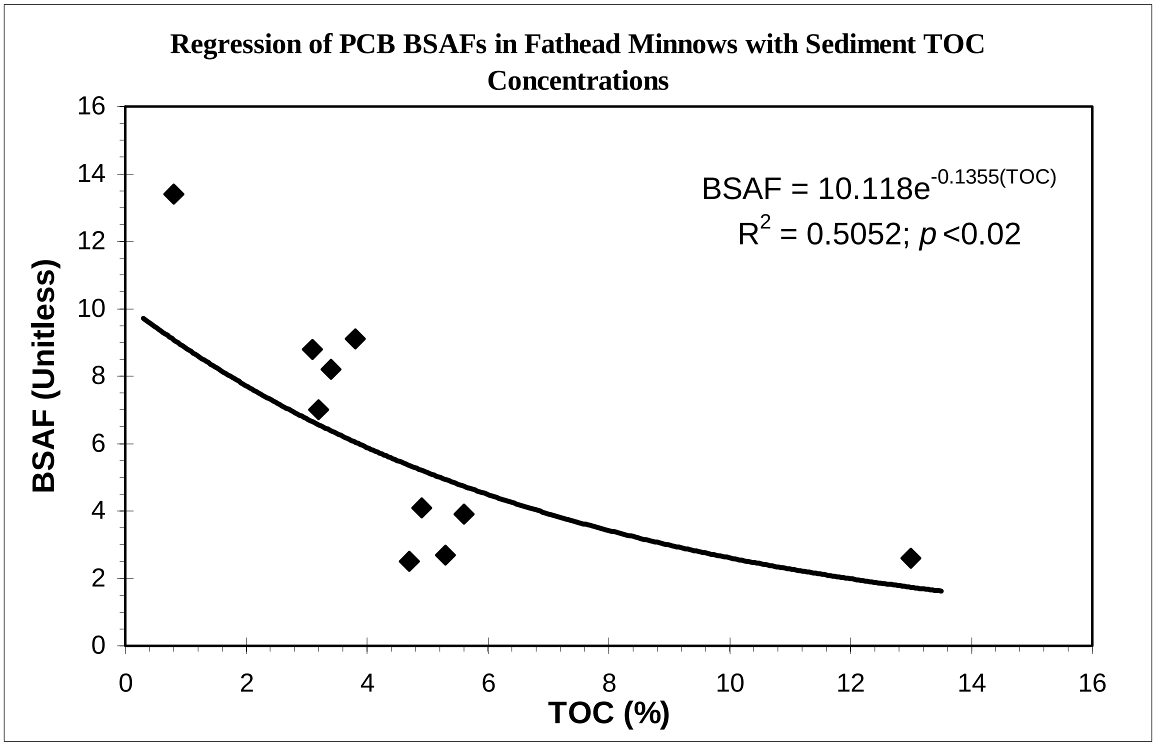
For bioaccumulative substances (PCBs, dioxins and furans, and mercury), where the calculation of risk quotients based on the MOE PSQGs may not be protective against the effects of bioaccumulation and biomagnification, the following approach was used:

- the maximum concentration of each potential contaminant is considered relative to the MOE LEL and a risk quotient (RQ_L) is calculated for each parameter. This level indicates negligible risk to biota.
- Where the RQ_L > 1, or, in the case of dioxins and furans, RQ_{PEL} > 1 (MOE guidelines were not available for these compounds and the CCME PEL was used as the benchmark) the existing concentrations are evaluated relative to a screening level risk assessment, as described below. Where risks are identified, the site is considered a candidate for detailed assessment under Phase III.

As noted above, the assessment of the effects of bioaccumulative compounds presents a special problem. Elevated levels of these compounds in sediment could result in accumulation of compounds in aquatic organism tissues that could result in an adverse effects in higher tropic level consumers. Due to biomagnification, elevated concentrations could occur in organisms at higher trophic levels (particularly when combined with body burden accrued from other sources), at tissue concentrations in benthic organisms well below the toxicity thresholds for the individual organisms used in the toxicity tests. Therefore, for bioaccumulative compounds, a more conservative approach would be warranted. Those compounds that could result in a significant accumulation in organism tissues could ultimately affect large numbers of individuals within a regional area or population. Therefore, for compounds with bioaccumulative potential, additional assessment is based on anticipated accumulation from sediments. This is assessed through the use of BSAFs (Biota-Sediment Accumulation Factors) calculated from sediment bioassay studies and field studies conducted by the MOE and Environment Canada. BSAFs are ratios that express the availability of a compound from sediments through the amount accumulated in tissue relative to the amount present in sediments. Calculation of relevant BSAFs permits estimation of tissue residues at other sites under similar exposure conditions.

Since mercury is a bioaccumulative substance, additional comparison was made with existing studies to ensure that the sediment concentrations at those locations that exceeded the LEL, while not exceeding the SEL, would not result in unacceptable tissue residues in aquatic organisms. The evaluation is based on a study of mercury bioaccumulation in Jellicoe Cove (Peninsula Harbour) undertaken by Environment Canada (Grapentine *et al* 2003). Since TOC has been shown to be a significant modifier of availability of mercury from sediments (as inorganic mercury), those sites in Jellicoe Cove with similar TOC concentrations to sediments in the current study sites were used to derive BSAFs. For both chironomids and amphipods in Peninsula Harbour, the highest BSAF from the range of TOCs calculated was used to estimate benthic organism tissue residues that could result, under very conservative assumptions, from the sediment concentrations at the site. To estimate the resultant tissue concentrations in bottom feeding (benthivorous) fish, the benthic organism tissue residue was multiplied by the low food chain multiplier derived by Grapentine *et al.* (2003) of 2.14 (estimates of fish tissue residues using the 2.14 multiplier in Peninsula Harbour corresponded most closely with field data on fish tissue levels). Since the BSAFs were calculated on a dry weight: dry weight basis, the tissue residue was converted back to a wet weight assuming 86% of the organism consisted of water. Benthivorous fish were selected for this comparison, since they are most likely to be in direct contact with sediments and feed mainly on sediment organisms.

Where sediment PCB concentrations exceeded the LEL, these were additionally evaluated with respect to potential bioaccumulation by fish. A review of studies conducted by the MOE in the Otonabee River (Jaagumagi *et al.* 1999) and in Lyon's Creek east (Bedard and Petro 1998) provided BSAFs for a number of PCB contaminated sediments across a range of TOC concentrations. Since TOC can affect availability of hydrophobic compounds such as PCBs, the approach to assessing potential bioaccumulation of PCB involved a regression of TOC concentrations relative to BSAF values (calculated as tissue residues in fathead minnows accumulated at the end of 21 day exposure tests), and this is presented in the figure below. For a given TOC concentration at any of the tests sites where an RQ>1 was noted relative to the LEL benchmark, the corresponding BSAF was determined. This was used to derive an estimate of tissue residues in fish from exposure to contaminated sediments (it did not include ingestion as a pathway - sufficient empirical data could not be located on accumulation of PCBs from benthic organisms). The fish tissue residue thus derived was then converted to a wet weight basis (the BSAFs in the MOE data were derived on a dry weight: dry weight basis) and the result compared to available criteria such as the 100 ng/g tissue residue limit derived by the IJC for the protection of aquatic life. It should be noted that this is a very conservative approach in that it assumes the exposed fish would be spending 100% of its time in the area, and there would be no dilution due to flows (the tests were performed under static conditions). This approach, however, can be useful to demonstrate that if under these very conservative assumptions there is little uptake, then under real-world exposure conditions there would be no concern regarding sediment concentrations of PCBs.



Dioxin and furan concentrations were initially evaluated with respect to CCME guidelines since MOE guidelines are not available for these compounds. Where concentrations resulted in a RQ > 1 when compared to the guidelines, additional evaluation with respect to bioaccumulation was undertaken. While few benchmarks exist for evaluating the effects of dioxins and furans on aquatic life, a recent study (Cook *et al.* 2003) has provided a potential screening concentration against which these compounds can be assessed.

Cook *et al.* (2003) note that doses responsible for TCDD-like toxicosis in sac fry are best related to concentrations of AhR agonists accumulated in eggs through maternal transfer. The influence of waterborne exposure of persistent, hydrophobic (i.e. lipophilic) contaminants in the aquatic environment to fish eggs is expected to be minimal under field conditions. As fish tissue and egg concentrations of persistent organochlorine contaminants at the sites were not available, biota-sediment accumulation factors (BSAFs) were used to relate measurement of sediment organic carbon-normalized concentrations of PCDD and PCDFs to lipid-normalized concentrations in eggs. Cook *et al.* (2003) reported that female lake trout and egg BSAF values ranged from 0.27 to <0.001 for PCDDs and PCDFs. The substantial differences in BSAF between congeners were not related to hydrophobicity, but rather biotransformation-related differences in bioaccumulation of PCDD/F and PCB congeners. The fish and egg BSAF value for 2,3,7,8-TCDD were 0.215 and 0.148, which is consistent with a BSAF value of 0.155 for TCDD in fathead minnow muscle (Loonen *et al.* 1994).

Maternal transfer of TCDD to lake trout eggs resulted in sac fry mortality when concentrations in the eggs exceeded 30 pg/g (wet weight). One hundred percent mortality occurred when concentrations exceeded approximately 50 pg TCDD/g wet egg. It should be noted, however, that gross pathologies were observed for brook trout (*Salvelinus fontinalis*) sac fry from eggs exposed to non-lethal doses of TCDD through maternal transfer, suggesting that survival of lake trout sac or alevins in the environment may be reduced when TCDD concentrations in egg are less than this initial toxicity threshold value. Upon further consideration of sublethal exposure and biological effects to salmonids, Cook *et al.* (2003) proposed a threshold No Adverse Effect Concentration (NOAEC) of 5 pg/g egg.

Fish mortality due to exposure to TCDD-like compounds is associated with blue sac disease, a non-infectious, oedematous condition in fish fry first observed when eggs were exposed to ammonia, was later observed for sac fry from Lake Ontario lake trout (*Salvelinus namaycush*). Subsequent research demonstrated that lake trout sac fry are extremely sensitive to TCDD, following exposure of fertilized eggs, with mortality following signs of toxicity that resembled the blue sac syndrome.

The No-Observed Adverse Effect Level (NOAEL) of 5 pg/g was used for the preliminary toxicity assessment to fish and was used to assess potential risks due to dioxin and furan concentrations in sediment. Where sediment concentrations resulted in RQ > 1 when screened against the CCME PELs, the sediment concentrations were considered with respect to potential effects on lake trout eggs. Comparison of the estimated exposure was based on the Risk Quotient approach, and in this case was calculated similarly to the other RQs as defined by the equation:

$$RQ = \frac{[Exposure]}{NOAEL}$$

where *[Exposure]* is the exposure concentration in sediment. This results in conservative estimates of potential effect, since it assumes a continuous exposure to the concentrations used in the model. In the case of eggs, this may be a reasonable exposure scenario.

The above evaluation focuses on the measurement of the effects on individuals, as measured in the toxicity tests or bioaccumulation studies. In order to be meaningful in an ecological context, this needs to be translated into effects at the community or population level since individual organisms can suffer adverse effects without affecting the sustainability of the community or population. Where effects are below the toxicity threshold values, the absence of effects on individuals can be taken as an indication that there will be no effects at the community level (i.e., if individual organisms do not suffer either chronic or acute effects, then it is unlikely there will be broader-based community effects).

However, if there is a potential for effects on individuals, then the effect needs to be considered within the broader ecological context. The most important factors ecologically are those that affect the survival and integrity of populations or communities, since these can affect their long-term sustainability. In this case, the relative size of the area affected also becomes important.

Acutely toxic results in a small, very confined area of a large waterbody will have little broad-based ecological effect. Since small fish (e.g., minnows) and young fish typically forage in shoreline areas that can extend up to 200-300 m, this is considered the minimum size for exposure in this assessment. Where adverse effects could occur within this area, the effect is considered significant at the community or population level. Fish were chosen since benthic invertebrate communities typically extend continuously, and in most larger waterbodies, elimination of invertebrates within a specific stretch will not likely result in a significant effect on the local population, since adjacent areas will provide suitable habitat to sustain populations or communities.

However, this does not apply to small, contained waterbodies, where the area of impact is much larger in size relative to the available habitat. Therefore, in the case of small water bodies, which would include some of the sites considered in this assessment, such as Lyon’s Creek west, the effects are assessed on the basis of the percentage of habitat affected. It is assumed for the purposes of this assessment that if more than 50% of the available habitat is adversely affected, there will be an adverse effect on the local invertebrate or fish population or community.

The types of compounds, and their modes of action are also important. For those compounds that do not biomagnify, the primary concerns are direct mortality or chronic effects that may reduce the fecundity of individuals. In these cases, the effects on individuals can be used to estimate the effects on populations or communities. However, the effects of bioaccumulative compounds on individuals can occur well beyond the margins of the waterbody, particularly where the compounds may be transferred to terrestrial organisms. Since the tissue residues in invertebrates may not adversely affect the individuals, but could result in accumulation of unacceptable levels in species at higher trophic levels, the effects need to be assessed through formal risk assessment processes that include a reasonable measure of exposure based on factors such as time spent in the area, feeding ranges, feeding rates, and dietary preferences. These lie outside the current study, but where potential risks are identified due to these compounds, are recommended for this type of evaluation in Phase III.

6.3 Review of Existing Studies

As noted above, the potential effects of metals in sediments are evaluated through review of a number of studies conducted at other sites in Ontario, and through sediment studies reviewed in the published scientific literature. The MOE has conducted a number of site-specific assessments where metals were identified as a potential concern. At many of these sites, one or more of the metals exceeded the MOE SELs, and could result in adverse effects on organisms. These studies therefore provide a suitable background upon which to base an evaluation of potential effects due to exceedances of PSQG levels.

The MOE has conducted three previous studies in the Welland River focusing on the Atlas Steel site in Welland (Jaagumagi and Bedard 1991; Jaagumagi and Bedard 1995; Schroeder 2002). In 1990, sediment bioassay tests were undertaken in both "reef" areas, and adjacent areas. While sediments from the "reef" areas were found to be acutely toxic, the adjacent areas had limited toxicity to the test organisms. Sediment with nickel and chromium concentrations of 480 μg/g and 740 μg/g respectively, did not result in either growth impairment (indicative of chronic effects) or lethality in the test organisms. In 1994, additional studies at the site found that in similar tests concentrations of nickel, chromium and copper that ranged up to 470 μg/g, 550 μg/g and 330 μg/g respectively, did not result in either chronic or acute effects on any of the three test organisms (mayflies, chironomids and fathead minnows). Follow-up studies undertaken in 2000 similarly found that sediments with nickel and chromium concentrations of 2000 μg/g and 1300 μg/g respectively did not result in measurable effects on the three test organisms used in the previous tests (Schroeder 2003).

In 1998, the MOE conducted a study of the Porcupine River system to determine the effects of release of metals such as copper, cadmium and nickel from mining activities in the watershed (Jaagumagi and Bedard 2001). Sediment toxicity testing conducted as part of the study showed no increase in mortality and no changes in growth in mayflies, chironomids or minnows in sediments from Porcupine Lake with 1800 μg/g copper and 200 μg/g of nickel. Young-of-the-year fish testing also showed no increase in tissue residues of copper in the same lake over levels in fish from background lakes.

In 1999, the MOE conducted a similar study in Junction Creek (Sudbury) (Jaagumagi and Bedard 2001a). Again, sediment bioassay testing was undertaken as part of the investigation. Sediment concentrations at the sites with no acute or chronic effects on any of the three test organisms were used. The highest concentrations of copper and nickel that did not result in adverse effects on the test organisms ranged up to 390 μg/g for copper and 500 μg/g for nickel. Since these occurred at the same site, this in effect considered the combined effects of copper and nickel on the test organisms. No adverse effects were noted on benthic communities at this location in field testing.

A study conducted by the MOE in 2000 at an abandoned lead mine (Jaagumagi and Bedard 2001c) found no effects on mayflies, chironomids of fathead minnows exposed to sediments containing up to 7200 μg/g lead and 9000 μg/g zinc. Fish caught in these areas also had similar lead tissue residues to fish in control sediments, and exhibited no uptake of lead or zinc despite very high sediment concentrations.

Krantzberg and Boyd (1992), conducted sediment bioassay tests with Hamilton Harbour sediments and found no effects on invertebrates or fish in sediments with chromium concentrations of 400 µg/g, and zinc of 4606 µg/g.

The above studies suggest that potential adverse effects due to metals contamination in sediments may occur at concentrations in excess of the SELs. Therefore, exceedance of the LELs is likely to present negligible risk to benthic organisms and the SELs can be considered as suitably protective of aquatic life.

In 1995, the MOE and Environment Canada conducted a study at the Northern Wood Preservers site in Thunder Bay Harbour (Jaagumagi *et al.* 1996). The site is a creosoting operation that has resulted in significant releases of creosote to the adjacent harbour. Toxicity testing at the site was used to derive cleanup criteria for sediments contaminated with PAH compounds. Based on the results, a criteria of 150 ppm total PAH was determined to result in 50% mortality in the test organisms, while 30 ppm was determined to be the lower threshold of effects (i.e., no mortality or growth impairment occurred below this concentration).

In 1992 and 1995, the MOE conducted sediment bioassay tests in the St Mary's River, which included sites with elevated levels of a number of metals (Bedard and Petro, 1997). The study found that at a chromium concentration of 2,600 µg/g there were no measurable effects on any of the test organisms (mayflies, chironomids and fathead minnows).

In 1992, the MOE conducted sediment assessment studies at a former coal gasification plant site in Deseronto. The sediment bioassay data showed no chronic effects, measured as changes in growth, or acute effects on mayflies, chironomids or fathead minnows at a sediment total PAH concentration of 20.7 µg/g. A similar study in Belleville in 1996, (Jaagumagi and Bedard, 1997) found no measurable effects at sediment total PAH concentrations up to 49.7 µg/g. Both of these can, therefore, be considered as no effect concentrations.

A study conducted by the MOE in the Toronto Waterfront in 1989 (Jaagumagi *et al* 1991) found no measurable effects on chironomids or fathead minnows (mayflies were not tested) at sediment concentrations of total PAHs ranging up to 51.8 µg/g.

Based on the above review, it would appear that while the LEL for PAH compounds is likely to be protective of aquatic life, effects appear to occur at concentrations well below the SEL. Therefore, for the purposes of this study, exceedances of the LEL for PAH compounds are considered to represent potential risks to biota.

In 1996, the MOE undertook a sediment study in the Otonabee River to determine the effects of PCB losses to the river (Jaagumagi *et al.* 1998). Sediment toxicity and bioaccumulation tests conducted as part of the investigation found no toxicity to any of the three test organisms at sediment PCB concentrations of 1200 ng/g and 1400 ng/g. BSAFs ranged from 2.5 to 8.8 across TOC concentrations that ranged from 3.1% to 13%.

In 1992 and 1995, the MOE undertook sediment bioassay tests in Lyon's Creek East. At exposure concentrations of up to 1 μg/g PCBs no mortality was noted in any of the test organisms, and only minor growth reduction was noted in one organism. BSAFs ranged from 2.7 to 13.4 across a TOC range of 0.8% to 5.3%. Mortality was noted at a concentration of 6 μg/g (the SEL for this sediment was 28 μg/g).

The results of these studies have been used in Section 6.2 to develop the BSAFs used in estimating potential exposure of fish.

6.4 Level One Sites

6.4.1 Lyon's Creek West

Lyon’s Creek consists of a small wetland area that receives runoff from the southwest via a drainage ditch from Southworth St and Humberstone Rd and a second ditch from the northwest (Figure 7). The south branch is approximately 1 m across, though standing water at the time of sampling was sparse, despite rains during the preceding days. The wet area was approximately 0.3 m across, and the ditch is heavily vegetated with cattails and other wetland vegetation. The substrate in the ditch consists of clay and rock/cobble, overlain by a layer of decomposing vegetation. Depth of penetration during coring was limited to the top 10 cm.

The south ditch drains to the wetland area, and currently is the major source of water to the upper section of the wetland. Prior to 1992, a ditch also drained from the west, but this drainage was severed when the City re-routed it’s drainage ditch around the wetland area (Figure 7). Substrates at the western end of the wetland consisted of dense mats of decomposing vegetation, also underlain by a grey, firm clay.

The wetland opens up to the northeast, and is heavily vegetated with cattails and *Fragmites*. During the time of sampling, surface water depth in this section (station 15) was approximately 0.3 m. Substrates consisted of organic detritus in various states of decomposition, and coring was limited by the dense accumulation of vegetation. Consequently, only surface samples were obtained in this area.

In the central section of the wetland, little surface water was apparent, though the ground surface was wet. Substrates were firm in this area, assisted by the dense growth of vegetation as noted above that, through extensive root networks, would have held the soil materials together. Substrates consisted of organic matter in various stages of decomposition and ranged from silt sized to large plant debris.

The western end of the wetland (where the wetland area narrows at the outlet) was characterised by deeper water depths (0.5 m) and very loose mats of decaying vegetation. Substrates were very soft, and considerable compression was apparent during sampling. Substrates consisted of a mix of fine-grained silt sized materials and organic detritus.

Near the northern end of the wetland, the remnant of the original ditch from the southeast section of Welland joins the creek. No flowing water was observed in this section during sampling, and the creek bottom was densely overgrown with woody shrubs and grasses, indicating that there has been little standing water in this section for a number of years. Substrates were typically clays with rocks and gravel interspersed.

The only open water in the creek occurs below the wetland area, in the short section before the creek drains to the Welland Canal. Water depths in this area were in the order of 0.3 to 0.5 meters, and substrates consisted of fine-grained sediments and organic detritus.

In contrast to the creek and wetland area, the ditch from the City of Welland has water depths of up to 1 m, and there was detectable flow within this section. The creek bottom was primarily clay with some rocks and gravel. A layer of silt covered the bottom in some areas.

The distribution of PCBs in surficial sediments of the creek, wetland and drainage ditch is shown in Figure 17. Historical results are also presented in Appendix A, Table A-14, while results from the current round of sampling are presented in Table 5.1.2. The results from the current round of sampling indicate that, in addition to elevated levels of PCBs, a number of metals and metalloids, including arsenic and zinc, were elevated in certain sections of the creek (Table 5.1.2).

The Lyon's Creek area can be subdivided into three main sections: the south branch from the Crowland Transformer station; the remnant of the tributary (ditch) from the south-eastern section of the City of Welland and; the north branch from the southeast section of the City that was re-routed around the wetland by the City in 1994 (Figure 7). The highest PCB concentrations were found in the downstream end of the wetland, the lower end of the remnant stream, and the main channel below the wetland leading to the mouth (Figure 17). The highest concentration recorded in the surficial sediments during this survey was 27,300 ng/g (ppb) in the downstream end of the wetland. In the core sample collected at station LC-6, concentrations of PCBs increased with depth, from 11,600 ng/g in the surficial sediments (0-5 cm depth) to 15,700 ng/g in the 10-15 cm depth.

Earlier studies (ESL 1992) showed that a number of PCB contaminant hotspots existed within the wetland and adjacent areas. While the most contaminated areas occurred at depth, surficial concentrations of PCBs were elevated above the MOE Hazardous Waste guideline of 50 ppm at a number of locations (Figure 17). Materials at depth can be considered biologically unavailable to most organisms, with the exception of rooted vegetation, where roots could penetrate the more contaminated layers. While the solubility of PCBs is low, the high concentrations present could result in elevated levels in some plant tissues.

The initial review in Section 4 indicated that PCB concentrations in the soils and sediments at the site exceed the available criteria for sediments and soils. Historical data show that the SEL and Table A/B soils criteria (MOE 1997) are exceeded at a number of locations, indicating that potential risks exist for biota.

The assessment of sediment conditions in Lyon's Creek proceeds through a two-step screening evaluation relative to existing criteria as described in Section 6.2. Table 6.4.1 below summarizes the results of this evaluation. For each of the RQ calculations, the actual number of sampling stations where a RQ > 1 was noted is recorded, and the percentage of stations exceeding the respective RQ level is provided in parentheses.

TABLE 6.4.1
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	**SQC**		**Highest concentration in Lyon's Creek μg/g**	**Risk Quotient**			
	LEL	**SEL**		**RQ_L**	**Sites with RQ_L>1 (%)**	**RQ_S**	**Sites with RQ_S>1 (%)**
Arsenic	6	33	167	27.8	4 (50)	5.1	3 (38)
Cadmium	0.6	10	0.6	1	-	-	-
Chromium	25	110	63	2.5	8 (100)	0.57	-
Copper	16	110	109	6.8	8 (100)	0.99	-
Iron	2%	4%	7.37%	3.7	8 (100)	1.8	-
Mercury	0.2	2.0	0.2	1	-	-	-
Manganese	460	1100	1050	2.3	8 (100)	0.95	-
Lead	32	250	99	3.2	4 (50)	0.4	-
Nickel	16	75	73	4.6	8 (100)	0.97	-
Zinc	120	820	4280	35.7	8 (100)	5.2	5 (63)
PCBs (total)	0.07	18.2*	27.3	390	14 (67)	0.64	-

* SEL based on TOC of 3.5%

Of the parameters considered, arsenic, chromium, copper, lead, nickel, zinc and PCBs yielded an RQ_L of >1 in the initial step and were compared to the SEL. Of these arsenic, iron and zinc yielded an RQ_S of >1, indicating that adverse effects on a number of benthic organisms could occur.

The distribution of metals in sediments suggests these originate from two separate sources. Arsenic appears to originate along the south branch from Southworth St while zinc and iron appear to be related to sources in the southeast section of the City, since concentrations were higher in this branch (existing ditch and remnant branch).

The distribution of PCBs on the site is summarized in Figure 17, and includes not only the results of the present study, but also those of earlier studies conducted by the St Lawrence Seaway Authority (SLSA), the City of Welland and Hydro One [as Ontario Hydro]. The current and historical analyses have detected different Aroclor mixtures in the different areas of the site, and these are presented in Tables 5.1.2 and Appendix A, Table A-14. The distribution with depth shows that most of the PCB contamination at depth occurs in the northern end of the site. The highest contamination extends from the current outlet area back upstream to the remnant of the original branch from the City, as well as into the northern part of the wetland. In this area, PCB contamination extends to depths of 200 cm in one area, though contamination in most areas is confined to the top 30 cm. In many cases, the subsurface layers have higher PCB concentrations than the surface layers, indicating that not only is the contamination due to long term historic release of PCBs, but that this release has been higher in the past.

The similarity of surficial concentrations during this study with levels determined at the same locations in previous studies indicates that there has not been significant deterioration of the PCBs, either through degradation or dechlorination, and also indicates that there has been little sediment or soils cover added since the studies in the early 1990's. Therefore, the data collected in the 1990's can still be considered relevant in terms of potential exposure.

On the basis of this, Figure 17 incorporates the available current and historical data to show the approximate areas of contamination that correspond to 5 μg/g, 25 μg/g and 50 μg/g concentration contours. The 5 μg/g contour is based on the MOE Table A Residential/Parkland value, while the 50 μg/g contour is based on the MOE Hazardous Waste guideline. The 25 μg/g contour was arbitrarily chosen as an intermediate value between these two guidelines. However, based on the typical TOC values for this section of the site, the 25 μg/g value is a reasonable approximation of the SEL.

The distribution with depth in the south branch from the Crowland Transformer station shows that PCB contamination is confined to the surficial layers. PCBs were only detected in the top 5 cm sections of the cores, and this would be consistent with a single spill of PCB-containing fluids, where contamination to depth would not be expected. In this section, only Aroclor 1260 was detected.

The distribution of PCBs in the remainder of the site is more complex. In the northern section elevated levels of PCBs extend to depth. As well, there is a mix of Aroclors 1248, 1254 and 1260. Aroclor 1248 only occurs at one site near the outlet of the creek, and suggests the single occurrence of this Aroclor may be related to dechlorination of historically deposited PCBs. Throughout the remainder of this area, the PCBs detected were a mix of Aroclors 1254 and 1260.

This differs from the south end of the site, where only Aroclor 1260 was detected and suggests that additional sources have resulted in contamination of this area. As well, the presence of both Aroclors in the remnant stream suggests that concentrations in this area are due to sources other than the spill at the Crowland Transformer Station. The higher concentrations that occurred at depth also indicate that contamination due to PCBs has been on-going for a much longer time, and the distribution with depth is therefore not consistent with a single spill event.

Based on the range of BSAFs, and the regression with TOC as discussed in Section 6.2, potential exposures to fish are estimated as a means of further evaluating the PCB concentrations in Lyon's Creek. Predicted PCB concentrations in fish ranged up to a high of 9.1 μg/g at station LC-8, which is well above the IJC criterion of 0.1 μg/g, and also above the human health consumption guideline of 0.5 μg/g for unrestricted consumption of sport fish. As shown on Figure 17, the size of the area affected, relative to the small size of the wetland area indicates that a sizable portion of the site could result in adverse effects to aquatic organisms.

Since elevated levels of PCBs were also found in the soils at concentrations in excess of the MOE Hazardous Waste criteria, there is also potential for risks to human receptors. Therefore, exposures to humans and terrestrial receptors are further evaluated through a screening level risk assessment, the details of which are presented in Appendix B. Risks were evaluated on the basis of data from previous studies and the current investigation. Both the human health and ecological risk assessments identified potential risks from PCBs at the concentrations present in the sediments and soils of Lyon's Creek.

In addition to PCBs, elevated levels of arsenic and zinc were also recorded from Lyon's Creek west sediments. The distribution of arsenic at the site indicates that the tributary from the Crowland Transformer station had the highest concentrations.

Since potential risks were identified due to both PCBs and arsenic to aquatic organisms, and to humans and non-human biota through a SLRA (Appendix B), additional investigation of this site would be warranted under Phase III.

6.4.2 Welland River - Pt Robinson to the Chippawa Power Canal

The Welland River in this section flows across a relatively flat plain, and as a result, the river is wide and deep (up to 3 m in the middle of the channel) with cattail marshes along the banks where currents are slower. The main channel is relatively scoured, and substrates consisted mainly of clays with a thin layer of silt (Table 5.1.1).

Shallow areas existed along the banks of the river, where the presence of fine-grained sediments indicated that most sediments deposited in the river, at least temporarily, are those along the banks. Sediments along the banks, where depths were typically less than 1 m, ranged from silty clays to black organic rich sediments adjacent to the cattail marshes. The lower section of the river, near the entrance to the Chippawa Power Canal was more heavily scoured, as indicated by the hard clay substrates with an absence of silt, and indicate an increase in river current in this section. The results of the sediment sampling are presented in Tables 5.1.2, 5.1.3 and 5.1.4. The initial evaluation of Welland River sediments relative to established sediment criteria (MOE PSQGs) is presented in Table 6.4.2 below.

TABLE 6.4.2
Calculation of Risk Quotients for Sediment Impacts, Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Welland River µg/g	Risk Quotient			
	LEL	SEL		RQ_L	No. of Sites with $RQ_L>1$ (%)	RQ_S	No. of Sites with $RQ_S>1$ (%)
Arsenic	6	33	7.4	1.2	4 (13)	0.25	-
Cadmium	0.6	10	0.8	1.3	4 (13)	0.08	-
Chromium	25	110	764	29.4	31 (100)	6.95	16 (52)
Copper	16	110	281	17.6	31 (100)	2.6	6 (19)
Mercury	0.2	2.0	1.77	8.85	19 (61)	0.89	-
Lead	32	250	76	2.4	8 (26)	0.3	-
Nickel	16	75	501	31.3	31 (100)	6.7	19 (62)
Zinc	120	820	435	3.6	20 (65)	0.5	-
PCBs (total)	0.07	26*	0.9	12.9	14 (45)	0.03	-
PAH (total)	4	850**	5.52[1]	1.38	3 (17)	0.006	-
Dioxins/furans	0.85[a]	21.5[b]	9.7 pg/g[c]	11.4	4 (100)	0.45[d]	-

* SEL based on TOC of 5%; ** SEL based on TOC of 8.5%. [1] does not include site at Oxy Vinyl (Geon) (WR-4), which is addressed in Section 6.6.1. [a] ISQG in pg/g total TEQ (CCME 2001). [b] PEL in pg/g total TEQ (CCME 2001). c Total TEQ based on fish TEFs (WHO 1998). [d] RQ_{PEL}

The results indicate that all of the COCs exceed the MOE LELs ($RQ_L >1$) at one or more sites, and that three of these, copper, chromium and nickel, exceed the SEL ($RQ_S >1$), and therefore, potential risks to aquatic biota are present.

The distribution of both chromium and nickel, as shown in the insets on Figure 18, indicate that they have accumulated in the depositional areas at the edges of the river. The concentrations in the middle of the channel were typically much lower, and suggest that the metals are present as metal-particulate complexes that have been deposited at the margins. This lends further credence to re-suspension and deposition of contaminated sediments from upstream sources, rather than local sources within this stretch of the river.

Current concentrations of copper, chromium and nickel in sediments are considered within the context of the entire river, based on sampling results from the MOE/EC 1996 study. Figures 19A and 19B show chromium and nickel concentrations in the current study within the context of results from the 1996 study. The figures show that concentrations of both metals are similar to the 1996 results, and also show, based on the attenuation of concentrations with distance downstream, that the most likely origin of the elevated concentrations is from the Atlas Steel site in Welland, since this is the only identified source of chromium and nickel (Acres 1990, Jaagumagi and Bedard 1991).

Copper concentrations in sediments increased beginning at WR-5 (adjacent to the Cytec site) suggesting the presence of a local source of copper. Elevated levels of copper also occurred at the mouth of Thompson's Creek in both 1996 as well as during this survey. However, a review of previous monitoring results indicate that copper has not been identified as a concern at the Cytec site. The results of the 1996 study indicate that copper concentrations in the Welland River were generally low (Figure 10C), and increased only at and below WR-5 (Figure 19B).

Since mercury is a bioaccumulative substance, additional comparison was made with existing studies to ensure that the sediment concentrations at those locations that exceeded the LEL (RQ_L >1), while not exceeding the SEL, would not result in unacceptable tissue residues in aquatic organisms. The evaluation is based on the methodology described in Section 6.2. Since TOC has been shown to be a significant modifier of availability of mercury from sediments (as inorganic mercury), five sites in Jellicoe Cove with similar TOC concentrations to sediments in Welland River (TOC ranged from 2.26% at station WR-4 N to 5.8% at WR-6 S) were used to derive BSAFs. BSAFs for chironomids (dry weight to dry weight) ranged from 0.30 to 0.37, while for amphipods these ranged from 0.05 to 0.2. Using the upper end of each estimate, for Welland River sediments with similar TOC concentrations, this could result in tissue residues in the Welland River at station WR-4 N (Hg = 1.77 μg/g) that ranged from 0.35 μg/g in amphipods to 0.65 μg/g in chironomids. At station WR-6 S (Hg=0.95μg/g), this would be expected to result in tissue residues that ranged from 0.19 μg/g in amphipods to 0.35 μg/g in chironomids.

Using the low food chain multipliers from Jellicoe Cove of 2.14 for benthivorous fish (Grapentine *et al* 2003), concentrations in benthivorous fish in the Welland River could reach 1.4 μg/g dry weight for a fish feeding exclusively on chironomids at station WR-4 N. Converting back to wet weight, this could result in tissue residues of 0.23 μg/g. Grapentine *et al* 2003 noted that a significant positive correlation existed in Jellicoe Cove sediments between total mercury and methyl mercury. However, they were unable to determine a strong relationship between sediment methyl mercury and tissue methyl mercury, aside from noting the sediment methyl mercury was a significant factor in tissue methyl mercury concentrations. Therefore, direct comparison with the CCME tissue residues for protection of consumers of aquatic biota is not possible, since these are presented as methyl mercury concentrations in tissues. As a result, comparison is made with the MOE consumption restrictions for human consumers of fish of 0.45 μg/g for the protection of most sensitive human receptors (women of child-bearing age and children under 15 years of age (MOE 2003). Benthivorous fish were selected for this comparison, since they are most likely to be in direct contact with sediments and feed mainly on sediment organisms. Similarly, at station WR-6 S, the sediment concentration of 0.95 μg/g mercury could result in tissue residues in benthivorous fish of 0.75 μg/g dry weight, which, when converted to a wet weight basis yielded a value of 0.125, which is also below the MOE criteria.

PCB concentrations in sediments that exceeded the LEL and were therefore identified with an $RQ_L > 1$, were subsequently evaluated with respect to their potential to accumulate in fish tissue to levels in excess of the IJC Guidelines of 0.1 ug/g for the protection of fish-eating wildlife. This was undertaken by multiplying the sediment concentration by the TOC corrected BSAF (reflecting the TOC concentration at the specific sampling location) as described in Section 6.2, and converting to wet weight concentrations. Sediment concentrations at three of the sites, WR-2 S WR-6 S and WR-8 M yielded tissue residue in excess of 0.1 μg/g (0.14 μg/g, 0.3 μg/g and 0.14 μg/g respectively). It should be noted that the above screening has been undertaken with a number of conservative assumptions as described in Section 6.2. Since it is unlikely that fish will feed exclusively in these areas, the estimated tissue residues are likely to be over-estimates. As well, the effects of dilution due to river flows will also reduce exposures. Since the tissue residues estimated were in most cases slightly above the IJC criteria, it is unlikely that actual levels in fish in the river will exceed the criteria.

Additional evaluation of the PCB concentrations has been undertaken on the basis of the size of the area affected. The distribution of PCB compounds in sediments (Table 5.1.2) shows that the elevated PCB concentrations are confined to areas along the margins of the river and that sediments in the middle of the channel typically have much lower concentrations of PCBs. Elevated levels of PCBs also occur only at a few locations, and accumulation in the shoreline area cannot be considered as a generalised condition. Since distances between sampling points were approximately 1 km at most stations, and the length of river sampled is approximately 8 km, the areas with identified risks, as calculated above, represents less than 12% of the river (it has been assumed that the area of PCB contamination extends only to the middle of the river at each of the sites, which is also an overestimate).

Therefore, for larger fish that would range over much of the length of the river, the potential tissue residues would be approximately 12% of the values calculated above. For small fish, which would be confined in their foraging ranges, the maximum exposure is calculated as 50% of the values derived above. This has been derived on the assumptions that PCB contamination up to the concentration measured at the site extends to midway between the site sampled, and the next adjacent site. The shortest distance to the next site was calculated as 0.5 km (station WR-8 to WR-9) and therefore the area affected would range to 250m on either side of the sampling point. Since the accumulation of fine-grained sediments was confined to a narrow strip of approximately 1-2 m of accumulated sediments along the shoreline before depths, and scour, increase, the exposure area, and therefore the concentrations were multiplied by 0.5 (this is also a conservative approach, since distances to mid-channel were typically 7 to 10m). This results in potential accumulations of less than 0.1 ug/g, which would be below the IJC criteria.

PAH concentrations ranged up to a high of 5.5 µg/g, not including one site adjacent to the Oxy Vinyl (Geon) site where concentrations ranged up to 107 µg/g. The latter is discussed in more detail in Section 6.6.1. The low concentrations in the remainder of the river indicate that there are no concerns with PAH. In particular, concentrations in sediments at and below the former Ford Glass plant site (stations WR-9 and WR-10) yielded low concentrations of PAH compounds (Table 5.1.3) and all of these sites resulted in RQ_L <1 (i.e., concentrations were below the MOE LEL). Concentrations at the other sites were well below the LEL, or, in the case of station WR-5S, marginally above the LEL. In many cases, PAH concentrations in sediments were higher upstream of the Welland Canal By-Pass (stations B1 to B14 in Table A-13, Appendix A), and suggest that upstream sources may be at least partly responsible for accumulation of PAHs in these sediments.

Dioxin and furan concentrations in sediments ranged up to a high of 9.7, which is less than the CCME PEL, and therefore resulted in an RQ_{PEL} < 1 at all sites. As a result, it is anticipated that the existing concentrations of dioxins and furans in the Welland River would not result in adverse effects on biota.

Based on the above evaluation, additional assessment of sediments in the Welland River would be warranted for the metals copper, chromium and nickel at the majority of sites, and PAHs at selected sites.

6.5 Level Two Sites

6.5.1 Sir Adam Beck Reservoir

The review of data collected by the MOE in 1983 (Kauss and Post 1987) indicates that sediment contaminant concerns in the Reservoir are minor. Comparison of concentrations with current sediment criteria indicates that only a few COCs exceeded the LEL.

The assessment of current sediment conditions is based upon the recent study undertaken by Environment Canada (Williams *et al.* 2003). The evaluation of sediment contaminant concentrations relative to established criteria is presented in Table 6.4.3 below.

It should be noted that the Environment Canada study used a combination of hydrofluoric acid and Aqua-Regia digestion. The hydrofluoric acid will result in higher concentrations of most metals, since the hydrofluoric digestion will also dissolve some of the mineral matrices. Consequently, the use of hydrofluoric extraction makes comparison with PSQGs difficult since PSQG levels are based on data using Aqua-Regia digestion. Nonetheless, if values are below the benchmark values using hydrofluoric acid digestion, then there is good assurance there will be no effects (typically those metals held in the mineral matrices are considered biologically unavailable).

Williams *et al*. (2003) note that sediment concentrations in the Reservoir in 1998 were similar to concentrations recorded in 1983. Therefore, since the method of analysis in 1998 differed from the method used to derive the benchmark values (MOE LELs and SEL), comparison is made to the 1983 sediment concentrations, with the assurance of Williams *et al.* (2003) that these are similar to current levels in reservoir sediments.

TABLE 6.4.3
Calculation of Risk Quotients for Sediment Impacts, Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Sir Adam Beck Reservoir μg/g	Risk Quotient	
	LEL	SEL		RQ_L	RQ_S
Arsenic	6	33	13.2	2.2	0.4
Cadmium	0.6	10	1.7	2.8	0.17
Chromium	25	110	36	1.4	0.33
Copper	16	110	32	2.0	0.3
Mercury	0.2	2.0	0.12	0.6	-
Lead	31	250	70	2.3	0.3
Nickel	16	75	46	2.9	0.6
Zinc	120	820	140	1.2	0.2
PCBs (total)	0.07	26*	0.03	0.4	-

* SEL based on TOC of 5%

While a number of the metals exceeded the LELs, as denoted by $RQ_L > 1$, none of the parameters noted above exceeded the SELs. As noted above, current concentrations in sediments are likely to be similar. Since none of the parameters resulted in an $RQ_S > 1$ when compared to the MOE SELs, and both mercury and PCBs resulted in $RQ_L < 1$ when compared to the MOE LELs, additional evaluation of sediment concentrations was not considered necessary. The sediments in the reservoir, based on the COCs evaluated, can be considered as presenting negligible risk of adverse effects to biota and additional studies would not be warranted.

6.5.2 Thompson’s Creek

Sediments at the mouth of Thompson's Creek were evaluated initially with respect to established criteria levels, such as the MOE PSQGs. The results are presented in Table 6.4.4.

TABLE 6.4.4
Calculation of Risk Quotients for Sediment Impacts, Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Thompson's Creek μg/g	Risk Quotient	
	LEL	SEL		RQ_L	RQ_S
Arsenic	6	33	3.7	0.62	-
Cadmium	0.6	10	<0.5	<0.8	-
Chromium	26	110	46	1.8	0.42
Copper	16	110	271	16.9	2.5
Mercury	0.2	2.0	0.34	1.7	0.17
Lead	32	250	20	0.6	-
Nickel	16	75	56	3.5	0.75
Zinc	120	820	105	0.9	-
PCBs (total)	0.07	26*	0.07	1	-
PAH (total)	4	500*	0.87	0.2	-

* SEL based on TOC of 5%

The single sample collected at the mouth of Thompson's Creek resulted in exceedances of the LEL for a number of metals, including copper, chromium and nickel. Of these, only copper exceeded the SEL.

Copper concentrations in sediments were generally lower in upstream areas, and as shown on the inset on Figure 18, increase at locations adjacent to the Cytec plant. In 1996, the sample at Thompson's Creek also showed elevated levels of copper in sediments, and the pattern of copper distribution in river sediments suggests that the elevated concentrations may originate from the Cytec site. The Beak (1994) study found elevated copper concentrations only at the upstream reference site.

Since mercury concentrations in sediments resulted in a $RQ_L > 1$ when compared to the MOE LELs, additional evaluation was undertaken using the same data as for the Welland River assessment (Section 6.4.2). BSAFs for chironomids and amphipods of 0.37 and 0.2 respectively, were predicted to result in residues of 0.12 μg/g in chironomids and 0.07 μg/g in amphipods. This in turn, using the magnification factor of 2.14 derived by Grapentine *et al* (2003) for Peninsula Harbour, yields a predicted fish tissue residue of 0.02 μg/g wet weight, which is below the tissue residue guideline of 0.45 μg/g for consumption of fish.

Based on the above assessment, additional studies focussing on sediment copper would be warranted for this site.

6.5.3 Frenchman's Creek

Frenchman's Creek is a small creek that alternately flows through riffle areas, and short, depositional pools. Much of the substrate can be characterized as gravel and rock, with areas along the banks where sands and silts have accumulated. The lower section, from Thompson Rd to the rail yards was flooded back by beaver activity (water levels in this area were low during the initial site visit in September, and indicate that the flooding is recent). North of the rail yard, the creek flows rapidly over riffle sections interspersed with flooded areas, again due to the presence of beaver dams (Figure 20).

A number of tributaries join the main branch of the creek. Below the QEW, the first is a tributary that flows past the Fleet Aerospace site, and is characterised by riffles and pool sections. The creek in this section flows through a golf course where it joins the main branch of the creek.

The results of the initial evaluation of sediment contaminant concentrations relative to established benchmark values derived from existing criteria (MOE PSQGs) are presented in Table 6.4.5 below.

TABLE 6.4.5
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Frenchman's Creek µg/g	Risk Quotient			
	LEL	SEL		RQ_L	Sites with $RQ_L>1$ (%)	RQ_S	Sites with $RQ_S>1$ (%)
Arsenic	6	33	7.9	1.3	1 (13)	0.24	-
Cadmium	0.6	10	33.6	56	6 (75)	3.36	3 (38)
Chromium	26	110	337	13	7 (88)	3.1	3 (38)
Copper	16	110	65	4.1	7 (88)	0.6	-
Mercury	0.2	2.0	0.8	4	2 (25)	0.4	-
Lead	32	250	70	2.2	6 (75)	0.28	-
Nickel	16	75	35	2.2	6 (75)	0.5	-
Zinc	120	820	619	5.2	7 (88)	0.75	-
PCBs (total)	0.07	18.4*	0.52	7.4	3 (38)	0.03	-
PAH (total)	4	356**	7.75	1.9	1 (20)	0.02	-
Dioxins/furans	0.85[a]	21.5[b]	51.1 pg/g[c]	60	5 (83)	2.4[d]	1 (17)

* SEL based on TOC of 3.47% **SEL based on TOC of 3.56%. [a] ISQG in pg/g total TEQ (CCME 2001). [b] PEL in pg/g total TEQ (CCME 2001). c Total TEQ based on fish TEFs (WHO 1998). [d] RQ_{PEL}.

The initial screening, based on MOE LELs, indicates that all of the COCs listed above resulted in an $RQ_L > 1$ at one or more of the locations sampled. In the case of arsenic, only one of the stations had sediment arsenic concentrations that exceeded the LEL and resulted in an $RQ_L > 1$.

In the second screening, where concentrations were compared to MOE SELs, two COCs, chromium and cadmium resulted in a $RQ_S > 1$, and indicate a potential risk to biota. Additional assessment would therefore be warranted for these metals.

Sediment cadmium concentrations resulted in $RQ_S > 1$ with respect to the SELs at both sites below Fleet (FC-2 and FC-4; a RQ_S of 3.36 (i.e., 3-times SEL) at FC2) and also on the branch from the Gould/ CanOxy sites. Sediment chromium also resulted in $RQ_S > 1$ relative to the SEL at both sites below Fleet, as well as at the station near the mouth. The results indicate that more than one source of cadmium has existed, but that chromium appears to originate from a single source. The data also indicate that mercury exceeds LELs below the Fleet site, though sediment concentrations did not identify a significant risk since comparison with the SEL criteria showed all sites had an $RQ_S < 1$. The elevated concentrations of both cadmium and chromium at station FC-8, located near the mouth of the creek, suggest that fluvial transport of these metals has occurred, likely from upstream sources. Concentrations of both metals were lower at this station than at upstream stations, and is consistent with attenuation with distance from the source(s).

While chromium has been identified in effluents from Fleet Manufacturing in the past, the re-routing of process effluents to the municipal sewer suggests that the chromium concentrations in sediments at station FC-2 are likely due to historical deposition. Since no record of cadmium in effluents from this site could be found, the source of this metal is uncertain.

Sample results for PCBs indicated slightly higher concentrations in the tributary from Durez, and are consistent with earlier MOE results (Richman 1992), which also noted higher PCB concentrations in this tributary with a maximum of 0.52 μg/g at station FC-5. Since TOC at station FC-5 was 16.8%, the BSAF for sediment to fish was estimated at 2.0. This resulted in an estimated tissue residue of 0.17 μg/g wet weight, which is above the IJC guideline of 0.1 μg/g. Given the conservative assumptions used in deriving this estimate, the actual tissue residues are likely to be lower.

Despite the presence of lead in sediments noted in the earlier studies (MOE 1993b), lead concentrations at all sites in the creek were below screening criteria, though sediment in both the tributary from the Fleet site and the tributary from the Durez site (stations FC-2 and FC-5) yielded slightly higher lead concentrations than at the other stations.

Dioxin and furan concentrations resulted in $RQ_{PEL}>1$ when compared to the CCME PEL, and additional assessment of these compounds would be warranted.

Since dioxins and furans were identified with potential risks in the tributary from the CanOxy and Gould sites, more detailed investigation would be warranted to determine if the concentrations present in the creek are likely to result in adverse effects on resident receptors.

6.6 Level Three Sites

6.6.1 Welland River at Geon

The samples collected at the Oxy Vinyl (Geon) site consisted of three samples along a transect near the downstream end of the property. These were collected as part of the sampling in the Welland River, and included samples in depositional areas along the north and south banks of the river, as well as a sample in the middle of the channel. Sediments sampled ranged from black silty sediments high in organic detritus adjacent to the cattail marsh on the north side (station WR-4 N) to firm clay in the middle of the channel (station WR-4 M). In all other respects the sites sampled were similar to the Welland River sites described in section 6.4.2.

The results of the analysis are presented in Tables 5.1.2, 5.1.3 and 5.1.4 under the Welland River as station WR-4. The significance of the sediment concentrations is assessed below in Table 6.4.6 relative to MOE LEL and SEL guidelines.

TABLE 6.4.6
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Welland River at Geon µg/g	Risk Quotient			
	LEL	SEL		RQ_L	Sites with RQ_L>1 (%)	RQ_S	Sites with RQ_S>1 (%)
Arsenic	6	33	7.4	1.2	1 (33)	0.2	-
Cadmium	0.6	10	0.8	1.3	1 (33)	0.08	-
Chromium	26	110	131	5	3 (100)	1.2	2 (66)
Copper	16	110	53	3.3	3 (100)	0.5	-
Mercury	0.2	2.0	1.77	8.85	3 (100)	0.9	-
Lead	32	250	27	0.9	-	-	-
Nickel	16	75	110	6.9	3 (100)	1.5	2 (66)
Zinc	120	820	435	3.6	3 (100)	0.5	-
PCBs (total)	0.07	53*	0.1	1.4	1 (33)	0.002	-
PAHs	4	1000*	107	26.8	1 (50)	0.1	-
Dioxin/furan	0.85[a]	21.5[b]	8.3 pg/g[c]	9.8	-	0.46[d]	-

* SEL based on maximum TOC of 10% (measured concentration was 11.7%). [a] ISQG in pg/g total TEQ (CCME 2001). [b] PEL in pg/g total TEQ (CCME 2001). c Total TEQ based on fish TEFs (WHO 1998). [d] RQ_{PEL}.

Both chromium and nickel were identified as potential risks due to $RQ_S > 1$ when assessed relative to the MOE SELs and indicate that additional assessment would be warranted.

PAH compounds also resulted in RQ_L>1 relative to the LELs, which as noted in Section 6.2 would be the more appropriate screening concentrations for these compounds. Comparison of the results with other studies shows that sediment at station WR-4 N exceeds the no effects range and indicates that adverse effects could occur as a result of elevated PAH concentrations at this site. However, the small area of contamination suggests that the effects would be localized to the benthic organisms within this area, and the effects on local communities would be negligible.

Comparison with upstream data from the MOE/EC 1996 study shows elevated levels of PAH in sediments upstream of the siphons at the Welland Canal by-pass, associated with the Atlas Steel site (Table A-12, Appendix A). Since this site was in a relatively protected area, the elevated PAH concentrations may represent accretion of sediments from upstream sources that were deposited in this area during high flows.

However, the possibility of local source(s) also needs to be considered. While PAH concentrations upstream of the siphons at the Welland Canal by-pass were also elevated, with highest concentration in the subsurface layers below the 30 cm depth, the maximum concentration recorded was 30.7 μg/g, which is considerably lower than the concentration of 107 μg/g recorded at WR-4 N, and suggests that other potential sources should be considered. Since the elevated concentration at this location was clearly much higher than either upstream or downstream in this section of the river, a number of possibilities could occur. The elevated concentration at this site may represent a local discharge. Further investigation would be required to identify the source(s).

Mercury in sediments at this location was assessed as part of the Welland River assessment in Section 6.4.2.

6.6.2 Black Creek Mouth

Since recent sampling has been undertaken by MOE and EC in Black Creek, additional samples were not collected. The results of previous sampling indicate that some of the parameters, such as copper and chromium, exceeded the LEL. These are further evaluated in Table 6.4.7 with respect to potential risks to aquatic organisms.

TABLE 6.4.7
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Black Creek μg/g	Risk Quotient	
	LEL	SEL		RQ_L	RQ_S
Arsenic	6	33	<5	-	-
Cadmium	0.6	10	<1	-	-
Chromium	26	110	38	1.5	0.35
Copper	16	110	25	1.6	0.23
Mercury	0.2	2.0	0.06	0.3	-

Compound	**SQC**		**Highest concentration in Black Creek μg/g**	**Risk Quotient**	
	LEL	**SEL**		**RQ_L**	**RQ_S**
Lead	32	250	49	1.6	0.2
Nickel	16	75	37	2.3	0.5
Zinc	120	820	109	0.9	-
PCBs (total)	0.07	21.2*	0.02	0.3	-
PAH (total)	4	560**	1.08[a]	0.3	-

* SEL based on TOC of 4%. ** SEL based on TOC of 5.6%. [a] assumes concentrations in creek were at detection limits.

Sediment copper and chromium exceeded the LEL guidelines at both sites sampled by MOE/EC in 2002 (Table A-15, Appendix A). The exceedances for both were minor. Toxicological evaluation of these concentrations indicates they are well below effects levels for copper or chromium. For example, copper concentrations at the sites reviewed (Section 6.3) were well over the SEL of 110 μg/g before adverse effects, such as growth inhibition or lethality were observed in laboratory sediment bioassays. Similarly, chromium concentrations in excess of 110 μg/g did not result in measurable adverse effects on test organisms (Section 6.3). Therefore, the exceedances of the LEL are not considered likely to result in adverse effects on biota.

Review of the analytical results for the organic parameters tested indicated that a limited number of pesticides were noted at concentrations above detection limits. These reflect historical uses of these compounds within the watershed since all of the compounds detected are used for agricultural purposes.

The above data suggests that conditions in Black Creek are typical of conditions in the Niagara Peninsula, and show no indications of contaminant loading from any particular source. In much of this area, concentrations of both copper and chromium exceed the existing LEL. Concentrations of chromium and copper were similar to upstream areas in the Welland River as determined during the MOE/EC 1996 study (Table A-11, Appendix A), and together, can be considered as typical of ambient conditions in these rivers. On the basis of the above results, it can be concluded that there are no identified contaminated sediment concerns in Black Creek.

6.6.3 Pell Creek

Pell Creek is a small, rapidly flowing creek with predominantly sand and gravel substrates. The lower section flows through the western end of the Town of Chippawa, through primarily residential areas. Little accumulation of fine-grained sediments has occurred in the creek, and suggests that most contaminants that may have been discharged to the creek would have been transported to Chippawa Creek. The evaluation of creek sediments with respect to MOE PSQGs is presented in Table 6.4.8.

TABLE 6.4.8
Calculation of Risk Quotients for Sediment Impacts, Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Pell Creek μg/g	Risk Quotient			
	LEL	SEL		RQ_L	Sites with RQ_L>1 (%)	RQ_S	Sites with RQ_S>1 (%)
Arsenic	6	33	1.2	0.2	-	-	-
Cadmium	0.6	10	<0.5	-	-	-	-
Chromium	26	110	27	1.04	1 (50)	0.25	-
Copper	16	110	49	3.06	1 (50)	0.45	-
Mercury	0.2	2.0	0.04	0.2	-	-	-
Lead	32	250	21	0.7	-	-	-
Nickel	16	75	11	0.7	-	-	-
Zinc	120	820	99	0.8	-	-	-
PCBs (total)	0.07	10.6*	<0.03	-	-	-	-
PAHs	4	201*	12.7	3.2	1 (50)	0.06	-

* SEL based on TOC of 2.01%

Creek sediments showed RQs of greater than one only in relation to the most conservative screening levels (LELs). Both metals and PCBs were below the MOE LELs for most parameters, with the exception of copper, which reached a high of 49 μg/g at station PC-2. However, this was still well below the SEL of 110 μg/g.

None of the parameters exceeded the SEL screening criteria, and RQs as a result were all less than one. There is no indication of contaminants in the system from upstream sources. This may be partly mitigated by the mainly sandy sediments in the creek. However, comparison of contaminant concentrations in the creek, with those in Chippawa Creek at the mouth of Pell Creek (station CC-2 N, Tables 5.1.2 to 5.1.4) indicates that no increases in any of the COCs have occurred, and that no additional COCs have been identified as originating in the creek. Consequently, no contaminant concerns were found to exist in Pell Creek that would require additional investigation, or consideration of remedial actions. However, as noted below, there are existing concerns regarding potential loadings of some compounds to the creek.

PAH compounds were also above the LEL of 4 μg/g (total PAHs, as the sum of the 16 priority compounds (Persaud *et al* 1993)). Concentrations ranged up to 13 μg/g, and, while below the concentrations that were found to elicit adverse effects in other studies (Section 6.2), in the sandy substrates that characterize this area, could be considered elevated (PAHs tend to accumulate with fine-grained sediments, and would be considered unusual in sandy materials). The use of power transformers on the site, the use of coke in the production of abrasive products at both the plants, and runoff from road surfaces could all potentially contribute PAHs to the creek.

Since no risks were identified in sediments in Pell Creek, additional studies under Phase III would not be warranted.

6.6.4 Chippawa Creek

As noted in Section 4.3.4, Chippawa Creek is the lower section of the Welland River that, through the construction of the Chippawa Power Canal, now conveys Niagara River flows upstream to the Chippawa Power Canal. The river is characterised as broad and swiftly flowing.

Depths at mid-channel were typically in the order of 10 m, with rapid drop-off along the banks. Substantial scour occurs along the river, with substrates in the main channel comprised mainly of hard-packed materials (coarse sand and gravel). Deposition of sediments occurs only in protected areas along the margins, such as on the inside bends of river meanders, in embayments, and at creek mouths. Even in these areas, sand typically forms a large component of the substrate, as indicated by visual inspection. In many of the upstream locations, near the former mouth of the river in the Town of Chippawa, the river channel is straighter, currents became stronger, and no depositional areas could be located. The locations sampled are described in detail in Table 5.1.1 and are shown on Figure 14.

The results of the sampling program are provided in Tables 5.1.2 and 5.1.3. The evaluation of sediments relative to the MOE PSQGs is presented in Table 6.4.9 below.

TABLE 6.4.9
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Chippawa Creek μg/g	Risk Quotient			
	LEL	SEL		RQ_L	Sites with RQ_L>1 (%)	RQ_S	Sites with RQ_S>1 (%)
Arsenic	6	33	4.2	0.7	-	-	-
Cadmium	0.6	10	0.7	1.2	1 (10)	0.07	-
Chromium	26	110	23	0.9	-	-	-
Copper	16	110	37	2.3	7 (70)	0.34	-
Mercury	0.2	2.0	0.1	0.5	-	-	-
Lead	32	250	19	0.6	-	-	-
Nickel	16	75	30	1.9	8 (80)	0.4	-
Zinc	120	820	96	0.8	-	-	-
PCBs (total)	0.07	11.3*	0.19	2.7	1 (10)	0.04	-
PAH (total)	4	213*	5.9	1.5	1 (10)	0.06	-

* SEL based on TOC of 2.13%

All of the COCs were present at low concentrations. With the exception of one location (CC6-S), no exceedances of MOE sediment criteria (LELs) were noted at any of the sites for metals, PCBs or PAHs. At location CC6-S, chromium and copper marginally exceeded the respective LELs while at station CC-5 N, potential risks ($RQ_L > 1$) were determined due to PCB concentrations of 0.19 μg/g. Sediment contaminant concerns in Chippawa Creek appear to be restricted to a few metals that marginally exceed the lowest MOE screening criteria (LELs) and therefore contribute negligible risk to aquatic biota. The review of studies conducted in other metals contaminated sites (Section 6.2) indicates that effects levels for metals are typically well in excess of the MOE SELs. As a result, no areas could be identified that presented unacceptable risks to biota and would warrant further investigation.

The marginally elevated levels of PAHs at one site, though slightly in excess of the MOE LEL and therefore, identified as having a slight potential risk ($RQ_L = 1.5$), when compared to the concentrations at other sites that resulted in no adverse effects, was identified as having negligible risk. Therefore, no additional concerns exist regarding PAH contamination of sediments.

PCBs in creek sediments were also elevated above screening criteria and yielded an RQ_L of 2.7, and therefore warranted additional assessment. Following the methodology described in Section 6.2, the TOC at the site was used to estimate the BSAF for uptake of PCBs from these sediments by fish. This resulted in a projected tissue residue of 0.25 μg/g wet weight, which is above the IJC criterion of 0.1 μg/g. However, this should be considered as a conservative estimate. Only one of the locations sampled in Chippawa Creek yielded PCB concentrations above detection limits and therefore, exposure of fish to PCBs would be confined to a limited area. As noted earlier, the test conditions under which the exposure factors were obtained would result in a higher estimate of uptake due to the static conditions of the test. The significant flows in Chippawa Creek would serve to dilute releases of PCBs from sediments, thereby reducing exposure to fish. Actual tissue residues of fish in the creek would be expected to be much lower.

Large fish will feed broadly within an area and therefore, their exposure to isolated areas of higher PCBs would be limited. The total length of the canal is estimated to be 6 km, while the area of contamination by PCBs is very conservatively estimated to be 1 km (i.e., one-half the distance to the next sampling point on either side). As a result, the exposure of sport fish to PCBs could be reduced by a similar factor. Since concentrations of PCBs were below the detection limits at the other sites, it is assumed that the contribution from these areas is negligible. Therefore, fish are likely to accumulate less than one-sixth the amount estimated.

6.6.5 Chippawa Power Canal

Strong flows in the Power Canal precluded collection of sediment samples from the Canal. Isolated areas along the banks of the canal had accumulations of fine-grained sediments, the most notable being a large storm drainage ditch on the east side of the canal. As noted in Section 5, sediments samples on the west side were collected from influent ditches, and not from the Power Canal. The evaluation of sediment quality is presented in Table 6.4.10.

TABLE 6.4.10:
Calculation of Risk Quotients for Sediment Impacts, Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Chippawa Power Canal µg/g	Risk Quotient	
	LEL	SEL		RQ_L	RQ_S
Arsenic	6	33	4	0.7	-
Cadmium	0.6	10	<D.L.	-	-
Chromium	26	110	28	1.1	0.25
Copper	16	110	24	1.5	0.22
Mercury	0.2	2.0	<D.L.	-	-
Lead	32	250	11	0.3	-
Nickel	16	75	31	1.9	0.41
Zinc	120	820	71	0.6	-
PCBs (total)	0.07		<0.03	-	-
PAH (total)	4	384*	342	96	0.89

* based on TOC of 3.84%

Sediment in the Power Canal and in the influent ditches were typically below the MOE LELs (RQ_L <1) except for copper and chromium, both of which marginally exceeded the respective LELs and resulted in negligible risk quotients. Since these concentrations were higher than recorded in Chippawa Creek, it seems reasonable to conclude that both the copper and chromium originated in the Welland River (both elements were recorded at higher concentrations upstream in the Welland River), though the drainage ditch may also be a potential source. Sediments could not be obtained in the drainage ditch due to the rocky substrate, which suggests that flows in the ditch will flush out any accumulated sediments.

Samples collected on the west side represent conditions in in-flow ditches to the canal. At one of the two sites, elevated levels of PAHs were noted (342 µg/g). Since the concentration exceeds the PSQG LEL, as noted in Section 6.2, potential adverse effects could occur. However, since this was recorded in a ditch, and not in the Power Canal, it is anticipated that any erosion of this material to the Power Canal would result in significant dilution. As a result, adverse effects to biota would not be anticipated.

The sample collected in the Power Canal suggests that there are no contaminant concerns with sediments in the Power Canal. This is supported by results of sediment sampling in both the Welland River and Chippawa Creek that found no contaminant concerns in either of these waterbodies. Since both of these are the major sources of water to the Power Canal, the conditions in the Power Canal would be expected to not exceed conditions in either of these tributaries. This is supported by the sample at CPC-3, which showed sediment concentrations of the metals ranged between the low concentrations recorded in Chippawa Creek sediments and the higher concentrations recorded in the lower part of the Welland River (station WR-9 and WR-10). In terms of contaminant loading, which would occur primarily through erosion and transport of river sediments, (since most of the historical sources have been controlled) the Welland River likely contributes a higher contaminant load than Chippawa Creek, since concentrations of a number of parameters were higher in Welland River sediments than in Chippawa Creek sediments. Nonetheless, the high flows contributed by Chippawa Creek would serve to further dilute any contribution from the Welland River, and this is apparent in the lower sediment concentrations in the Power Canal, compared to the Welland River.

The samples collected from some of the influent streams and ditches, however, indicate that there are continued loadings of some contaminants. In particular, the elevated levels of PAH compounds in one of the ditches (CPC-1) indicates potential concerns. Comparison of the results of this sample (total PAH 342 μg/g) with the results of other studies (Section 6.3) indicates that risks could be present and potential adverse effects on biota could occur. It is unlikely that this would result in adverse effects in the Power Canal, should this material erode and reach the power canal due to the large volume of flow in the Power Canal.

Due to the lack of potential risks, additional investigations in the Power Canal under Phase III are not warranted.

6.6.6 Niagara River at Queenston

The strong flows in the Niagara River have precluded deposition of fine particles except in protected areas. As noted, these tend to occur on the leeward side of points along the river, and these formed the areas sampled during this survey. A total of 4 separate embayments along the river, from Queenston to Niagara-on-the-Lake were sampled. The locations sampled are shown on Figure 15, and the results are presented in Tables 5.1.2, and 5.1.4.

The results of the sediment sampling are screened relative to existing criteria in Table 6.4.11.

TABLE 6.4.11:
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	SQC		Highest concentration in Niagara River at Queenston μg/g	Risk Quotient			
	LEL	SEL		RQ_L	Sites with RQ_L>1 (%)	RQ_S	Sites with RQ_S>1 (%)
Arsenic	6	33	2.9	0.5	-	-	-
Cadmium	0.6	10	<0.5	-	-	-	-

Compound	SQC		Highest concentration in Niagara River at Queenston µg/g	Risk Quotient			
	LEL	SEL		RQ$_L$	Sites with RQ$_L$>1 (%)	RQ$_S$	Sites with RQ$_S$>1 (%)
Chromium	26	110	19	0.7	-	-	-
Copper	16	110	19	1.2	2 (50)	-	-
Mercury	0.2	2.0	0.23	1.15	3 (75)	-	-
Lead	32	250	16	0.5	-	-	-
Nickel	16	75	21	1.3	2 (50)	-	-
Zinc	120	820	95	0.8	-	-	-
PCBs (total)	0.07	4.7*	0.07	1	-	-	-
Dioxins/furans	0.85[a]	21.5[b]	28.7 pg/g[c]	33.8	4 (100)	1.3[d]	1 (25)

* SEL based on TOC of 0.88%. [a] ISQG in pg/g total TEQ (CCME 2001). [b] PEL in pg/g total TEQ (CCME 2001). [c] Total TEQ based on fish TEFs (WHO 1998). [d] RQ$_{PEL}$.

The results indicate that only minor exceedances of the most conservative criteria occurred for the metals, with RQ$_L$s marginally above a value of one for three of the metals. In all cases where the RQ$_L$ >1, the sediment metals concentrations were only marginally in excess of the LELs.

Concentrations of all metals were low in these sediments, and with the exception of mercury at one location (NR-3), were all below the MOE LEL guidelines. Mercury at station NR-3 only marginally exceeded the LEL (0.23 µg/g, compared to the LEL of 0.2 µg/g), resulting in a negligible risk.

Comparison of the dioxin and furan concentrations, presented as fish TEQs based on the 1998 WHO TEFs, with the CCME ISQG resulted in an RQ>1 at all four of the sites sampled. Additional evaluation against the CCME PELs resulted in sediments at 2 of the 4 stations resulting in RQ$_{PEL}$>1, and therefore, therefore, sediment concentrations at these locations were evaluated with respect to potential adverse effects on lake trout eggs.

The highest sediment concentration of 28.7 pg/g TEQ was calculated to result in a concentration of 4.2 pg/g TEQ in lake trout eggs, as described in Section 6.2 (based on a BSAF of 0.148 from Cook *et al* 2003). Since this was lower than the value of 5.0 ug/g in sediment that Cook *et al.* (2003) estimated could result in adverse effects on lake trout eggs, potential risks to these sensitive receptors are likely to be low.

Therefore, additional assessment under Phase III was not considered to be warranted for these sites.

6.6.7 Niagara River at Niagara-on-the-Lake

The combination of river flow velocity from the Niagara River and wave action from Lake Ontario resulted in most areas being well scoured. Where softer substrates did occur, sand predominated as sediment material. Only one location, in a protected area, again on the leeward (downstream) side of a point of land, had accumulations of fine materials, and this is shown on Figure 16.

Sediment analytical results are presented in Tables 5.1.2 and 5.1.4, and indicate that with the exception of mercury all metals were below their respective LELs. Evaluation of sediment concentrations with respect to the screening level criteria are presented in Table 6.4.12.

TABLE 6.4.12:
Calculation of Risk Quotients for Sediment Impacts,
Based on Available Sediment Quality Criteria

Compound	**SQC**		**Highest concentration in Niagara River at Niagara-on-the-Lake µg/g**	**Risk Quotient**	
	LEL	**SEL**		**RQ_L**	**RQ_S**
Arsenic	6	33	2.5	0.42	-
Cadmium	0.6	10	<0.5	-	-
Chromium	26	110	14	0.54	-
Copper	16	110	15	0.94	-
Mercury	0.2	2.0	0.52	2.6	0.26
Lead	32	250	14	0.45	-
Nickel	16	75	15	0.94	-
Zinc	120	820	89	0.74	-
PCBs (total)	0.07	5.8*	0.11	1.6	0.28
Dioxins/furans	0.85[a]	21.5[b]	55.5 pg/g[c]	65.3	2.6[d]

* SEL based on TOC of 1.1% . [a] ISQG in pg/g total TEQ (CCME 2001). [b] PEL in pg/g total TEQ (CCME 2001). [c] Total TEQ based on fish TEFs (WHO 1998). [d] RQ_{PEL}.

The above evaluation indicates that mercury and PCBs exceeded the most stringent of the screening criteria (the MOE LEL) and indicated a low potential for risks, while dioxin and furan concentrations exceeded both the CCME ISQGs and the PEL, and suggest the potential for risks to some receptors. Mercury concentrations in the Niagara River were within the range of mercury concentrations recorded from the Welland River, and suggest that sources on the Canadian side of the river could be contributing to accumulation of mercury in Niagara River sediments. Similarly, PCB concentrations in the Welland River and Frenchman's Creek both exceeded the concentration at Niagara-on-the-Lake, and could theoretically be contributing to the accumulation. However, the broad usage of these COCs in the past indicates that a variety of sources on both the Canadian and U.S. sides of the river could have contributed either of these compounds to the river.

Since mercury is considered a bioaccumulative compound, and can biomagnify through trophic levels, evaluation relative to toxicity benchmarks is typically not sufficient to address concerns related to mercury. Therefore, despite concentrations that were below the SEL criteria, the exceedance of the LEL indicates that additional evaluation of mercury in sediments would be warranted.

In order to provide some context for mercury concentrations in sediments, a review of sites in Jellico Cove (Peninsula Harbour, Grapentine *et al.* 2003) with similar TOC concentrations (1% to 1.5%) to those in the Niagara River at Niagara-on-the-Lake (1.1%) was undertaken. In the Jellico Cove study, BSAFs (based on dry weight : dry weight) ranged from 1.3 for both chironomids and amphipods in mainly silt-clay substrates, to 2.75 for chironomids and 2.25 for amphipods in mainly sand substrates. Again, chironomids had higher BSAFs than amphipods. Since Niagara River sediments were mainly sandy sediments, the 2.75 value was selected as the most appropriate. Therefore, at the concentration of 0.52 μg/g Hg in Niagara-on-the-Lake sediments, chironomid tissue residues of up to 1.43 μg/g Hg would be anticipated. Using the benthivorous fish (see Section 6.2) biomagnification factor of 2.14, this could result in tissue residues in fish of 3.06 μg/g dry weight. Converting to wet weight would result in a concentration of 0.51 μg/g, which is marginally in excess of the MOE criteria of 0.45 ug/g.

Since dioxin and furan concentrations in sediment resulted in $RQ_{PEL} > 1$ in the screening level assessment relative to CCME PEL criteria, additional evaluation was undertaken based on potential risks to fish as described in Section 6.2. The predicted level in lake trout eggs in this preliminary assessment (8.14 pg/g TEQ, based on a BSAF of 0.148 from Cook *et al* 2003) was greater than the 5 pg/g level associated with adverse effects (Section 6.2) and therefore, potential risks exist for some sensitive receptors under the conservative assumptions made in this screening assessment. It should be noted that these represent a “worst-case” scenario that may not be truly representative of site-specific conditions, and it is questionable whether this area would be a suitable spawning area for lake trout. Since other species may be less sensitive, the above assessment may over-estimate the risks to aquatic life. Nonetheless, the result of this screening indicates that adverse effects could occur on some sensitive receptors, and additional assessment of the existing levels of contamination would be warranted.

Since sediments at both Frenchman's Creek and Niagara-on-the-Lake had elevated dioxin and furan concentrations, a comparison of congeners was undertaken to determine whether sediments from Frenchman's Creek could have contributed to elevated levels at the mouth of the Niagara River. The distribution of congeners in Frenchman's Creek and the Niagara River are shown graphically on Figures 12 and 16 respectively, and indicates that the dioxins and furans in Frenchman's Creek differ from those at Niagara-on-the-Lake. At Niagara-on-the-Lake, most of the total TEQ was due to 2,3,7,8-TCDD (80%), while in Frenchman's Creek this congener contributed only 9% of the total TEQ. Since Richman (1995) has identified a number of sources on the U.S. side where 2,3,7,8-TCDD was the predominant congener, it is likely that sources other than Frenchman's Creek are responsible for the elevated levels of dioxins and furans at Niagara-on-the-Lake.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following sections summarize the findings of the Phase I and Phase II assessments, and based on these factors, determine whether additional investigation under Phase III would be warranted. The results are also summarized in Table 7.1.

7.1 Lyon's Creek West

The review of the historical activities on the site, as well as the current sampling program have identified contaminant concerns on the site. PCBs, zinc and arsenic are elevated in sediments in the wetland area to levels in excess of the PSQGs, and suggest that adverse effects on some biota could occur.

PCBs appear to be confined to the wetland area, and the remnant of the former north branch from the City. Concentrations ranged up to over the Hazardous Waste guideline, and in a large area, exceeded the MOE Table A/B criterion for Residential/Parkland use. Arsenic appears to be confined to the southwest section of the site.

The PCB evaluation also indicates there could be risks to human users of the site. Since the risks to biota and humans have been determined on the basis of conservative assumptions, it is recommended that additional delineation of the risks be undertaken to refine the estimates. As well, the potential for contaminated sediments to be carried off-site during high flow periods has not been assessed, and should be included in any follow-up work.

7.2 Welland River - Pt Robinson to Chippawa Power Canal

Due to elevated levels of copper, chromium and nickel in sediments, potential risks were identified to biota and additional investigation of these sites would be warranted under Phase III.

Localized risks were due to concentrations of mercury and PCB. However, the very conservative assumptions are likely to over-estimate potential risks. The localized area in which these occur further suggest that under natural conditions, exposure would be much lower than predicted. The assessment of risks did not identify any concerns with PCBs that would warrant additional investigation.

7.3 Sir Adam Beck Reservoir

Concentrations of all COCs were low, and were judged to pose a negligible risk to biota. Consequently, the assessment of risks to biota did not identify any concerns that would require additional investigation.

7.4 Thompson's Creek

With the exception of copper, none of the COCs identified in the Welland River adjacent to the Cytec Welland Plant would appear to be associated with the operations of the plant. Both chromium and nickel are elevated upstream of the site, and appear to be associated with past operations of the Atlas Specialty Steel mill. The issue of copper in sediments at the mouth of the creek, which was particularly high in the sample collected in 1996 by MOE-EC, would warrant additional investigation at this site.

7.5 Frenchman's Creek

Cadmium and chromium concentrations were both in excess of the SELs, and additional assessment of these COCs would be warranted.

Concentrations of dioxins and furans exceeded the CCME PELs and there is a possibility that biota in the creek could be affected through accumulation of dioxins and furans. In addition, since the evaluation is based on a single result from the tributary in question, uncertainty regarding the assessment is considered to be high. PCBs were also noted as a potential concern at one site.

Since the assessment of dioxins and furans is based on a single sample from the southeast tributary, additional investigation would be warranted to determine the degree and extent of contamination, and potential off-site transport to the main branch of Frenchman's Creek in order to more accurately assess the potential impacts of these contaminants.

7.6 Welland River at Geon

One area of elevated PAH concentrations was identified adjacent to the site though it is not clear if this has originated from the site, particularly since the review of historical activities at the site suggests that the material may originate from known sources upstream in the river. The assessment has indicated potential risks to biota could be present, but the area affected is small relative to aquatic habitats in the river. As well, both chromium and nickel exceeded the SELs at this site and would warrant further investigation.

7.7 Black Creek Mouth

Potential risks to biota due to contaminants in sediments were not identified in Black Creek. Concentrations of the COCs, while elevated above the LEL in some cases, were well below the levels associated with adverse effects. Consequently, additional investigations are not warranted.

7.8 Pell Creek

Potential risks to biota due to contaminants in sediments were not identified in Pell Creek. Concentrations of the COCs, while elevated above the LEL in some cases, were well below the levels associated with adverse effects. Consequently, additional investigations are not warranted.

7.9 Chippawa Creek

Potential risks to biota due to contaminants in sediments were not identified in Chippawa Creek though potential risks were conservatively estimated in isolated areas due to PCBs. Concentrations of PCBs and PAHs were below the levels that would likely result in adverse effects on benthic organisms. Due to the small areas affected and the mobility of fish, these are unlikely to result in adverse effects, or accumulation to unacceptable levels.

The flow of the Creek precludes the deposition of contaminants, with any contaminants entering the Creek likely conveyed to the Niagara River and Adam Beck Reservoir. Therefore, additional investigation at this site is not indicated.

7.10 Chippawa Power Canal

Potential risks to biota from contaminated sediments were not identified in the Canal and therefore, additional investigation has not been recommended for this site. However, the sampling does suggest there are continued sources of contaminants to the canal, that could be carried to the Niagara River or the Sir Adam Beck Reservoir, contributing to contaminant loading to these waterbodies.

7.11 Niagara River at Queenston

Elevated levels of dioxins and furans occurred in river sediments, and suggest potential risks due to bioaccumulation may be present in sediments from Queenston to Niagara-on-the-Lake. Due to the variety of sources to the Niagara River preclude any effective action at remediation until sources have been controlled. Previous monitoring in the river indicates that a substantial load of organic contaminants continues to be present in the river. The sediment survey, however, indicates that much of this load is being transported to Lake Ontario, with only minor amounts accumulating in depositional areas along the river.

7.12 Niagara River at Niagara-on-the-Lake

Concentration of dioxins and furans during this study were similar to levels noted during previous studies. The range in dioxin and furan concentrations in the lower Niagara River suggests that sediment accumulation (and thereby contaminant accumulation) may occur in isolated areas and that such accumulation may be temporary due to the dynamic nature of the environment. Nonetheless, dioxins and furans were detected at levels in excess of the CCME PELs.

While potential risks have been estimated under very conservative assumptions, exposure of organisms is likely to be low given the confined area affected. Therefore, additional investigation would not be warranted under this study, though the results indicate that long-term monitoring programs on the Niagara River currently conducted by the responsible agencies should be continued.

GOLDER ASSOCIATES LTD.

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Table 4.1.1:
Summary of Discharges and Monitoring Activities - Lyon's Creek West

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( ).** (Values in ug/g unless otherwise indicated).	**Biological Monitoring**	**Comments**
Stelpipe (Welland Pipe Works, formerly Page Hersey)	Welland	Stelco Inc.	1896 to 2003 (formally closed in March 2003)	20 to 60" diameter pipe. Potential use of PCB containing oils and fluids.	Settling lagoon prior to discharge to Lyons Ck	Metals, PCBs	1991: Pb (0.03 kg/d) (MOE 1993)	PCBs, metals	Pb (0.06 mg/L) > PWQO in 1986 (MOE 1993a).	None directly associated with the site. See below under Lyon's Creek for receiver-based monitoring.	None directly associated with the site. See below under Lyon's Creek for receiver-based monitoring.	None recorded	PCBs occasionally detected in effluent (B. Slattery, T. Koch, MOE Pers Comm 1991).
OPG Crowland Transformer Station	Humberstone Rd, Welland	OPG	19__ to present.	Electrical transformer station. Use of PCB-containing transformers.	Spill of transformer fluids in 1989.			PCBs		Beak 1990:14 samples analyzed for PCBs in relation to OPG spill.	Beak 1990: maximum PCB concentration of 10.6 ppm. Majority of sites <0.05 ppm.		OPG undertook cleanup of spill.
Number of potential sources.	Lyon's Creek and wetland	City of Welland, St Lawrence Seaway Authority and OPG all own sections of the site.								MOE 1991: 25 samples analyzed for PCBs throughout wetland. SLSA 1991: 62 samples analyzed for PCBs, including cores, on SLSA property. ESL 1992: 107 samples collected and analyzed, including some core samples.	MOE 1991: maximum PCB concentration of 65 ppm. Majority of sites >5 ppm. SLSA 1991: maximum surficial PCB concentration of 86 ppm. Maximum subsurface concentration of 648 ppm. Sampling showed PCBs concentrated in wetland and stream from se corner of City of Welland. ESL 1992: maximum surficial PCB concentration of 78 ppm. Maximum subsurface concentration of 304 ppm.	None recorded.	City of Welland remediated north branch to boundary of SLSA property in 1991 (removed soils from ditch). Ditch was re-routed around wetland area in 1994-5.

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Table 4.1.2:
Summary of Dischargers and Monitoring Activities - Welland River, City of Welland to Chippawa Power Canal.

Source	Location	Ownership	Years of Operation	Products/ Process	Discharges (point and non-point)	Discharge Monitoring (compounds)	Loadings	Potential CoCs	Exceedance of WQC and max. values	Sediment Monitoring	Exceedance of SQC and maximum values in ( ) (Values in ug/g unless otherwise indicated)	Biological Monitoring	Comments
Atlas Specialty Steel, Welland	upstream of Welland Canal and Pt Robinson, <1 km from river	Slater Steel Inc.	1928 to present	Specialty steels (stainless, carbon, low and high alloy, tool, machinery and mining steels in billet and ingot form)	2 discharges - McMaster St outfall until 1976 discharged process water; 42" outfall (Atlas-Mansfield). Discharges included loss of mill scale containing metals residues that formed deposits in Welland River.		1988: As (0.85 kg/d), Hg (0.005), Pb (2) (MOE 1993a)	Ni, Cr PAHs (oil and grease)	MOE 1993a - Pb (0.1 mg/L) > PWQO in 1988.	Numerous studies by Acres and MOE lead to reef areas (most contaminated areas) being remediated in 1995. Moderately contaminated adjacent areas remain. Subsequent monitoring by MOE/EC (1996) found elevated levels of Ni and Cr extend past Pt Robinson to Chippawa Power Canal. MOE (2000) conducted sediment sampling in cleanup & adjacent areas.	MOE 2000. Cu (139), Fe (7.9%), Mn (1210), Ni (506) and Cr (505) > SEL. As (10.4), Pb (63) > LEL. MOE 1990 - PAH >LEL (max 25 ppm) (MOE 1990)	Biological studies were conducted by MOE in 1990 and 1994, prior to cleanup. MOE study in 2000 found no benthic community impairment and no toxicity at Ni concentration of 506 ug/g and Cr concentration of 505 ug/g.	Due to recent assessment, additional studies not required.
Atlas Steel Landfill	Welland, adjacent to Welland River at Cambridge Rd & River Rd.	Slater Steel Inc.	1930s-present (1993)	Electric furnace slag, baghouse dust, concrete and refractory rubble, and waste acids (waste acids discontinued 1986)	Surface water runoff has discharged in the past directly to Welland River. Currently is diverted to a holding pond prior to discharge to Welland River. Groundwater from site flows westward to Welland R.	Metals (nickel, chromium, molybdenum, strontium, manganese and aluminum) detected in groundwater (MOE 1991)	Total loadings = 0.0543 kg/d, mainly inorganic (As, Hg and Pb at trace levels) (MOE 1993b)	Heavy metals (Cr, Ni, Sr, Mn, Al)	MOE 1993b - Pb (0.033 mg/L), Hg (0.02-0.03) > PWQO.	MOE and EC studies (1990, 1994, 1996, 2000) have included areas below landfill sites.	No studies specific to landfill site.	No studies specific to landfill site.	Due to similar contaminants, difficult to separate effects of landfill from mill discharge.
Welland WPCP	Welland, upstream of Welland Canal	City of Welland	1968 to present (1993)	Primary treatment plant built 1968. Secondary treatment added 1974. Plant expanded 1982. Modified in 1989 to split dry & wet weather flows.	Single discharge to Welland River. McMaster Ave CSO re-routed to plant in 1989.	High Hg & Pb detected after McMaster CSO routed in 1989. After 1991, no exceedances of PWQOs. (MOE 1993c)	1990: Hg (0.0007 kg/d), Pb (0.46) (MOE 1993a)	Metals (Hg, Pb)	MOE 1993a - Pb (0.25 mg/L) > PWQO in 1989.	No studies specific to landfill site.	No studies specific to landfill site.	No studies specific to landfill site.	
Pt Robinson Lagoons	Pt Robinson	Municipality	1990 to present	Aerated lagoon with 5 day retention time followed by facultative cells with 76 day hydraulic retention time.	Single effluent discharge to Welland R below Welland Canal.	Trace levels of As and variable levels of Pb (MOE 1993c)	1990: Pb (0.3 kg/d) (MOE 1993a)	As, Pb	MOE 1993a - Pb (> 0.075 mg/L) > PWQO in 1990.	MOE/EC 1996 - stations C3 & C4 approx. 1.5 km downstream.	MOE/EC 1996 - Ni (280), Fe (4.2%), Cr (420) > SEL. Mn (690), As (9.8), Cu (75), Zn (190), Cd (1.4), Pb (72) > LEL	None recorded.	Metals > SEL likely due to upstream sources
Geon Canada	Niagara Falls, downstream of Welland Canal	B.F. Goodrich 1957-1993; Geon Canada 1993-1999; Oxy Vinyls, LP (Geon & Occidental Petroleum) 1999-	1957-present	Manufactures polyvinyl chloride and PVC/polyvinyl acetate resins from vinyl chloride monomer.	Until 1988, emulsion/ polymerization wastes steam stripped, with biological treatment, aeration pond and polishing lagoon prior to discharge. Since 1991use equalization ponds, activated sludge, secondary clarifier and tertiary treatment (gravity sand filter). Sludges vacuum filtered and supernatant routed back to treatment system.	Trace levels of As and Hg. Trace Pb from 1991.	1987: chrysene (0.03 kg/d) (MOE 1993a)	Lead, mercury		Tarandus 1993 (MOE 1993d) sediment sample collected at mouth of small creek from site.	Tarandus 1993 (MOE 1993d). Cr (300) > SEL; oil & grease (1690) >LEL.	Dickman (1991) noted higher incidence of chironomid deformities.	Pb and As only metals associated with discharge. Other metals likely from upstream sources.

Table 4.1.2:
Summary of Dischargers and Monitoring Activities - Welland River, City of Welland to Chippawa Power Canal.

Source	Location	Ownership	Years of Operation	Products/ Process	Discharges (point and non-point)	Discharge Monitoring (compounds)	Loadings	Potential CoCs	Exceedance of WQC and max. values	Sediment Monitoring	Exceedance of SQC and maximum values in ( ) (Values in ug/g unless otherwise indicated)	Biological Monitoring	Comments
Cytec Canada Welland Plant	Niagara Falls Welland boundary, downstream of Welland Canal	Cyanamid Canada until 1990's. Currently operated by Cytec Specialty Chemicals	1907 to present	Inorganic nitrogen and phosphorus products including ammonia, 50% cyanamide solutions, phosphine and phosphine derivatives. Dicyanamide production ceased in 1992. Nitric acid, ammonium nitrate & calcium phosphate production ceased in 1987.	Waste waters from boiler, compressor, cooling tower, steam plant, barometric condensers & sludge pond discharged to Thompson's Creek. Chromium use in cooling tower discontinued in early 1990's.		NRTC 1984 - Cr (4.87 kg/d), Ni (2.34), Zn (2.04). Cu (0.65), CN (2.29). 1986: Pb (1.63 kg/d) highest (MOE 1993a)	Ammonia, metals	MOE 1993a - Pb (> 0.08 mg/L) > PWQO in 1989.	Hart 1983 (Hart 1986) - sediment sample from Welland R. at mouth of Thompsons Ck MOE 1989 - sediment sample at mouth of creek. (Richman 1992) Tarandus 1993 (MOE 1993d) - sediment sample in Welland R at mouth of Thompson's Ck. Beak 1994 - sediment assessment in Thompson's Creek (Beak 1994). MOE/EC 1996 - stations C10 and C11 adjacent to site, sediment sample (stn C-13) downstream of Thompson's Ck.	Hart 1983 - Cr(350), Ni (160) >SEL; Cu (110), Pb (130), Zn (280), Fe (3.8%) > LEL. Beak 1994 - Mn (1100), Ni (120) > SEL; As (7), Cd (0.8), Cu (81), Cr (60), Fe (34000), Pb (44), Hg (0.85), P (1700), Ag (1.6), Zn (180) > LEL MOE 1993d - Cr (260), Ni (190) > SEL MOE/EC 1996 - Ni (240), Cr (360) > SEL. Cu (82), Zn (210), Pb (62), As (15), Fe (3.5%) > LEL. PAHs < LEL adjacent to site; Cr (140), Ni (110) >SEL below Thompson's Ck	MOE 1993d - benthic community assessment found diversity high (S-W Diversity Index 3.19). Beak 1994 - Benthic invertebrates indicated some impairment. Toxicity to Chironomus at both downstream and reference in bioassay tests. MOE 1989 - mussel biomonitoring at mouth of creek showed trace levels of pesticides (g-BHC).	Ni not associated with process or discharges. As present in discharge in trace amounts and minor contributor to sediments.
Cyanamid Landfill, Welland	Border of Welland and Niagara Falls	Cyanamid Canada		Sludge basins north of Thompson's Creek. Industrial waste site between Thompson's Ck and Welland River.	Effluent from Thompson Ck to Welland R		Total loadings = 0.3677 kg/d, mainly Pb, CN (MOE 1993b)	cyanide and nitrogen-based cmpds such as ammonia and nitrates	MOE 1993b - Pb (0.266 mg/L), Hexachlorobenzene (0.000005) > PWQO.			None specific to the landfill.	Considered as part of studies at Cytec Canada on Thompson's Ck.
Ford Glass	Welland, upstream of Welland Canal	Ford Canada. Plant decommissioned in 1994.		Windshields, windows, body glass for automobiles from float glass and polyvinylbutyral resin. Processes included cutting, seaming, edge grinding & laminating using cutting oils, grinding coolants, detergents, CaCO3 powder & autoclave oil. Periodic use of xylene and silver paste.	Wastewater included continual non-contact cooling water and batch discharges of coolant tanks, wash baths & rinse tank overflows. Process water was treated in lagoons prior to discharge to Welland River.		1990: As (0.002 kg/d), Hg (0), Pb (0.05), PCE (0.00202), Octachlorostyrene (0.00001) (MOE 1993a)	Lead	MOE 1993a - Pb (> 0.06 mg/L) > PWQO in 1991.	Hart 1983 (Hart 1986) - sediment sample in Welland R at Power Canal. MOE 1993d - Sediment sample at Power Canal, below Ford Glass discharge. Beak 1994 -	Hart 1983 - Cr(180), Ni(100) > SEL; Cu(68), Zn (130), As (8) > LEL (Hart 1986). MOE 1993d - Cu(94), Cr (97), Ni (75), As (6) > LEL. Beak 1994 -	Beak 1994 -	

References

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Table 4.2.1:
Summary of Discharges and Monitoring Activities - Sir Adam Beck Reservoir.

Source	Location	Ownership	Years of Operation	Products/ Process	Discharges (point and non-point)	Discharge Monitoring (compounds)	Loadings	Potential CoCs	Exceedance of WQC and max. values	Sediment Monitoring	Exceedance of SQC and max. values in ( ). (Values in ug/g unless otherwise indicated).	Biological Monitoring	Comments
Cytec (Niagara Falls)	See notes in Table 4.3.2												
Niagara Falls WPCP	Niagara Falls	Municipality	1963 to present	In 1985 rotating biological contactors were added	Effluent discharged to Queenston-Chippawa PC	Pb and Hg	1986: As (1.07 kg/d), Hg (0.009), Pb (3.6), PCE (0.073), Dieldrin (0.001) (MOE 1993a)		Pb (0.15 mg/L) > PWQO in 1986 (MOE 1993a)	No sediment studies conducted in narrow section of Power Canal due to high flow velocities (no depositional areas).		None reported	
Chippawa Power Canal	See notes in Table 4.3.2												
Upstream sources in Welland R., and Chippawa Ck. See notes in Tables 4.1.2 and 4.3.3.	Sir Adam Beck Reservoir	Ontario Power Generation	1954 to present	Water reservoir for hydro-electic power generation.	None directly to reservoir but numerous sources to watercourses feeding reservoir.	As, Cd, Cr, Cu, Fe, Pb, Ni, Ag, Zn exceed MOE guidelines for dredged sed.		Cd and Pb, DDT & metabolites	Cu and Zn > PWQO in 1983 (Kauss 1987)	MOE 1983 (Kauss & Post 1987) - seven sediment stations sampled in reservoir.	MOE 1983 - As (13), Cd (1.70), Cr (36), Cu (32), Ni (46), Pb (70), Ag (1.8), Zn (140) > PSQG LEL (Kauss & Post 1987)	Cr, Pb, Ni, Se, Zn in Cladophora; p,p'-TDE in clam tissue; p,p'-DDE and p,p'-TDE in yellow perch (NRTC 1984, in Kauss 1987)	

References

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Table 4.2.2:
Summary of Dischargers and Monitoring Activities - Frenchman's Creek

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( ).** (Values in ug/g unless otherwise indicated).	**Biological Monitoring**	**Comments**
Fleet Aerospace	Fort Erie	Division of Ronyx Corp. Since 1996, division of Magellan Aerospace. Closure announced in 2003 but currently still operating.	1928 to 2003?	Airplane and satellite components, sonar and radar assemblies. Processes included degreasing, bonding and chemical cleaning for painting.	Wash water, cooling water, and overspill effluents were in the past discharged via culvert to Frenchman's Ck. Currently process effluents discharged to municipal sewer. Storm water discharged to Frenchman's Creek.	Chromium	1986: As (0.016 kg/d), Hg (0.0002), Pb (0.05) (MOE 1993a) 1997: Cr < d.l.	Arsenic, mercury, chromium.		See entry below for upstream sources to Frenchman's Ck.		None specific to this site.	Sediment samples collected at mouth of creek include effects of all upstream sources, not just Fleet Aerospace.
Upstream sources in Frenchmans Ck	mouth of Frenchmans Ck.	N.A.		N.A.	N.A.			Pb (0.07 mg/L) > PWQO (MOE 1988-1989)		NRTC 1983 (NRTC 1984) - sediment sample in Niagara R. collected at mouth of creek. Hart 1983 (Hart 1986) - sediment sample in Niagara R. at mouth of creek. MOE 1987 (Anderson et al 1991) - I station sampled at mouth for PAH and dioxins/furans.	NRTC 1983 - DDT > LEL. Hart 1983 - Cr > SEL; As, Cd, Cu, Ni, Pb, Fe, Zn > LEL. MOE 1987 - PAH < LEL; Furans detected (H_6CDF, H_7CDF, O_8CDF) TEQ = 7.5 pg/g	NPCA 1995-97 (Attema & Forsey 1998) - BioMAP study found good abundance and species composition, dominated by chironomids.	Most sediment samples have been collected in Niagara R., and not in Frenchmans Ck (e.g., Creese 1983). Recent MOE mussel studies were conducted upstream of the mouth of Frenchmans Ck (Richman 2003, Pers. Comm) and are not included.
CanadianOxy Chemicals Ltd.-Thermoset (Durez) Div.	Fort Erie	Occidental Chemical Corp.		Phenol-formaldehyde resins, moulding compounds, furfuryl alcohol-fomaldehyde resins and ethylene bis-stearamide wax in semi-continuous batches for use as outomotive binders, for mouldings, and production of furan resins used for coatings and insulation. Raw materials include nonyl phenol, phenol, cresol, formaldehyde and various catalysts.	Cooling water from P/F resin area was recycled through cooling towers while P/F distillates are stored on-site prior to shipping off-site for disposal/recovery. Other non-contact cooling water was discharged without treatment to Frenchman's Ck until system closed looped in 1993.		1987: As (0.03 kg/d), Hg (0.0004), Pb (0.02) (MOE 1993a)			MOE 1987 (Anderson et al 1991) - sediment sample from creek below Durez. MOE 1989 (Richman 1992) - sediment sample from creek below Durez.	MOE 1987 (Anderson et al 1991) - PAH < LEL; furans detected (H_6CDF, H_7CDF, O_8CDF) TEQ = 5.4 pg/g MOE 1989 (Richman 1992) - PCB(0.285) > LEL, PAH (2.13)<LEL.	MOE 1987 (Anderson et al 1991) - trace levels of pp-DDE and PAHs (naphthalene, acenaphthylene, fluorene). MOE 1989 (Richman 1992) - low concentration of pp-DDE and some PAHs in mussels; metals similar to ambient sites. MOE 1993 (Richman 1994) - similar results to previous studies.	
Fort Erie WPCP	Anger Ave, Fort Erie	Municipality	1963 to present	Domestic and industrial. Initial primary treatment plant expected in 1974. Upgraded to secondary treatment in 1989.	Niagara R or Frenchmans Ck ?								

Table 4.2.2:
Summary of Dischargers and Monitoring Activities - Frenchman's Creek

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( ).** (Values in ug/g unless otherwise indicated).	**Biological Monitoring**	**Comments**
Gould Manufacturing of Canada Ltd.	1 km north of Niagara river, Fort Erie			Lead acid storage batteries using lead, lead-antimony, lead-calcium, lead oxide power and sulphuric acid.	Process water from washing and cooling in battery disassembly, casting and charging. Clsoed loop system (as of 1993). Open storm line to Frenchman's Ck until 1987 when discharge routed to Fort Erie WPCP.		Last measurement before redirection; 1986: As (0.004 kg/d), Hg (0.0001), Pb (0.55) (MOE 1993a)	Lead, Sb, Ca	Pb (> 7.0 mg/L) > PWQO in 1986 (MOE 1993a)	As of 1993, sediment remediation of lead contaminated sediment in the stream bed has been completed.		None specific to this site.	

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Richman, L. 1994. Preliminary Technical Report. Niagara River Mussel Biomonitoring Survey, 1993. Ont. Ministry of Environment. 1994.

Table 4.3.1:
Summary of Dischargers and Monitoring Activities - Black Creek.

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( ).** (Values in ug/g unless otherwise indicated)	**Biological Monitoring**	**Comments**
Upstream sources in watershed				Agricultural runoff from sources in watershed						Creese 1983 (Creese 1987) collected a sediment sample in Niagara R at mouth of creek. EC-MOE 2002: Sediment monitoring at two locations in lower watershed.	Creese 1983: No exceedances of PSQGs. EC-MOE 2002: Cr (38 ug/g), Cu (25), Pb (49) and Ni (37) > LEL. No exceedances of SEL.	EC-MOE 2002. Benthic community analysis showed benthic community dominated by chironomids and oligochaetes. Would be typical of slow-flowing rivers in agricultural areas.	

References

Creese, E.E. 1987. Report on the 1983 Benthic Invertebrate Survey of the Niagara River and Nearby Lake Ontario. Integrated Explorations Report to Ont. Ministry of Environment. August 1987.

Table 4.3.2:
Summary of Dischargers and Monitoring Activities - Chippawa Power Canal

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( )** (Values in ug/g unless otherwise indicated).	**Biological Monitoring**	**Comments**
Welland R upstream	Lower section of Power Canal	Various (see Table 4.1.2).	Various, since 1896.	See individual listings in Table 4.1.2.	Includes Cr and Ni, and PAH componds. See notes in Table 4.1.2 on sources to Welland River.					NRTC 1984 - 2 sediment samples collected from Power Canal. One at juction of Chippawa Ck and Power Canal, the other upstream of Welland R.	NRTC 1984 - All metals concentrations were very low.	None recorded.	TOC was not provided, but metals results indicate mainly sand substrate.
Cyanamid Canada (Niagara Plant)	Niagara Falls	Cytec	Mothballed in 1992	Calcium carbide, calcium cyanide, calcium cyanamide and desulphurization polymers for use in desulphurizing steel, generaiton of acetylene and production of calcium cyanide for gold refining.	Approx. 50% of cooling water discharged to Power Canal. Remaining 50% sent to cooling pond for re-use. Overflow discharged to Whitty's Ck, small tributary to Niagara R. Spills within plant collected in storm drains which discharge to cooling water channels.		1989: Hg (0.00003 kg/d), Pb (0.168), BaA (0.041), BbF (0.033), Chry (0.025) (MOE 1993a)			No sediment studies conducted in narrow section of Power Canal due to high flow velocities (no depositional areas).		None recorded.	No depositional areas in Power Canal. Contaminants will likely settle in Sir Adam Beck Reservoir or be carried to Niagara River.
Cyanamid Landfill, Niagara Falls	City of Niagara Falls-6 sites east of canal between Stanley Ave. and Whirlpool Rd.	Cytec Canada	1940s to 1979.	Lime, carbon, slaked lime, calcium carbide, ash, calcium carbonate, calcium oxide wastes, lining bricks, coal, coke, and limestone dust	Queenston-Chippawa Power Canal via groundwater flow through bedrock and overburden. Also to Niagara R. through same pathways. (MOE 1993b).	Metals and organics (inc. phenols) (MOE 1993b)	Total loadings = 6.4176 kg/d, 99% is Pb, Zn, CN (MOE 1993b)	Total cyanide, Pb, Hg	Pb (0.086 mg/L), Hg (0.05) > PWQO in surface water (MOE 1993b)	No sediment studies conducted in narrow section of Power Canal due to high flow velocities (no depositional areas).		None recorded.	Pb and Hg were detected in surface water samples. No depositional areas occur in Power Canal, so contaminants will likely be deposited in Sir Adam Beck Reservoir, or be carried to Niagara R.
Niagara Falls WPCP	Stanley Ave, Niagara Falls	Municipality	1963 to present	Original primary treatment plant expanded in 1978. Secondary treatment (rotating biological contactors) added in 1985 when plant was expanded again. P removal with ferric chloride.	Effluent discharge to Chippawa Power Canal	Metals (Hg & Pb). PCE, PCBs and pesticides eliminated in 1989.				No sediment studies conducted in narrow section of Power Canal due to high flow velocities (no depositional areas).		None recorded.	No depositional areas occur in Power Canal, so contaminants will likely be deposited in Sir Adam Beck Reservoir, or be carried to Niagara R.
CNR Victoria Avenue Landfill, Niagara Falls		CNR	1960s to 1981	Car cleaning wastes at NF railyards (scrap metal and wood, foundry magnets, paper, lube pads, and some domestic waste)	Main groundwater discharge appears to be east to Niagara River.			Trace metals and nitrogen compounds		No sediment studies conducted in this section of Niagara River due to high flow velocities (no depositional areas).		None recorded.	No depositional areas occur in this section of the Niagara River, so contaminants will likely be deposited in downstream embayments, or be carried to Lake Ontario.

References

Table 4.3.2:
Summary of Dischargers and Monitoring Activities - Chippawa Power Canal

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and max. values in ( )** (Values in ug/g unless otherwise indicated).	**Biological Monitoring**	**Comments**

MOE 1993c. Update Report. Reduction of Toxic Chemicals from Ontario Point Sources Discharging to the Niagara River. 1986-1991. Ont. Ministry of Environ. July 1993.

NRTC (Niagara River Toxics Committee) 1984. Report of the Niagara River Toxics Committee. October 1984.

Table 4.3.3:
Summary of Dischargers and Monitoring Activities - Chippawa Creek from Niagara River to Chippawa Power Canal and Pell Creek

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and maximum values in ( )** (Values in ug/g unless otherwise indicated)	**Biological Monitoring**	**Comments**
Saint-Gobain Ceramics (Norton Abrasives)	(Chippawa) Niagara Falls, north bank of Chippawa Ck.	Norton Advanced Ceramics, from 1905 to 199_. Currently operated by Saint Gobain Ceramics Materials Canada since 199_.	1905 to present	Abrasives manufacturing (aluminum oxide, dark aluminum oxide, alumina-zirconia, and infrequently, chromic oxide) from bauxite, coke, iron borings, baddelyite, chromic oxide and sulphur. Process includes acid slaking and water washing.	Two to Pell Ck, two directly to Welland River/ Chippawa Ck. Contact cooling water from furnace shells, power transformers, cooling of molds treated in settling basin prior to dischagre to Welland River. System was closed-looped in 1991. Wash water from the light aluminum oxide process is neutralized with lime prior to discharge to settling lagoon for solids removal. The lagoon discharged to Pell Ck.	lead	1986: As (0.31 kg/d), Hg (0.0016), Pb (0.1) (MOE 1993a)	lead	1986 - Pb (0.15 mg/L) > PWQO (MOE 1993a)	Hart 1983 (Hart 1986) - sediment sample at mouth of Pell Ck.	Hart 1983 - Cu(160) > SEL; solvent extractables > ambient.	None reported.	
Washington Mills (Canadian Carborundum)	Niagara Falls	Canadian Carborundum to 1986. Washington Mills since 1986.	1980 to present	Abrasives manufacturing (aluminum oxide grains, ferro-silicon & crude aluminum oxide) from bauxite, coke and iron filings in electric arc furnaces.	Cooling water from furnace shells and melt pots directed to cooling pond for settling and aeration. Water is partilly recirculated. Remainder combined with storm water and discharged to Chippawa Creek. Separate closed loop system for furnace transformer and cable cooling water.	lead	1991: As (0.001 kg/d) Pb (0.13) (MOE 1993a)		Pb (0.17 mg/L) > PWQO in 1991 (MOE 1993a)	None reported		None rpeorted	
Washington Mills Electro Minerals Canada Inc.	Niagara Falls	Washington Mills Electro Minerals Inc, since 1916.	1916 to present	Abrasive metallic rods including brown alumina, pink alumina, alumina bubbles, ferro-silicon, fused mag-chrome & ferro-carbo briquettes from bauxite, coke, iron borings, white alumina, chromic oxide, ferro-silicon, magnesite and chrome ore.	Process water (mainly contaminated cooling water from furnace heads and power transformers) sent to one of two lagoons for solids reduction and oil& grease removal. Water is partially recirculated, with rest discharged. Lagoons discharge to Pell Ck and Stanley Avenue Combined Sewer.	Lead, trace levels of arsenic (MOE 1993c).	1990: Pb (0.29 kg/d) (MOE 1993). 1990 (Stanley CSO): Pb (0.3), PCE (0.72) (MOE 1993a)		1989 - Pb (0.033 mg/L) > PWQO (MOE 1993a). 1991- Stanley CSO, Pb (> 0.3 mg/L) > PWQO (MOE 1993a)	Hart 1983 (Hart 1986) - sediment sample at mouth of Pell Ck.		None reported	
Pell Ck at Front St (Norton Abrasives)	See notes under Norton Abrasives								Pb (0.19 mg/L) > PWQO (MOE 1988-1989)				
Stanley Ave CSO	Niagara Falls	Municipality		42" segregated sewer discharging surface runoff and industrial non-contact cooling water from Washington Mills Electro Minerals	Chippawa Ck at Stanley Ave (north side of creek).	Pb regularly found at levels below PWQOs. As, Hg and TCE irregularly detected (MOE 1993c)				None reported		None reported	

Table 4.3.3:
Summary of Dischargers and Monitoring Activities - Chippawa Creek from Niagara River to Chippawa Power Canal and Pell Creek

Source	**Location**	**Ownership**	**Years of Operation**	**Products/ Process**	**Discharges (point and non-point)**	**Discharge Monitoring (compounds)**	**Loadings**	**Potential CoCs**	**Exceedance of WQC and max. values**	**Sediment Monitoring**	**Exceedance of SQC and maximum values in ( )** (Values in ug/g unless otherwise indicated)	**Biological Monitoring**	**Comments**
Upstream sources in Chippawa Ck	Chippawa Ck at Power Canal	N.A.	N.A.		Downstream of industrial sources in Chippawa					MOE 1993d - 2 sediment samples collected in Chippawa Ck. Ist approx. 1 km east of Power Canal, 2nd on s. side at entrance to Power Canal.	MOE 1993d - No exceedances of SEL or LEL for metals. Total PAH < LEL	None reported.	
	Kane Dock, Chippawa			Coal tar. Believed to be from contaminated fill during construction of Power Canal system.						Sediment remediation of coal tar contaminated area undertaken in 1985-6		Dickman reported no chironomid deformities after remediation.	

References

MOE 1993c. Update Report. Reduction of Toxic Chemicals from Ontario Point Sources Discharging to the Niagara River. 1986-1991. Ont. Ministry of Environ. July 1993.

Table 4.3.4:
Summary of Dischargers and Monitoring Activities - Niagara River from Queenston to Niagara-on-the-Lake.

Source	Location	Ownership	Years of Operation	Products/ Process	Discharges (point and non-point)	Discharge Monitoring (compounds)	Loadings	Potential CoCs	Exceedance of WQC and max. values	Sediment Monitoring	Exceedance of SQC and max. values in ( ). (Values in ug/g unless otherwise indicated).	Biological Monitoring	Comments
CNR Victoria Avenue Landfill, Niagara Falls	Niagara Falls.	CNR	1960s to 1981	Car cleaning wastes at NF railyards (scrap metal and wood, foundry magnets, paper, lube pads, and some domestic waste)	Groundwater flow is eastwards to Niagara River (MOE 1991)			Trace metals and nitrogen compounds		No sediment studies conducted in this section of Niagara River due to high flow velocities (no depositional areas).			No depositional areas occur in this section of the Niagara River, so contaminants will likely be deposited in downstream embayments, or be carried to Lake Ontario.
Upstream sources to Niagara River	Queenston									Creese 1983 (Creese 1987) - sediment sampling along Canadian shore	Creese 1983 - PCB (0.34), Fe (3.1%), Hg (0.31) > LEL		
Queenston WPCP	Queenston	Municipality	1990 to present	Extended aeration with coarse bubbling diffusers for minimum of 18 hrs, followed by gravity settling and chlorination prior to discharge.	Single shore-based headwall outlet to Niagara River.	Trace levels of Pb, occasional occurences of As, Hg, TCE & chlordane (MOE 1993c)				None reported		None reported	
Upstream sources to Niagara River	Niagara-on-the-Lake	N.A.			Various Canadian and U.S. sources/ discharges to Niagara R.					Creese 1983 (Creese 1987) - sediment sampling along Canadian shore adjacent to Town of Niagara-on-the-Lake. MOE 1993 (Richman 1994) - sediment sample at Niagara-on-the-Lake,adjacent to Town	Creese 1983 (Creese 1987) - Hg (1.2), Cr (40) > LEL. MOE 1993 (Richman 1994) - TCDD/F (TEQ 14.8 pg/g) > CSQG ISQG.	MOE 1993 (Richman 1994) - mussel biomonitoring yielded no detectable levels of PCDD/Fs.	

References

Creese, E.E. 1987. Report on the 1983 Benthic Invertebrate Survey of the Niagara River and Nearby Lake Ontario. Integrated Explorations Report to Ont. Ministry of Environment. August 1987.

MOE 1993c. Update Report. Reduction of Toxic Chemicals from Ontario Point Sources Discharging to the Niagara River. 1986-1991. Ont. Ministry of Environ. July 1993.

Richman 1994. Preliminary Technical Report. Niagara River Mussel Biomonitoring Survey, 1993. Ont. Ministry of Environment. 1994.

Table 5.1.2
Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	TOC LECO %	TKN Titr. ppm	As SW 7061 ppm	Se SW 7741 ppm	Hg SW 7470 ppm	Ag ICP/MS ppm	Al ICAP ppm	Ba ICAP ppm	Be ICAP ppm	Ca ICAP ppm	Cd ICAP ppm	Co ICAP ppm	Cr ICAP ppm	Cu ICAP ppm
Welland River														
WR1-N	6.90	3360	2.6	0.6	0.18	0.2	20400	116	0.8	21600	< 0.5	13	117	51
WR1-M	5.70	1560	4.3	0.2	0.23	0.2	13100	90	0.5	27300	< 0.5	24	764	107
WR1-S	7.59	1400	3.9	0.4	0.19	0.3	17100	122	0.7	28800	< 0.5	14	349	62
WR2-N	5.75	1120	3.6	0.3	0.08	0.1	11800	61	0.5	49000	< 0.5	10	72	33
WR2-M	6.45	1400	4.4	< 0.2	0.07	< 0.1	14800	77	0.7	43100	< 0.5	11	34	30
WR2-S	7.28	3520	4.4	0.7	0.78	0.6	14000	89	0.6	23600	0.5	18	348	79
WR3-N	12.20	4980	4.6	0.9	0.28	0.3	13900	90	0.6	24000	0.7	18	335	75
WR3-M	1.40	1280	3.8	0.4	0.12	0.1	17800	83	0.8	35800	< 0.5	13	78	39
WR3-S	4.04	2120	3.3	0.2	0.10	0.1	11600	62	0.5	38300	< 0.5	11	118	39
WR4-N	2.26	2910	2.2	0.3	1.77	0.5	14400	84	0.7	23400	< 0.5	15	131	35
WR4-M	0.88	2460	7.4	0.6	0.41	0.3	22100	110	0.9	16000	0.8	18	71	53
WR4-S	11.70	4250	3.3	0.7	1.44	0.2	13400	80	0.6	31500	< 0.5	12	131	51
WR5-N	4.59	3190	5.1	1.9	0.24	0.3	15100	101	0.6	46600	< 0.5	14	197	63
WR5-M	1.60	1170	3.6	0.5	0.16	0.2	14500	73	0.6	33900	< 0.5	11	109	43
WR5-S	8.47	3020	7.2	1.2	0.36	0.3	13800	87	0.6	28900	0.5	14	110	117
WR6-N	6.79	3520	4.6	1.1	0.55	0.4	15200	99	0.7	42400	0.6	12	134	241
WR6-M	0.35	560	4.6	< 0.2	0.03	< 0.1	18400	66	0.8	53900	< 0.5	11	27	27
WR6-S	5.82	2530	6.3	1.6	0.95	0.5	12600	103	0.6	34900	< 0.5	22	516	145
WR7-N	9.01	4310	6.5	2.5	0.53	0.4	14000	107	0.7	26300	0.7	17	326	281
WR7-M	0.47	728	4.6	0.2	0.04	< 0.1	17300	75	0.8	47500	< 0.5	11	32	27
WR7-S	2.77	1790	3.6	0.5	0.15	0.1	12700	77	0.6	45700	< 0.5	10	94	41
WR8-N	4.47	2800	3.7	0.9	0.27	0.2	17900	107	0.8	25700	< 0.5	13	122	94
WR8-M	3.30	1790	8.2	1.9	0.58	0.4	18600	108	0.9	47300	< 0.5	13	125	227
WR8-S	4.68	3470	3.7	0.8	0.22	0.2	16800	104	0.7	39300	< 0.5	13	167	79
WR9-N	4.97	2910	3.6	0.7	0.24	0.2	16500	103	0.7	31300	< 0.5	11	71	101
WR9-M	3.73	2520	4.6	0.7	0.38	0.2	20500	153	0.9	32400	< 0.5	12	90	73
WR9-S	3.71	2800	3.8	0.8	0.35	0.2	18400	103	0.8	31800	< 0.5	12	109	66
WR10-N	3.67	2630	4.0	0.5	0.20	0.2	12800	72	0.6	43300	< 0.5	9	69	70
WR10-M	2.65	2290	4.3	0.4	0.08	< 0.1	27100	140	1.0	7770	< 0.5	12	34	24
WR10-S	3.58	2010	3.7	0.7	0.16	0.2	16700	101	0.7	45100	< 0.5	10	91	56
WR11	3.88	2850	3.7	0.7	0.34	0.1	17000	100	0.8	39000	< 0.5	11	46	271
Chippawa Creek														
CC2-N	1.19	896	1.6	< 0.2	0.05	< 0.1	6000	37	0.3	31700	< 0.5	6	17	37
CC3-N	2.72	2240	2.4	0.4	0.07	< 0.1	7780	48	0.4	45700	< 0.5	7	15	21
CC3-S	1.48	1230	2.0	0.3	0.07	< 0.1	5010	31	0.3	55200	0.5	6	12	14

Table 5.1.2
Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	TOC LECO %	TKN Titr. ppm	As SW 7061 ppm	Se SW 7741 ppm	Hg SW 7470 ppm	Ag ICP/MS ppm	Al ICAP ppm	Ba ICAP ppm	Be ICAP ppm	Ca ICAP ppm	Cd ICAP ppm	Co ICAP ppm	Cr ICAP ppm	Cu ICAP ppm
CC4-N	1.11	1000	1.8	< 0.2	0.08	< 0.1	5400	31	0.3	53300	< 0.5	5	14	22
CC4-S	0.91	896	1.9	< 0.2	0.08	0.1	4960	27	0.3	42000	< 0.5	6	11	13
CC5-N	2.13	2740	3.4	0.4	0.07	< 0.1	10000	67	0.5	61200	< 0.5	9	20	24
CC5-M	0.58	728	1.1	< 0.2	0.03	< 0.1	3690	22	0.2	40800	< 0.5	4	8	8
CC5-S	6.75	4870	1.9	0.4	0.06	< 0.1	14300	85	0.8	20800	< 0.5	9	23	27
CC6-N	5.34	2910	2.2	0.5	0.07	< 0.1	8710	59	0.5	42000	< 0.5	6	16	24
CC6-S	2.62	1960	4.2	0.5	0.10	< 0.1	10400	68	0.6	65400	0.7	10	21	27
Chippawa Power Canal														
CPC-1	3.84	2350	6.1	0.4	0.11	0.1	13300	123	0.7	30200	< 0.5	10	40	25
CPC-2	2.65	1840	2.3	0.2	0.07	< 0.1	9970	67	0.5	24600	< 0.5	8	17	24
CPC-3	0.92	952	4.0	< 0.2	0.03	< 0.1	19900	140	1.0	51300	< 0.5	14	28	24
Pell Creek														
PC-1	0.50	392	1.2	< 0.2	0.02	< 0.1	3730	32	0.2	35300	< 0.5	4	14	16
PC-2	2.01	1120	1.2	< 0.2	0.04	0.1	5940	37	0.3	26600	< 0.5	5	27	49
Frenchman's Creek														
FC-C	5.64	3920	2.4	0.6	0.11	< 0.1	22900	170	1.0	31000	0.6	10	32	29
FC-2	3.47	2240	5.5	0.5	0.28	1.2	19100	128	1.0	20500	33.6	15	308	49
FC-3	8.25	4030	7.9	0.8	0.14	< 0.1	18700	162	1.0	40200	0.7	14	32	46
FC-4	3.75	1510	2.6	0.2	0.20	1.4	16900	109	0.9	14000	11.1	12	337	25
FC-5	16.90	3750	5.2	0.7	0.18	< 0.1	14900	114	0.8	34600	10.6	13	62	65
FC-6	1.44	560	0.8	< 0.2	0.04	< 0.1	3380	23	0.2	37600	0.6	3	14	14
FC-7	3.56	1790	2.0	0.3	0.09	< 0.1	8900	58	0.6	20400	0.9	7	34	21
FC-8 0-10	4.84	2800	2.1	0.6	0.17	< 0.1	16400	81	0.8	35100	5.1	10	187	32
FC-8 10-20	5.35	1960	2.2	0.4	0.15	1.1	15100	82	0.8	28700	5.8	9	272	30
Lyon's Creek														
LC-1	6.89	4420	167	0.7	0.09	< 1	17700	148	0.9	35200	< 0.5	12	37	58
LC-2	3.25	2350	47	0.3	0.05	< 1	21400	124	1.1	30200	< 0.5	16	33	34
LC-3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-5 0-5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-5 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-5 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-6 0-5	3.50	2460	8.2	0.4	0.10	< 0.1	11600	63	0.5	49800	< 0.5	10	41	59
LC-6 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-6 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-8	13.20	8560	71.1	0.9	0.21	0.2	12900	81	0.6	23600	1.5	12	63	109

Table 5.1.2

Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	TOC LECO %	TKN Titr. ppm	As SW 7061 ppm	Se SW 7741 ppm	Hg SW 7470 ppm	Ag ICP/MS ppm	Al ICAP ppm	Ba ICAP ppm	Be ICAP ppm	Ca ICAP ppm	Cd ICAP ppm	Co ICAP ppm	Cr ICAP ppm	Cu ICAP ppm
LC-9	1.96	1280	5.1	0.2	0.04	< 1.0	11200	73	0.6	45100	< 0.5	12	37	48
LC-10	1.16	840	5.5	0.2	0.03	< 1.0	15200	129	0.8	47400	< 0.5	12	34	41
LC-11 0-5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-11 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-11 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-12	3.20	2800	4.4	0.4	0.09	< 1.0	19200	114	1.0	7220	< 0.5	16	33	29
LC-13	8.40	6270	14.3	0.7	0.34	< 1.0	16300	121	0.9	13500	0.6	17	52	89
LC-14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
LC-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Niagara River														
NR-1	1.14	1230	2.9	0.2	0.11	0.1	6850	31	0.3	28700	< 0.5	6	17	19
NR-2	0.44	560	1.1	< 0.2	0.06	< 0.1	2720	10	< 0.2	19900	< 0.5	3	7	5
NR-3	0.88	840	1.6	0.2	0.23	0.1	4930	20	0.3	32500	< 0.5	5	18	13
NR-4	1.27	1120	2.5	0.2	0.13	0.1	7570	30	0.4	27600	< 0.5	7	19	17
NOTL-1	1.10	560	2.5	0.2	0.52	0.1	4310	27	0.2	35800	< 0.5	4	14	15

Table 5.1.2
Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	Fe ICAP ppm	K ICAP ppm	Mg ICAP ppm	Mn ICAP ppm	Mo ICAP ppm	Na ICAP ppm	Ni ICAP ppm	P ICAP ppm	Pb ICAP ppm	Sr ICAP ppm	Ti ICAP ppm	V ICAP ppm	Zn ICAP ppm	PCB's GC/ECD ug/g
Welland River														
WR1-N	35400	2630	12000	554	8	164	81	1110	23	52.0	235	39	161	0.09 b
WR1-M	99300	1850	11400	1380	108	147	501	936	21	53.2	207	55	121	0.05 b
WR1-S	42000	2210	12400	681	19	162	179	1120	39	63.5	233	39	145	0.16 a
WR2-N	26800	1740	11100	600	4	172	55	835	9	103.0	243	27	96	0.05 c
WR2-M	29700	2140	11900	643	< 3	169	34	733	9	84.6	297	32	82	< 0.03
WR2-S	45400	1800	10900	634	33	139	243	1050	38	53.5	221	40	188	0.21 a
WR3-N	40800	1900	9230	530	25	165	228	1500	39	63.4	217	37	200	0.17 b
WR3-M	35800	2530	13200	693	5	184	67	875	12	71.4	280	37	120	< 0.03
WR3-S	30200	1750	10100	593	12	167	88	821	14	83.3	232	28	106	0.04 b
WR4-N	33400	1640	9360	637	12	167	88	1070	17	58.8	210	32	121	< 0.03
WR4-M	40000	2750	11000	570	5	170	71	954	27	49.5	256	44	435	< 0.03
WR4-S	28300	1730	10200	449	9	154	110	909	25	75.7	220	30	174	0.10 b
WR5-N	37200	2230	10600	515	18	173	136	981	26	102.0	209	35	151	0.10 b
WR5-M	32100	2240	12400	583	9	172	83	780	12	62.4	243	33	107	0.08 b
WR5-S	33500	1980	10400	405	8	172	161	859	37	64.9	216	35	343	0.03 c
WR6-N	31500	2120	9990	396	9	185	105	764	24	108.0	210	33	179	0.08 b
WR6-M	33000	3670	13600	604	< 3	229	28	667	< 5	109.0	339	39	66	< 0.03
WR6-S	52000	1940	10700	641	51	172	340	1120	47	77.0	213	44	169	0.41 a
WR7-N	36500	2030	8710	443	19	166	224	1230	46	69.8	205	36	211	0.90 a
WR7-M	31600	3180	12700	591	< 3	213	30	687	< 5	95.2	310	37	68	< 0.03
WR7-S	29400	2310	10400	526	8	164	69	743	7	94.8	240	31	77	< 0.03
WR8-N	33500	2700	9970	573	8	198	90	1050	17	63.9	237	37	131	0.08 b
WR8-M	35800	2880	11400	550	4	188	149	840	41	82.1	285	40	180	0.12 a
WR8-S	34800	2570	10100	435	16	196	124	719	19	101.0	233	37	135	0.05 b
WR9-N	28500	2440	9450	431	3	171	64	946	15	74.6	230	33	118	0.07 b
WR9-M	37000	2940	10700	552	4	230	75	1120	76	80.4	234	42	134	0.05 b
WR9-S	33500	2840	11400	519	6	195	78	869	19	75.6	241	38	140	0.08 b
WR10-N	26100	1990	10200	508	5	230	56	801	14	91.4	220	28	98	0.06 b
WR10-M	35500	3520	9940	378	< 3	167	31	594	12	43.5	227	47	105	< 0.03
WR10-S	30100	2450	10800	453	6	174	68	813	15	107.0	221	34	125	0.05 b
WR11	27100	2590	7760	528	< 3	178	56	1020	20	59.8	257	35	105	0.07 b
Chippawa Creek														
CC2-N	11100	588	6720	320	< 3	108	14	857	19	51.1	219	18	78	< 0.03
CC3-N	14900	1230	15400	342	< 3	152	20	667	14	57.7	193	20	67	< 0.03
CC3-S	10700	862	17600	295	< 3	127	20	567	13	60.6	161	15	74	< 0.03

Table 5.1.2
Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	Fe ICAP ppm	K ICAP ppm	Mg ICAP ppm	Mn ICAP ppm	Mo ICAP ppm	Na ICAP ppm	Ni ICAP ppm	P ICAP ppm	Pb ICAP ppm	Sr ICAP ppm	Ti ICAP ppm	V ICAP ppm	Zn ICAP ppm	PCB's GC/ECD ug/g	
CC4-N	10900	734	19800	322	< 3	126	17	551	15	51.8	196	17	73	< 0.03	
CC4-S	11300	760	15000	294	< 3	125	17	582	12	45.1	204	18	51	< 0.03	
CC5-N	20200	1740	15600	440	< 3	170	26	702	16	89.4	201	25	84	0.19	d
CC5-M	8540	591	14700	251	< 3	119	11	417	10	40.6	147	13	59	< 0.03	
CC5-S	18200	1710	9780	280	< 3	131	29	547	11	42.6	215	29	81	< 0.03	
CC6-N	13600	1260	13800	335	< 3	144	21	587	13	59.4	178	22	66	< 0.03	
CC6-S	20300	1670	15600	434	< 3	173	30	679	19	93.7	194	26	96	< 0.03	
Chippawa Powe															
CPC-1	24700	1790	11400	539	< 3	182	29	918	31	50.3	208	36	355	< 0.03	
CPC-2	18100	1280	8870	471	< 3	173	19	837	26	43.8	185	25	81	< 0.03	
CPC-3	33200	2910	12600	626	< 3	191	31	585	11	88.0	287	44	71	< 0.03	
Pell Creek															
PC-1	8730	407	9290	368	< 3	110	9	911	16	49.2	155	14	47	< 0.03	
PC-2	11000	495	7270	315	< 3	123	11	1060	21	42.3	339	20	99	< 0.03	
Frenchman's Cr															
FC-C	28000	2510	14500	232	< 3	2600	30	789	32	829.0	140	42	167	< 0.03	
FC-2	31600	2170	12400	636	< 3	247	32	884	70	162.0	171	43	273	0.19	c
FC-3	32900	2930	24900	1390	< 3	913	31	1180	48	168.0	203	43	360	0.09	d
FC-4	24100	2080	10400	493	< 3	268	23	765	34	112.0	185	34	158	< 0.03	
FC-5	25400	2060	22300	790	3	230	35	1070	74	198.0	182	35	619	0.52	e
FC-6	7620	423	8510	221	< 3	118	6	399	14	115.0	139	12	113	< 0.03	
FC-7	17700	1100	8940	297	< 3	146	14	727	31	122.0	179	24	142	< 0.03	
FC-8 0-10	24400	2050	9970	268	< 3	239	27	809	33	289.0	181	31	180	< 0.03	
FC-8 10-20	22100	2020	8670	229	< 3	200	25	760	47	236.0	205	30	155	0.03	d
Lyon's Creek															
LC-1	33500	2560	16200	1000	< 3	443	37	949	49	205	179	37	970	0.07	c
LC-2	36200	2770	11600	622	< 3	244	43	818	19	155	197	41	397	< 0.03	
LC-3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.08	c
LC-4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.03	
LC-5 0-5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.04	c
LC-5 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.03	
LC-5 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	< 0.03	
LC-6 0-5	43900	2020	17000	626	< 3	196	39	1170	32	118.0	218	34	1440	11.60	a
LC-6 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11.00	a
LC-6 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	15.70	a
LC-7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18.60	a
LC-8	92100	2060	11500	961	6	289	60	3900	99	130.0	171	46	4280	27.30	a

Table 5.1.2
Sediment Metals, Nutrients and PCBs. November 2003.

Parameter	Fe	K	Mg	Mn	Mo	Na	Ni	P	Pb	Sr	Ti	V	Zn	PCB's	
	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	ICAP	GC/ECD	
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ug/g	
LC-9	39700	1780	18800	617	< 3	165	38	1090	25	71.1	225	27	1710	1.14	b
LC-10	47300	2110	12900	1050	< 3	153	37	727	20	83.9	239	34	211	0.76	b
LC-11 0-5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.41	b
LC-11 5-10	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.18	d
LC-11 10-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.05	d
LC-12	37900	2020	8340	682	< 3	180	37	933	22	43.5	160	37	376	0.52	b
LC-13	73700	1870	9480	737	6	237	73	1350	49	50.0	143	38	2920	12.20	b
LC-14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11.50	b
LC-15	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.41	b
Niagara River															
NR-1	16800	1020	12600	325	< 3	109	18	560	13	31.8	159	20	95	0.03	d
NR-2	8530	451	10000	165	< 3	76	8	429	5	16.4	195	14	45	< 0.03	
NR-3	12200	896	13200	216	< 3	95	13	486	9	34.2	160	16	78	0.07	d
NR-4	19900	1270	12300	351	< 3	103	21	586	16	32.7	147	22	89	0.04	d
NOTL-1	12000	757	16100	285	< 3	107	15	491	14	31.3	180	16	89	0.11	d

< + value - concentration was below the detection limit, which is given as the value following the < symbol.

a - mix of Aroclors 1242, 1254 and 1260

b- mix of Aroclors 1254 and 1260

c - Aroclor 1260

d - Aroclor 1254

e - Aroclor 1248

Table 5.1.3
Sediment PAH. November 2003

Compound		Naphthalene	2-Methylnaphthalene	1-Methylnaphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Welland River - Pt. Robinson to Chippawa Power Canal													
WR1-N		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.17	<0.1	0.32	0.29	0.16	0.24
WR1-M		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.26	*0.07	0.48	0.39	0.22	0.28
WR1-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	<0.1	0.26	0.25	0.12	0.17
WR1-S	Dup.	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.10	<0.1	0.27	0.26	0.14	0.20
WR4-N	DF=5	*0.43	<0.5	<0.5	<0.5	2.45	2.40	22.6	3.33	23.6	17.9	5.97	6.70
WR4-M		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.13	<0.1	0.25	0.32	0.12	0.17
WR4-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.17	*0.06	0.29	0.38	0.19	0.35
WR5-S		<0.15	<0.15	<0.15	<0.15	*0.06	*0.09	0.53	0.15	0.78	1.12	0.42	0.78
WR5-S	Dup.	<0.15	<0.15	<0.15	<0.15	<0.15	*0.06	0.34	0.12	0.55	0.95	0.33	0.65
WR8-N		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	*0.08	<0.15	0.14	0.15	*0.09	0.11
WR8-M		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	0.13	<0.15	0.19	0.24	*0.09	0.14
WR8-S		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	*0.13	<0.15	0.23	0.23	*0.11	0.15
WR9-N		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	0.18	0.20	0.12	0.16
WR9-M		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	*0.07	*0.07	<0.05	*0.05
WR9-S		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	*0.06	<0.05	0.13	0.13	*0.09	0.14
WR10-N		<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	*0.11	*0.14	0.15	*0.10	*0.12
WR10-M		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
WR10-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.06	<0.1	0.14	0.15	*0.07	0.12
Chippawa Creek - Niagara River to Chippawa Power Canal													
CC2-N		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.40	0.11	0.53	0.43	0.27	0.33
CC2-N	Dup.	0.10	0.07	<0.05	<0.05	0.08	0.14	0.97	0.20	0.97	0.74	0.40	0.49
CC3-N		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.08	*0.05	0.12	0.10	0.15	0.22
CC3-S		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10	0.08	0.06	0.07
CC4-N		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	0.19	0.15	0.08	0.10
CC4-S		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.05	0.05	0.20	0.39
CC5-M		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.08	0.07	<0.05	<0.05
CC5-N		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	*0.05	0.32	0.25	0.16	0.18
CC5-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
CC6-N		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.07	*0.06	*0.06	0.10
CC6-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*0.09	*0.08	*0.06	*0.08

Table 5.1.3
Sediment PAH. November 2003

Compound		Naphthalene	2-Methyl-naphthalene	1-Methyl-naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)-anthracene	Chrysene
Pell Creek													
PC-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
PC-2		0.09	0.06	<0.05	<0.05	0.20	0.18	1.91	0.24	2.11	1.76	0.68	0.83
PC-2	Dup.	0.08	0.05	<0.05	<0.05	0.16	0.14	1.75	0.33	2.30	1.92	0.89	0.96
Chippawa Power Canal													
CPC-1	DF=10	1.02	1.31	1.02	1.39	3.12	9.84	79.9	20.1	70.7	44.6	20.6	19.8
CPC-2		<0.05	0.06	<0.05	<0.05	0.06	0.06	0.62	0.12	0.79	0.66	0.30	0.34
CPC-3		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Frenchman's Creek													
FC-C		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
FC-5	DF=5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
FC-6		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07	0.06	<0.05	0.05
FC-7		<0.1	<0.1	<0.1	*0.05	<0.1	<0.1	0.68	0.16	1.81	1.41	0.53	0.73
FC-8	0-10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.12	0.10	*0.06	*0.07
FC-8	10-20	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.10	0.09	<0.05	0.06

Table 5.1.3
Sediment PAH. November 2003

									Surrogate Standard Recoveries		
Compound		Benzo(b)-fluoranthene	Benzo(k)-fluoranthene	Benzo(a)-pyrene	Indeno-(1,2,3-cd)-pyrene	Dibenzo-(a,h)anthracene	Benzo-(ghi)-perylene	Total PAH	Acenaphthene-d10 (19-121%)	Anthracene-d10 (27-126%)	Benzo(a)-pyrene-d12 (44-136%)
Welland River - Pt. Robi											
WR1-N		0.32	0.11	0.21	0.18	<0.1	0.12	2.11	67%	81%	90%
WR1-M		0.38	0.14	0.24	0.19	<0.1	0.13	2.70	63%	76%	85%
WR1-S		0.25	*0.07	0.15	0.13	<0.1	0.10	1.53	71%	85%	94%
WR1-S	Dup.	0.31	*0.09	0.18	0.14	<0.1	0.11	1.70	67%	81%	92%
WR4-N	DF=5	7.90	2.92	5.23	3.53	0.64	2.25	107.45	74%	88%	91%
WR4-M		0.20	*0.07	0.14	0.11	<0.1	*0.09	1.44	59%	75%	83%
WR4-S		0.36	0.12	0.22	0.17	<0.1	0.13	2.37	63%	77%	86%
WR5-S		0.64	0.19	0.40	0.29	*0.07	0.22	5.52	61%	70%	76%
WR5-S	Dup.	0.49	0.11	0.29	0.17	*0.05	0.14	4.15	62%	69%	74%
WR8-N		0.16	*0.05	0.10	*0.07	<0.15	*0.05	0.66	60%	72%	78%
WR8-M		0.18	*0.05	*0.09	*0.05	<0.15	*0.05	0.87	61%	70%	71%
WR8-S		0.23	<0.15	*0.14	*0.09	<0.15	<0.15	0.85	55%	65%	71%
WR9-N		0.21	*0.07	0.12	*0.09	<0.05	*0.06	1.10	61%	74%	80%
WR9-M		*0.09	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	56%	71%	77%
WR9-S		0.22	*0.09	0.15	0.13	<0.05	0.10	1.00	53%	66%	72%
WR10-N		0.16	<0.15	*0.08	*0.08	<0.15	<0.15	0.31	52%	64%	69%
WR10-M		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	49%	65%	79%
WR10-S		0.17	*0.06	*0.09	*0.07	<0.1	*0.07	0.58	58%	70%	78%
Chippawa Creek - Niaga											
CC2-N		0.36	0.13	0.25	0.20	0.06	0.13	3.19	59%	71%	78%
CC2-N	Dup.	0.56	0.22	0.39	0.30	0.07	0.20	5.88	57%	69%	77%
CC3-N		0.20	*0.08	0.13	*0.09	<0.1	*0.07	0.93	51%	63%	69%
CC3-S		0.09	<0.05	0.07	0.05	<0.05	<0.05	0.51	54%	66%	71%
CC4-N		0.13	0.05	0.09	0.07	<0.05	0.06	0.99	64%	79%	88%
CC4-S		0.32	0.13	0.25	0.17	<0.05	0.13	1.72	63%	78%	88%
CC5-M		0.06	<0.05	<0.05	<0.05	<0.05	<0.05	0.20	57%	73%	82%
CC5-N		0.23	*0.08	0.17	0.13	<0.1	*0.08	1.56	55%	68%	77%
CC5-S		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.00	55%	66%	71%
CC6-N		*0.07	<0.1	*0.05	<0.1	<0.1	<0.1	0.10	58%	69%	75%
CC6-S		*0.09	<0.1	*0.07	<0.1	<0.1	<0.1	0.00	50%	62%	68%

Table 5.1.3
Sediment PAH. November 2003

									Surrogate Standard Recoveries		
Compound		Benzo(b)-fluoranthene	Benzo(k)-fluoranthene	Benzo(a)-pyrene	Indeno-(1,2,3-cd)-pyrene	Dibenzo-(a,h)anthracene	Benzo-(ghi)-perylene	Total PAH	Acenaphthene-d10 (19-121%)	Anthracene-d10 (27-126%)	Benzo(a)-pyrene-d12 (44-136%)
Pell Creek											
PC-1		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.00	55%	66%	72%
PC-2		1.15	0.36	0.76	0.59	0.11	0.41	11.42	57%	67%	72%
PC-2	Dup.	1.33	0.54	0.95	0.70	0.16	0.48	12.74	57%	67%	74%
Chippawa Power Canal											
CPC-1	DF=10	21.7	7.72	16.4	11.6	2.84	8.52	342.02	66%	83%	85%
CPC-2		0.48	0.17	0.31	0.26	0.05	0.18	4.44	62%	73%	81%
CPC-3		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	55%	69%	77%
Frenchman's Creek											
FC-C		<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.00	47%	57%	62%
FC-5	DF=5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.00	66%	76%	80%
FC-6		0.07	<0.05	<0.05	<0.05	<0.05	<0.05	0.24	61%	70%	76%
FC-7		0.99	0.32	0.56	0.34	*0.08	0.24	7.75	56%	65%	72%
FC-8	0-10	0.12	<0.1	*0.06	*0.06	<0.1	<0.1	0.34	53%	61%	67%
FC-8	10-20	0.10	<0.05	0.05	0.05	<0.05	<0.05	0.44	56%	64%	70%

< + value - concentration was below the detection limit, which is given as the value following the < symbol.
* - Detected below Estimated Quantitaiton Limit, but passed compound identification criteria
DF - Dilution Factor
Dup - Duplicate analysis

Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans												2378	
Location	Depth	T4CDF	T4CDD	P5CDF	P5CDD	H6CDF	H6CDD	H7CDF	H7CDD	OCDF	OCDD	TCDF	
WHO Mammalian TEF										0.0001	0.0001	0.1	
WHO Fish TEF										0.0001	0.0001	0.05	
Welland River													
WR-4 N	0-5 cm	5.9	3.1	12	6.1	28	83	46	930	51	10000	1.5	<
	Fish TEQ									0.0051	1	0.075	
WR-5 N	0-5 cm	29	19	48	16	64	97	120	430	80	5500	< 3.4	
	Fish TEQ									0.008	0.55		
WR-8 N		18	8.7	31	16	50	87	97	480	53	5100	3.1	
	Fish TEQ									0.0053	0.51	0.155	
WR-10 N		13	9.7	20	12	37	76	40	430	48	5200	2.9	<
	Fish TEQ									0.0048	0.52	0.145	
Frenchman's Creek													
FC-C		16	4.7	18	4	96	60	160	260	140	840	3.7	
	Fish TEQ									0.014	0.084	0.185	
FC-5		75	41	94	67	310	460	600	3000	460	10000	11	
	Fish TEQ									0.046	1	0.55	
FC-6		2.5	< 0.39	8.7	1.1	22	31	26	190	30	700	1.3	<
	Fish TEQ									0.003	0.07	0.065	
FC-7		2	1	13	< 1.9	11	14	15	110	23	350	< 1.4	<
	Fish TEQ									0.0023	0.035		
FC-8	0-10	20	2.5	27	3.2	55	45	34	190	37	620	3.6	<
	Fish TEQ									0.0037	0.062	0.18	
FC-8	10-20	24	4.9	30	4.2	47	40	63	150	40	560	3.8	<
	Fish TEQ									0.004	0.056	0.19	
Niagara River													
NR-1		24	13	30	4.8	60	32	72	74	110	360	3.6	
	Fish TEQ									0.011	0.036	0.18	
NR-2		13	7.5	10	1.2	18	9.3	23	32	29	140	2.3	
	Fish TEQ									0.0029	0.014	0.115	
NR-3		74	31	60	7.1	100	44	110	86	160	320	8.5	
	Fish TEQ									0.016	0.032	0.425	
NR-4		46	18	47	6.7	86	37	100	130	120	610	5.2	
	Fish TEQ									0.012	0.061	0.26	
NOTL-1		98	74	120	24	150	76	170	120	470	490	11	
	Fish TEQ									0.047	0.049	0.55	

Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans Location	Depth	T4CDF	T4CDD	P5CDF	P5CDD	H6CDI	H6CDD	H7CDF	H7CDD	OCDF	OCDD	2378 TCDF
WHO Mammalian TEF										0.0001	0.0001	0.1
WHO Fish TEF										0.0001	0.0001	0.05

Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans		2378	12378	23478	12378	123478	123678	234678	123789	123478	123678	
Location	Depth	TCDD	PCDF	PCDF	PCDD	HCDF	HCDF	HCDF	HCDF	HCDD	HCDD	
WHO Mammalian TEF		1	0.05	0.5	1	0.1	0.1	0.1	0.1	0.1	0.1	
WHO Fish TEF		1	0.05	0.05	1	0.1	0.1	0.1	0.1	0.1	0.1	
Welland River												
WR-4 N	0-5 cm	0.94	< 1.2	< 1.2	< 0.58	< 2	1.4	1.4	< 0.57	2.1	8.7	
	Fish TEQ						0.14	0.14		0.21	0.87	
WR-5 N	0-5 cm	1.1	1.4	2.4	2.4	6.3	4.1	2.7	< 0.42	3.3	7.7	
	Fish TEQ	1.1	0.07	0.12	2.4	0.63	0.41	0.27		0.33	0.77	
WR-8 N		0.99	1.1	1.9	2.7	4.1	2.2	2.2	< 0.71	3.4	8.6	
	Fish TEQ	0.99	0.055	0.095	2.7	0.41	0.22	0.22	0.071	0.34	0.86	
WR-10 N		0.75	< 0.97	1.7	1.9	3.2	1.8	1.5	< 0.7	3.2	6.1	
	Fish TEQ			0.085	1.9	0.32	0.18	0.15	0.07	0.32	0.61	
Frenchman's Creek												
FC-C		3.5	< 1.5	3	< 1.7	10	4.6	3.5	< 1.1	3.6	7.9	
	Fish TEQ	3.5		0.15		1	0.46	0.35		0.36	0.79	
FC-5		4.5	3.5	5.2	12	23	12	11	< 1.2	16	55	
	Fish TEQ	4.5	0.175	0.26	12	2.3	1.2	1.1		1.6	5.5	
FC-6		0.39	< 0.6	1.2	1.1	1.8	< 1.2	< 1.1	< 0.67	1.5	4.2	
	Fish TEQ			0.06	1.1	0.18				0.15	0.42	
FC-7		0.49	< 0.74	< 0.9	< 0.99	2.1	< 0.99	< 1.1	< 1.1	< 0.83	< 2.4	<
	Fish TEQ					0.21						
FC-8	0-10	0.65	1.5	2	1.9	4.3	4.1	2.7	< 0.7	2.2	5	
	Fish TEQ		0.075	0.1	1.9	0.43	0.41	0.27		0.22	0.5	
FC-8	10-20	0.5	1.5	< 1.8	1.5	3.5	4.1	< 2.2	< 0.38	< 1.7	4.5	
	Fish TEQ		0.075		1.5	0.35	0.41				0.45	
Niagara River												
NR-1		5.6	1.6	< 3.8	1.1	25	5.1	1.9	< 0.58	1.2	2.6	
	Fish TEQ	5.6	0.08		1.1	2.5	0.51	0.19		0.12	0.26	
NR-2		3.7	< 0.93	1.8	< 0.72	6.6	1.6	0.87	< 0.43	0.41	1.2	<
	Fish TEQ	3.7		0.09		0.66	0.16	0.087		0.041	0.12	
NR-3		20	4.1	< 7.7	1.6	42	6.2	2.4	< 0.58	1.2	4.2	
	Fish TEQ	20	0.205		1.6	4.2	0.62	0.24		0.12	0.42	
NR-4		5.3	2.6	< 6.5	1.1	34	8.9	2.1	< 0.56	1.3	4.4	
	Fish TEQ	5.3	0.13		1.1	3.4	0.89	0.21		0.13	0.44	
NOTL-1		44	5	8.9	< 2.1	63	10	4	1.3	1.9	8	
	Fish TEQ	44	0.25	0.445		6.3	1	0.4	0.13	0.19	0.8	

Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans Location Depth	2378 TCDD	12378 PCDF	23478 PCDF	12378 PCDD	123478 HCDF	123678 HCDF	234678 HCDF	123789 HCDF	123478 HCDD	123678 HCDD
WHO Mammalian TEF	1	0.05	0.5	1	0.1	0.1	0.1	0.1	0.1	0.1
WHO Fish TEF	1	0.05	0.05	1	0.1	0.1	0.1	0.1	0.1	0.1

< + value = concentration wa

Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans		123789	1234678	1234789	1234678	Total
Location	Depth	HCDD	HCDF	HCDF	HCDD	TEQ
WHO Mammalian TEF		0.1	0.01	0.01	0.01	
WHO Fish TEF		0.1	0.001	0.01	0.01	
Welland River						
WR-4 N	0-5 cm	8.7	< 20	< 1.9	500	
	Fish TEQ	0.87			5	8.3101
WR-5 N	0-5 cm	10	63	3.7	180	
	Fish TEQ	1	0.063	0.037	1.8	9.558
WR-8 N		9.6	37	2.7	210	
	Fish TEQ	0.96	0.037	0.027	2.1	9.7553
WR-10 N		9.4	< 27	< 1.3	180	
	Fish TEQ	0.94			1.8	7.0448
Frenchman's Creek						
FC-C		8.7	67	3.6	150	
	Fish TEQ	0.87	0.067	0.036	1.5	9.366
FC-5		55	240	14	1500	
	Fish TEQ	5.5	0.24	0.14	15	51.111
FC-6		4.5	< 17	< 0.75	96	
	Fish TEQ	0.45			0.96	3.458
FC-7		2.5	< 14	< 1.1	46	
	Fish TEQ				0.46	0.7073
FC-8	0-10	6.6	< 30	< 1.4	97	
	Fish TEQ	0.66			0.97	5.7807
FC-8	10-20	6	28	1.8	76	
	Fish TEQ	0.6	0.028	0.018	0.76	4.441
Niagara River						
NR-1		2.9	68	2.6	32	
	Fish TEQ	0.29	0.068	0.026	0.32	11.291
NR-2		0.62	17	1	14	
	Fish TEQ		0.017	0.01	0.14	5.1569
NR-3		3.1	110	4.9	39	
	Fish TEQ	0.31	0.11	0.049	0.39	28.737
NR-4		3.7	94	4	55	
	Fish TEQ	0.37	0.094	0.04	0.55	12.987
NOTL-1		6.1	140	6.9	56	
	Fish TEQ	0.61	0.14	0.069	0.56	55.54

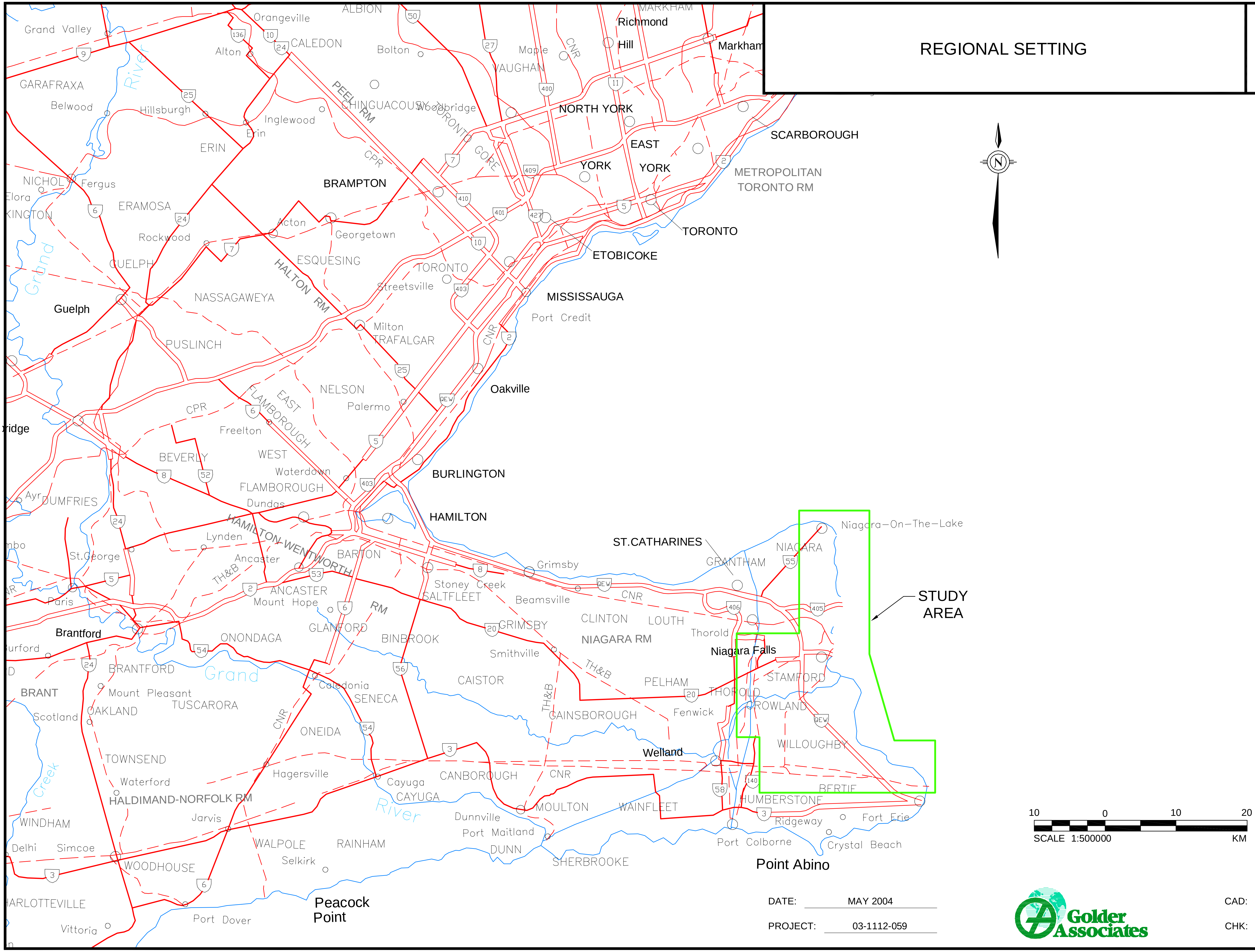
Table 5.1.4
Sediment Dioxins and Furans. November 2003.

Dioxins and Furans	123789	1234678	1234789	1234678	Total
Location Depth	HCDD	HCDF	HCDF	HCDD	TEQ
WHO Mammalian TEF	0.1	0.01	0.01	0.01	
WHO Fish TEF	0.1	0.001	0.01	0.01	

as below the detection limit, which is given as the value following the "<" symbol

REGIONAL SETTING

FIGURE 1



DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

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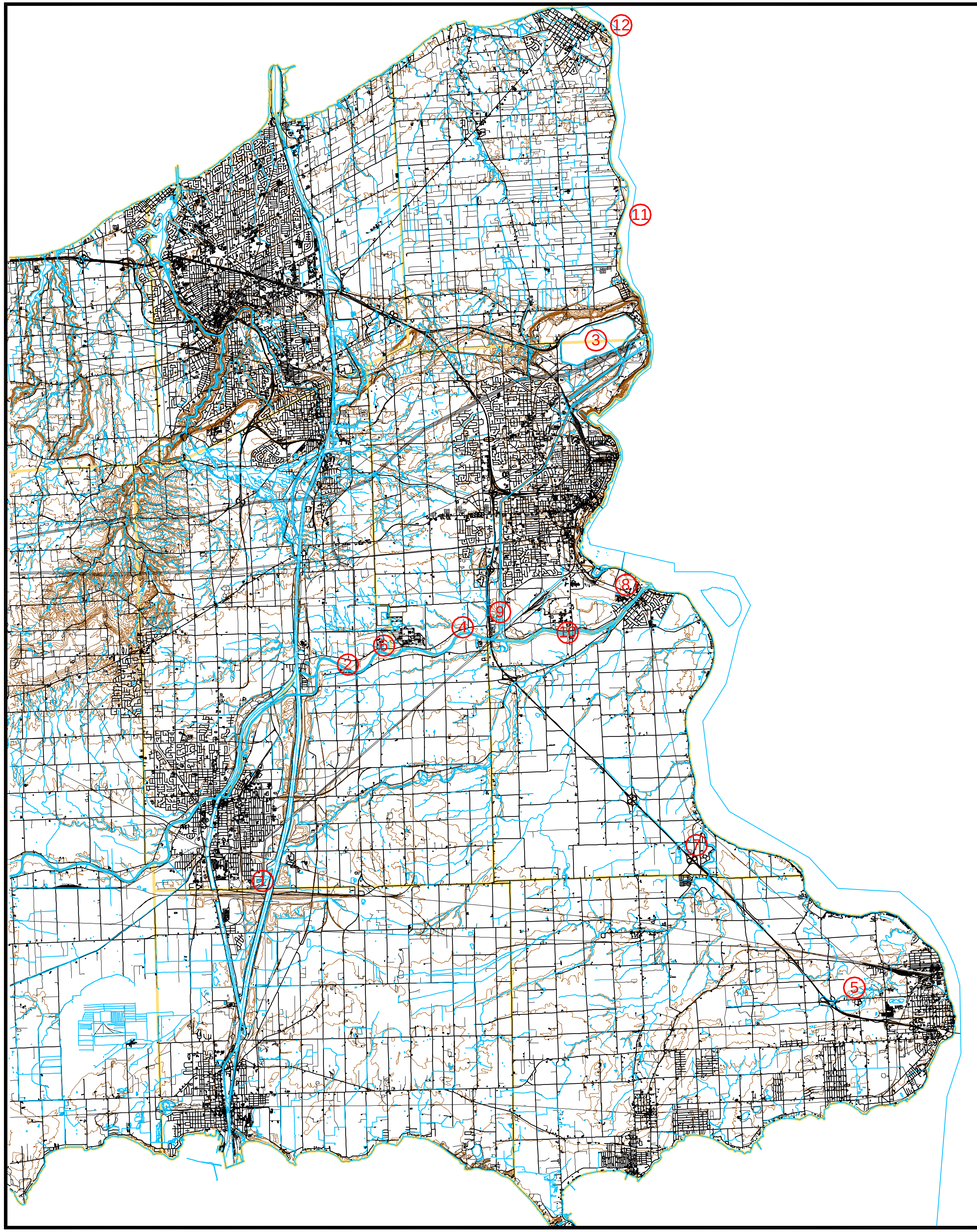
STUDY AREAS

FIGURE 2



LEGEND

STUDY AREA LOCATIONS

1. LYON'S CREEK WEST
2. WELLAND RIVER - PORT ROBINSON TO CHIPPAWA POWER CANAL
3. SIR ADAM BECK RESERVOIR
4. THOMPSON'S CREEK
5. FRECHMAN'S CREEK
6. WELLAND RIVER AT GEON
7. BLACK CREEK MOUTH
8. PELL CREEK MOUTH
9. CHIPPAWA POWER CANAL
10. CHIPPAWA CREEK
11. NIAGARA RIVER AT QUEENSTON
12. NIAGARA RIVER AT NIAGARA-ON-THE-LAKE

3.5 0 3.5 7

SCALE 1:175000 KM

DATE: MAY 2004

PROJECT: 03-1112-059

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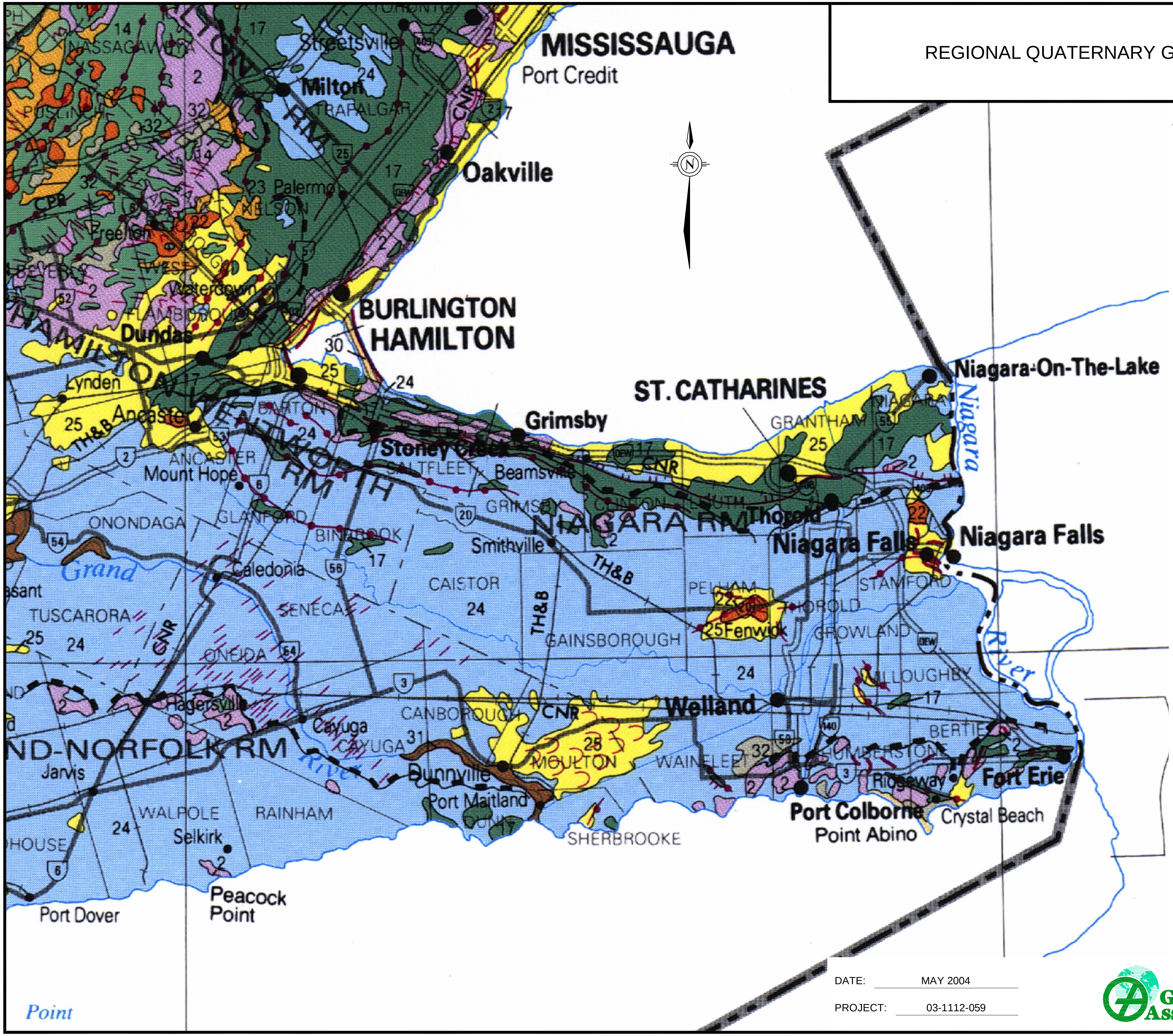
REGIONAL QUATERNARY GEOLOGY

FIGURE 3



LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT

30	**Lacustrine deposits:** sand, gravelly sand and gravel; nearshore and beach deposits

PLEISTOCENE

25	**Glaciolacustrine deposits:** sand, gravelly sand and gravel; nearshore and beach deposits
24	**Glaciolacustrine deposits:** silt and clay, minor sand; basin and quiet water deposits
23	**Glaciofluvial outwash deposits:** gravel and sand; includes proglacial river and deltaic deposits
22	**Glaciofluvial ice-contact deposits:** gravel and sand; minor till; includes esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits
17	**Halton Till (Ontario–Erie lobe):** predominantly silt to silty clay matrix, high in matrix carbonate content and clast poor
14	**Wentworth Till (Ontario–Erie lobe):** sandy silt to silt matrix becoming finer grained to silty clay near Lake Erie, highly calcareous, clast content moderate to low decreasing southward
9	**Port Stanley Till (Ontario–Erie lobe):** silt to sandy silt matrix becoming silt to silty clay near Lake Erie, strongly calcareous, moderate to low clast content decreasing southward

PALEOZOIC

2	**Bedrock:** undifferentiated carbonate and clastic sedimentary rock, exposed at surface or covered by a discontinuous, thin layer of drift

REFERENCE

Quaternary geology of Ontario, southern sheet; Ontario Geological Survey, Map 2556, scale 1:1 000 000.

8 0 8 16
1:400000 KM

DATE: MAY 2004
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CHK: RJ

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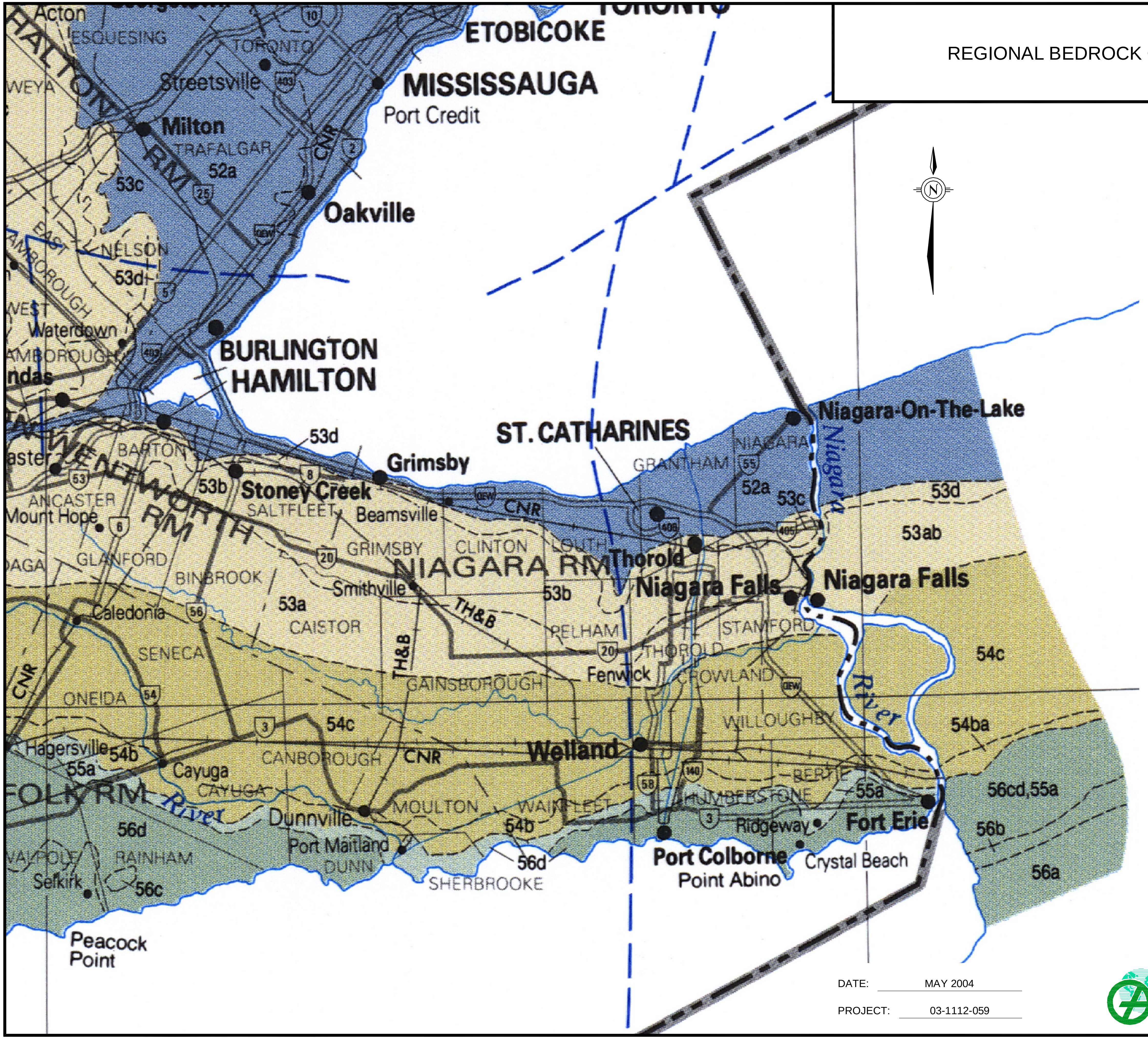
REGIONAL BEDROCK GEOLOGY

FIGURE 4



LEGEND

MIDDLE DEVONIAN

56 **Limestone, dolostone, shale**
- 56a Hamilton Gp.
- 56b Marcellus Fm.
- 56c Dundee Fm.
- 56d Detroit River Gp.; Onondaga Fm.
- 56e Williams Island Fm.
- 56f Murray Island Fm.
- 56g Moose River Fm.
- 56h Kwataboahegan Fm.

LOWER DEVONIAN

55 **Sandstone, dolostone, limestone**
- 55a Bois Blanc Fm.; Oriskany Fm.
- 55b Stooping River Fm.
- 55c Sextant Fm.

SILURIAN

UPPER SILURIAN

54 **Limestone, dolostone, shale, sandstone, gypsum, salt**
- 54a Bass Islands Fm.
- 54b Bertie Fm.
- 54c Salina Fm.
- 54d Kenogami River Fm. (Upper Silurian to Lower Devonian)

MIDDLE AND LOWER SILURIAN

53 **Sandstone, shale, dolostone, siltstone**
- 53a Guelph Fm.
- 53b Lockport Fm.
- 53c Amabel Fm.
- 53d Clinton Gp.; Cataract Gp.
- 53e Thornloe Fm.; Earlton Fm.
- 53f Wabi Gp.
- 53g Attawapiskat Fm.
- 53h Ekwan River Fm.
- 53i Severn River Fm.

ORDOVICIAN

UPPER ORDOVICIAN

52 **Shale, limestone, dolostone, siltstone**
- 52a Queenston Fm.
- 52b Georgian Bay Fm.; Blue Mountain Fm.; Billings Fm.; Collingwood Mb.; Eastview Mb.
- 52c Liskeard Gp.
- 52d Red Head Rapids Fm.
- 52e Churchill River Gp.
- 52f Bad Cache Rapids Gp.

REFERENCE

Ontario Geological Survey 1991. Bedrock geology of Ontario, southern sheet; Ontario Geological Survey, Map2544, scale 1:1 000 000.

8 0 8 16
1:400000 KM

DATE: MAY 2004
PROJECT: 03-1112-059

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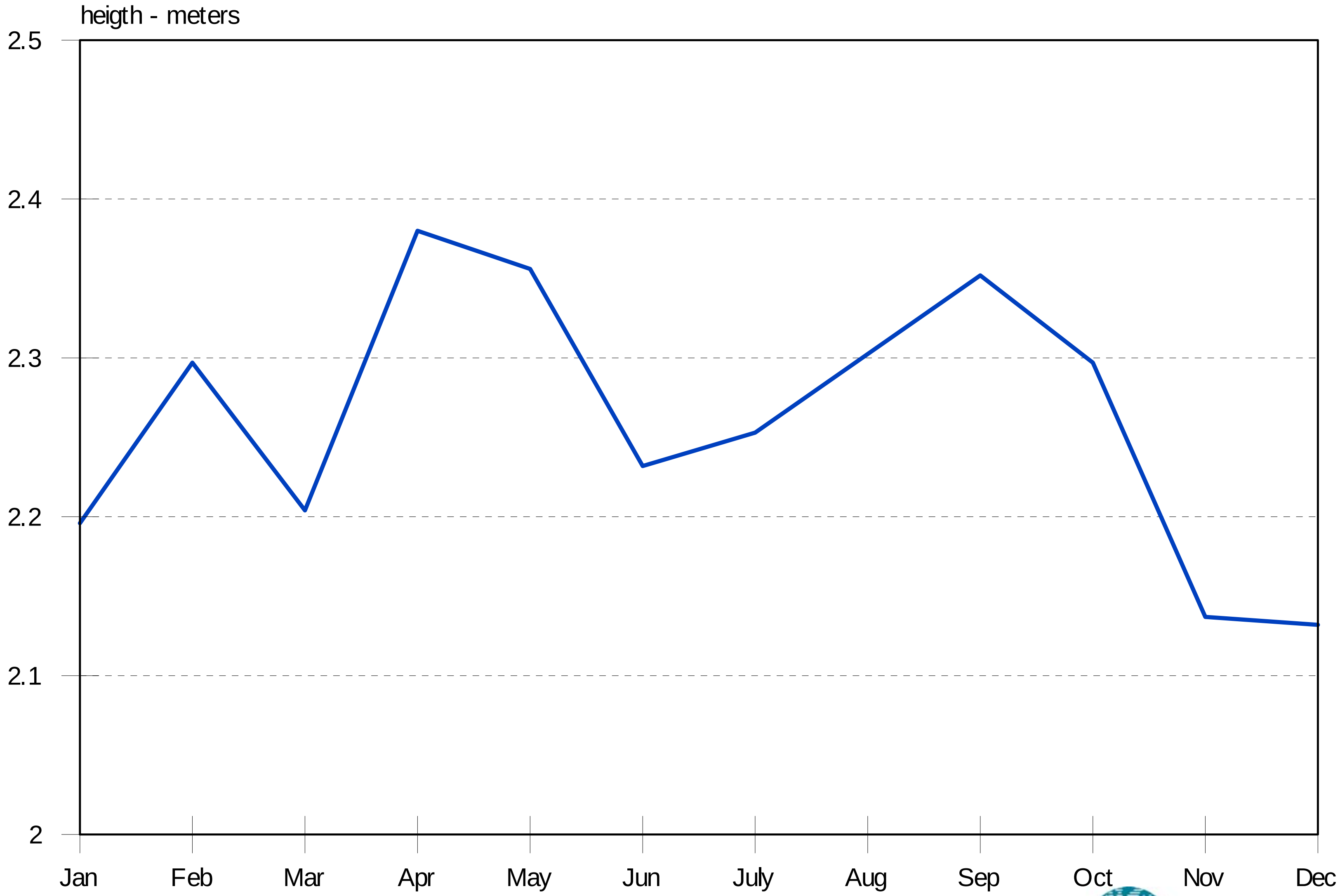
CAD: KD
CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\0311120 59BC04.dwg

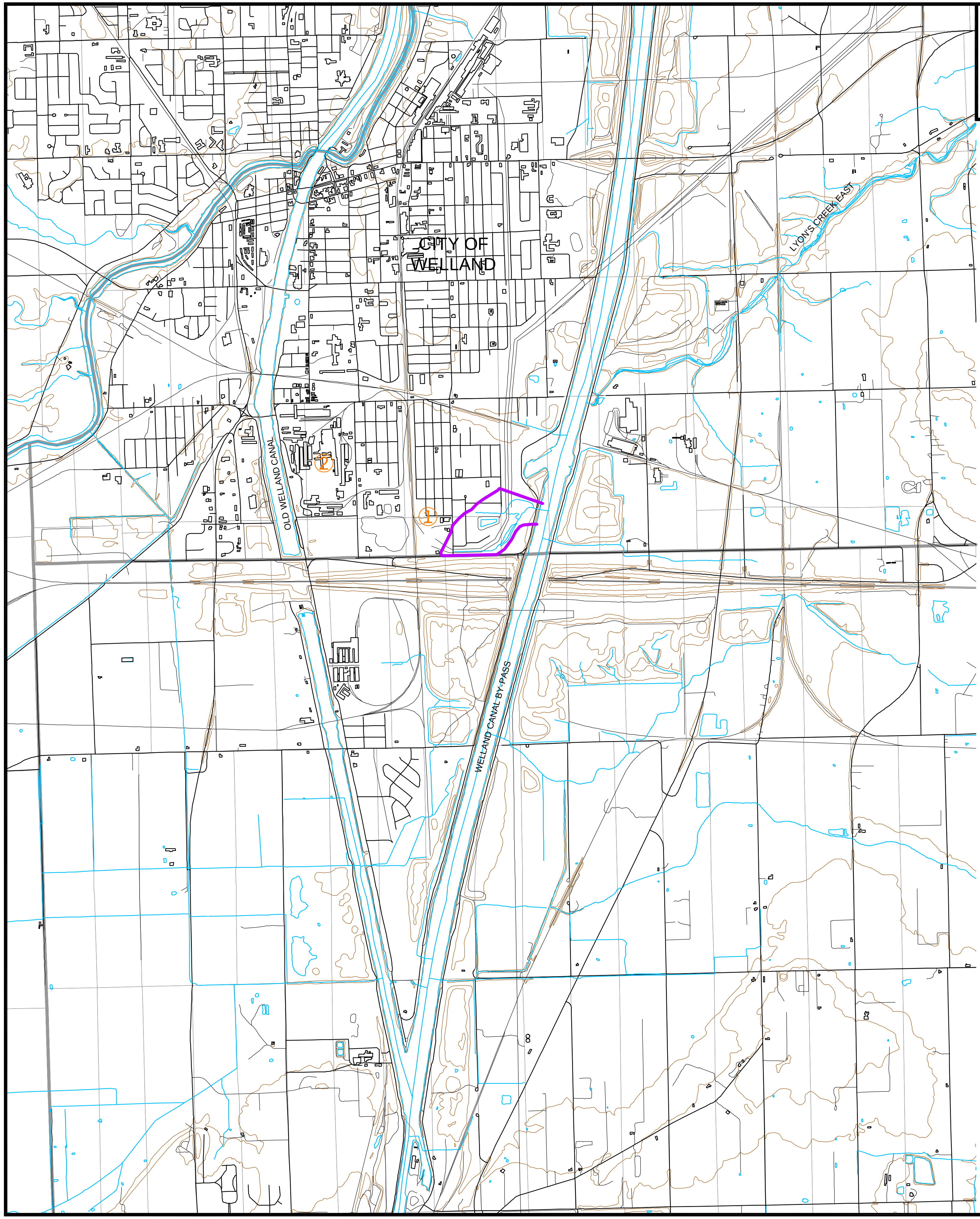
Figure 5:
Welland River: Mean Monthly Water Levels, 2002



Golder Associates

LYON'S CREEK WEST

FIGURE 6



LEGEND

━ LYON'S CREEK WEST WATERSHED

① CROWLAND TRANSFORMER STATION (HYDRO ONE)

② STEL PIPE PAGE HERSEY WORKS

800 0 800 1600

SCALE 1:40000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

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CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004

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LYON'S CREEK WEST LOCATION OF SEDIMENT SAMPLES

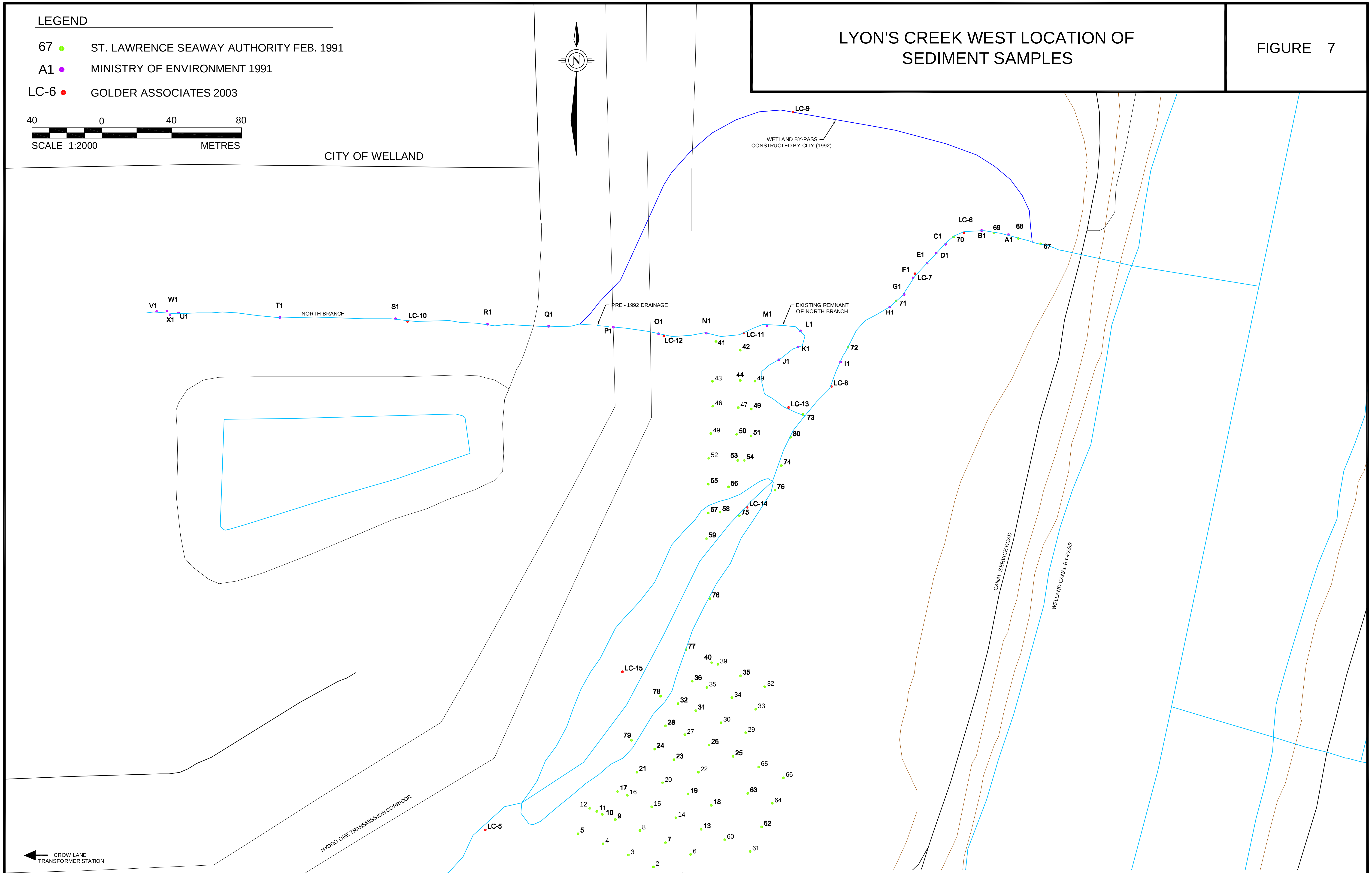
FIGURE 7

LEGEND

67 ● ST. LAWRENCE SEAWAY AUTHORITY FEB. 1991

A1 ● MINISTRY OF ENVIRONMENT 1991

LC-6 ● GOLDER ASSOCIATES 2003



DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004

FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC07.dwg

WELLAND RIVER
UPSTREAM OF CITY OF WELLAND TO THE WELLAND CANAL BY-PASS

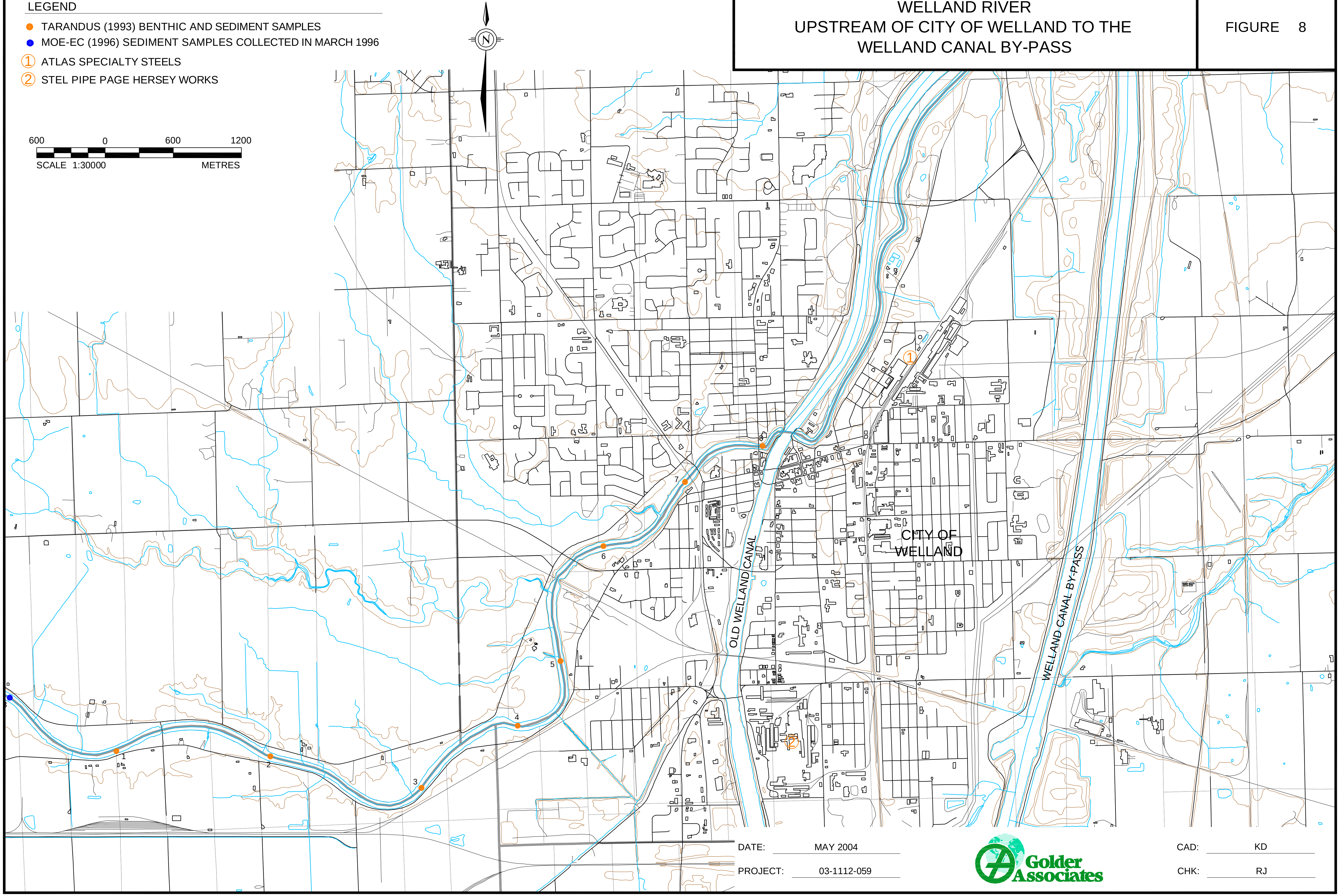
FIGURE 8

LEGEND

- ● TARANDUS (1993) BENTHIC AND SEDIMENT SAMPLES
- ● MOE-EC (1996) SEDIMENT SAMPLES COLLECTED IN MARCH 1996
- ① ATLAS SPECIALTY STEELS
- ② STEL PIPE PAGE HERSEY WORKS

600 0 600 1200

SCALE 1:30000 METRES



DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004

FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\0311112059BC08.dwg

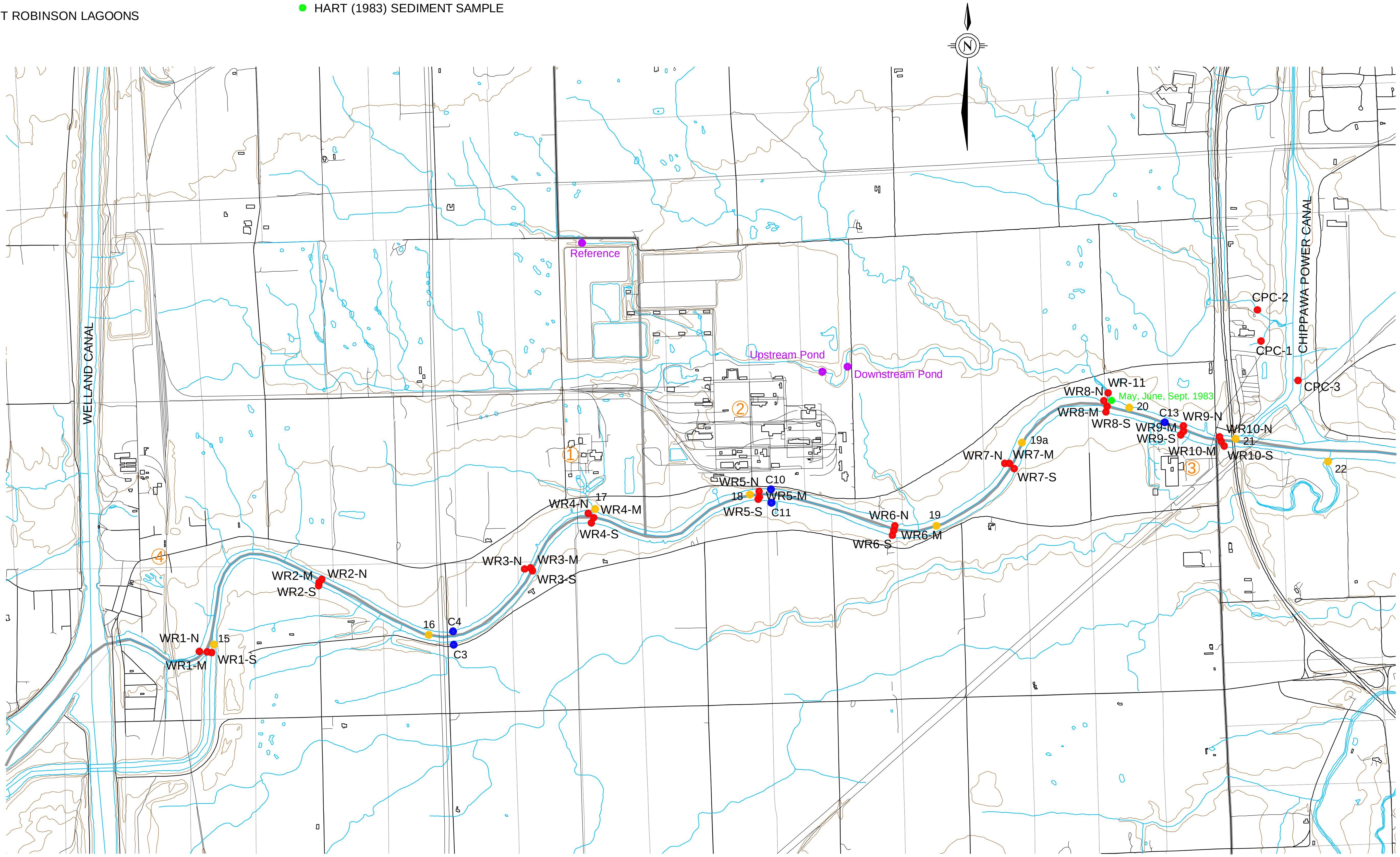
WELLAND RIVER
PT ROBINSON TO CHIPPAWA POWER CANAL

FIGURE 9

LEGEND

① GEON (OXY VINYLS) LTD.
② CYTEC CANADA
③ FORD GLASS (DECOMMISSIONED)
④ PT ROBINSON LAGOONS

● GOLDER (2003) SAMPLING LOCATION
● TARANDUS (1993) BENTHIC AND SEDIMENT SAMPLES
● MOE-EC (1996) SEDIMENT SAMPLES COLLECTED IN MARCH 1996
● BEAK (1994) BENTHIC AND SEDIMENT SAMPLES
● HART (1983) SEDIMENT SAMPLE



500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC09.dwg

Figure 10A:
Chromium in Welland River Sediments. 1996

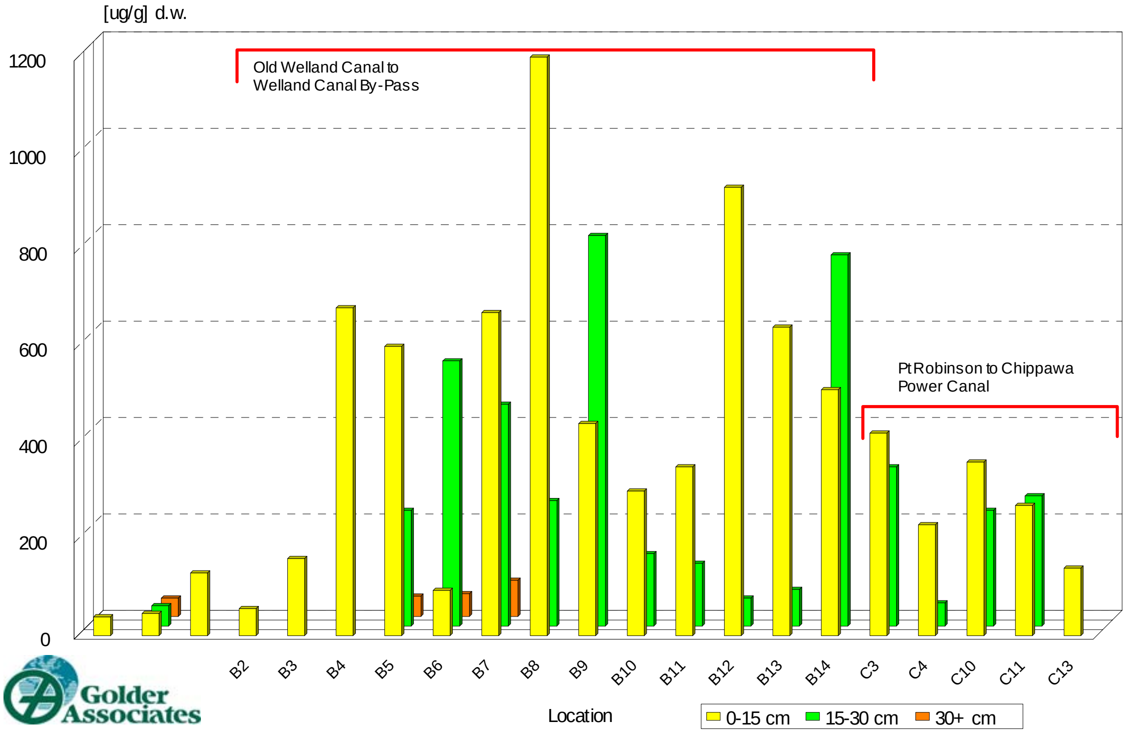


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Figure 10B:
Nickel in Welland River Sediments. 1996

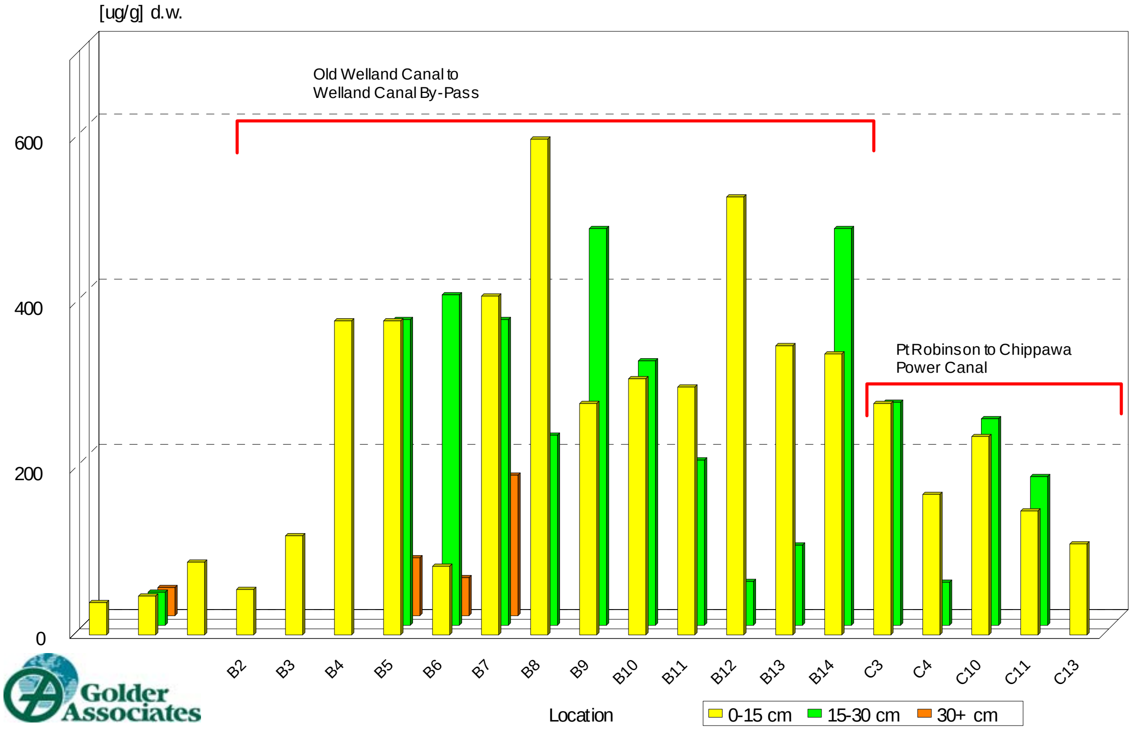

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Figure 10C:
Copper in Welland River Sediments. 1996

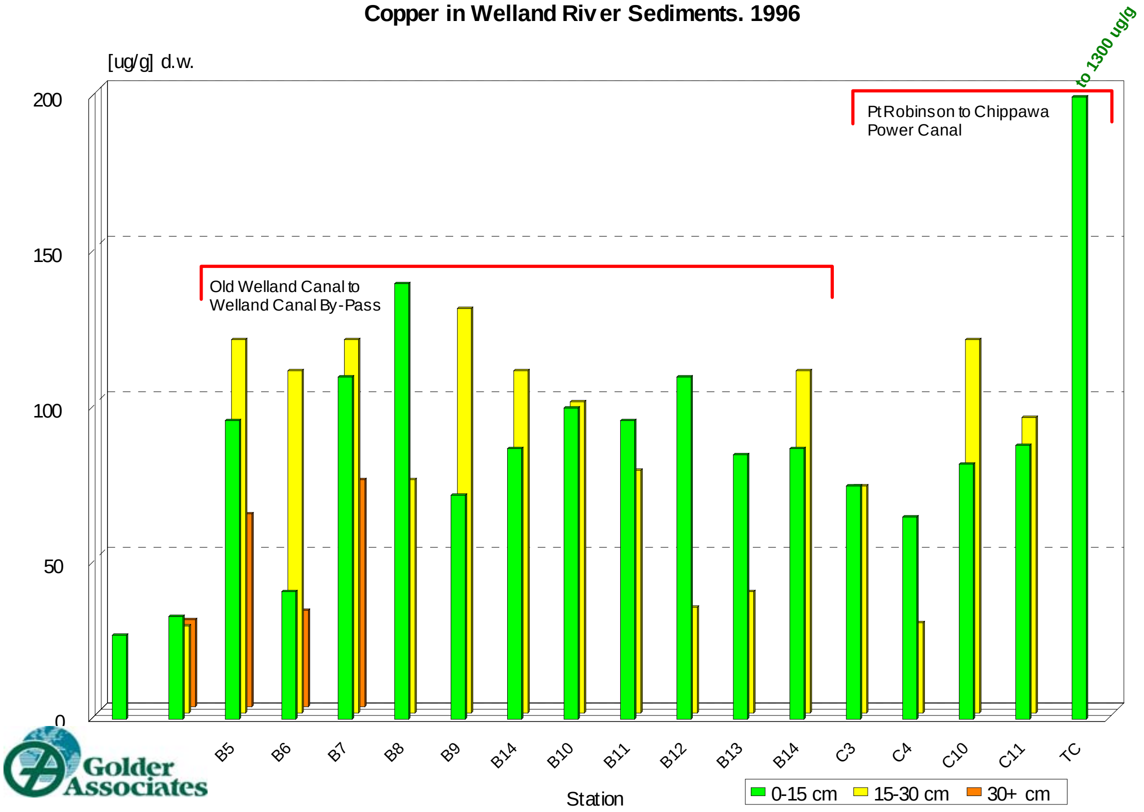
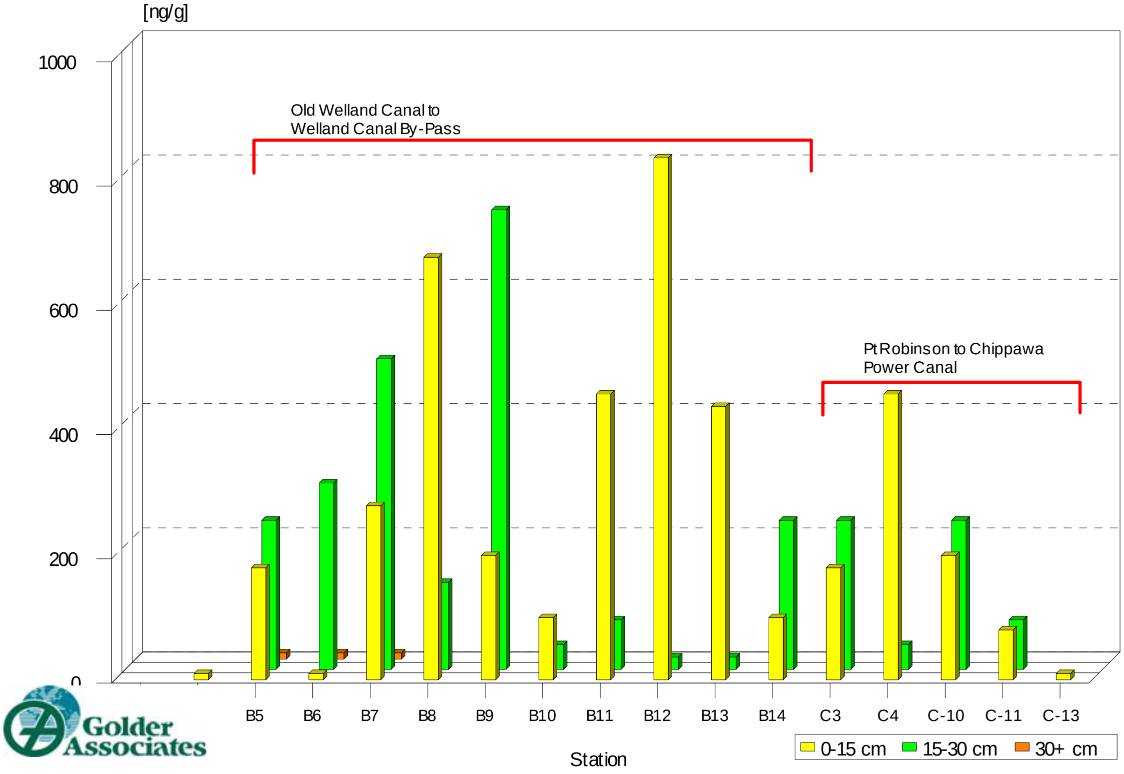
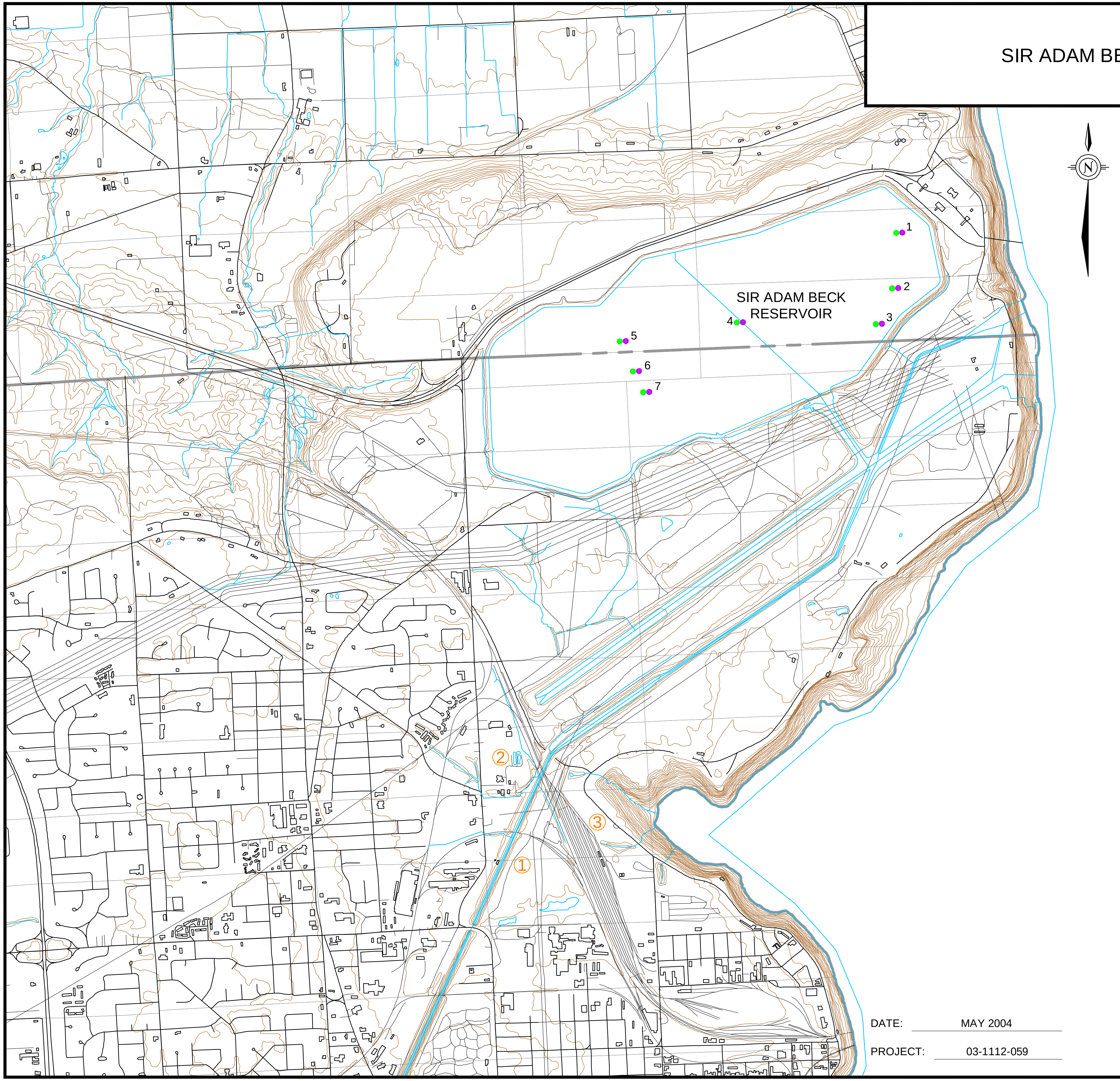


Figure 10D:
Distribution of PCBs in Welland River Sediments. 1996.



SIR ADAM BECK RESERVOIR

FIGURE 11



LEGEND

- ● 1983 SAMPLE (KAUSS & POST 1987)
- ● 1998 SAMPLE (WILLIAMS, MCCREA, SVERKO 2003)
- ① CYANAMID CANADA (NIAGARA FALLS)
- ② NIAGARA FALLS WPCP
- ③ CNR VICTORIA AVE LANDFILL

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

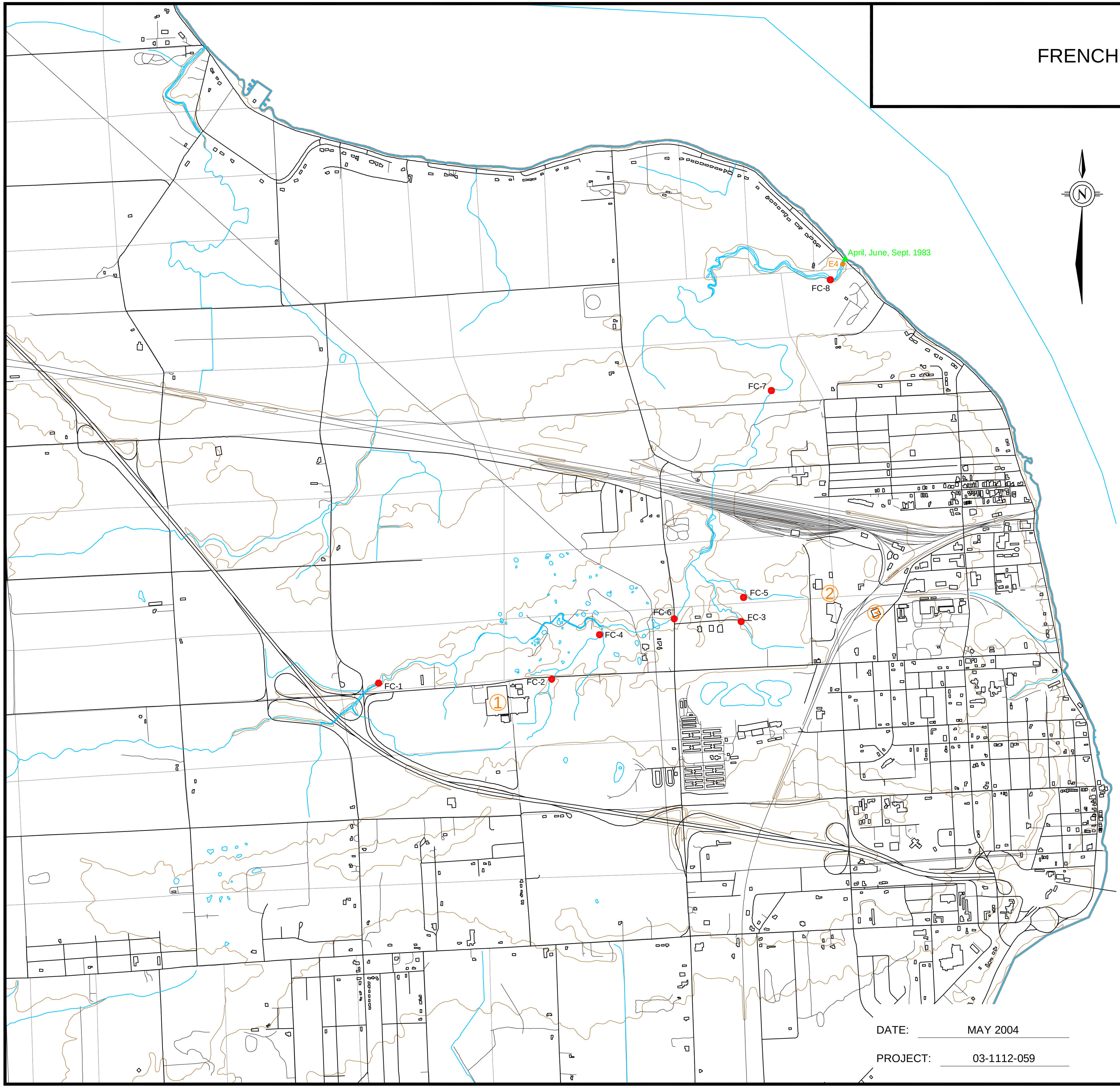
CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC11.dwg

FRENCHMAN'S CREEK

FIGURE 12



LEGEND

- ● NRTC (1984) SEDIMENT SAMPLES COLLECTED BETWEEN 1979 & 1982
- ● HART (1983) SEDIMENT SAMPLES COLLECTED IN 1983
- ● GOLDER (2003) SAMPLING LOCATION
- ① FLEET AEROSPACE
- ② CANADIAN OXY CHEMICALS - DUREZ DIVISION
- ③ GOULD NATIONAL BATTERY

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

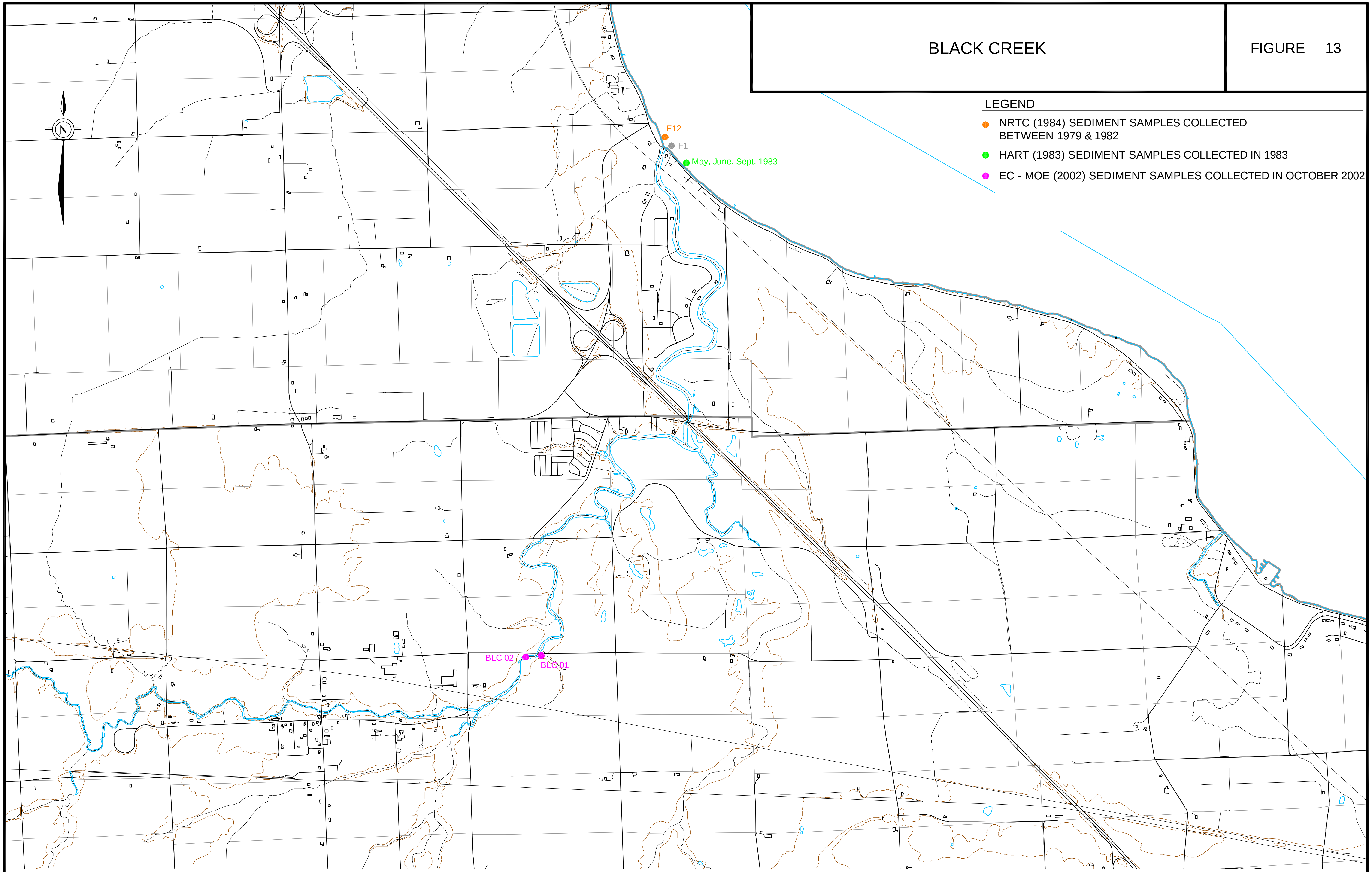
CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC12.dwg

BLACK CREEK

FIGURE 13



LEGEND

- ● NRTC (1984) SEDIMENT SAMPLES COLLECTED BETWEEN 1979 & 1982
- ● HART (1983) SEDIMENT SAMPLES COLLECTED IN 1983
- ● EC - MOE (2002) SEDIMENT SAMPLES COLLECTED IN OCTOBER 2002

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

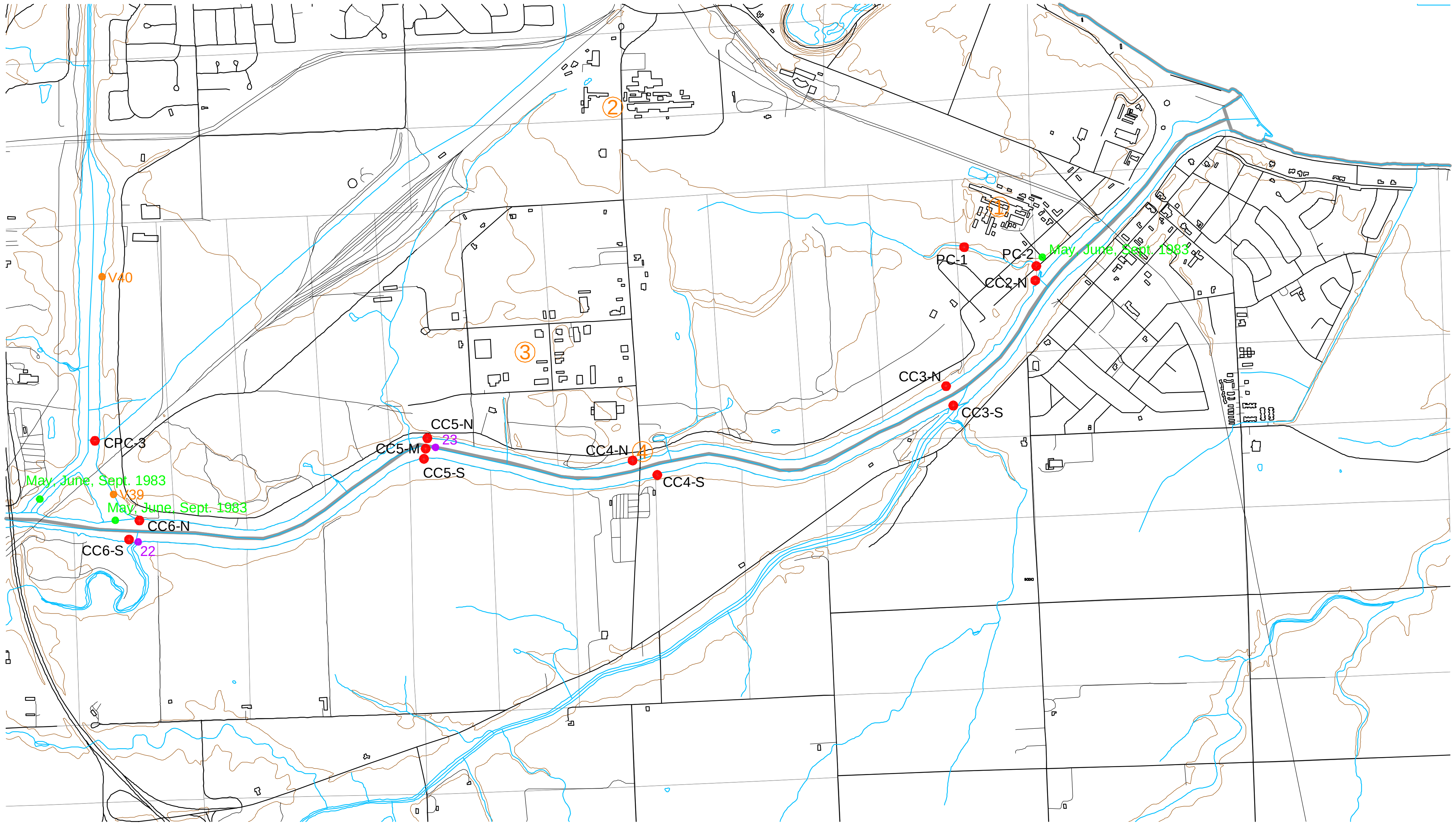
CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC13.dwg

CHIPPAWA CREEK AND CHIPPAWA POWER CANAL

FIGURE 14



LEGEND

- ● NRTC (1984) SEDIMENT SAMPLES COLLECTED BETWEEN 1979 & 1982
- ● HART (1983) SEDIMENT SAMPLES COLLECTED IN 1983
- ● TARANDUS (1993) BENTHIC AND SEDIMENT SAMPLES
- ● GOLDER (2003) SAMPLING LOCATIONS
- ① SAINT-GOBAIN (NORTON)
- ② WASHINGTON MILLS ELECTRO MINERALS
- ③ WASHINGTON MILLS
- ④ STANLEY AVE CSO

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 031-1112-059

Golder Associates

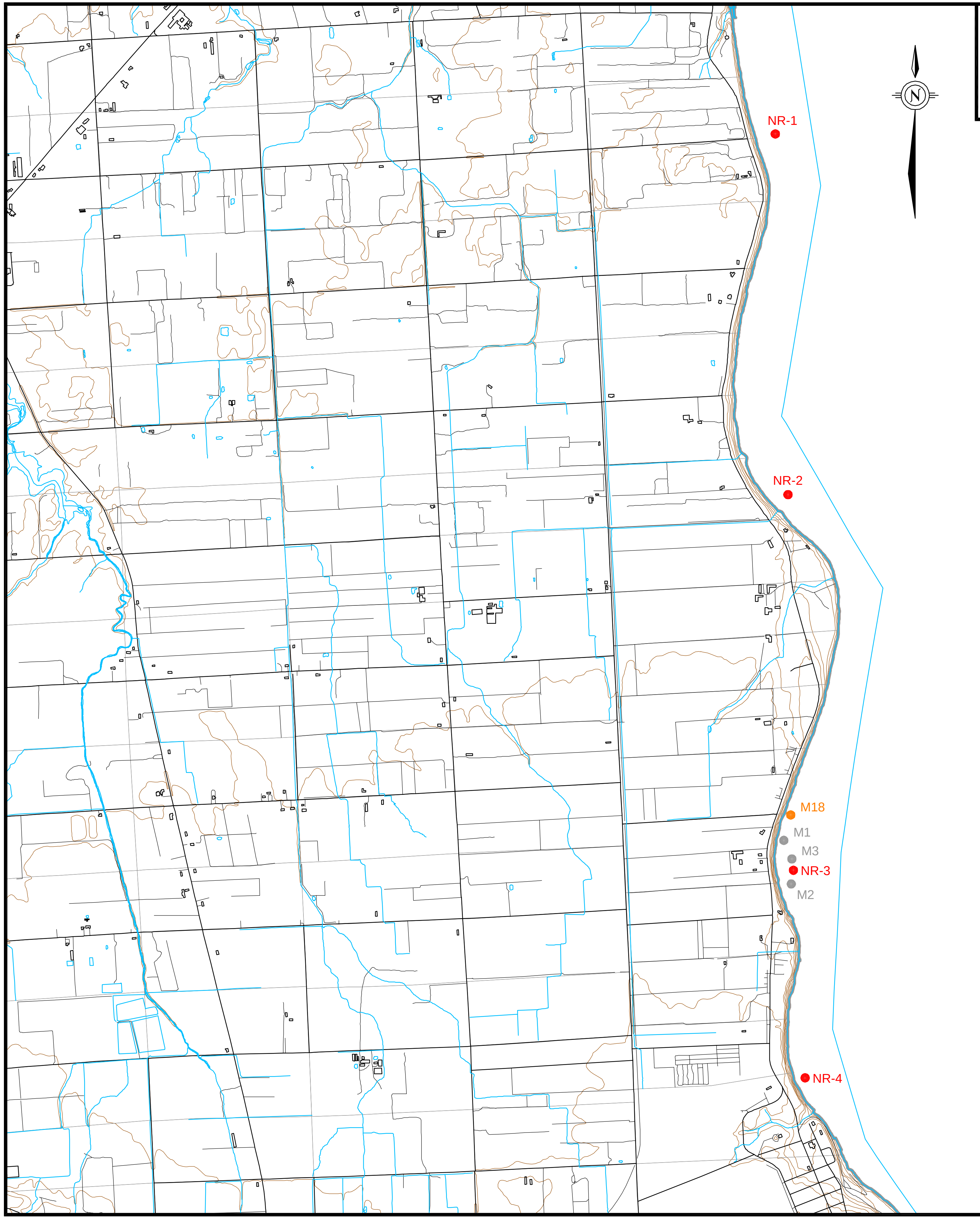
CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC14.dwg

NIAGARA RIVER AT QUEENSTON

FIGURE 15



LEGEND

- 🟠 NRTC (1984) SEDIMENT SAMPLES COLLECTED BETWEEN 1979 & 1982
- ● CREESE (1987) BENTHIC SAMPLES COLLECTED IN 1983
- 🔴 GOLDER (2003) SAMPLE LOCATIONS

600 0 600 1200

SCALE 1:30000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

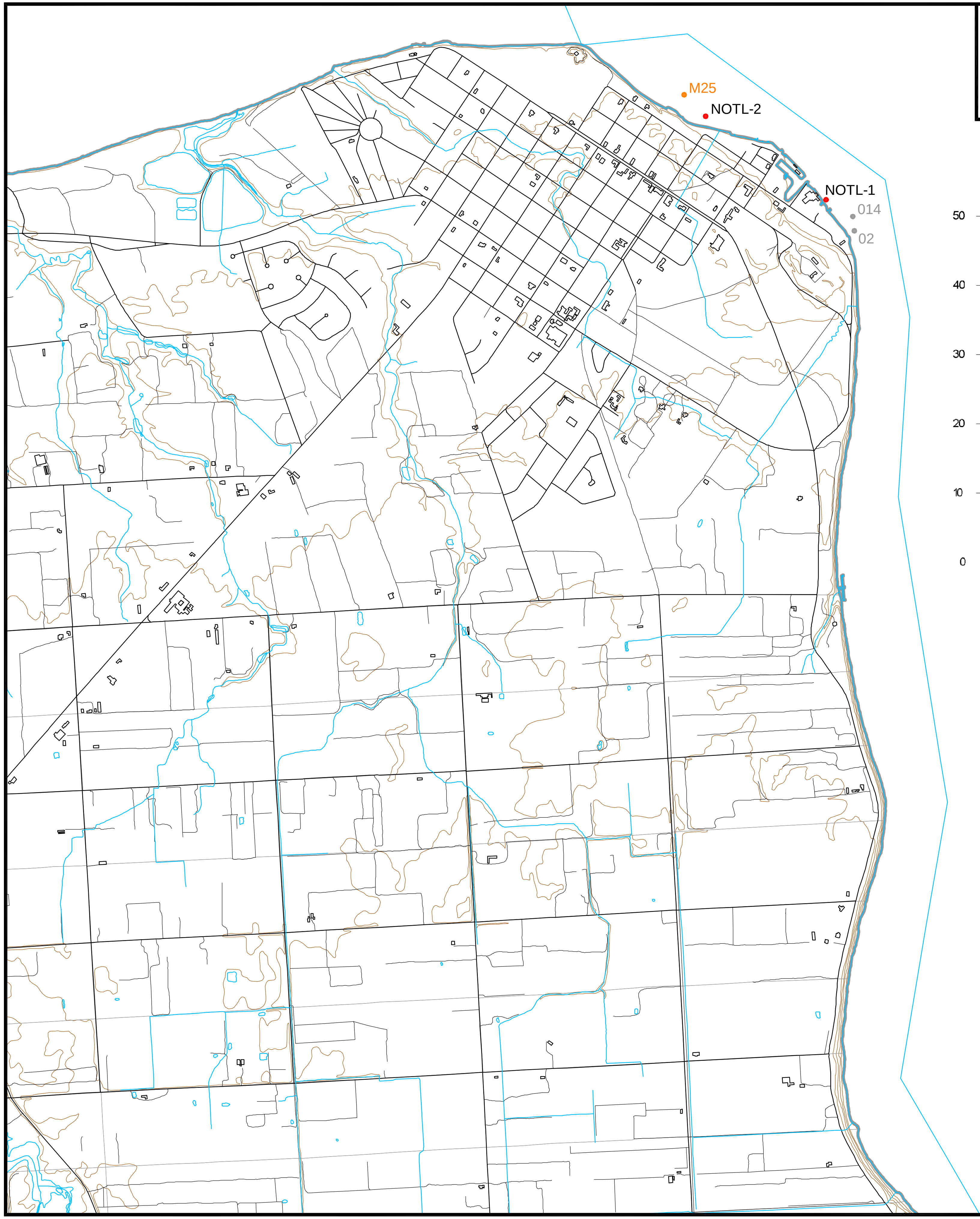
CHK: RJ

PLOT DATE: May 18, 2004

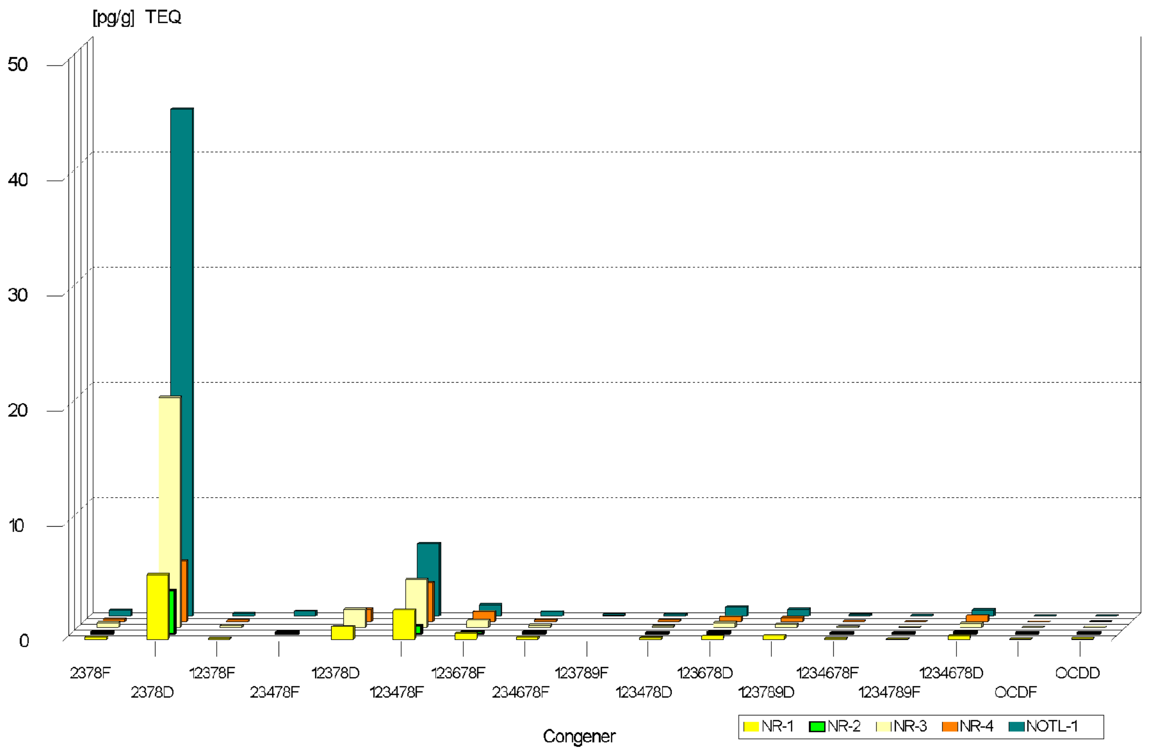
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC15.dwg

NIAGARA RIVER AT NIAGARA - ON - THE - LAKE

FIGURE 16



Distribution of Dioxin and Furan Congeners in Niagara River, November, 2003.



LEGEND

- ● NRTC (1984) SEDIMENT SAMPLES COLLECTED BETWEEN 1979 & 1982
- ● CREESE (1987) BENTHIC SAMPLES COLLECTED IN 1983
- ● GOLDER (2003) SAMPLING LOCATION

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC16.dwg

LYON'S CREEK WEST LOCATION OF
PCB SURFICIAL SEDIMENT CONCENTRATIONS (ug/g)

FIGURE 17

LEGEND

67 ●	ST. LAWRENCE SEAWAY AUTHORITY FEB. 1991
LC-6 ●	GOLDER ASSOCIATES 2003
A1 ●	MINISTRY OF ENVIRONMENT 1991
- - -	INFERRED 5 ug/g CONCENTRATION CONTOUR
- - -	INFERRED 25 ug/g CONCENTRATION CONTOUR
- - -	INFERRED 50 ug/g CONCENTRATION CONTOUR

DATE: MAY 2004

PROJECT: 03-1112-059

CAD: KD

CHK: RJ

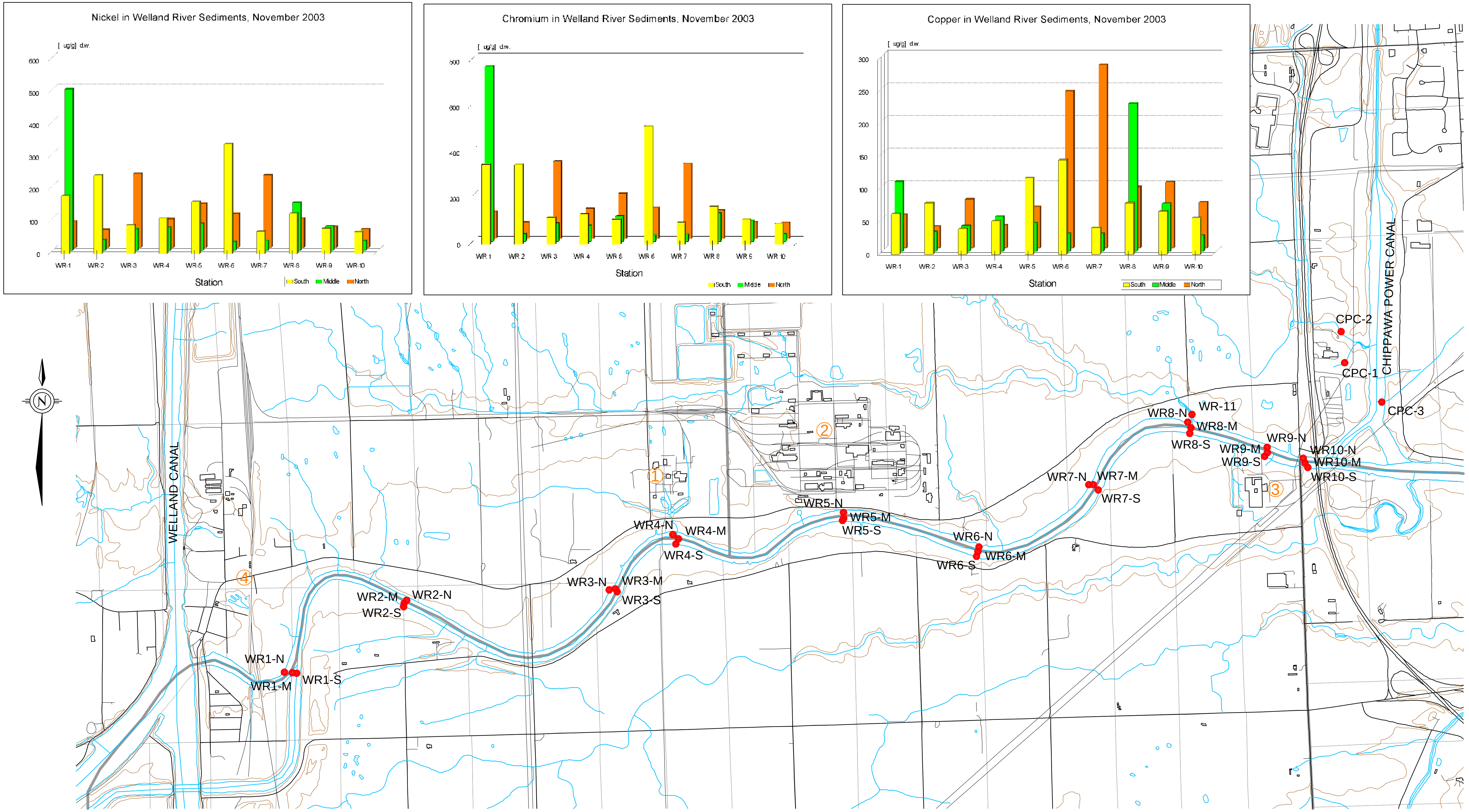
PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC17.dwg

WELLAND RIVER
DISTRIBUTION OF SELECTED PARAMETERS IN SEDIMENTS - 2003

FIGURE 18

LEGEND

- ● GOLDER (2003) SAMPLING LOCATION
- ① GEON (OXY VINYLS) LTD.
- ② CYTEC CANADA
- ③ FORD GLASS (DECOMMISSIONED)
- ④ PORT ROBINSON LAGOONS



DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\03111205918C18.dwg

Figure 19A:
Chromium in Welland River Sediments. 1996 & 2003

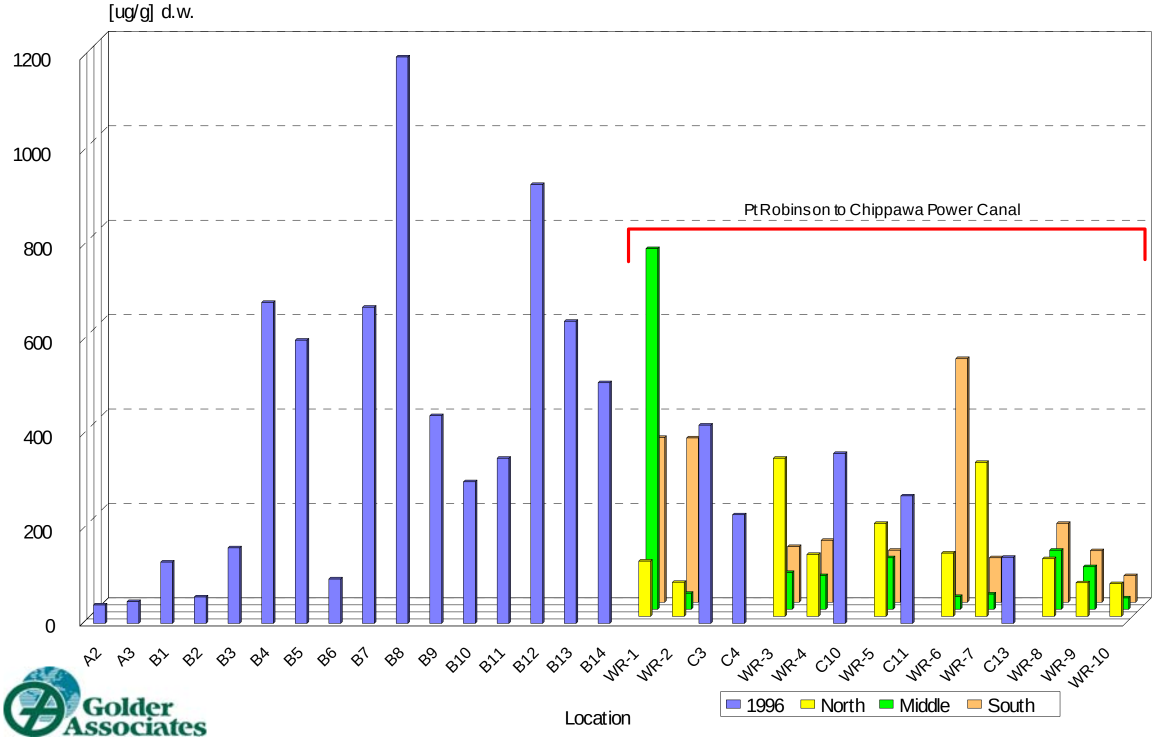


Figure 19B:
Copper in Welland River Sediments. 1996 and 2003

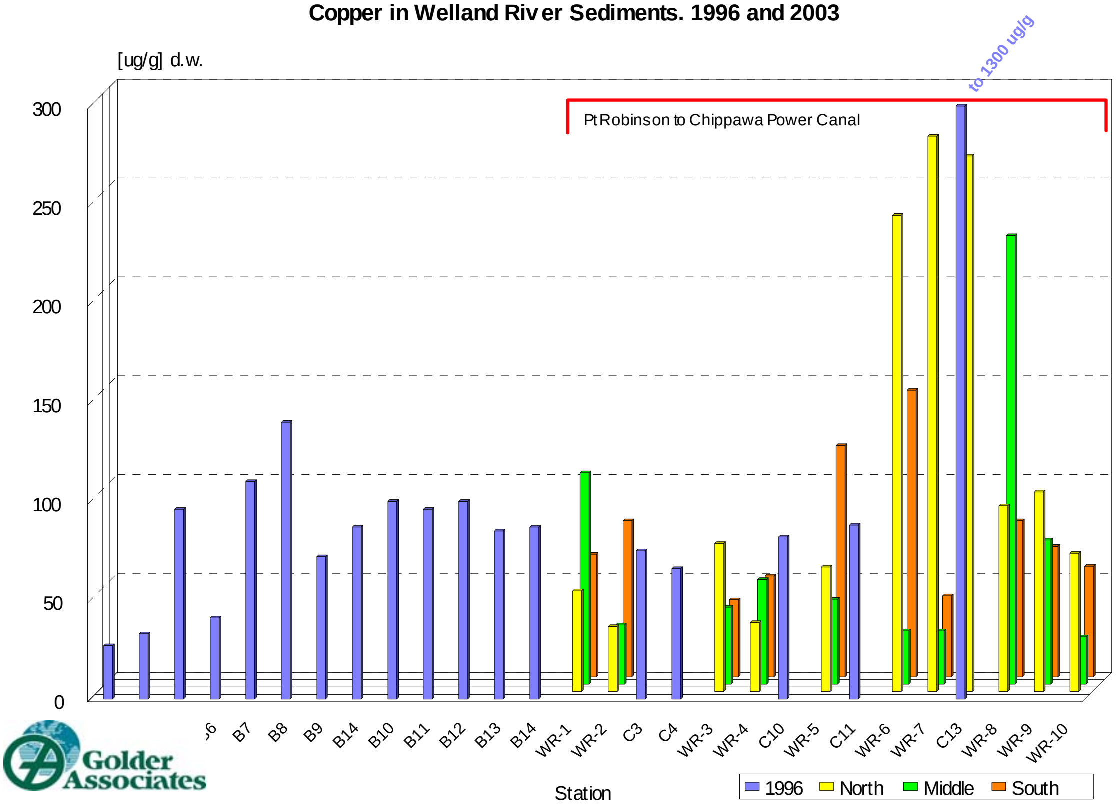


Figure 19C:
Nickel in Welland River Sediments. 1996 & 2003

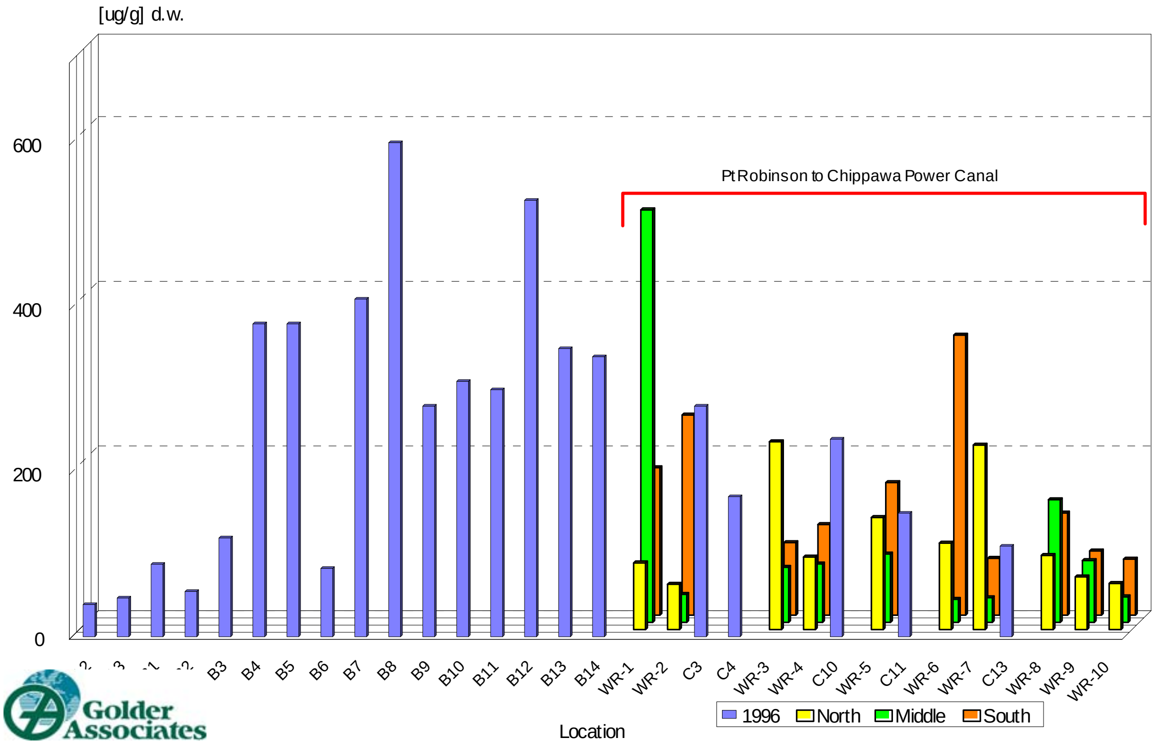
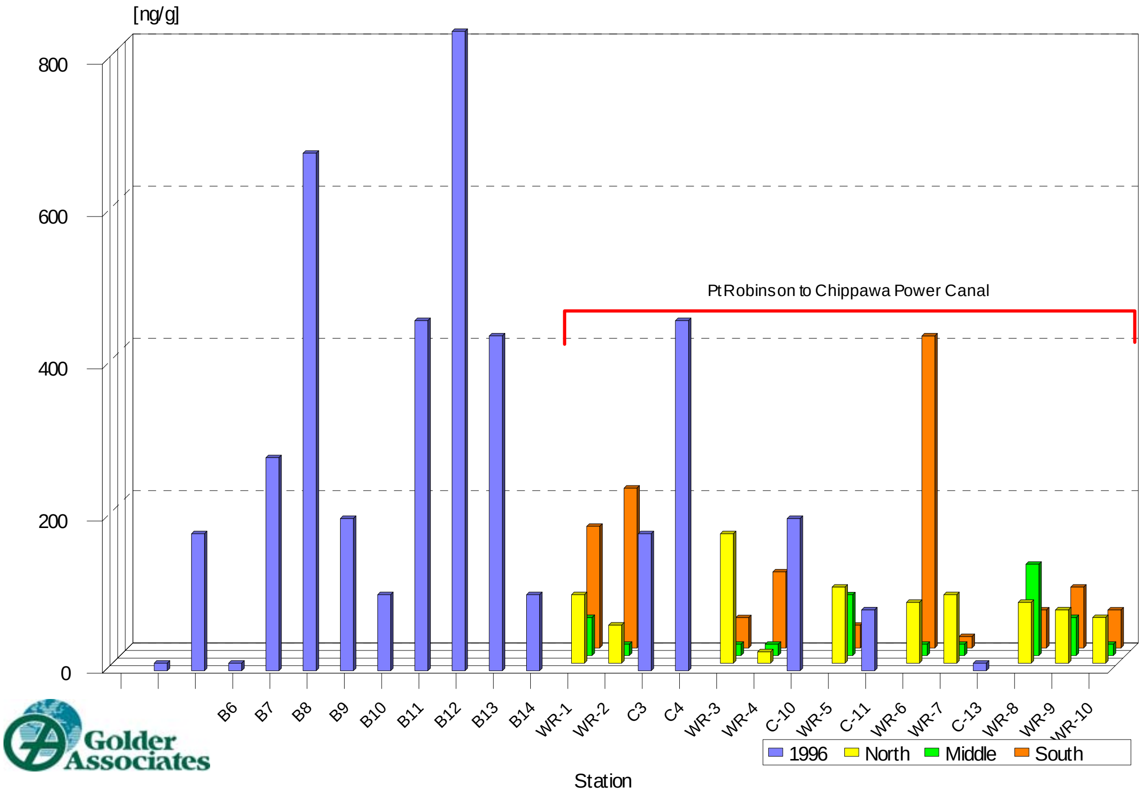
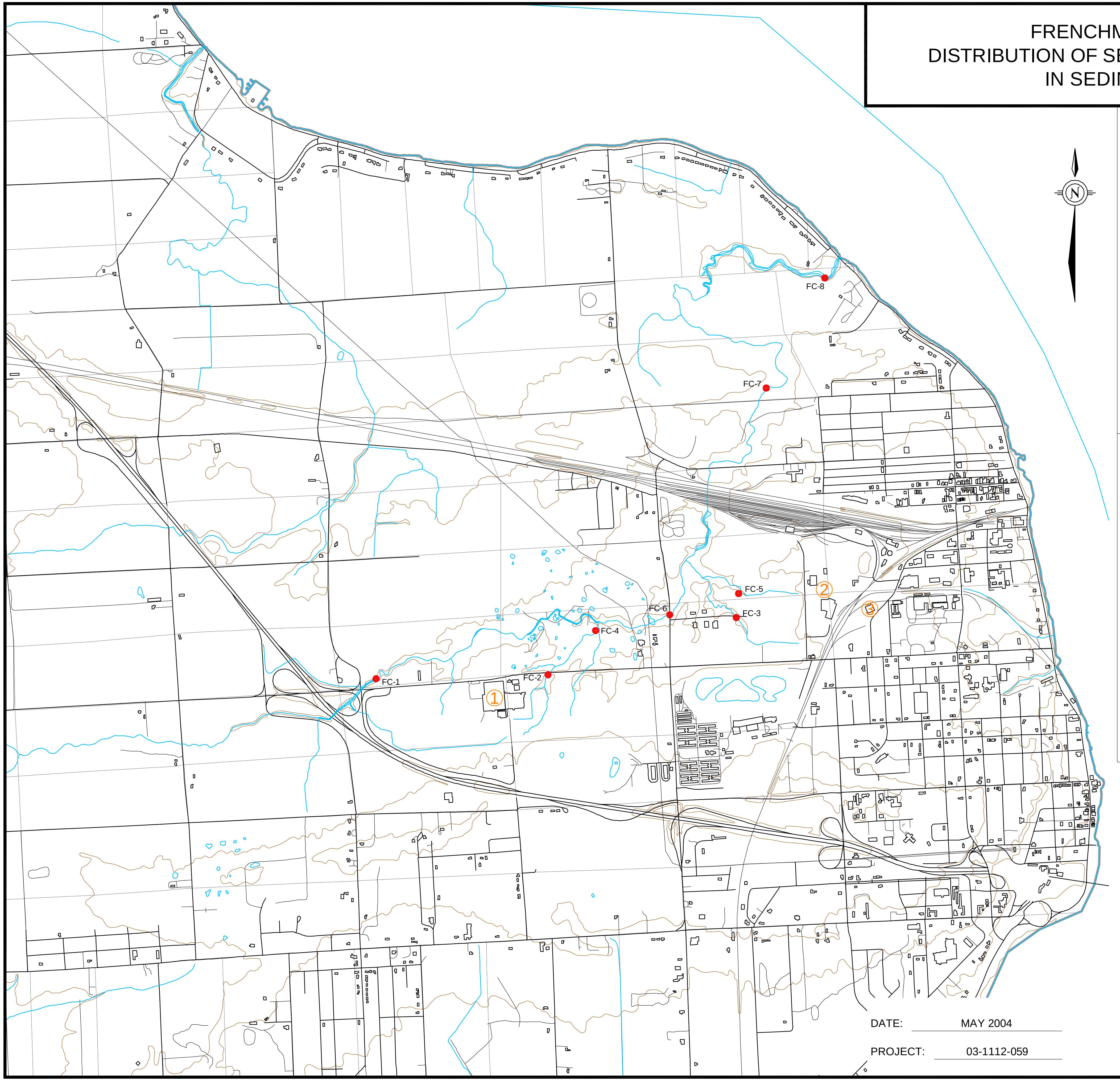


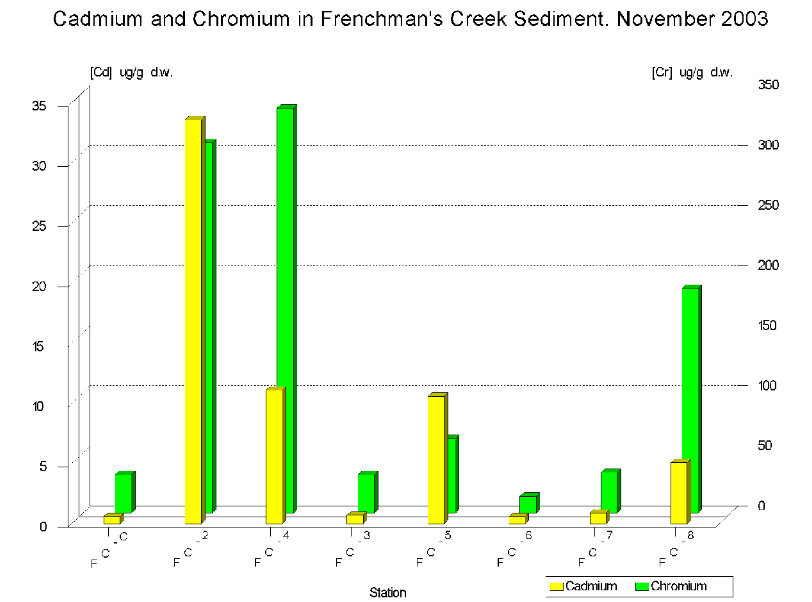
Figure 19D:
Distribution of PCBs in Welland River Sediments. 1996 and 2003.

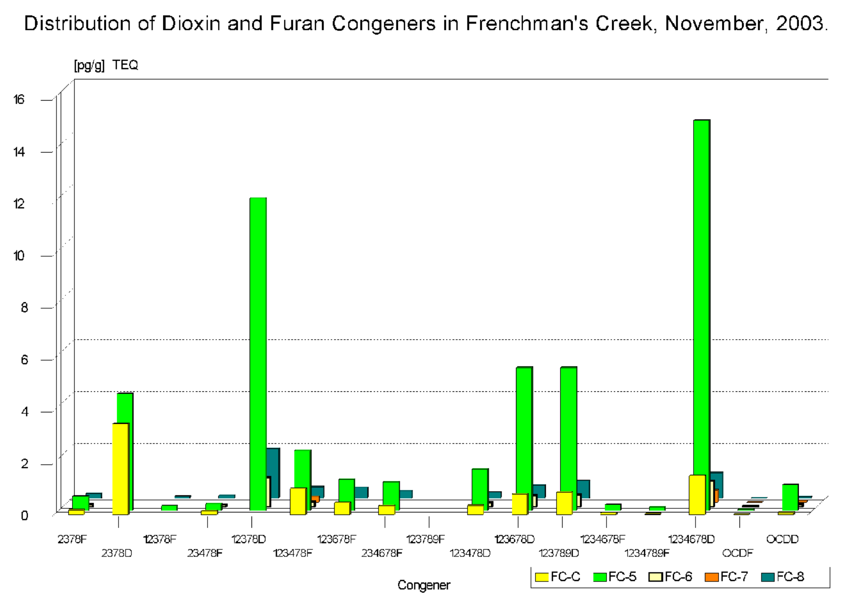


FRENCHMAN'S CREEK
DISTRIBUTION OF SELECTED PARAMETERS IN SEDIMENT - 2003

FIGURE 20




Cadmium and Chromium in Frenchman's Creek Sediment. November 2003


Distribution of Dioxin and Furan Congeners in Frenchman's Creek, November, 2003.

LEGEND

- ● 2003 GOLDER SEDIMENT SAMPLE LOCATIONS
- ① FLEET AEROSPACE
- ② CANADIAN OXY CHEMICALS - DUREZ DIVISION
- ③ GOULD NATIONAL BATTERY

500 0 500 1000

SCALE 1:25000 METRES

DATE: MAY 2004

PROJECT: 03-1112-059

Golder Associates

CAD: KD

CHK: RJ

PLOT DATE: May 18, 2004
FILENAME: T:\Projects\2003\03-1112-059 (NPCA, Niagara)\-BC-\031112059BC20.dwg

APPENDIX A

ANALYTICAL RESULTS FROM HISTORICAL STUDIES

Appendix A
Table A-1:
Niagara River Toxics Committee Sediment Sample Results.

Samples collected as noted. (ug/g dry weight)

		Al	As	Ba	Cd	Co	Cr	Cu	Fe	Pb	Mn	Hg
Frenchmans Ck (E-4)		-	4	-	0.44	3	5	4	-	13	-	0.1
Black Creek (E-12)		-	8	-	<0.1	4	3	19	-	9	-	0.02
Chippawa Ck at P.C. (U-39)		260	1.7	28	0.5	-	2.7	-	1500	23	110	-
Chippawa PC (u-40)		420	4.1	24	0.8	-	2.3	-	1100	17	290	-
Niagara R. below Queenston (	1981	-	5	-	0.38	-	26	15	-	13	-	0.15
	1979	-	3.7	-	0.72	-	27	21	-	19	-	0.96
Niagara R at Niagara-on-the-L	1981	-	2.9	-	0.41	-	18	13	-	11	-	0.14
	1979	-	4.2	-	0.88	-	35	28	-	33	-	3.2
Niagara-on-the-Lake at mouth	1981	-	2.3	-	0.3	-	14	7.8	-	4.7	-	0.1
	1979	-	2.5	-	0.72	-	15	8.8	-	13	-	0.19

		Ni	Se	Zn	a-BHC	b-BHC	g-BHC	a-Chlordane	pp-DDT	pp-DDD	pp-DDE	Methoxychlor	HCB
Frenchmans Ck (E-4)		11	0.25	11	-	-	-	-	0.024	-	0.005	-	-
Black Creek (E-12)		7	0.17	7	-	-	-	-	n.d	-	n.d.	-	-
Chippawa Ck at P.C. (U-39)		-	-	26	-	-	-	-	-	-	-	-	-
Chippawa PC (u-40)		6.1	-	9.3	-	-	-	-	-	-	-	-	-
Niagara R. below Queenston (	1981	18	-	94	0.002	0.002	0.001	0.002	-	0.002	-	0.007	0.014
	1979	18	-	110	0.038	n.d.	0.02	0.07	-	0.063	-	-	0.031
Niagara R at Niagara-on-the-L	1981	10	-	69	-	-	-	-	-	-	-	-	0.005
	1979	20	-	140	0.11	n.d.	n.d.	0.064	-	0.065	-	-	0.25
Niagara-on-the-Lake at mouth	1981	5	-	43	n.d.	n.d.	n.d.	n.d.	-	n.d.	-	n.d.	0.004
	1979	7.2	-	63	n.d.	n.d.	n.d.	0.006	-	n.d.	-	-	0.045
MDL					0.001	0.001	0.001	0.001	-	0.005	0.001		0.001

▨ = > LEL

Value = > SEL

Appendix A
Table A-2:
1983 Benthic Invertebrate Survey Sediment Results (Creese 1987)

Location	Station	Al ug/g	Co ug/g	Ni ug/g	P mg/g	N mg/g	LOI %	TOC mg/g	O&G	Se ug/g	Cd ug/g	Zn ug/g	Ba ug/g
Black Ck mouth	F1	4200	3.5	12	0.4	0.2	0.6	1.6	110	0.11	0.4	81	26
Queenston	M1	7900	5.7	17	0.6	0.7	1.8	10.8	430	0.3	0.85	100	35
	M2	6200	4.4	15	0.6	0.3	1.2	5.9	280	0.21	0.35	86	36
	M3	6100	3.8	12	0.5	0.2	0.6	4.3	<10	0.12	0.25	130	45
	Mean	*6733*	*4.6*	*15*	*1*	*0.4*	*1.2*	*7*	*355*	*0.21*	*0.48*	*105*	*39*
Niagara-on-the-Lake	O2	4400	2.5	7.3	0.4	0.1	0.9	10.4	20	0.12	<0.2	120	22
	O14	3600	2.4	8.9	0.4	0.2	0.9	6.3	20	0.12	0.25	81	25
	O13	4700	3.3	11	0.4	0.4	0.8	7.1	140	0.12	<0.2	59	22
	O12	4700	3	9.7	0.4	0.2	0.6	3.2	120	0.12	0.35	120	26
	Mean	*4350*	*2.8*	*9*	*0.4*	*0.2*	*0.8*	*6.8*	*75*	*0.12*	*0.3*	*95*	*24*

Location	Station	As ug/g	Fe mg/g	Cr ug/g	Cu ug/g	Pb ug/g	Hg ug/g	Ag ug/g	Dieldrin ng/g	Mirex ng/g	HCB ng/g	PCB ng/g
Black Ck mouth	F1	1.54	11	14	9	4.5	0.01	<1	2	<5	<1	<20
Queenston	M1	2.79	17	25	17	9.5	0.31	1	9	40	23	245
	M2	2.66	16	22	16	21	0.16	1	7	55	23	705
	M3	2.47	31	25	12	20.4	0.22	<1	<2	<5	11	70
	Mean	*2.64*	*21*	*24*	*15*	*17*	*0.23*	*1*	*8*	*48*	*19*	*340*
Niagara-on-the-Lake	O2	2.4	23	40	10	28	1.2	<1	12	<5	9	30
	O14	2.53	8.7	14	9.7	26	0.08	<1	3	<5	15	<20
	O13	1.33	12	20	7.6	20	0.26	<1	17	<5	76	95
	O12	2.22	15	20	7.6	26	0.22	<1	7	<5	3	90
	Mean	*2.12*	*15*	*24*	*8.7*	*25*	*0.44*	*<1*	*9.75*	*<5*	*26*	*72*

▨ => LEL

Appendix A
Table A-3:
MOE 1983 Sir Adam Beck Reservoir Sediment Survey Results

Station	TP mg/g	TKN mg/g	LOI %	SolEx ug/g	Al ug/g	As ug/g	Ba ug/g	Cd ug/g	Co ug/g	Cr ug/g	Cu ug/g
1 (northeast)	0.6	1.5	4.4	920	17000	10	56	1.6	9.6	36	30
2 (east-middle)	0.7	1.8	4.7	1030	17000	9.7	57	1.6	9.6	34	32
3 (southeast)	0.9	2	4.5	1030	15000	9.03	50	1.6	9.2	36	28
4 (centre)	0.7	1.8	4.5	1050	15000	8.65	49	1.7	9.3	36	28
5 (northwest)	0.7	1.2	4.3	760	15000	6.43	54	0.9	8	24	13
6 (west-middle)	0.9	0.7	3.4	290	21000	9.41	68	0.84	11	28	10
7 (southwest)	1.1	0.6	3.7	620	17000	13.23	67	1.3	10	30	6.9

Station	Fe ug/g	Hg ug/g	Ni ug/g	Pb ug/g	Se ug/g	Ag ug/g	Zn ug/g	%Sand	%Silt	%Clay
1 (northeast)	23000	0.11	41	70	0.73	1.8	130	2.4	65.9	31.7
2 (east-middle)	23000	0.11	38	65	0.67	1.2	130	4.7	63.6	31.7
3 (southeast)	22000	0.12	44	59	1.15	<1	140	5.7	67.4	26.9
4 (centre)	22000	0.12	46	56	0.88	1.8	140	4.6	64.9	30.5
5 (northwest)	22000	0.06	22	40	0.25	<1	90	11.6	59.4	29
6 (west-middle)	32000	0.06	17	50	0.3	<1	79	14.1	40.6	45.3
7 (southwest)	40000	0.05	14	59	0.41	<1	74	32	37.3	30.7

Station	PCB ng/g	pp-DDE ng/g	op-DDT ng/g	pp-DDD ng/g	pp-DDT ng/g
1 (northeast)	27	25	<D.L.	50	10
2 (east-middle)	33	16	<D.L.	50	15
3 (southeast)	30	3	<D.L.	50	12
4 (centre)	<D.L.	36	<D.L.	30	10
5 (northwest)	<D.L.	2	<D.L.	10	5
6 (west-middle)	<D.L.	1	<D.L.	5	<D.L.
7 (southwest)	<D.L.	2	<D.L.	<D.L.	<D.L.
MDL	20	1	5	5	5

▨ = > LEL

Appendix A
Table A-4:
1983 MOE Niagara River Tributary Survey (Hart 1986)

		Ag ug/g	Al ug/g	As ug/g	Ba ug/g	Cd ug/g	Co ug/g	Cr ug/g	Cu ug/g	Hg ug/g	Ni ug/g
Frenchmans Ck (at mouth)	Apr-May	2	14000	7.93	90	na	9.5	250	32	0.16	20
	June	1.2	23000	7.53	99	8.2	11	290	36	0.13	24
	Sept	1.5	12000	4.08	64	3.8	7	150	23	0.09	16
Black Creek (at mouth)	Apr-May	na	na	na	na	na	na	na	na	na	na
	June	nd	10000	44	69	0.35	5.4	19	19	0.06	13
	Sept	1.5	26000	4.14	140	1.2	9.5	32	19	0.06	33
Pell Creek (at mouth)	Apr-May	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	June	2	26000	11.8	50	0.7	12	60	160	0.04	23
	Sept	1.5	24000	8.11	78	nd	6.9	55	120	0.08	20
Chippawa Creek (at power canal)	Apr-May	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	June	nd	11000	5.63	46	0.82	7	25	19	0.03	22
	Sept	1.2	7600	2.98	31	0.3	4.7	16	16	0.05	22
Welland at PC	Apr-May	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	June	1	18000	8.06	88	0.48	14	180	68	0.11	100
	Sept	1	15000	3.55	190	nd	8.9	79	37	0.08	86
Thompsons Ck (at mouth)	Apr-May	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	June	1	24000	8.7	120	0.75	19	180	71	0.45	120
	Sept	2.2	23000	6.08	140	nd	20	350	110	1	160

Appendix A
Table A-4:
1983 MOE Niagara River Tributary Survey (Hart 1986)

		Pb ug/g	Se ug/g	Zn ug/g	Fe ug/g	TP mg/g	TKN mg/g	SolEx ug/g	LOI %
Frenchmans Ck	Apr-May	66	3.4	240	23000	1	1.2	1650	5.1
(at mouth)	June	61	0.93	250	28000	na	na	1520	5.9
	Sept	73	0.34	190	21000	0.6	0.7	2460	3.5
Black Creek	Apr-May	na	na	na	na	na	na	na	
(at mouth)	June	28	0.21	50	16000	na	na	1510	3.3
	Sept	28	0.45	280	27000	0.9	3.3	1450	20
Pell Creek	Apr-May	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(at mouth)	June	81	2.27	210	29000	na	na	9340	5.8
	Sept	89	0.88	150	28000	0.9	0.8	2950	5.9
Chippawa Creek	Apr-May	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
(at power canal)	June	25	0.51	91	16000	n.a.	n.a.	1010	3.4
	Sept	26	0.23	73	12000	0.5	0.5	710	2
Welland at PC	Apr-May	ns	ns	ns	ns	ns	ns	ns	ns
	June	44	0.81	130	31000	na	na	3240	8
	Sept	80	0.23	75	22000	0.9	0.9	1390	2.5
Thompsons Ck	Apr-May	ns	ns	ns	ns	ns	ns	ns	ns
(at mouth)	June	110	1.11	190	35000	n.a.	n.a.	1270	6
	Sept	130	0.77	280	38000	2.7	2.7	3080	6.4

▨ = > LEL Value = > SEL

Appendix A
Table A-6:
MOE 1989 Niagara River Mussel and Leech Biomonitoring Study Sediment Results (Richman 1992)

	Al ug/g	As ug/g	Ba ug/g	Cd ug/g	Cr ug/g	Cu ug/g	Fe %	Hg ug/g	Mn ug/g	Ni ug/g	Pb ug/g
Thompsons Creek 1989	24000	5.3	120	0.32	100	52	3	0.54	480	130	69

	Se ug/g	Zn ug/g	PCB ng/g	ACE ug/g	ACY ug/g	ANT ug/g	BAA ug/g	BAP ug/g	BBF ug/g	BGHI ug/g	BKF ug/g
Thompsons Creek 1989	0.68	150	285	0.04	0.05	0.02	0.21	0.16	0.38	0.09	0.08

	DBA ug/g	IND ug/g	CHY ug/g	NAP ug/g	PYR ug/g	PHE ug/g	FLA ug/g	FLU ug/g	T-PAH ug/g
Thompsons Creek 1989	0.04	0.12	0.2	0.04	0.28	0.15	0.36	0.04	2.26

░ = > LEL

Value = > SEL

Appendix A
Table A-7:
MOE 1993 Niagara River Biomonitoring Sturvey Sediment Results (Richman 1994)

All values in pg/g dry weight

	T4CDD	P5CDD	H6CDD	H7CDD	O8CDD	T4CDF	P5CDF	H6CDF	H7CDF	O8CDF
Niagara-on-the-Lake	15	8.7	56	120	390	21	29	39	75	120

	2378-TCDD	12378-PCDD	123478-HCDD	123678-HCDD	123789-HCDD	1234678-HCDD	2378-TCDF	12378-PCDF	23478-PCDF	123478-HCDF
Niagara-on-the-Lake	8.2	n.d.	n.d.	11	5.7	67	n.d.	n.d.	3.1	21

	123678-HCDF	234678-HCDF	123789-HCDF	1234678-HCDF	1234789-HCDF
Niagara-on-the-Lake	n.d.	n.d.	n.d.	56	4

Appendix A

Table A-8:

MOE Mussel Biomonitoring Studies 1987-1995. Mussel Tissue Residues.

All values in ng/g wet weight

		a-BHC	b-BHC	g-BHC	a-Chlordane	g-chlordane	Mirex	pp-DDD	pp-DDE	pp-DDT	OCS	PCBs
Wellland R at airport	1987	nd	nd	nd	nd	nd	nd	nd	8	nd	nd	nd
Frenchmans Creek	1989	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	1987	nd	nd	nd	nd	nd	nd	nd	11	nd	nd	nd
	1993								5			
	1995							10	19			
Frenchmans at Durez	1987	nd	nd	nd	nd	nd	nd	nd	5	nd	nd	nd
Black Creek	1987	nd	nd	nd	nd	nd	nd	nd	10	nd	nd	nd
Thompsons Creek	1989	nd	nd	nd	nd	nd	nd	nd	2	nd	nd	nd
Niagara Falls WPCP	1993			3								
NotL	1989	nd	nd	nd	nd	nd	nd	nd	2	nd	nd	nd
	1987	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	1993								3			
	1995								4			

	246-TCP	245-TCP	234-TCP	2356-TCP	2345-TCP	PCP
Frenchman Ck	nd	nd	nd	nd	nd	110
Frenchmans at Durez	85	nd	nd	nd	nd	350
NotL	nd	nd	nd	nd	nd	nd

Appendix A
Table A-9:
Sediment Quality Survey Results of Thompson's Creek. (Beak 1994).

Location	Depth	Al	As	Ba	Be	B	Cd	Ca	Cr	Co	Cu
Reference		16000	5.2	110	0.9	<10	0.3	14000	50	20	110
Upstream pond	0-2 cm	16000	3.2	120	0.7	<10	0.8	33000	37	16	39
	10-15 cm	18000	3.7	110	0.9	<10	0.4	8200	24	16	20
Downstream Pond	0-2 cm	19000	4.2	120	0.7	<10	0.5	23000	25	14	35
	10-15 cm	20000	7	130	1	<10	0.6	23000	60	27	81

Location	Depth	Fe	Pb	Mg	Mn	Mo	Ni	P	K	Si	Ag
Reference		30000	80	8000	610	3	100	1800	1400	110	1.6
Upstream pond	0-2 cm	25000	31	8800	550	2	36	1700	1600	480	1.5
	10-15 cm	23000	15	5300	420	2	26	910	1300	130	0.9
Downstream Pond	0-2 cm	24000	20	12000	1000	1	29	1000	1800	590	1.3
	10-15 cm	34000	44	8800	1100	4	120	1500	1800	520	1.6

Location	Depth	Na	Sr	S	Th	Sn	Ti	Va	Zn
Reference		120	40	1100	<20	<5	160	44	140
Upstream pond	0-2 cm	150	64	2200	<20	<5	140	31	150
	10-15 cm	95	33	3900	<20	<5	110	34	87
Downstream Pond	0-2 cm	240	37	1800	<20	<5	130	34	180
	10-15 cm	140	55	1000	<20	<5	180	48	140

▨ = > LEL

Value = > SEL

Appendix A
Table A-10:
1993 MOE (Tarandus) Lower Welland River Sediment Survey Results

All values in ug/g unless otherwise noted

		Cyanide	LOI	Oil & grease	Phenolics	pH	Zn	Cd	TOC	TKN	Mn
1	Airport	0.13	14	2900	0.01	6.8	116	0.6	7.4	2800	580
2	Airport	<0.05	11	1040	0.01	7	97	0.5			
3	below Airport	<0.05	12	980	0.01	6.9	116	0.45			
4		0.075	10.5	845	0.01	6.95	104	0.425			
5		<0.05	12	1070	0.02	7	108	0.55			
6		<0.05	7.2	870	0.01	7.3	112	0.4			
7		<0.05	7	1800	0.01	6.9	135	0.55			
8		<0.05	7	2500	0.01	7	112	0.4			
9	below old Canal	<0.05	7	4550	0.01	7	335	0.8	3.55	1910	430
10		<0.05	7	2000	0.01	7	550	0.975			
10a	Atlas Steel site	<0.05	5	1990	0.01	7	270	0.4			
11		<0.05	2	250	0.01	7.3	98	0.15			
12		<0.05	6	3200	0.01	7.1	620	1.4			
13		<0.05	2	195	0.01	7.5	75	0.25			
14		<0.05	2	320	0.01	7.5	76	0.1			
15	below New Canal	<0.05	2	410	0.01	7.3	83	0.15	0.92	290	960
16	Moyer Rd	<0.05	4	1110	0.01	7.1	116	0.2			
17	Geon	<0.05	5	1670	0.01	7.2	163	0.35			
18	beside Cytec	<0.05	5	3100	0.01	7.1	191	0.5			
19	below Cytec	<0.05	5	2500	0.01	7.1	330	0.9			
19a		<0.05	5	750	0.01	7.2	127	0.25			
20	Thompson's Ck mouth	0.18	5	1280	0.01	7.2	69.5	0.1			
21	at QEW	0.1	3	860	0.01	7.2	95	0.2	1.13	800	650
22	Chippawa at P.C.	<0.05	5	1240	0.025	7	75.5	0.675			
23	Chippawa below WM	<0.05	6	1670	0.01	7	55	0.3	2.5	1340	330

Appendix A
Table A-10:
1993 MOE (Tarandus) Lower Welland River Sediment Survey Results

		Co	Cu	Fe	Pb	Cr	Ni	Be	Mo	V	Al
1	Airport	14.5	35	32000	49	40	33	1.5	0.5	58	34000
2	Airport		24		26	40					33000
3	below Airport		33		37	49					38000
4			29		31	43.5					34000
5			31		34	43					32000
6			30		34	40					31000
7			35		85	45					31000
8			51		40	44					26000
9	below old Canal	10.75	93.5	30000	74.5	55.5	54	1	1.75	34.5	17750
10			77		86	95					34000
10a	Atlas Steel site		50		38	91					35000
11			28		25	53					35000
12			85		62	260					38000
13			34		21	162					29000
14			26		22	79					29000
15	below New Canal	19	47	58000	26	300	178	1	24	42	23000
16	Moyer Rd		31		23	43					32000
17	Geon		58		50	300					31000
18	beside Cytec		64		45.5	265					22000
19	below Cytec		115		41	107					38000
19a			33		24	59					28000
20	Thompson's Ck mouth		54.5		40.5	53					25000
21	at QEW	13	94	35000	29	97	75	1	3.5	43	26000
22	Chippawa at P.C.		19		20.5	22.5					15750
23	Chippawa below WM	6.5	15	16400	16	19	19.5	0.5	0.5	27	12400

Appendix A

Table A-10:

1993 MOE (Tarandus) Lower Welland River Sediment Survey Results

		Mg	Ba	Hg	Ag	Sb	TP	As
1	Airport	9400	139	0.08	0.5	1	1020	5
2	Airport			0.04				5
3	below Airport			0.12				7
4				0.07				5
5				0.06				5
6				0.06				5
7				0.1				6
8				0.4				5
9	below old Canal	15900	102.5	2.22	0.5	1	1005	5
10				0.18				11
10a	Atlas Steel site			1.4				8
11				0.02				6
12				0.68				17
13				0.02				6
14				0.02				6
15	below New Canal	13900	118	0.06	0.5	1	1060	6
16	Moyer Rd			0.28				6
17	Geon			0.1				6
18	beside Cytec			0.28				6.5
19	below Cytec			0.26				10
19a				0.08				6
20	Thompson's Ck mouth			0.04				5.5
21	at QEW	14000	127	0.1	0.5	1	1300	6
22	Chippawa at P.C.			0.07				4
23	Chippawa below WM	17200	51	0.06	0.5	1	620	3

Appendix A
Table A-11:
MOE-Environment Canada 1996 Welland River Survey - Sediment Metals and Nutrients

All values in ug/g dry weight unless otherwise indicated.

Stn	Core Depth	Hg	Be	Mg	Al	As	Ca	Va	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ti
A2 (Wainfleet)	0 -15 cm	0.05	1.2 <T	8300	32000	7.5	4800	57	39	300	30000	14	39	27	120	90 <T
	15-30 cm	0.06	1.5 <T	6600	33000	4.5	5300	50	40	220	24000	10	35	34	94	40 <T
	30-80 cm	0.04 <T	1.3 <T	8000	29000	4.2	4800	51	40	220	24000	12	37	30	100	150
A3 (Wainfleet)	0 -15 cm	0.02 <T	1.3	9400	35000	9.4	5800	63	46	700	38000	17	47	33	160	140
	15-30 cm	0.02 <T	1.2	9200	33000	7.6	5600	57	42	770	35000	15	41	28	140	11
	30-80 cm	0.06	1.2	8000	30000	5.5	5900	51	38	280	24000	12	34	28	110	50
B1	0 -15 cm	0.1	1 <T	8200	24000	7.4	7500	48	130	1200	36000	16	88	41	160	150
	15-30 cm	0.36	1 <T	10000	24000	10	11000	51	230	430	33000	21	210	75	240	260
	30-80 cm	0.5	1 <T	11000	24000	13	25000	48	74	510	42000	20	230	89	870	210
	80-130 cm	0.33	1 <T	13000	21000	12	41000	44	36	620	36000	16	76	66	410	280
	130-190 cm	0.23	1 <T	11000	25000	11	29000	48	35	540	36000	16	44	45	260	220
	190-250 cm	0.06	0.9 <T	9900	20000	5.1	22000	40	29	470	27000	14	30	23	99	270
B2	0 -15 cm	0.14	1.1 <T	8500	27000	7.3	5600	49	56	600	33000	15	55	38	160	150
	15-30 cm	0.28	1 <T	10000	25000	10	15000	50	210	400	34000	21	180	65	230	210
	30-90 cm	0.49	0.9 <T	12000	21000	15	35000	44	62	560	43000	20	260	93	1000	220
B3	0 -15 cm	0.13	1.1 <T	9000	28000	9.1	6400	53	160	550	34000	17	120	44	190	220
	15-30 cm	0.3	0.9 <T	10000	22000	11	12000	48	360	390	32000	22	240	71	220	190
	30-90 cm	0.36	1 <T	12000	23000	12	38000	46	55	570	39000	18	150	70	580	250
B4	0 -15 cm	0.28	1 <T	11000	24000	11	14000	55	680	510	42000	27	380	93	250	210
	15-30 cm	0.42	0.9 <T	13000	20000	16	42000	42	32	580	32000	14	52	46	280	300
	30-80 cm	0.32	0.9 <T	13000	19000	8.3	42000	41	32	580	32000	14	53	46	270	280
B5	0-15 cm	0.31	1 <T	11000	23000	9.2	11000	54	600	510	42000	26	380	96	240	100
	15-40 cm	0.43	1 <T	12000	25000	16	26000	52	240	570	51000	24	370	120	930	120
	40-100 cm	0.39	1 <T	13000	23000	12	34000	46	42	590	36000	15	70	62	430	210
B6	0 -15 cm	0.1	1 <T	7700	21000	6.5	9400	43	94	470	34000	16	83	41	150	260
	15-30 cm	0.36	0.9 <T	10000	23000	11	19000	55	550	600	47000	26	400	110	420	140
	30-80 cm	0.07	0.9 <T	6900	18000	5	8800	37	47	430	25000	15	46	31	99	260
B7	0 -15 cm	0.35	1 <T	9400	24000	10	9600	59	670	820	52000	26	410	110	240	90 <T
	15-30 cm	0.29	1.1 <T	11000	28000	11	10000	60	460	460	47000	24	370	120	430	120
	30-80 cm	0.25	0.9 <T	12000	22000	12	26000	46	75	540	40000	18	170	73	650	150
	80-130 cm	0.09	0.9 <T	7300	20000	5.2	8700	39	32	380	26000	15	35	26	110	210
B8	0-15 cm	0.28	1.1 <T	11000	27000	9.8	20000	68	1200	620	55000	31	600	140	290	170
	15-30 cm	0.17	1.1 <T	12000	26000	9.6	35000	55	260	610	41000	20	230	75	510	260
B9	0-15 cm	0.16	1.1 <T	8900	29000	7.9	6600	63	440	430	42000	22	280	72	200	280
	15-40 cm	0.32	1.1 <T	12000	24000	9.7	22000	59	810	500	48000	31	480	130	360	190

Appendix A
Table A-11:
MOE-Environment Canada 1996 Welland River Survey - Sediment Metals and Nutrients

All values in ug/g dry weight unless otherwise indicated.

Stn	Core Depth	Hg		Be		Mg	Al	As	Ca	Va	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ti
B10	0-15 cm	0.32		1.1	<T	9300	25000	8.4	8000	54	300	550	48000	23	310	100	630	90
	15-30 cm	0.5		0.9	<T	12000	21000	12	17000	49	150	510	44000	23	320	100	980	160
B11	0-15 cm	0.25		1	<T	10000	24000	9.9	18000	56	350	540	44000	22	300	96	500	140
	15-30 cm	0.35		0.9	<T	11000	22000	7.7	13000	49	130	430	38000	19	200	78	640	170
B12	0-20 cm	0.19		0.9	<T	9900	22000	8.1	19000	58	930	480	52000	32	530	110	250	180
	20-80 cm	0.05		1.1	<T	8600	2200	3.8	7700	45	58	350	28000	16	53	34	120	270
B13	0-15 cm	0.21		1	<T	11000	23000	8.5	12000	53	640	390	37000	27	350	85	230	120
	15-30 cm	0.09		0.8	<T	13000	18000	6.5	43000	39	76	690	31000	16	97	39	180	200
B14	0-15 cm	0.22		1	<T	10000	23000	8.2	9600	53	510	750	51000	23	340	87	190	140
	15-30 cm	0.17		1	<T	11000	24000	9.5	11000	59	770	760	58000	29	480	110	220	110
C3 (Moyer Rd)	0-15 cm	0.21		0.9	<T	8600	22000	8.4	9800	53	420	690	42000	21	280	75	190	160
	15-30 cm	0.17		1	<T	11000	24000	9.9	9600	53	330	340	35000	21	270	73	210	230
C4 (Moyer Rd)	0-15 cm	0.21		0.9	<T	8600	21000	9.8	14000	47	230	500	37000	18	170	65	250	150
	15-30 cm	0.06		1.1	<T	8800	24000	4.8	6800	46	48	300	29000	18	52	29	130	230
C10 (Cytec)	0 -15 cm	0.01	<W	0.9		8900	20000	15	35000	48	360	380	35000	25	240	82	210	160
	15-30 cm	0.04	<T	1	<T	11000	23000	17	56000	48	240	440	40000	21	250	120	400	190
C11 (Cytec)	0 -15 cm	0.1		0.9	<T	7800	22000	9.7	8200	46	270	340	31000	18	150	88	180	110
	15-27 cm	0.05		0.8	<T	10000	17000	10	28000	41	270	500	34000	20	180	95	130	150
C13 (Thompson's Ck	0 -18 cm	0.81		1.4	<T	7000	22000	19	62000	46	140	280	32000	11	110	1300	280	320

Stations B1 to B14 are located between the Old Welland Canal and the Welland Canal By-Pass

Appendix A
Table A-11:
MOE-Environment Canada 1996 Welland River Survey - Sediment Metals and Nutrients

All values in ug/g dry weight unless o

Stn	Core Depth	Cd		Ba	Pb	Sr	TKN mg/g	TP mg/g	TOC mg/g
A2 (Wainfleet)	0 -15 cm	0.7	<T	160	18	52	4.3	1.2	58
	15-30 cm	1		180	13	60	5.1	1.6	59
	30-80 cm	0.7	<T	160	12	51	4	0.76	56
A3 (Wainfleet)	0 -15 cm	1		170	28	53	3.7	1.2	52
	15-30 cm	0.8	<T	160	19	53	3.6	1.1	48
	30-80 cm	0.6	<T	160	12	47	4.8	0.76	76
B1	0 -15 cm	0.8	<T	150	41	50	6.8	2.2	100
	15-30 cm	1.3		140	81	42	4.1	1.3	77
	30-80 cm	1.6		150	84	68	2.7	1.5	58
	80-130 cm	1		120	37	91	1.4	1	22
	130-190 cm	1		140	30	94	2.1	1	28
	190-250 cm	0.4	<T	110	10	79	2.7	0.84	43
B2	0 -15 cm	0.6	<T	150	26	43	4.2	1.4	60
	15-30 cm	0.9	<T	160	80	62	3.4	1.4	25
	30-90 cm	1.5		140	79	87	2.2	1.3	47
B3	0 -15 cm	0.9	<T	160	45	64	4.7	1.5	56
	15-30 cm	1.1		140	70	61	3.6	1.4	70
	30-90 cm	1.1		140	55	99	2.2	1.1	38
B4	0 -15 cm	1.2		180	110	98	2.9	1.4	61
	15-30 cm	0.7	<T	100	28	110	2.6	1.8	49
	30-80 cm	0.7	<T	100	27	110	1.7	0.88	23
B5	0-15 cm	1.1		160	83	85	3.1	1.2	60
	15-40 cm	1.4		160	100	87	2.5	1.3	52
	40-100 cm	1.4		130	43	91	1.8	0.84	34
B6	0 -15 cm	0.7	<T	79	21	68	3.6	0.8	75
	15-30 cm	1.1		130	88	68	3	1.4	66
	30-80 cm	0.9	<T	72	21	84	3.7	0.72	81
B7	0 -15 cm	0.8	<T	160	93	50	3.1	1.5	59
	15-30 cm	1.4		160	100	45	2.7	1.1	52
	30-80 cm	1.2		130	61	68	2.3	1	48
	80-130 cm	0.7	<T	88	9	110	3.4	0.68	71
B8	0-15 cm	2		160	160	91	4.2	1.8	84
	15-30 cm	1.7		150	73	93	1.9	1.2	37
B9	0-15 cm	1.5		160	82	54	4.6	1.2	82
	15-40 cm	1.8		140	140	76	3.6	1.5	81

Appendix A
Table A-11:
MOE-Environment Canada 1996 Welland River Survey - Sediment Metals and Nutrients

All values in ug/g dry weight unless o

Stn	Core Depth	Cd		Ba	Pb	Sr	TKN mg/g	TP mg/g	TOC mg/g
B10	0-15 cm	2		140	100	52	4	1.5	70
	15-30 cm	2.1		140	100	53	3.1	1.1	99
B11	0-15 cm	2.1		110	100	110	4	1.1	120
	15-30 cm	1.6		150	87	51	3	1	100
B12	0-20 cm	1.5		29	250	65	4.2	1.2	140
	20-80 cm	0.8	<T	130	22	58	5.2	0.7	86
B13	0-15 cm	1.3		120	94	65	4.2	1.4	68
	15-30 cm	0.9	<T	130	30	95	1.1	0.8	21
B14	0-15 cm	1.3		140	77	39	2.8	1.3	50
	15-30 cm	1.4		170	120	40	2.8	1.3	63
C3 (Moyer Rd)	0-15 cm	1.4		140	72	59	6.7	1.7	98
	15-30 cm	2.2		130	72	44	4	1.1	58
C4 (Moyer Rd)	0-15 cm	1.3		130	66	58	6.8	1.5	110
	15-30 cm	1.1		130	22	52	4.6	0.7	69
C10 (Cytec)	0 -15 cm	1		140	62	80	5.2	1.5	110
	15-30 cm	1.1		130	60	92	2.2	0.92	56
C11 (Cytec)	0 -15 cm	0.6	<T	110	44	55	6.8	1.6	120
	15-27 cm	0.3	<T	92	29	70	3	0.92	61
C13 (Thompson's Ck	0 -18 cm	0.6	<T	140	92	85	2.7	1.5	170

Value = >LEL

Value = >SEL

Table A-12:

MOE-Environment Canada 1996 Welland River Survey - Sediment PCBs and Organochlorine Pesticides

All values in ng/g.

Stn	Core depth	PCB, total	Heptachlor	Aldrin	pp-DDE	Mirex	a-BHC	b-BHC	g-BHC	a-Chlordane	g-Chlordane
A2 (Wainfleet)	0 -15 cm	20 <W	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	20 <W	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	30-80 cm	20 <W	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
A3 (Wainfleet)	0 -15 cm	20 <W	1 <W	1 <W	3 <T	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	20 <W	1 <W	1 <W	2 <T	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	30-80 cm	20 <W	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	240 PS1	1 <W	1 <W	3 <T	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
C3 (Moyer Rd)	0-15 cm	180 PS1	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	240 PS1	1 <W	1 <W	1 <W	5 <W	1 <W	4 <T	1 <W	2 <W	2 <W
C4 (Moyer Rd)	0-15 cm	460 PS1	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	40 PS1	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
C10 (Cytec)	0 -15 cm	200 P40	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-30 cm	240 P40	1 <W	1 <W	3 <T	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
C11 (Cytec)	0 -15 cm	80 P40	1 <W	1 <W	2 <Y	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
	15-27 cm	80 P40	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W
C13 (Thompson's Ck)	0 -18 cm	20 <W	1 <W	1 <W	1 <W	5 <W	1 <W	1 <W	1 <W	2 <W	2 <W

Appendix A

Table A-12:

MOE-Environment Canada 1996 Welland River Survey - Sediment PCBs and Organochlorine Pesticides

All values in ng/g.

Stn	Core depth	Oxychlordane	op-DDT	pp-DDD	pp-DDT	Methoxychlor	H. epoxide	Endo-I	Dieldrin	Endrin	Endo-II	Endo-sulph
A2 (Wainfleet)	0 -15 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	30-80 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
A3 (Wainfleet)	0 -15 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	30-80 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
C3 (Moyer Rd)	0-15 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
C4 (Moyer Rd)	0-15 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
C10 (Cytec)	0 -15 cm	2 <W	10 <T	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-30 cm	2 <W	5 <W	25 <T	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
C11 (Cytec)	0 -15 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
	15-27 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W
C13 (Thompson's Ck)	0 -18 cm	2 <W	5 <W	5 <W	5 <W	5 <W	1 <W	2 <W	2 <W	4 <W	4 <W	4 <W

▨ = > LEL

Table A-13:
MOE-Environment Canada 1996 Welland River Survey - Sediment PAHs.

All values in ng/g.

Location	Depth	NAP	ACY	ACE	FLU	PHE	ANT	FLA	PYR	BAA
Molecular weight		129.19	152.21	154.21	166.23	178.24	178.24	202.26	202.26	228.3
A-2	0-15 cm	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
	15-30 cm	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
	30-80 cm	40 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
C-10	0 -15 cm	40 <T	20 <W	20 <W	20 <W	120	80 <T	200	240	120
	15-30 cm	40 <T	20 <W	20 <W	40 <T	180	80 <T	440	720	260

Location	Depth	CHY	BBF	BKF	BAP	IND	DBA	BGHI	TotPAH
Molecular weight		228.3	252.32	252.32	252.32	276.34	278.38	276.34	
A-2	0-15 cm	40 <T	20 <W	20 <W	40 <W	40 <W	40 <W	40 <W	180
	15-30 cm	40 <T	20 <W	20 <W	40 <W	40 <W	40 <W	40 <W	180
	30-80 cm	40 <T	20 <W	20 <W	40 <W	40 <W	40 <W	40 <W	200
C-10	0 -15 cm	160	200	60 <T	120 <T	80 <T	40 <W	120 <T	860
	15-30 cm	580	420	120	200	160 <T	40 <W	160 <T	1800

Table A-13:
MOE-Environment Canada 1996 Welland River Survey - Sediment PAHs.

All values in ng/g.

Location	Depth
Molecular weight	
A-2	0-15 cm
	15-30 cm
	30-80 cm
C-10	0 -15 cm
	15-30 cm

Location	Depth
Molecular weight	
A-2	0-15 cm
	15-30 cm
	30-80 cm
C-10	0 -15 cm
	15-30 cm

Appendix A
Table A-14:
Summary of PCB Sampling in Soils and Sediment.
Lyon's Creek West

BEAK 1990			*SLSA 1991*			*MOE 1991*			*ESL 1992*		
Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g
E4-10	0-10	2.80	**LC-05A**	0-17	0.01	**A1**	0-20	32.00	**A1'**	0-50	0.01
E4-20	10-20	5.60	**LC-05B**	17-34	0.01	**LC2**	0-20	15.00	**A3'**	0-50	0.01
E5-10	0-10	2.90	**LC-07**	0	0.03	**B1**	0-20	3.30	**A1-1**	0-50	0.58
E5-20	10-20	10.60	**LC-09**	0-20	0.02	**C-1**	0-20	14.00	**A1-2**	365-395	0.01
E6-10	0-10	0.05	**LC-10**	0-20	0.01	**D-1**	0-20	6.70	**A2-1**	0-50	0.01
EF-1-1	40	0.05	**LC-11**	0-20	0.08	**E1**	0-20	32.00	**B1-1**	100-150	0.01
F1-1	20	0.10	**LC-13**	0	0.01	**F1**	0-20	6.50	**B2-1**	100-150	0.01
F1-2	75	0.05	**LC-17**	0-10	0.03	**G1**	0-20	11.00	**C2-1**	0-50	0.01
F2-1	30	0.05	**LC-18**	0-18	0.01	**H1**	0-20	16.00	**D1**	100-150	0.01
F2-2	90	0.05	**LC-19A**	0-20	0.01	**I1**	0-20	40.00	**D2-1**	100-150	1.86
F2-2A	90	0.05	**LC-19B**	20-40	0.05	**J1**	0-20	65.00	**D2-2**	150-190	0.01
FG-1	20	0.05	**LC-21**	0-20	0.22	**K1**	0-20	34.00	**E1-A**	100-150	0.01
FG-2	90	0.15	**LC-23**	0-20	0.01	**L1**	0-20	6.30	**E1-B**	150-200	0.01
H3-10	0-10	0.05	**LC-24**	0-21	0.02	**M1**	0-20	15.00	**E2**	100-150	8.25
H3-20	0-20	0.05	**LC-25**	0-14	0.01	**N1**	0-20	42.00	**F1**	0-30	0.01
I2-10	0-10	0.56	**LC-26A**	0-13	0.01	**O1**	0-20	7.70	**F2**	100-150	0.01
I1-10	0-10	0.05	**LC-26B**	13-60	0.51	**P1**	0-20	5.10	**G1-1**	20	0.05
A2-10	0-10	0.05	**LC-28A**	0-19	0.04	**Q1**	0-20	16.00	**G3-10**	0-10	78.00
B3-10	0-10	0.05	**LC-28B**	19-38	0.01	**R1**	0-20	7.00	**G3-20**	10-20	67.00
C2-10	0-10	0.05	**LC-31A**	0-15	0.01	**S1**	0-20	6.80	**G3-20B**	20-30	3.90
D2-10	0-10	0.05	**LC-31B**	15-30	0.01	**T1**	0-20	0.02	**G1**	0-50	0.01
			LC-32	0-20	0.01	**U1**	0-20	21.00	**G2-1**	0-50	19.00
			LC-36A	0-20	0.01	**V1**	0-20	29.00	**G2-2**	100-150	6.11
			LC-36B	0-40	0.01	**W1**	0-20	4.00	**G2-3**	150-200	88.60
			LC-38	0-20	0.02	**X1**	0-20	4.50	**G3**	100-150	6.54
			LC-40	0-20	0.40				**I3-1**	100-150	114.00
			LC-41	0-20	2.98				**I3-2**	250-300	1.68
			LC-42	0-20	19.90				**I1**	0-50	0.01
			LC-44A	0-22	0.56				**I2**	0-50	2.13
			LC-44B	22-40	0.47				**K2-1**	100-150	3.59
			LC-45A	0-20	21.00				**L1-1**	0-40	1.89
			LC-45B	20-39	22.90				**L1-2**	40-85	0.01
			LC-48	0-17	0.11				**L3-1**	200-225	0.96
			LC-50	0-20	0.01				**L2-1**	90-140	8.04
			LC-51A	0-18	86.90				**L4**	370-410	0.01
			LC-51B	18-36	**648.00**				**M1**	0-50	0.38
			LC-51C	36-49	123.00				**N1**	0-20	0.01
			LC-51D	49-61	40.50				**N2-1**	100-150	0.01
			LC-53	0-20	0.02				**N2-2**	300-350	0.75
			LC-54	0-24	55.60				**N3-1**	100-150	8.51
			LC-55	0-19	0.01				**N3-2**	25-55	0.05
			LC-56	0-18	26.00				**O2**	0-50	8.00
			LC-57	0-19	0.03				**O3**	50-100	0.64
			LC-58A	0-20	4.30				**P2-1**	0-50	57.90
			LC-58B	20-31	33.50				**P2-2**	100-150	5.03
			LC-59	0-16	41.70				**P1**	0-50	0.41

Table A-14:
Summary of PCB Sampling in Soils and Sediment.
Lyon's Creek West

BEAK 1990			*SLSA 1991*			*MOE 1991*			*ESL 1992*		
Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g
			LC-62	0-20	0.01				**Q1-1**	45-70	15.90
			LC-63	0-20	0.02				**Q2**	0-50	28.60
			LC-67A	0-23	35.00				**R1**	0-50	0.28
			LC-67B	23-47	0.03				**R2-1**	0-50	10.00
			LC-68A	0-21	0.04				**R2-2**	100-130	13.90
			LC-68B	21-42	3.34				**R2-3**	100-150	0.01
			LC-69A	0-20	17.60				**R3**	0-30	0.05
			LC-69B	20-43	0.01				**T1-1**	0-50	0.01
			LC-70A	0-22	71.20				**T1-2**	100-150	0.01
			LC-70B	22-42	0.72				**T2-1**	0-50	0.01
			LC-70C	42-62	0.32				**T2-2**	100-150	0.24
			LC-71A	0-16	21.80				**T3**	30-80	0.01
			LC-71B	16-33	0.44				**W3**	30-60	0.26
			LC-72A	0-19	64.10				**V3**	30-60	0.01
			LC-72B	38-57	0.02				**1A**	30	0.30
			LC-73A	0-22	27.80				**1B**	30	0.10
			LC-73B	22-43	0.31				**1C**	30	1.59
			LC-74A	0-23	9.40				**2A**	15	3.00
			LC-74B	23-46	0.73				**2B**	15	0.10
			LC-75A	0-20	82.10				**2C**	15	0.21
			LC-75B	40-59	304.00				**3A**	30	0.10
			LC-75C	59-72	0.26				**3B**	30	0.37
			LC-76A	0-20	7.23				**3C**	30	1.57
			LC-76B	20-39	18.20				**4A**	15	1.57
			LC-77A	0-19	44.80				**4B**	15	5.29
			LC-77B	19-38	14.90				**4C**	15	515.00
			LC-78A	0-20	11.80				**5A**	30	0.77
			LC-78B	20-40	2.22				**5B**	30	2.96
			LC-79A	0-16	24.40				**5C**	30	75.50
			LC-79B	16-32	2.19				**6A**	15	5.49
			LC-80A	0-16	17.60				**6B**	15	4.30
			LC-80B	16-31	0.79				**6C**	15	67.10
			LC-81A	0-23	9.40				**7A**	30	1.21
			LC-81B	23-46	0.73				**7B**	30	0.74
			LC-82A	0-24	1.41				**7C**	30	3.90
			LC-82B	24-49	1.36				**8A**	15	0.13
			LC-83A	0-19	45.00				**8B**	15	2.58
			LC-83B	19-38	2.81				**8C**	15	1.11
			LC-84A	0-22	72.60				**9A**	30	0.75
			LC-84B	20-39	1.30				**9B**	30	1.51
			LC-85A	0-22	25.10				**9C**	30	2.97
			LC-85B	22-45	0.32				**10A**	15	1.53
			LC-86A	0-20	43.90				**10B**	15	1.12
			LC-86B	20-40	0.28				**10C**	15	4.33
			LC-87	0-20	8.59				**11A**	30	2.02
			LC-88A	0-22	68.00				**11B**	30	12.30

Appendix A

Table A-14:

Summary of PCB Sampling in Soils and Sediment.

Lyon's Creek West

BEAK 1990			*SLSA 1991*			*MOE 1991*			*ESL 1992*		
Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g	Sample Id	Soil Sample Depth (cm)	PCB's GC/ECD µg/g
			LC-88B	22-45	0.16				**11C**	30	1.96
			LC-89A	0-23	40.40				**12A**	15	4.06
			LC-89B	46-70	304.00				**12B**	15	2.34
			LC-90A	0-17	10.80				**12C**	15	0.10
			LC-90B	17-34	4.70				**13A**	30	3.21
			LC-91A	0-19	2.48				**13B**	30	2.96
			LC-91B	38-57	0.05				**13C**	30	2.78
									14A	15	1.17
									14B	15	4.32
									14C	15	2.81
									15A	30	0.20
									15B	30	2.94
									15C	30	5.10
									DITSED-A	0-10	0.01
									DITSED-B	0-10	0.01
									117-3	0-30	0.01
									109-A	30-60	0.19
									110-A	30-60	0.29
									107-A	30-60	0.31
									108-A	30-60	0.05
									105-A	30-60	0.01
									106-A	30-60	0.01
									116-3	30-60	0.01
									118-3	30-60	0.01
									103-A	30-60	0.05
									104-A	30-60	0.73
									101-A	30-60	0.01
									102-A	30-60	0.21
									115-3	60-90	0.01
									114	60-90	0.01
									113	60-90	0.01
									111	60-90	0.01
									112	90-120	0.01

Table A-15:
Distribution of Metals and Nutrients in Black Creek Sediments. MOE and Environment Canada, 2002.

Sample ID	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu
Units	µg/g	pct	µg/g	µg/g	µg/g	µg/g	pct	µg/g	µg/g	µg/g	µg/g
Detection Limit	0.5	0.01	5	1	0.2	5	0.01	1	1	1	1
BLC01	0.5	1.19	<5	77	0.8	<5	0.79	<1	14	31	25
BLC02	1.6	1.41	<5	95	0.7	<5	5.42	<1	15	38	23

Sample ID	Fe	Fe	Mg	Li	Mg	Mn	Mo	Na	Nb	Ni	Pb
Units	%	µg/g		µg/g	pct	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Detection Limit	0.01			1	0.01	1	1		5	1	1
BLC01	2.39	23942.119	19	19	0.02	250	1	373.239	<5	37	26
BLC02	2.82	28161.408	28	28	0.06	624	1	451.002	<5	35	49

Sample ID	Sb	Sn	Ti	V	Zn	Phosphorus	TOC	Mercury
Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	pct	µg/g
Detection Limit	5	20	1	25	1	0.3	0.1	0.005
BLC01	<5	<20	217	19	109	630	5.6	0.061
BLC02	<5	<20	255	19	81	875	4	0.034

APPENDIX B

SCREENING LEVEL RISK ASSESSMENT LYON'S CREEK WEST

TABLE OF CONTENTS

SECTION PAGE

1.0 SCREENING LEVEL RISK ASSESSMENT FOR LYON'S CREEK

1.1 Overview and Context

As noted in Section 6.4.1, high concentrations of PCBs in soils and sediments, in particular the exceedances of the hazardous waste guideline of 50 ppm, have identified the need to undertake a screening level risk assessment to provide additional context for the elevated levels of PCBs. This screening level risk assessment (SLRA) has been carried out to examine the potential risks to human health and wildlife due to exposure from polychlorinated biphenyls (PCBs). This SLRA is based on the results of the soil and sediment analyses obtained from various locations in, and in close proximity to, the Lyons Creek Study Area. To address potential effects to human health, exposure to PCBs via direct and indirect pathways were considered. Inhalation from soil vapours were also assessed in the human exposure model. Additionally, potential ecological effects to various receptors from exposure to PCB contaminated media were considered in this preliminary SLRA.

The SLRA is computationally rigorous, but has not been completed in strict compliance with MOE (Ministry of the Environment) administrative requirements for site-specific risk assessments (SSRAs). The SLRA can be used to provide an assessment of the likely risks to the human health and ecological receptors in the natural environment. The risk assessment is intended only to provide additional information on potential risks on the Site and has not been prepared with the intention to be submitted to the Ministry of the Environment as a formal site specific risk assessment (SSRA) for Lyons Creek.

1.2 Technical Details of the SLRA

The SLRA was conducted in 4 steps.

1. PCB data from numerous soil and sediment samples, and the physiochemical properties required for contaminant modeling, were compiled and evaluated.
2. The data were initially compared to MOE guideline values (MOE, 1997) to ascertain if potential risks to human and ecological receptors are likely to occur at current PCB concentrations found in soil and sediment of the Lyons Creek Study Area.
3. Human and ecological receptor models were established to estimate the potential risk associated with PCB exposure from multiple pathways.
4. The data from the exposure assessment were utilized in the risk characterization process, in which risks to human health and the environment were estimated for the calculated exposure concentrations.

Due to the conservative, and therefore, protective nature of this preliminary SLRA, the exposure assessment was based upon the measurements of PCBs in surficial soil (i.e. 0 – 150 cm below grade) and sediment as the primary source term for predicting exposure concentrations to all receptor models at the Lyons Creek Site Area.

1.2.1 Concentrations of PCBs at Lyons Creek

The SLRA evaluated the potential risk to human health and ecological receptors associated with PCBs quantified in surficial soil and sediment from the Lyons Creek Site Area. Numerous samples were collected (n=291) and analyzed by various laboratories from 1990 to 2003 (Table 1). Golder has assumed that it can have full reliance on this information and that there has been little change to site conditions over this period.

TABLE B-1

Mean (± 1 Standard Error; SE) Total PCB Concentrations (µg/g; wet weight) in Soil and Sediment Samples from the Lyons Creek Study Area

Parameter	**Year**	**PCB Concentration (µg/g) Mean ± SE**	**n**	**Maximum**
BEAK International[a]	1990	1.11 ± 0.57	21	10.6
St. Lawrence Seaway[a,b]	1991	25.8 ± 7.93	99	648
Ministry of the Environment[a]	1991	17.6 ± 3.15	25	65.0
Environmental Strategies Limited[a]	1992	12.0 ± 6.04	88	515
Golder Associates Limited	2003	5.37 ± 1.74	21	27.3
Overall		***15.3 ± 3.33***	***291***	***648***
95% Upper Confidence Interval		***21.8***		

[a] cited in ESL (1992); [b] SLSA (1991)

The physiochemical properties of PCBs were compiled from established chemical databases, including the Integrated Risk Information (IRIS; U.S. EPA, 2003) the Risk Assessment Information Systems (RAIS; Oak Ridge National Laboratory, U.S. DOE, 2003), and the *Risk Integrated Software for Cleanups* (RISC) database, version 4.03 (Environmental Software Online LLC, Groton, MA, U.S.A.). These values were used to predict outdoor air concentrations of PCBs volatilizing from surficial soil at the Lyons Creek Study Area. This information was subsequently used as part of the human exposure component of the SLRA. In addition, these properties were used in evaluating the fugacity of PCB in the environment and the potential risk to ecological receptors from modelled exposure concentrations.

1.2.2 Initial Screening of PCB Concentrations in Soil, Sediment

Ontario's generic soil quality criteria are "effects-based" criteria that have been derived under the guiding principle that "*remediation of contaminated sites will take place to such a degree to protect against potential adverse effects or the likelihood of adverse effects to human health, ecosystem health, and the natural environment*" (MOE, 1996). Regardless of whether the "generic" or "SSRA" approach is used for site restoration, this guiding principle is the basis for the site restoration process in the Province.

The potential risks to human health were initially evaluated by "screening" PCB concentrations against guideline values established in the Ministry of the Environment document *"Guideline for Use at Contaminated Sites in Ontario"* (MOE, 1997). The purpose of the guideline document is "*to provide protection of human health, ecological health and the natural environment from potential adverse effects associated with existing or future exposure to contaminated soil, sediment, and groundwater"* (MOE, 1997). The intent of this document is to support the *Environmental Protection Act* (R.S.O. 1990), *Ontario Water Resources Act* (R.S.O. 1990), *Pesticides Act* (R.S.O. 1990), and the *Environmental Assessment Act* (R.S.O. 1990).

The generic soil criteria found in the Guideline document have been developed using environmental exposure models which rely on conservative or protective assumptions about exposure to contaminants (MOE, 1997). Table A (residential/parkland) criteria (fine-grained soil texture, potable water situation) are the most conservative and protective criteria for screening potential risks to human and ecological receptors from exposure to contaminated soil. In addition, Table E reflects sediment quality criteria and is protective of both aquatic life and human health. If PCB concentrations in soil and sediment samples are less than the Table A/E criterion, then unacceptable risks to either human health or the environment are not expected and further risk assessment is not warranted. However, if the maximum concentration of PCBs identified in soil/sediment exceed Table A/E criteria, then potential effects to human health and environmental welfare are possible and will require further investigation (MOE, 1997).

The maximum concentration of PCBs found in the soil and sediment (648 µg/g and 65.0 µg/g; respectively) exceeded the Table A and E criterion for this class of chemicals (5.0 and 0.07 µg/g; respectively). As a result, further risk assessment was required so that the potential risks of PCB exposure to human and ecological receptors at the Lyons Creek Study Area could be identified.

1.2.3 Receptor Selection

Representative human and ecological receptors were selected based on the current condition of the Lyons Creek Study Area and surrounding land use. For human receptors, the exposure assessment involved quantifying the estimated dose of the contaminant received for each route of exposure. It was assumed that the human receptor was exposed to PCBs in the surficial soil at the

Lyons Creek Site for 365 days a year via incidental ingestion of contaminated soils, dermal contact, inhalation of fugitive dust and PCB vapours.

The “toddler” is generally considered to be the most sensitive life stage, due to high soil contact rates for this age group per unit body weight relative to the other age classes. Therefore, this age class alone was used in assessing the risks resulting from the “worst-case” exposure scenario for non-carcinogenic toxicosis (MOE, 1997). To address the potential cancer risks associated with exposure to PCBs in the soil, a human receptor model spanning 70 years was considered. This slightly different approach for non-carcinogens relative to carcinogens reflects the primary difference between cancer and non-cancer risk assessment, namely, that the averaging time for non-carcinogens is simply the exposure duration, while the averaging time for carcinogens is 70 years.

However, if risks to human health were apparent from the aforementioned scenario, a second scenario was investigated. This scenario evaluates the risks to a human receptor of age 5-11 (i.e. “child”) that is in direct contact with the contaminated soil at the Lyons Creek Site from April to October (i.e. 214 days), for 8 hours a day. An example of this scenario would be a child (that lives in the near-by residential area) that is exposed to PCB-contaminated soil from the Lyons Creek Site via recreational activities for a prolonged period during the spring/summer season. This cohort was selected due to the considerable amount of time spent outdoors (relative to other age cohorts), potential sensitivity of contaminant exposure, and high soil contact rates per unit body weight relative to the other age classes (U.S. EPA, 1989). In addition, it is during the spring/summer period that exposure to human receptors via dust and soil-bound contaminants is expected to be the greatest (e.g. not impeded by snow cover during the winter months), thus this exposure model provides a more realistic scenario, while still maintaining the conservative and protective nature of this preliminary SLRA.

To evaluate the potential risks to wildlife resulting from exposure to PCBs in the soil/sediment of Lyons Creek Study Area, a preliminary screening level aquatic and terrestrial risk assessment was conducted using multiple receptors and exposure pathways. The ecological exposure models calculated in this report were based on biological and toxicological information for the white-footed mouse (*Peromyscus leucopus*), American robin (*Turdus migratorius*), and fathead minnow (*Pimephales promelas*). These species were selected based on the availability of relevant toxicity data (e.g. U.S. DOE, 1997; U.S. EPA, 2002a; U.S. EPA, 2002b), their potential abundance at the Site, sensitivity to PCB exposure, and habitat range.

1.2.4 Exposure Assessment

As previously stated, this exposure assessment was based upon the measurements of PCBs in surficial soil and sediment (<150 cm below grade) as the primary source term for predicting maximum exposure concentrations to all receptor models at the Lyons Creek Site Area. Soil collected from this depth is considered to represent a more significant source of contaminant exposure to human and ecological receptors compared to subsurface strata (>150 cm) (MOE, 1997).

To maintain the conservative nature of this preliminary risk assessment, the maximum PCB concentration for soil collected from the Lyons Creek Study Area (648 µg/g) was used in the estimation of risks in the human and ecological receptor scenarios (excluding fathead minnow). The PCB exposure assessment for fathead minnows will incorporate the maximum sediment concentration (65.0 µg/g) collected from the Lyons Creek Study Area.

In addition, an outdoor air concentration of PCBs via volatilization from surficial soil was modelled using *Risk Integrated Software for Cleanups* version 4.03 (Environmental Software Online LLC, Groton, MA, U.S.A.). A maxima airborne PCB concentration of 2.04×10^{-3} µg/m^3 resulted from the volatizing of PCB from soil containing 648 µg/g and was derived using various physiochemical properties of this class of persistent organochlorine contaminants and generic conditions of the site (Appendix I).

Human Exposure Scenario

The toxicity benchmarks for PCBs are given in Table B-2. The Toxicity Reference Values (TRVs) were given in units of µg/kg/d, whereas slope factors (SF) were given in units of $(\mu g/kg\text{-}d)^{-1}$. Toxicity values were obtained from the *Risk Assessment Information Systems* (RAIS; Oak Ridge National Laboratory, U.S. DOE, 2003) and Health Canada (2003).

TABLE B-2

Toxicity Benchmark Values for Potential Effects to Human Health

Route	**Non-Cancer Risk** **Toxicity Reference Values (TRVs)**[a] **(µg/kg-d)**	**Cancer Risk** **Slope Factor (SF)**[b] $(\mu g/kg\text{-}d)^{-1}$
Dermal	6.51×10^{-3} [b]	2.22×10^{-3}
Inhalation	1.0	2.0×10^{-3}
Ingestion	1.0	2.0×10^{-3}

[a] Health Canada (2003); [b] U.S. DOE (2003); [c] "NV" = No current guideline value available.

Chemical compounds may exhibit different toxicological mechanisms of action depending on the route of exposure (i.e., ingestion, inhalation, dermal). No TRV for the inhalation exposure pathway for PCBs was available at the time of this report. Therefore, to maintain the protective nature of this preliminary SLRA, the oral TRV was used to assess the contribution of inhalation (via fugitive dust or aerosol) to the overall non-cancer toxicity of PCBs to human receptors.

Non-cancer risks

The risks of non-cancer toxicosis to human receptors associated with PCB exposure were considered in the SLRA using the maximum soil (and resulting modeled outdoor air concentrations) quantified at the Lyons Creek Study Area. The potential threshold (i.e. non-carcinogenic) effects caused by exposure to total PCBs was calculated as the hazard quotient (HQ); the ratio of the exposure rate (or dose) to the applicable toxicity reference value (TRV). For example, when calculating the risk due to ingestion (*"ing"*) exposure, the exposure expected through the ingestion pathway is divided by the ingestion reference dose. The equation for the hazard quotient is given below in equation 2.

$$HQ = \frac{Exp_{ing}}{TRV_{ing}}$$

For non-carcinogens, 20% of the TRV for each exposure pathway is considered an acceptable risk based on provincial guidance (MOE, 1997). The HQ calculated for the maximum PCB concentration quantified in soil was 16.3 for most sensitive human receptor (i.e. "toddler" exposure scenario). For the child receptor in contact with the PCB-contaminated soil at the Site under the spring/summer exposure scenario, the HQ calculated using the maximum PCB soil concentrations was 8.7. Therefore, the estimated non-cancer risk for PCBs is considered unacceptable under the current guidelines and toxicological information under all exposure scenarios outlined in this preliminary SLRA (HQ > 0.2) and requires more detailed examination.

Cancer risks

The U.S. EPA has developed cancer risk estimates (cancer slope factors; SF) for exposure to PCBs as this class of contaminants has been classified as a Group 2A carcinogen (i.e. probably carcinogenic to humans; IARC, 1987). Subsequently, cancer risk estimates were derived to provide a risk estimate for this contaminant:

$$ILCR = \sum_{y=1}^{y=30} \left(\sum_{e=inh}^{e=ing} SF_e \times Exp_e \right)_y$$

where ILCR is the cumulative incremental lifetime cancer risk for exposure concentrations (*"Exp"*) multiplied by the corresponding SF for all exposure (*"e"*) pathways (i.e. ingestion, dermal, inhalation) and summed for all age cohorts (*"y"*) from age 1 to 30 (i.e. from toddler to adult).

In order for a carcinogenic risk to be present, the total ILCR for a chemical must be less than the *de minimis* or Level 1 Risk Management criterion of 1 in 1,000,000. An ILCR for a chemical higher than this *de minimis* value is considered to be an unacceptable cancer risk under Level 1 risk management in Ontario. The maximum estimated risk for a human receptor was 8.70×10^{-4}. Under the spring/summer exposure scenario (i.e. 214 days a year, 8 hours a day), the ILCR is 5.56×10^{-4}. Therefore, under the conservative parameters used by this preliminary risk assessment, the cumulative cancer risk to a composite human receptors is unacceptable at current exposure concentrations and requires more detailed examination.

Ecological Receptor Scenarios

The potential for the selected exposure species to uptake impacted soil on the Site area was based on the "*Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*" document (U.S. DOE, 1997).

Terrestrial wildlife may be exposed to contamination via oral, dermal contact and inhalation routes (i.e., $E_{oral} + E_{dermal} + E_{inhalation} = E_{total}$). Generally, dermal and inhalation exposure to wildlife on most contaminated sites can not be accurately assessed because there is inadequate data available to make a reasonable estimation. It should be noted, however, that the physiochemical properties of PCBs (e.g. high K_{oc}), general physiology of the target receptors (e.g. reduced skin absorption due to the presence of feathers and fur), and site conditions (e.g. vegetation cover) will likely minimize, if not negate, the contribution of dermal and inhalation exposure pathways to the overall exposure scenario. Therefore, for this quantitative preliminary evaluation, it is assumed that the majority of PCB exposure experienced by wildlife on the Site area is from the oral exposure pathway (i.e., $E_{oral} \cong E_{total}$).

As wildlife move across the Site area, oral exposure is believed to primarily occur from multiple sources such as uptake of plant (or prey) and contaminated soil. Concentrations of total PCBs in surface water were not available at the time of this preliminary assessment. Subsequently, potential exposure to the selected ecological receptors from this environmental media could not be evaluated at this time.

Soil ingestion was hypothesized to be incidental, and estimated to be <2% of total food consumption (U.S. DOE, 1997; U.S. EPA, 1993). For grazing herbivores (such as the white-footed mouse), exposure may occur via consumption of soil deposition on foliage or adhered to roots, along with direct uptake of vegetation. Thus, the total oral exposure experienced by mice is the diet-adjusted sum of the exposures from food and soil (i.e., $(0.98 \times E_{vegetation}) + (0.02 \times E_{soil}) = E_{total\ oral}$). Due to the paucity of PCB data in vegetation from the Lyons Creek Site, concentrations in this exposure medium were modeled using conservative assumptions regarding PCB accumulation in terrestrial vegetation (e.g. McLachlan, 1996; Trapp and Matthies, 1997).

The exposure scenario for the American robin is slightly more complicated as PCBs will bioaccumulate from soil into potential prey items. As with the above exposure scenarios, the rate of soil ingestion was established as <2% of total food consumption rate. Previous studies have demonstrated that the relative dietary contribution of invertebrates and vegetation to the American robin is approximately 60% and 40%, respectively (U.S. EPA, 1993). Subsequently, the diet-adjusted oral exposure ($E_{\text{total oral}}$) was calculated from the equation:

$$E_{\text{total oral}} = (0.39 \times E_{\text{vegetation}}) + (0.59 \times E_{\text{invertebrate}}) + (0.02 \times E_{\text{soil}})$$

As PCBs concentrations were not quantified in invertebrates from the Lyons Creek Study Area, estimated levels in soil invertebrates (e.g. earthworms) were calculated using average values for modelled and empirical bioaccumulation factors from soil (BAF_{soil}) (Sample et al., 1998; Sample et al., 1999) from the following equation:

$$BAF_{\text{soil}} = [\text{worm}] / [\text{soil}]$$

where [worm] and [soil] are the dry-weight concentrations (µg/g) of modelled and quantified PCB concentrations in earthworms and soil samples, respectively. Earthworms are in direct contact with the contaminated soil and were anticipated to represent the “worst-case” exposure scenario to the American robin from the ingestion of soil invertebrates. The modeled earthworm concentrations were adjusted for moisture content (assumed to be 87% moisture; Janssen et al., 1996) to provide a realistic value of exposure to the American robin from the ingestion of this potential prey species.

The examination of chemical availability from sediment to aquatic organisms is valuable for assessing the potential for chemical transfer through the food web. The benthic-feeding fathead minnow is commonly used to assess the relative accumulation of chemicals by comparing whole body tissue concentrations to sediment levels. From this analysis, PCBs accumulated in fathead minnow can be estimated by a simple manipulation of the biota-sediment accumulation factor (BSAF) equation:

$$BSAF = [\text{fish}] / [\text{sediment}]$$

where [fish] and [sediment] are the dry weight element concentrations in mg/kg. A BSAF greater than unity indicates that the concentration of a compound in the organism surpasses that found in the sediment. In general, the accumulation of PCBs in fish from exposure to sediment is significant (i.e. BSAF > 1.0; U.S> EPA, 2002b). This is consistent with the known toxicokinetics and disposition of recalcitrant, lipophilic contaminants in teleosts (Rand and Petrocelli, 1985).

Ecological Exposure Assessment

Table 3 presents the PCB concentrations and exposure estimates for the white-footed mouse, American robin, and fathead minnow. The No-Observed Adverse Effect Level (NOAEL) used for the toxicity assessment are also provided. The NOAEL-based toxicological benchmark represent concentrations of a particular chemical in environmental media that does not elicit a statistically-different response in exposed organisms compared to unexposed (i.e. “control”) organisms and therefore, is considered to be non-hazardous under the specified exposure scenario.

Comparison of the estimated exposure to the NOAEL (from U.S. DOE, 1997; 2002b) was completed in order to determine whether PCBs presented a potential risk to selected ecological receptors at the Site. Adverse health impacts were preliminary assessed using a hazard quotient (HQ):

$$HQ = \frac{[Exposure]}{NOAEL}$$

where *[Exposure]* is the exposure rate or concentration. In screening the potential risks to ecological receptors, HQ <1.0 are considered safe since NOAEL-based toxicological benchmarks are considered to represent acceptable concentrations of chemicals in environmental media.

TABLE 3

Estimation of PCB Exposure to Ecological Receptors at the Lyons Creek Study Area

Terrestrial Receptor	**Maximum PCB Concentration (mg/kg)**			**Exposure Estimates (mg/kg-d)**			**NOAEL[a] (mg/kg-d)**	**HQ**
	Soil	**Vegetation[b]**	**Invertebrate[c]**	**Soil**	**Vegetation[b]**	**Invertebrate[c]**		
White-footed Mouse	648	6.48	NA	2.00	0.98	NA	0.061	**49**
American Robin	648	6.48	3298	16.0	3.0	2399	0.180	**13400**
Aquatic Receptor	**Maximum Sediment Concentration (mg/kg)**			**Estimated Body Concentration (mg/kg)[d]**			**NOAEL (mg/kg)**	**HQ**
Fathead Minnow	65.0			192			15.0	**13**

[a] Toxicity data from Sample et al. (1996) and U.S. EPA (2002b); [b] Derived using a soil-plant transfer fraction of 0.01 (McLachlan, 1996; Trapp and Matthiers, 1997); [c] Calculated from Sample et al. (1999); [d] BSAFs from U.S. EPA (2002b); “NA” = Not applicable.

The HQ values for all ecological receptors selected in this preliminary assessment were significantly greater than unity (Table 3). Therefore, the risks to wildlife on the Lyons Creek Study Area are deemed unacceptable under the current exposure scenario. However, it should be noted that this “worst-case” scenario is heavily dependent upon modeled data and therefore, may not be truly representative of site-specific conditions.

1.3 Summary of Screening Level Risk Assessment

The results of the preliminary human health and ecological risk assessment indicate that there are considerable risks to multiple species and human receptors from exposure to PCB-contaminated soil and sediment at the Lyons Creek Study Area. However, this conclusion is based on the maximum surficial soil and sediment PCB concentrations at the site and modeled PCB data in various matrices (i.e. vegetation, terrestrial invertebrates, tissue residue concentrations). It is our recommendation that the collection of additional data focused on these pathways of exposure will assist in a more realistic, site-specific risk assessment of PCB exposure to humans and selected ecological receptors.

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APPENDIX C

ANALYTICAL RESULTS