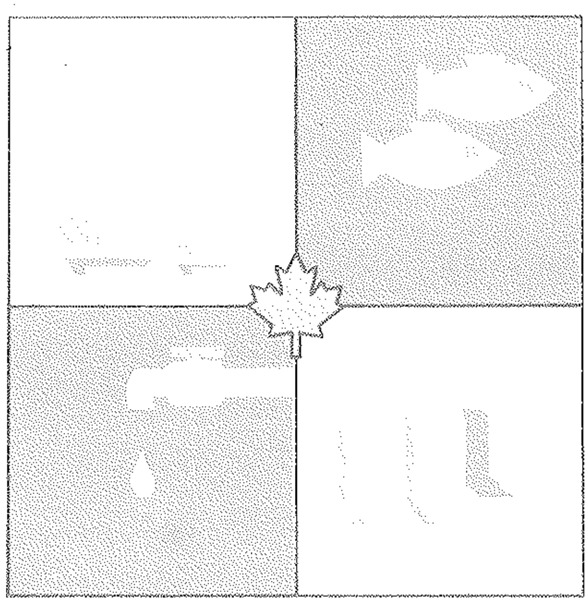
NIAGARA RIVER REMEDIAL ACTION PLAN

Stage 1: Environmental Conditions and Problem Definition



NIAGARA RIVER REMEDIAL ACTION PLAN

October 1, 1993

Canada and the United States have designated the Niagara River an Area of Concern (AOC) under the terms of the Great Lakes Water Quality Agreement. The agreement calls for the development of Remedial Action Plans (RAPs) for the Areas of Concern, and documentation in three stages to the International Joint Commission. RAPs are being developed separately for the Canadian and U.S. portions of the Niagara River AOC.

The Stage 1 RAP document provides a description of environmental conditions, problems and their causes based on information available at the time of preparation. On behalf of the Niagara River RAP Team, I am pleased to provide you with a recently released final copy of the Niagara River RAP Stage 1 document for the Canadian portion of the Niagara River AOC. This document has been submitted to the International Joint Commission for its review.

Sincerely,

B. Koblik-Berger

Belinda Koblik-Berger, P.Eng.
RAP Co-ordinator
Niagara River Improvement Project

Remedial Action Plan
Plan d'Assainissement

Canada Ontario

Canada Ontario

September 30, 1993

Mr. Claude Lanthier
Chairman, Canadian Section
International Joint Commission
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Mr. Gordon K. Durnil
Chairman, United States Section
International Joint Commission
1250 23rd St. N.W., Suite 100
Washington, D.C. 204400
U.S.A.

Dear Sirs:

The Niagara River has been designated by Canada and the United States as an Area of Concern under the terms of the Great Lakes Water Quality Agreement (GLWQA), as amended by the Protocol of 1987. Annex 2 of the Agreement calls for the development of Remedial Action Plans for Areas of Concern and submission of documentation in three stages to the IJC. Remedial Action Plans are being prepared separately for the Canadian and U.S. portions of the Niagara River Area of Concern.

In Canada, the Remedial Action Plan process is a joint federal-provincial initiative. The Niagara River RAP is being developed with the active involvement of a Public Advisory Committee (PAC) representing many sectors of society, including the general public, local governments, interest groups and industry.

On behalf of participating agencies and the Niagara River PAC, we are pleased to submit Stage 1 of the Niagara River Remedial Action Plan. The document has been developed in close cooperation with the Public Advisory Committee and their letter of support is attached.

The New York Department of Environmental Conservation, which has responsibility for development of the RAP for the U.S. portion of the AOC has received Canadian Federal/Provincial comments on their draft RAP document and anticipate that they will be submitting their RAP report to the IJC for review in the near future. American and Canadian agencies are cooperating in the exchange of information and documentation on their respective RAP programs. The Canadian Stage 1 Report is being forwarded to U.S. agencies and the U. S. Niagara River Advisory Committee. In addition, the four-party Niagara River Toxics Management Plan provides a joint mechanism for furthering clean-up of the Niagara River.

Both the Canadian Niagara Stage 1 Report and conclusions of the Niagara River Toxics Management Plan highlight the significance of U.S. sources as major contributors to impairments in the Niagara River ecosystem. It is apparent that complete restoration of impaired uses will not occur without concrete study, planning and action on these U.S. point and non-point sources. We will continue to urge U.S. regulatory agencies to take prompt and effective action and to provide clear evidence of reductions in toxic discharges to the Niagara River.

The Stage 1 RAP provides a description of environmental conditions and problems based on information available at the time of preparation. Results of more recent investigations and further consultation with the public will be reflected in the Stage 2 submission.

Twenty-five copies of the Stage 1 RAP have been forwarded directly to the IJC Regional Office in Windsor. The RAP Coordinator for Ontario, Belinda Koblik-Berger, would be pleased to make a presentation on this document to the Commission or its staff at your invitation. We look forward to receiving comments from the Commission.

Victor Shantora

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Attachment

3B070301.MEM

NIAGARA RIVER REMEDIAL ACTION PLAN

PUBLIC ADVISORY COMMITTEE

The Honourable Claude Lanthier
Chairman, Canadian Section
International Joint Commission

Mr. Gordon K. Durnil
Chairman, U.S. Section
International Joint Commission

The Honourable Ruth Grier
Minister, Ontario Ministry
of the Environment

The Honourable Pauline Browes
Minister of State for the Environment

November 10, 1992.

Dear Madams/Sirs:

RE: Niagara River Remedial Action Plan - Stage I Report

On behalf of the Niagara River Remedial Action Plan Public Advisory Committee (PAC), I wish to express our endorsement of the Niagara River Stage I Remedial Action Plan (RAP). I would also like to convey our appreciation to the governments of Canada and Ontario for initiating and conducting the Niagara River Remedial Action Plan, and for involving the public through its PAC. It is refreshing to note that the input of the PAC has been given serious consideration by the RAP Team, and our input has more than once altered the nature of the final product. One such example is provided by the PAC's recommendation in 1989 to extend the boundaries of the Area of Concern (AOC) to the headwaters of the Welland River.

The Niagara River PAC is a group of dedicated volunteers, who have been holding meetings of the whole committee and various subcommittees regularly for 3 1/2 years. The commitment of the PAC to providing input to the Stage I report through its meetings, workshops, and various public outreach activities is detailed in section 1.6 of the document. All Niagara River PAC members have had an opportunity to share their individual concerns during the process, and all PAC meetings are open to the public.

While supporting and endorsing the Stage I Remedial Action Plan, the PAC has raised some issues, namely:-

* The Stage I component of the RAP and the production of the Stage I report has taken too long. This is due mainly to the effort by the RAP Team and PAC to ensure that the document accurately represents the views of all concerned parties. However, some may not still be entirely satisfied with the consensus on an issue for which they have a particular concern.

* The PAC is concerned that delays occurred due to over-worked RAP Team members who, despite their dedication, had insufficient hours and other resources to expedite the process; further funding cut-backs can only exacerbate this situation.

* The submission of the Stage I report represents a milestone in the RAP for the Niagara River. While the report paints a picture in time, it would be more viable to issue annual or bi-annual reports that depict the present state of knowledge, the current trends, and information on improvements made and plans for the future. Shorter summary reports might be more effectively used to reflect the public's concerns and to demonstrate progress being made under the ongoing programs of the involved agencies.

* While it is recognized that the RAP process is new to both RAP Teams and to PACs, better procedures are required to reduce the duplication of effort that presently exists as each PAC struggles through the process. These procedures should ensure that more productive processes are developed to deliver more timely responses to the public.

* There are 2 RAPs being developed for the Niagara River. The Niagara River PAC is concerned that the remedial measures which will be implemented on the Canadian side of the river will not be sufficient to restore the Niagara River ecosystem.

Finally, it is hoped that as Stage 2 progresses, these issues previously outlined will be addressed. Our over-riding concern is to move forward to the restoration of the Niagara River ecosystem. We have been honoured in being allowed to participate in this endeavour. In addition to our endorsement of the Stage I report, we offer to provide our continued support to the cleanup of the Niagara River, the Great lakes, and our global environment.

Yours truly,

Ted Simonen

Ted Simonen
Chair
Niagara River Public Advisory Committee

c.c. H. Wong, Director, MOE - WCR
S. Irwin, Coordinator, Niagara River Improvement Project MOE - WCR
V. Shantora, A/Regional Director General, Conservation & Protection, Ontario Region
H. Shear, Director, Great Lakes Environment Office (GLEO)
D. Epstein, Chief Program Coordinator, GLEO
M. Malhotra, RAP Public Involvement Coordinator, GLEO

The Niagara River (Ontario) Area of Concern

Environmental Conditions and Problem Definitions

Remedial Action Plan – Stage 1

Prepared jointly by:

Ontario Ministry of Environment and Energy

Environment Canada

Ontario Ministry of Natural Resources

Fisheries and Oceans Canada

September 1993

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PREFACE

The Niagara River has been designated by the International Joint Commission (IJC) as one of forty-three Areas of Concern in the Great Lakes Basin. This designation is due to degraded water quality which impairs complete use of the river's resources.

In response to concerns over the health of the entire Niagara River ecosystem, this Remedial Action Plan (RAP) is being developed by a RAP team comprised of scientists from Canada and Ontario environment and resource agencies with the advice and assistance of a Public Advisory Committee which represents various sectors of the community. All parties involved share a common interest in the Niagara River and its ecosystem.

The development of the Niagara River (Ontario) RAP is a dynamic three stage process based on the framework established in Annex 2 of the 1987 Protocol of the Great Lakes Water Quality Agreement (GLWQA).

This Stage I document describes the current environmental conditions in this Area of Concern, identifies the sources of contamination, outlines the beneficial uses which are impaired and the extent of that impairment.

Stage II will identify the remedial activities necessary to restore the desired beneficial uses and achieve the environmental goals. Goals and objectives for the Niagara River AOC will be identified. Commitments and a schedule for implementation of remedial options will be outlined.

Results of ongoing studies that will be used in both updating Stage 1 and incorporated into Stage 2 include:

1) Continuation of weekly upstream/downstream monitoring at Niagara-on-the-Lake and Fort Erie by Environment Canada, as part of the Four Agency Niagara River Toxics Management Plan commitment for 50% reduction in loading of chemicals of concern from point and non-point sources;

2) data from MOE biomonitoring sampling programs;

3) Misa monitoring data for the applicable industries in the area;

4) results from ongoing Pollution Control Plans and Infrastructure Needs Studies developed by the local municipalities;

5) a re-assessment of loadings from the four Ontario landfills;

6) research in the study of biota in the Welland River to determine the extent and cause of deformities in aquatic species;

7) information on the success of a sediment dredging and treatment demonstration project undertaken in fall 1991, and;

8) data to assess water quality of shorewells along the Niagara River.

Data gaps have also been noted. These include:

1) cause of degradation of fish populations in the Welland River and other tributaries, both in numbers and diversity;

2) additional information on the impact of chemical uptake on fish and wildlife regarding reproductive impairments and physical deformities;

3) additional information is required to establish cause and to determine whether there is a recurrent problem regarding taste and odour, and

4) status of phytoplankton and zooplankton populations in the Welland River.

In the third (and final) stage of the RAP, the evaluation of the success of remedial measures will be documented. Details of monitoring and surveillance programs will also be presented.

This Niagara River Remedial Action Plan relates only to the Canadian side of the Niagara River. Canada and Ontario would prefer that a binational RAP be developed for the Niagara River; however, New York State has chosen to develop a separate Remedial Action Plan for the U.S. side. For the New York RAP, the Niagara River Action Committee (NRAC), comprised of state environment agency, public, industry and municipal representatives, provides community input.

As a bridge between the two RAPs an International Advisory Committee (IAC) was established to provide a linkage between the two RAP teams and their advisory committees. The Niagara River recognizes no international boundary; its problems are manifested on both sides. Likewise its solutions are intertwined and concerns over the river must be addressed by solutions on both sides. There is a concern that the efforts undertaken by the Ontario RAP to restore beneficial uses will have limited impact unless significant U.S. sources are addressed.

ACKNOWLEDGEMENTS

The Ontario Ministry of the Environment, Niagara River Improvement Project and the RAP Coordinator would like to express appreciation to the many groups and individuals who participated in the development of this document.

We would like to thank the members of the RAP writing team for their extensive efforts in the creation of this document and review of the many drafts that preceded it. They have also participated in numerous meetings and several public workshops to provide specialized expertise to the public in understanding the issues.

The RAP team would like to express its gratitude to the members of the Niagara River Public Advisory Committee who committed themselves to the process in early 1989 and stayed with it through many tough monthly meetings, giving freely of their time and contributing enthusiasm and knowledge to the process. It is through their efforts that local interest and support is building for implementation of the Niagara River Remedial Action Plan.

The additional contributions of the members of the PAC Technical Subcommittee also need to be recognized. This group provided detailed review of the draft documents and suggested improvements which resulted in a better Stage I report.

The bulk of the final editing and compilation was carried out under contract to Envirosearch Ltd.

In addition, the RAP Team would like to extend its appreciation to Belinda Koblik-Berger, newly appointed RAP Coordinator for her assistance in the final editing and release of this document.

The RAP team would also like to express a special thanks to the RAP Coordinator, Paul Odom. His efforts in writing, coordinating and developing this document were paramount to its creation and completion.

We would like especially to thank Professor Ian Brindle, the PAC Chair, for his steady efforts in guiding a difficult public process, participating in many committee meetings, advising the RAP team on a host of issues and safeguarding the public interest.

Our thanks also to Ms. Valerie Cromie, the PAC Community Liaison Coordinator for all of her organizational work and her public outreach activities throughout the Niagara Peninsula relating to the Niagara River Remedial Action Plan.

The RAP team would like to dedicate this Stage I report to the late Con Eidt, alternate chair of the PAC, who believed in the need to protect Niagara's environment and the Niagara River Remedial Action Plan and who would have liked to have reached this milestone with us.

Niagara River RAP Team Contributors to this Report
(as of Fall 1991)

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Great Lakes Environment Office

Tom Tseng

Conservation and Protection - Ontario Region

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Serge Metikosh

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Members of the Public Advisory Committee
Past Members in {Brackets} (as of Fall 1991)

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Community Liaison Coordinator	**Valerie Cromie**	
Atlas Specialty Steels	**Don Marr, Karen Starrs**	
Bruce Trail Association	**Ron Cook**	{Elsie Koop}
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Cyanamid of Canada Inc.	**George Slaney**	
D.G. Bawtinheimer Ltd.	**Vern Fulcher**	
Environmental Teachers Association	**Brent Zimmerman**	
{Federation of Ontario Naturalists}		{John Cooper}
Great Lakes United	**Phil Weller**	
Maid of the Mist Steamboat Co.	**Lawrence McGinn**	
Niagara & District Labour Council	**Wayne Pine**	
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Town of Niagara-on-the-Lake	**Robert Howse**	
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EXECUTIVE SUMMARY

Public concern for the quality of life and of the environment over the last decade, has led to an increased awareness of environmental issues. The Niagara River has been a particular focus of environmental concern. It is a major source of water to Lake Ontario and some four million residents of the Province of Ontario and one million residents of the State of New York.

Many of the concerns have been noted by the International Joint Commission in designating the Niagara River as one of forty-three Areas of Concern in the Great Lakes Basin. This Remedial Action Plan (RAP) is being developed to restore impaired beneficial uses to the Area of Concern.

Separate Remedial Action Plans are being developed for the Ontario side and the New York side of the Niagara River.

Many sources discharge a wide range of conventional and toxic chemical contaminants to the Niagara River. Many of these contaminants are chemicals of concern due to their effects on human and other lifeforms. Some of these chemicals are found at levels that exceed aquatic life criteria. These chemicals concentrate in the aquatic food chain, resulting in fish consumption advisories for the Niagara River.

Environmental degradation caused by excessive loading of conventional contaminants and bacteria occurs in the tributary streams of the Niagara River. In these tributaries suspended solid concentrations have caused significant loss of some aquatic biological production. Sediment in the Welland River is also contaminated with heavy metals which has further reduced benthic diversity in some sections.

The Niagara River Toxics Committee (NRTC) in 1984 provided the first comprehensive catalogue of sources of toxics contamination to the Niagara River. The report also provided a preliminary assessment of the environmental condition and the extent of degradation of the river and the nearshore area of Lake Ontario. Because toxic contaminants is the prime concern in this area, the NRTC report and a large number of government follow-up studies form the largest part of the scientific information used in this report.

The RAP development program is occurring concurrently with a toxics reduction plan, organized by the environmental agencies of the four governments with jurisdiction over the Niagara River. This 1987 government program, known as the Niagara River Toxics Management Plan (NRTMP) has identified 18 Niagara River Chemicals of Concern and established goals for reduction of discharge of 10 persistent toxic chemicals to the river. The NRTMP reflects the philosophy of the International Joint Commission. The NRTMP states that "this (reduction) is consistent with the goal of virtual elimination of toxic discharges, as agreed upon in 1978 by the Governments of the United States and Canada under the Great Lakes Water Quality Agreement".

<u>Niagara River Priority Toxic Chemicals</u>

Scheduled for 50% Reduction	Other Priority Toxics
benz(a)anthracene	chrysene
benzo(a)pyrene	chlordane
benzo(b)fluoranthene	dieldrin
benzo(k)fluoranthene	octachlorostyrene
tetrachloroethylene	DDT and metabolites
mirex	lead
hexachlorobenzene	arsenic
PCB's	toxaphene
mercury	
2,3,7,8-TCDD (dioxin)	

The NRTMP goal of 50% reduction of persistent toxic discharges by 1996 for 10 of these 18 Chemicals of Concern identified for the Niagara River, is viewed as an important step on the way to virtual elimination of these substances and reduction of all contaminants released to the Niagara River. The four agencies hold periodic consultation with the public in the Niagara area to present progress reports and to outline new initiatives.

The Niagara River RAP goes beyond the bounds of the NRTMP, addressing the entire Niagara River ecosystem. In addition to addressing toxics discharges, the RAP addresses in-situ contamination, problems associated with conventional contaminants, bacteria, physical contaminants and undesirable biological species and concerns over the impact of future activities. It is as much a plan for the future as it is a plan for cleaning up past mistakes.

The Remedial Action Plan team also recognized the necessity for public participation and acceptance early in the development process. This participation involved three components:

1)providing the public with the facts concerning the environmental condition of the Niagara River;

2)establishing a dialogue between the public and the government agencies to get public information and advice in preparation of the RAP;

3)establishing a means of bringing together the two RAPs for the Niagara River under the scrutiny of the public to ensure that issues of mutual interest and concern are addressed.

Following a series of public meetings in 1988, a public advisory committee (PAC) was established for the Niagara River (Ont.) RAP. The PAC consists of some 20-30 members of various groups and individuals with a strong interest in the Niagara River and has met monthly since January 1989 to advise the RAP team during creation of the Stage I and II documents. Two members of the PAC have sat on the RAP team since spring 1990 to represent the PAC's interests in the development of this document. The past several drafts have been reviewed by all PAC members, the last draft involving a workshop in January 1991. Concerns raised by the PAC have been outlined in the Stage I document along with the RAP team response. The suggestions of the PAC have been incorporated in this document, wherever possible.

Environmental Description

The Niagara River is the principal connecting channel between Lakes Erie and Ontario. The Niagara River has a drainage basin of 686,000 square kilometres and a long-term average flow of 5860 cubic metres per second. This flow accounts for 83% of the water flowing into Lake Ontario and significantly influences Lake Ontario's water quality and fish productivity. Velocity and flow in the river itself are regulated by a control structure above Niagara Falls, operated primarily to divert water for hydro-electric generation purposes by Ontario and New York State. Flow over the falls at Niagara and through the power plants is governed by the 1953 Niagara River Treaty.

The Niagara River is highly utilized for recreation, predominantly fishing, but also includes recreational boating, swimming and birdwatching. It is used as a source of potable water for the City of Niagara Falls, Ontario, as well as a number of towns and cities in New York State. The river is the source of water for many industries as well as the receiver of their effluents. It also receives the treated effluents of a number of municipalities that line both shores. Commercial navigation occurs in the lower river up to Queenston and in the upper river to Niagara Falls and Chippawa via the Black Rock Canal and Erie Barge Canal. The Niagara and Welland Rivers receive a number of stormwater discharges and combined sewer overflows from the older portions of most urban areas that line their shores.

One of the major uses of the Niagara River is aesthetic appreciation. The Horseshoe Falls and the American Falls, the Niagara River, the Niagara Gorge, the Whirlpool, the Whirlpool Rapids and Devils Hole Rapids and the Niagara Escarpment are world-renowned tourist attractions. Visitors from around the world come to view the river, making tourism a major industry in the Niagara Peninsula.

The Niagara River (Ont.) Area of Concern extends from Lake Erie at Fort Erie to Lake Ontario at Niagara-on-the-Lake and includes several small tributaries to the upper Niagara River and the entire drainage basin of the Welland River. Diversions of water to the Welland River and Lyon's Creek from the Welland Ship Canal augment the natural flows in these basins. The combined flow from these tributaries (including riparian flow) is a very small portion of the flow to the Niagara River compared to outflow from Lake Erie.

The two sides of the Niagara River are markedly different in development. The New York side is highly urbanized and heavily developed by industry along its banks between Buffalo and Niagara Falls. Extensive residential development continues from Niagara Falls to the top of the escarpment. Below the escarpment, the area is predominantly undeveloped, with the exception of the residential communities of Lewiston and Youngstown.

The Ontario side of the river is much less developed. Most of the upper river is undeveloped parkland and open space between Fort Erie and Niagara Falls. Between Niagara Falls and the Whirlpool the area is urbanized. North of the Whirlpool and extending to Lake Ontario, the area is mixed parkland/fruitland with the exceptions of the residential communities of Queenston and Niagara-on-the-Lake. The upland area of the Niagara tributaries, including the Welland River basin is mixed agricultural/undeveloped land with the exception of the City of Welland and a number of small rural communities. Very little heavy industry is established within the entire Niagara River (Ont.) Area of Concern.

Since the early 1900's, the Niagara River has been identified as a river with serious water pollution problems. Most sources of pollution and the problems they cause have existed for decades. Over the past decade, contamination of the Niagara River by persistent toxic substances has become a major public concern in both the United States and Canada. Public concern has arisen over the quality of the water, toxic chemicals in the mist and in the air and the appearance of foam in the pool beneath the Falls. Environmental concern in this area focuses on exceedances of water quality criteria for the protection of aquatic life, sediment contamination which impairs benthic organisms and both reductions in aquatic populations and habitat loss due to a number of causes.

Six municipal sewage plants and fourteen industries on the Ontario side of the Niagara River discharge directly to surface waters. Monitoring programs for the industrial and sewage plant discharges have shown that remedial measures undertaken between 1982 and 1989 have resulted in a greater than 80% reduction in gross loading of toxic contaminants discharged by Ontario-based point sources from 152.5 kg/d in 1981-82 to 22 kg/d in 1988-89. This monitoring shows that heavy metals contribute more than 70% of this total load from Ontario. On the New York shore, over 100 industries and sewage plants discharge to the Buffalo or Niagara Rivers. Inputs of toxics from these U.S. point sources have been reduced from 1160 kg/d in 1984 to 184 kg/d in 1987-88. A considerable number of storm and combined sewer discharges are located on the U.S. shore. No estimate of contaminant load from these sources has been made.

The Niagara is also known to receive leachate from a number of hazardous waste sites on the U.S. side; 24 sites (or clusters) have been estimated to contribute some 307 kg/d of EPA priority pollutants directly to the river, 179.1 kg/d of which are organic compounds. These sites, currently under various stages of investigation or remediation are considered to be the most significant of the more than 200 hazardous waste sites in Niagara and Erie Counties. In comparison, the Ontario portion of the Area of Concern contains 16 landfill sites, five of which have the potential to introduce contaminants to the Niagara River. Detailed investigations into each of these five sites were reported in a 1991 study to estimate the potential contribution of priority pollutants reaching the Niagara River. Heavy metal contamination was identified as a minor component (est. 4 kg/d) of input from these sites; however, cyanide (toxic, not persistent) was identified as the major potential contaminant (from 1 site at an estimated load of 26 kg/d). From those five sites, no persistent toxic chemicals have been found and none of the 18 NRTMP Chemicals of Concern were identified. Remediation programs are completed or underway at all sites.

Ground water on the Ontario side of the Niagara River contains high levels of naturally occurring minerals and is therefore generally of poor quality as potable water without treatment. No significant contamination of this resource by human activity has been detected.

The Chippawa Channel and the lower Niagara River do not contain extensive areas of sediment accumulation. The fast-flowing nature of the Niagara carries sediment and contaminants alike rapidly downstream to Lake Ontario. Sediment is deposited in Lake Ontario on the Niagara Bar. Relatively uncontaminated sands and gravels are deposited on the Ontario side while fine silts and clays are carried into the New York waters.

Fine silts and clays are also deposited within the Ontario Area of Concern in the Niagara River tributaries, particularly the Welland River. A considerable amount of clay soils from the basin erode from the land due to agriculture, ditching and land development. These generally low-flowing, low gradient streams often appear murky due to the suspended solids. Many of the finer clays are suspended (or resuspended) in the water column all the way to the Niagara and hence to Lake Ontario; however, larger size solids deposit on the tributary streambeds causing loss of aquatic habitat. The soils readily adsorb contaminants from the water column both in the Welland River and in the Niagara River. Significant zones of contaminated (heavy metals) sediment exist in the lower Welland River.

Stage I Of The Remedial Action Plan

One of the tasks in the development of this Stage I document is the establishment of impaired beneficial uses within the Area of Concern. Although a wide range of impairments may exist, the RAP program focuses on water quality impairments. To that end the IJC has identified fourteen use impairment criteria for listing Areas of Concern.

The impaired uses in the Niagara River AOC have been identified independently by the government agency RAP team and the Public Advisory Committee. Both sets of impaired uses are presented in the report. In most, the uses are similar; none are conflicting. The RAP team uses have been used to assess whether or not the 14 IJC criteria apply. The criteria have been separated into parts a and b where they are multiple because only part may apply (eg. fish have consumption advisories but not wildlife consumption advisories).

Table A summarizes the 14 IJC beneficial use impairments as they pertain to the Niagara River (Ont.) Area of Concern. Several criteria are not definitively impaired or unimpaired due to a lack of data on the topic. These are reflected in Table A. Some impairments have been noted that are not related to water quality or cannot be remediated.

TABLE A BENEFICIAL USE IMPAIRMENTS - SUMMARY TABLE IJC AREA OF CONCERN: NIAGARA RIVER

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
I (a)	Restrictions on Fish Consumption	Impaired	Fish consumption advisories are in effect for the lower Niagara River for larger sizes of freshwater drum, coho salmon, chinook salmon, white perch, lake trout, american eel, rainbow trout, yellow perch, channel catfish and smallmouth bass. Similar consumption advisories are in effect for the upper Niagara River for freshwater drum and white sucker. Contaminants involved are: mercury, mirex, PCBs, metals, pesticides and 2,3,7,8 dioxin.	
I (b)	Restrictions on Wildlife Consumption	Not Known	There are no Canadian Guidelines directly applicable to the Niagara River Area of Concern regarding human consumption of wildlife. Wildlife is not a large source of food along the Niagara River. Hunting does occur in the Area of Concern but no restrictions on consumption exist in the Niagara Peninsula. Deer on Navy Island are hunted occasionally on a controlled basis to thin the herd; the deer are generally stunted because of lack of both feed and natural predators on the island.	Consumption advisories for waterfowl are currently being investigated.

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
II (a)	Tainting of Fish Flavour	Not Impaired	Although chlorophenols, the chemicals generally associated with tainting fish with an organic taste and smell are known to be present in the Niagara River, only one complaint of tainting of fish caught in the Niagara River has ever been made to MNR offices. There is no record of the type of tainting experienced.	
II (b)	Tainting of Wildlife Flavour	Not Impaired	Wildlife is not a large source of food along the Niagara River. Hunting does occur in the Area of Concern but no record of tainting of meat has been recorded for this area.	
III (a)	Degradation of Fish Populations	Impaired	Fish populations in the Niagara River itself reflect the populations of the nearby Great Lakes and are not generally degraded. Fish populations in the Welland River and other tributaries are degraded, both in numbers and diversity; however, the cause of the degradation has not been identified.	The nature of this impairment warrants further study.
III (b)	Degradation of Wildlife Populations	Not Known	There is little information available on wildlife populations in the Area of Concern. A number of species are endangered or extinct; however, these appear to be widespread in the developed portion of Ontario. It is believed to be associated more with the encroachment of civilization than water quality related.	Existing information needs to be summarized and a baseline established.

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
IV (a)	Fish Tumours	Not Impaired	Although fish tumours have been identified in goldfish-carp hybrids in the Welland River, recent scientific studies have identified this as a genetic phenomenon of the hybrid rather than having some environmental link	Although there has been no tumour incidence reported in other species in the Area of Concern despite the number of fish captured, no detailed scientific studies have been undertaken.
IV (b)	Fish Deformities	Not Impaired	No evidence of deformity has been identified in any fish species taken from the Niagara River or its tributaries.	There have been no incidence of fish deformities reported in the Area of Concern. No detailed scientific studies have been undertaken.
V (a)	Bird or Animal Deformities	Impaired	Formerly, deer associated with the Cyanamid Welland property have exhibited jaw deformities, but the cause has not been identified (1950's). Deformities of 5 species of invertebrates (midge larvae) in contaminate sediments of several tributaries and the Welland River have been identified. Concerns have been raised about chemical uptake by birds in the Niagara River; however, no incidence of deformity has been identified for these colonies, despite its popularity as a birdwatching area.	Cause and effect relationships needs to be further investigated.

TABLE A (Con't)

LIC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
V (b)	Bird or Animal Reproductive Problems	Not Known	Eggs of herring gulls and black-crowned night heron were found to contain elevated levels of some organic chemicals. These levels appear to be declining over time; however, no evaluation has been made of the effect on these colonies in the Niagara River area. Reproductive success of Bald Eagles and Mink is a Great lakes basin-wide problem.	Further assessment is required to determine the degree and extent of reproductive impairment in the Niagara River.
VI	Degradation of Benthos	Impaired	Benthos (sediment dwelling organisms) are relatively sparse in the Niagara River due to the lack of suitable substrate. However, in backwater areas of the Niagara River, the species abundance and diversity is unimpaired. In the Welland River, particularly the lower river below Welland and in other tributaries, benthic diversity has decreased to more pollution tolerant species. These have been linked to sediments with elevated metal concentrations. In three areas with extremely high metal concentrations, no benthic organisms exist.	

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
VII	Restriction on Dredging Activities	Impaired	Little sedimentation occurs on the Ontario side of the Niagara River and dredging is not required for channel maintenance. Sediments in the lower Welland River show metal concentrations above open water disposal guidelines and draft Provincial Sediment Quality Guidelines for benthic organisms.	
VIII (a)	Eutrophication	Impaired	Accelerated eutrophication occurs in the Welland River and in parts of the Niagara tributaries. This is a result of a combination of low flow conditions and elevated nutrient levels in summer months.	
VIII (b)	Undesireable Algae	Not Impaired	Some algal species (principally Cladophora) are found in the Area of Concern but not at nuisance levels. Less desirable algae can be carried into the Niagara River from Lake Erie to Lake Ontario. This occurs occasionally, the latest occurrence was in summer of 1991.	

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
IX (a)	Restrictions on Drinking Water Consumption	Not Impaired	Although drinking water taken from the Niagara River continues to be a public concern, no exceedence of drinking water quality criteria has been recorded for water supplies in the Ontario portion of the Area of Concern. There continues to be public concern over chronic exposure to low concentrations of chemicals in municipal water supplies.	
IX (b)	Taste and Odour Problems	Impaired	Until 1991, general taste and odour problems have not been noted in Niagara area municipal water supplies. In the summer and fall of 1991 taste and odour problems were identified in most Niagara municipal supplies (including those drawing water from Lake Erie and the Welland Canal). These problems were also noted for other systems drawing from eastern Lake Erie. The cause is believed to be algal blooms and die-off in Lake Erie. Ground water in the Niagara Area of Concern also exhibits taste and odour problems, mainly due to high levels of naturally-occurring sulphides in the aquifer. Most of the problem is resolved using conventional water treatment technology.	Additional monitoring required to establish cause and to determine whether this is a recurrent problem.

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
X	Beach Closings	Impaired	Beaches along the Niagara River are generally found in small quiescent areas away from the rivers high velocities. Beach closings have occurred on a fairly routine basis over the past decade. In addition to the contributions from CSO's, the slow moving waters of swimming areas combined with high use and a plentiful waterfowl community are all believed to contribute to the problem.	
XI	Degradation of Aesthetics	Not Impaired	Public complaints are received routinely on aesthetics at Niagara Falls. High suspended solids levels contribute to a tan colouration in the spring that is often mistaken for chemical contamination. Similarly, significant quantities of foam are generated by the action of the falls, this foam is predominantly decayed vegetative matter, coloured by the same clay solids. Although aesthetically displeasing, it is mostly natural in origin.	There may be a correlation between the naturally occurring foam, artificial surfactants and other contaminants.

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
XII (a)	Added Costs To Agriculture	Not Impaired	Water used for agricultural purposes in the Area of Concern comes mainly from wells and small tributaries. There is a shortage (volume) during drought conditions in the Niagara Peninsula; however, water quality problems are with high mineral content of the ground water. Surface waters although low in quantity appear to be acceptable in quality. Some fruitbelt areas use Niagara River water without additional costs for water treatment.	
XII (b)	Added Costs To Industry	Not Impaired	Industrial and Municipal water pretreatment and maintenance costs have increased with the introduction of zebra mussels to the Area of Concern.	
XIII (a)	Degradation of Phytoplankton Populations	Not Known	No extensive floating plant community stays in the Area of Concern. The swift flowing nature of the river prevents a buildup of any phytoplankton. If it is present, it is received from Lake Erie and passed rapidly on to Lake Ontario. Little is known about the status of attached algae and aquatic plants.	This does not appear to be a factor in the Niagara River but further information may be needed particularly in the Welland River and its tributaries.
XIII (b)	Degradation of Zooplankton Populations	Not Known	Similar to phytoplankton, no extensive floating animal community stays in the Niagara River. All species inherited from Lake Erie pass quickly on to Lake Ontario.	This does not appear to be a factor in the Niagara River but further information may be needed in the Welland River and its tributaries.

TABLE A (Con't)

IJC Criterion	Beneficial Use Impairment	Status of Impairment	Description of Environmental Conditions	Requires Further Assessment
XIV (a)	Loss of Fish Habitat	Impaired	Within the Niagara River itself, the habitat is largely unchanged by human activity. The Niagara River flow maintains and changes its own system. In the tributary streams, activity by humans has caused a large loss in aquatic habitat through filling, channelization, drainage, shoreline reconstruction and development. A combination of erosion of native clay soils and introduction of contaminants has led to high suspended solids in the water column and siltation of spawning areas often including elevated levels of nutrient and heavy metal contamination.	
XIV (b)	Loss of Wildlife Habitat	Impaired	The encroachment of civilization within the Niagara River (Ont.) Area of Concern has led to a decrease in the native habitat of wildlife over the past century. The loss of habitat has led, in part, to the extinction or endangerment of several species. Water quality degradation may play a part; however, little data exists on wildlife habitat in the Niagara River Ont.) Area of Concern.	

Impaired Beneficial Uses

The determination of impaired beneficial uses in the Niagara River (Ont.) Area of Concern was made using the IJC Listing/Delisting Criteria, MOE/MNR Fish Guides and Provincial Water Quality and Drinking Water Objectives and Provincial Sediment Quality Guidelines.

Impaired beneficial uses are identified individually in Table A along with a brief discussion of the impairment.

Other Environmental Concerns

During the RAP process, there were several issues raised which were not necessarily related to the IJC 14 use impairment criteria. These additional concerns are identified in Table B along with a brief discussion of the issue.

Cause Of Use Impairments

A cross reference matrix of the impaired uses versus known and potential sources is presented in Table C. This table summarizes the linkages that have been established using the database available and also identifies where other linkages may exist but more information is needed to definitely establish the link.

Sources of contamination within the Area of Concern are discussed in detail in Chapter 5 of this report. Since many problems are associated with outside sources, these are discussed separately in Chapter 6.

Unimpaired Beneficial Uses

A considerable number of beneficial uses are currently unimpaired by water quality in the Niagara River (Ont.) Area of Concern. The list of beneficial uses which are not impaired are presented in Table A along with a short discussion on the current state of that use.

The Future

A recent trend towards water quality improvement appears to be continuing despite human encroachment on the ecosystem. Some past problems have already been rectified, many more are currently being addressed. Present problems are being abated and new issues are being resolved before they become problems. The Niagara River AOC has an adaptive ecosystem; however, civilization has enacted some dramatic changes on it. For decades, people have been part of the problem; we must now be part of the solution. This region will never return to pristine condition but, with our help, it can return to a useful, balanced, self-sustaining ecosystem.

In order to allow nature to restore the Niagara River while we clean up past practices, we must no longer abuse its resources. The principles of sustainable development and environmental responsibility must guide our activities for the future.

TABLE B

OTHER ENVIRONMENTAL CONCERNS		
	Concern	Description of Impairment
	Zebra Mussels	The influx of the zebra mussel into the Niagara River Area of Concern has affected a number of beneficial uses of the river and its tributaries. Chief concerns involve clogging of drinking water intakes and submerged outfalls, accumulation at swimming areas, loss of aquatic habitat, competition for food and the impact on the scenic resource at Niagara Falls.
	Uncontrolled Development	Uncontrolled community development, whether it is industrial, commercial or residential and its impact on the ecosystem has been raised as a concern.
	Uncontrolled Development	Uncontrolled community development, whether it is industrial, commercial or residential and its impact on the ecosystem has been raised as a concern.
	Human Health	There has been concern expressed over the need for source control of contaminants in order to protect water supplies and ensure that fish from the river are safe to eat.

TABLE C

CAUSES of USE IMPAIRMENT Area of Concern: NIAGARA RIVER											
	Impaired Use Criterion										
SOURCES OF PROBLEM WITHIN AREA OF CONCERN	Ia Fish consumption restrictions	IIIa Degradation of fish populations	VI Degradation of benthos	VII Dredging activity restrictions	VIIIa Eutroph-ication	IXb Taste and odour problems	X Beach closings	XI Degradation of aesthetics	XIIb Added cost to industry	XIVa Loss of fish habitat	XIVb Loss of wildlife habitat
Industrial Point Sources	YES	MAY	YES	YES	YES						
Municipal Point Sources	YES				YES						
Combined Sewer Overflows			MAY		YES		YES				
Urban Runoff	MAY	MAY	MAY		YES		YES				
Rural Runoff		MAY			YES		YES				
Landfills											
Sediments	MAY	MAY	YES	YES	MAY					YES	
Short-range Atmos. Deposition											
Contaminated Groundwater											
Spills	MAY	MAY	MAY								
Contaminated Industrial Plantsites											
Natural Sources						MAY	MAY	YES		MAY	MAY
Development Pressures		MAY	MAY		MAY			YES		YES	YES
SOURCES OF PROBLEM OUTSIDE AREA OF CONCERN											
Niagara River (NY) AOC	YES	MAY	MAY	MAY				YES	YES	YES	
Natural Sources						MAY		YES			
Exotic Biological Species		MAY							YES	YES	
Lake Erie / Lake Ontario	MAY	MAY				MAY					
Buffalo River AOC	MAY	MAY									
Long-range Atmos. Deposition											

For those interested in more detailed Niagara-related environmental information, repositories of reports, papers, texts and mapwork have been established for public access by Public Advisory Committees of both Niagara River RAPs at the following locations:

In Canada	In the United States
Niagara Falls Public Library Main Branch 4848 Victoria Avenue Niagara Falls, Ontario	New York State Department of Environmental Conservation Region IX Office 270 Michigan Avenue Buffalo, New York

1.0 ENVIRONMENTAL CONCERNS

1.0 ENVIRONMENTAL CONCERNS

Governmental agencies and private interests have been investigating the Niagara River for decades. In the beginning, concerns and studies centred on conventional contaminants such as bacteria, colour, oil, metals and nutrients. These concerns were not unique to the Niagara River but existed as a global problem: the discharge of raw or partially treated sewage to the waters of the world. In the mid-1950's, in the Great Lakes basin, the Province of Ontario and the Government of Canada started a massive construction programme of municipal sewage treatment plants in conjunction with Ontario municipalities.

Over the last three decades, treatment of sanitary sewage has improved tremendously in terms of the number of plants and improvements in technology, both in Ontario and in the eight Great Lakes States. As technological advances in science during the same period led to the identification, investigation and understanding of more complex substances in more complex media, concern has changed to the problem of eliminating toxic substances from the environment.

The environmental agencies of Canada, the United States, Ontario and New York have recognized that the vast majority of the pollution in the Niagara River comes from the New York side of the river.

The State of New York is currently preparing similar Remedial Action Plans (RAPs) for both the American side of the Niagara River and the Buffalo River. The Buffalo River RAP is currently in Stage III while the U.S. Niagara River RAP is in Stage I generation.

1.1 Pollution of the Great Lakes

Canada and the United States of America signed the Boundary Waters Treaty in 1909 and established the International Joint Commission for the Great Lakes (IJC). The IJC was formed to co-operatively resolve problems along the common border, including water and air pollution, lake levels, power generation and other issues of mutual concern.

The Governments of Canada and the United States, as early as 1912, asked the IJC to examine the extent and causes of pollution in the Great Lakes. The Commission identified specific water bodies, including the St. Marys, St. Clair, Detroit, Niagara and St. Lawrence Rivers, as being polluted with raw sewage. This pollution affected nearby human populations; waterborne diseases such as typhoid and cholera were common. The Commission identified sources of pollution and recommended specific remedial actions such as water purification and wastewater treatment. Such actions eventually contributed to the elimination of these diseases in the Great Lakes basin.

In the early 1960's, nutrient enrichment was being accelerated, particularly in the lower Great Lakes. In 1964 Canada and the United States requested the IJC to undertake a study into the causes of pollution in the lower Great Lakes, including the recommending of solutions. The IJC investigated the problem from 1964 to 1968 and a final report was submitted to the governments of Canada and the United States in 1970. The study concluded that the lower lakes were suffering from accelerated eutrophication. The IJC's recommendations were embodied in the 1972 Great Lakes Water Quality Agreement (GLWQA) that was signed by the Governments of Canada and the United States. The Governments of Canada and Ontario are both represented on the IJC boards. In Canada, joint federal-provincial environmental commitments are coordinated through the Canada-Ontario Agreement. This agreement sets the rules and the responsibilities of the various agencies and is renewed every five years by the parties.

In response to pollution problems reported by the IJC in 1948 and other Great Lakes studies, the governments undertook a programme in the 1960's and 1970's to provide adequate sewage treatment to municipal discharges within the Great Lakes basin. These facilities, together with similar controls on industrial discharges have largely eliminated problems with conventional contaminants in the basin.

Since the early 1970's, the complexity of environmental problems has become evident. In 1978, the GLWQA was revised and expanded to address the loading of toxic substances to the Great Lakes. An ecosystem approach was adopted whereby the interactions of land, air, water and all lifeforms were considered.

In 1987, the two nations reaffirmed their commitments to clean up the Great Lakes in a second revision of the Great Lakes Water Quality Agreement. The 1987 I.C. PROTOCOL incorporated more recent concerns and information including the issue of persistent toxic substances, Areas of Concern and the development of Remedial Action Plans.

As a result of the Agreements, considerable monies have been spent by the two countries, the eight Great Lakes States and the Province of Ontario to reduce the pollution of the lower Great Lakes and the International portion of the St. Lawrence River by municipal sources through treatment of sewage streams and separation of storm water from sanitary sewage. Large amounts have also been spent by government and industry to reduce or eliminate pollution from industrial sources.

Health and Welfare Canada is currently embarked on health effect studies programmes to assess public health in the Great Lakes basin in general and the RAP Areas of Concern in particular.

Goals of the program include determining the nature, magnitude and extent of effects on human health of exposure to contaminents, developing strategies to reduce the risk and improving communication and consultation on health-environment issues.

1.2 Pollution of the Niagara River

Early development of the Niagara Frontier, based largely on economic criteria, has proven to be the cause of environmental problems both in the Niagara River and the surrounding area. (Fig. 1.1)

The earliest recognized chemical pollution problems in the Niagara River were identified in a 1948 study by the IJC as sewage, bacteria, oil, phosphorus, chloride, phenol, mercury and general discolouration.

In the 1980's, the focus shifted to contamination by toxic substances. This shift has been particularly true for the Niagara River, where concern has also centred on the effects of these chemicals on human health and the ecosystem. A toxic substance is defined by the IJC as one which can cause death, disease, behaviourial abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring or which can become poisonous after concentration in the food chain or in combination with other substances. A persistent toxic substance in water is defined as a toxic substance with a half-life (time at which half of the original amount of chemical still exists) of greater than eight weeks.

In addition to the activities and attention of government agencies, public attention around the Great Lakes basin focused on the Niagara River in 1981 when the New York Public Interest Research Group (NYPIRG) released its study on toxic contamination of the Niagara River entitled "The Ravaged

River"[2]. In that study the authors restricted their concerns and subsequent investigations to the U.S. side of the Niagara River. The report presented information on discharge of industrial wastewater, historical landfilling activities and the threat that both present to the natural integrity of the Niagara River, the quality of its surrounding environment and the health and well-being of the people who drink water drawn from this source.

The NYPIRG recognized that during the 1970's, environmental awareness had led to a substantial amount of public funds being used to improve water quality. These efforts had centred, by and large, on controlling degradable biological wastes and little progress had been made on the control or elimination of toxic chemicals. The same conclusions could be drawn for the Canadian side of the Niagara River, although to a much smaller degree, since the Canadian side is much less developed and populated.

Since the early 1980's, technological advances have produced far more sophisticated analytical equipment and methodology than before. This has enabled scientists to detect a far greater number of chemicals and at much lower concentrations (several orders of magnitude) than in previous decades. These capabilities have contributed to the perception that the Niagara River is more polluted now than in the past. Our ability to detect chemicals at these lower concentrations has outpaced our understanding of the short and long term effects at these levels on either human health or the ecosystem. In many cases, the scientific basis for understanding the environmental and human health significance of these chemicals, both alone and in concert with other chemicals, is not well understood. The determination of toxicological effects is both difficult and expensive; it will also take considerable time to establish results with some certainty.

Research is only now clarifying the link between toxic substances in the Niagara River and the subsequent effects on the ecosystem. Some conditions in Lake Ontario such as the occurrence of dioxin and mirex in Lake Ontario sports fish can be attributed directly to conditions in the Niagara River. In some instances, commercial fishing in Lake Ontario has been restricted as a result of mirex and PCB levels; these restrictions are partly attributable to contaminants introduced by the Niagara River. There is also a possibility that some chemicals from the Niagara River, although not a problem themselves, may, in the presence of chemicals from other sources around Lake Ontario, generate synergistic reactions which contaminate the water, sediment or biota in the lake. Such synergistic reactions, although less direct, can have just as significant an effect as specific contaminants.

Toxic chemical contamination of the Niagara River is a complex problem. Toxic chemicals have probably been in the Niagara River for years, over the entire period of their production and continuing to the present. Analyses of sediment cores taken from the Niagara Sediment Bar in Lake Ontario have indicated that many of these substances were present in the river as long ago as the first quarter of this century. This time period coincides with the establishment of industrial complexes on the banks of the river.

Existing long-term water quality data generally show a decline in the concentration of many contaminants in the river when compared to levels found during the 1960's.

One of the biggest worries to the public is the contamination of potable water. There is widespread concern among the public that the consumption of water containing toxic contaminants has led to a general decline in the health of the residents of the Great Lakes area. For those chemicals for which drinking water standards exist, monitoring data shows that Niagara River levels are below current Canadian, U.S. and World Health Organization limits. Development of drinking water standards, as for other standards, is a dynamic process. There are chemicals present in the Niagara River for which drinking water standards do not exist. It has not yet been determined whether standards should be established for these chemicals or if these substances have any detrimental effect on humans. With respect to the public's perceived de-

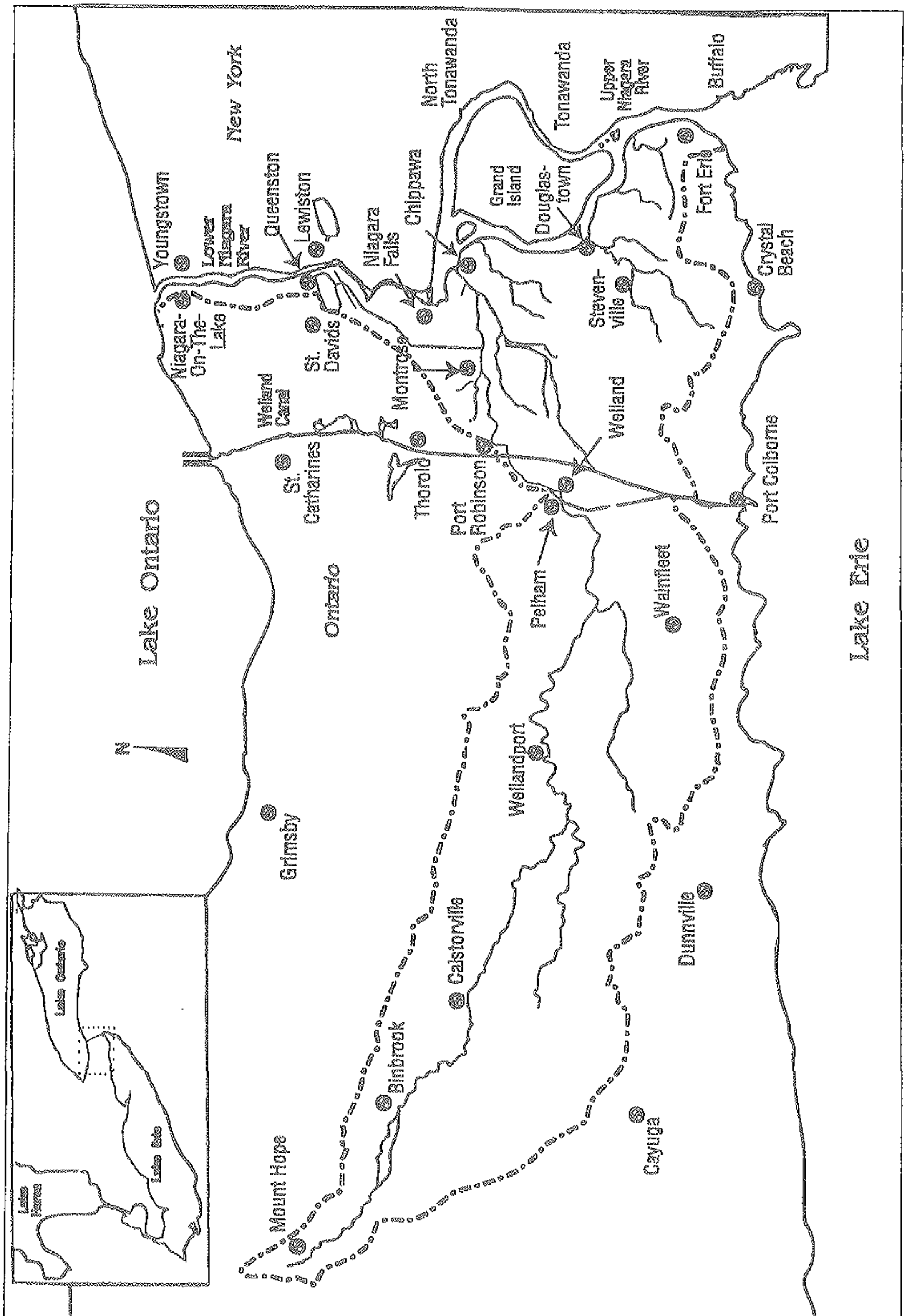

Figure 1.1

Niagara River Area Of Concern - Municipalities

cline in health due to contaminants in drinking water, it may be that, similar to advances in science, parallel advances in medicine have increased our capabilities to detect disease far more readily than was possible in the past. Therefore some consideration must be given to the possibility that increasing instances of disease may be related to a better capability of diagnosing these diseases. To date, study information is not available comparing differences in health between residents of the Great Lakes basin and control groups that would confirm whether or not the perceived deterioration in health levels is a real phenomenon.

Toxic substances have been detected and are routinely monitored in the effluents of industrial and municipal facilities discharging to the river. They have also been detected in urban stormwater runoff. In addition, major toxic waste disposal sites have been identified along the eastern bank of the Niagara River and many of these are known to leak contaminants into the river.

Contamination of the Niagara River Area of Concern (Figure 1.1) by toxic chemicals may be the predominant issue; however, environmental degradation by conventional contaminants such as nutrients and bacteria is still a problem in the Niagara tributaries and feeder streams and to a lesser extent in the Niagara itself. In the tributary portions of this Area of Concern, aquatic and wetland habitat has been disturbed or lost due to the activities of man. Siltation is also a significant problem in the Niagara River tributaries, particularly the Welland River. In significant portions of these streams, soil has been carried downstream and deposited in critical habitat areas. This sediment, although not normally thought of as a contaminant, has nonetheless physically degraded the environment.

Soils in the upland areas of the Area of Concern are eroded both by the activities of people and their livestock and by precipitation runoff. The soil is suspended in the tributary waters as sediment and either drops out in the tributary or is carried out into the Niagara River and deposited on the Niagara Sediment Bar. This area, referred to as the 'Niagara Bar' (Figure 1.2), is located in Lake Ontario to the north of Niagara-on-the-Lake.

During their passage down the Niagara River, the finer clay particles become highly contaminated, and subsequently, where these clay sediments fall out of the water column, a heavily contaminated depositional area is found.

1.3 Environmental Data Base

Data collections which started in the mid-1970's have now developed into immense databases. In the early 1980's, the Niagara River Toxics Committee (NRTC) collated and analyzed all of the 1980-1982 data for the Niagara River[343,209]. That work is presented in a 1984 report[30].

Since 1984, Environment Canada, the Ontario Ministry of Natural Resources and the Ontario Ministry of the Environment have undertaken subsequent studies both in concert with, and in addition to, the NRTC report recommendations. These studies involve the following:

1) annual monitoring of a wide range of conventional and toxic contaminants from all point source discharges;
2) detailed investigations of all landfills identified in the NRTC report and estimation of the loading of contaminants to the Niagara River from these sources;
3) regular biomonitoring of contaminants using freshwater mussels and leeches, <u>Cladophora</u> and spottail shiners;
4) intensive year-round monitoring of river water for chemical concentrations at Fort Erie and Niagara-on-the-Lake;

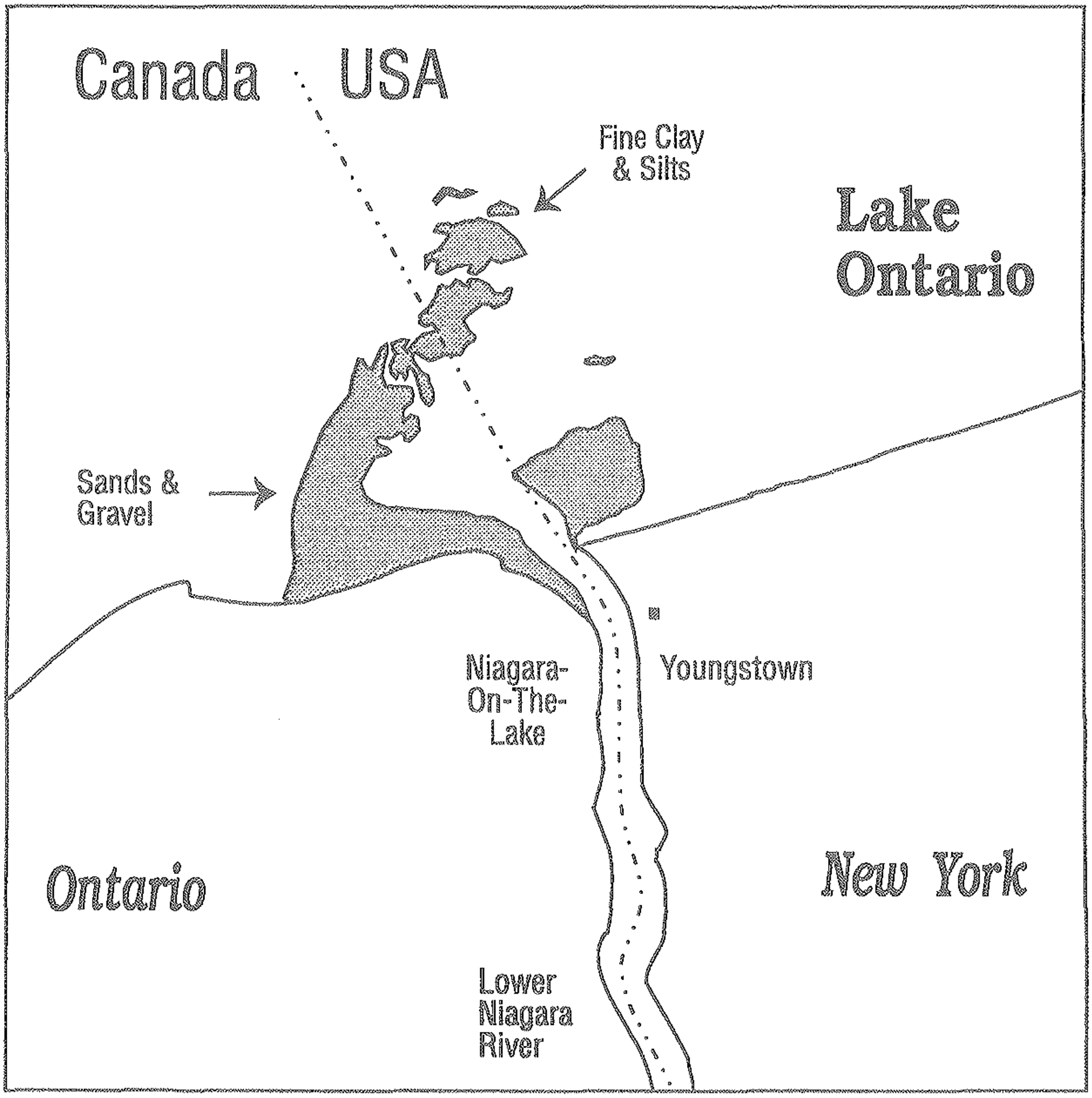

Figure 1.2 ***Niagara Sediment Bar***

5) intensive monitoring of chemical concentrations in raw and treated drinking water at filtration plants in the Niagara Peninsula;
6) annual sampling and analysis of fish flesh from sport and forage species in the upper and lower Niagara River and nearby areas of Lake Ontario to determine toxic contaminant body burden and establish consumption advisories where required;
7) detailed, intensive monitoring of tributaries to the Niagara River to establish the relative proportion of contamination from each of these sources.

1.4 Areas of Concern

Over the past decade, great progress has been made to overcome the effects of more than a century of unabated pollution in the Great Lakes basin. Despite this progress, serious problems remain. The Great Lakes Water Quality Board, which advises the IJC on water quality issues has identified 43 Areas of Concern in the Great Lakes basin. These Areas of Concern include the major municipal and industrial centres on Great Lakes tributaries, Great Lakes harbour areas and the interconnecting channels. In each of these areas, the objectives, standards, criteria or guidelines of one or more environmental agency have been exceeded. The IJC requires that remedial measures be instituted to restore and maintain desired beneficial uses. These may include use as municipal and industrial water supplies, recreational activities and unrestricted use by aquatic life.

1.5 Remedial Action Plans

The Province of Ontario and the eight Great Lakes States have committed themselves to the development of Remedial Action Plans to restore all beneficial uses in the Areas of Concern within their jurisdictions. In Ontario, the Governments of Canada and Ontario are working under the framework of the Canada-Ontario Agreement Respecting Great Lakes Water Quality (COA), to jointly develop Remedial Action Plans for the 17 Areas of Concern within the Province.

A Remedial Action Plan or RAP is a plan to restore and protect water quality in an Area of Concern. The complete ecosystem must be considered as it relates to the aquatic component within this Area of Concern.

The RAPs ultimately will identify specific measures necessary to control existing sources of pollution, abate environmental contamination already present restore beneficial uses and pre pollution sources.

The development of RAPs will be a coordinated effort amongst all programmes, agencies, communities and the public in an Area of Concern. These diverse groups will come together to work on common goals and objectives. These RAPs represent the first concerted effort in most Areas of Concern to restore beneficial uses. They reflect the ecosystem approach outlined in the 1978 Agreement to protect the waters of the Great Lakes system. The ecosystem approach[66] involves consideration of all water dwellers and users in addressing pollution concerns.

Components of any Remedial Action Plan include, but are not limited to, municipal and industrial wastewater treatment, hazardous waste management, non-point source pollution control, ground water management, fisheries and wildlife management, harbour maintenance and dredging, land use planning and recreation.

Eight specific elements will be included in the Remedial Action Plan. These are:

1) Definition and detailed description of the environmental problem, including the extent of the affected area,

2) Identification of the beneficial uses that are impaired including the degree of impairment,

3) Description of the causes of the use impairment and identification of all sources of pollution that may have contributed to these problems,

4) Evaluation of the remedial actions in place, as well as those additional measures necessary to restore the impaired beneficial uses to the Area of Concern,

5) Selection of remedial measures and development of a schedule for their implementation and completion,

6) Identification of the parties responsible for the implementation and regulation of these remedial measures,

7) Development of a method for monitoring the implementation and evaluating the effectiveness of the remedial programme and

8) Design of a surveillance and monitoring programme that will be used by the various participants to gauge the effectiveness of the remedial measures and eventually confirm that the impaired uses have been restored to the Area of Concern.

This Stage I addresses elements 1) through 3).

1.6 Public Involvement

Public involvement is an important part in the RAP process. Every person or organization that has an interest in or responsibility for the Niagara River is considered to be part of the public, and is encouraged to become involved in the development of the RAP.

1.6.1 The Public Advisory Committee

In November of 1988 the Ministry of the Environment held a series of public meetings in Niagara-on-the-Lake, Niagara Falls and Fort Erie to present the RAP programme. These meetings provided an opportunity for those citizens, organizations, etc., who wanted greater involvement in the RAP to join and participate in a Public Advisory Committee (PAC). As a result, the Niagara River Public Advisory Committee was established in January of 1989.

The PAC operates as an advisory body to the RAP Team, representing a variety of views on key aspects of the RAP preparation and implementation. Information was provided to the PAC on the issues within the Niagara River Area of Concern during early 1989. This included presentations by the Ontario Ministry of Natural Resources on the ecosystem components, the Ontario Ministry of the Environment on the new sediment quality criteria development and by Environment Canada on the Niagara River sampling program.

The PAC considers all views presented by the general public in formulating its consensus during the development of the RAP. The committee consists of representatives from major sectors having interests in the Niagara River Area of Concern. Representatives from the following sectors are participating on the PAC:

- environmental and public interest groups
- university and high school staff & students
- recreation and tourism interests
- industry
- municipalities
- labour
- health
- agriculture.

1.6.2 PAC Organization

The PAC is chaired by Prof. Ian Brindle from Brock University. It meets regularly on the evening of the second Tuesday of each month at Niagara Falls in the City Hall Council Chambers. The meetings are conducted using the parliamentary system and minutes are recorded and filed. The PAC has appointed sub-committees to address specific issues. The RAP Co-ordinator or alternate attends all meetings. All PAC meetings are open to the general public and are advertised in the local media.

1.6.3 The Community Liaison Coordinator

The PAC has employed the services of a Community Liaison Coordinator (CLC), through whom all PAC matters are directed. The CLC has established the PAC office and the telephone/fax number is advertised in the local and Toronto directories for the convenience of those members of the public who wish to obtain information on the RAP program, etc. Collect calls are accepted. The CLC co-ordinates all meetings and activities of the PAC and its subcommittees; this includes attending all meetings (including RAP Team meetings), recording minutes, preparing agendas and circulating reports. To facilitate the flow of information between various groups during the development of the RAP, the CLC liaises with the public, government agencies (both in Ontario and the U.S.) and the PAC. The CLC networks with other PACs through such events as the Ontario PAC Council meetings, and the IJC RAP Forum (Traverse City, Michigan, September 27 & 28, 1991) and reports back to the PAC.

Special projects or proposed public outreach activities are planned and carried out with the help of the Community Liaison Coordinator. Details are presented in the section on public outreach activities.

1.6.4 The PAC Terms of Reference

The PAC operates under a Terms of Reference it established in 1988 and revised in January 1992. This includes a description of how it relates with the RAP Team and the public at large and defines the roles and responsibilities of the PAC as a whole, the PAC Chair, PAC Commission Liaison Coordinator and each of the individual member organizations and their representatives. The criteria for membership on the PAC are outlined and the rules of PAC operation are identified.

The Terms of Reference are summarized in a Factsheet entitled "Public Advisory Committee (PAC) Terms of Reference" which outlines these responsibilities, roles and objectives of the PAC.

1.6.5 The PAC and Input Into the RAP

The PAC has a three-fold mandate:

- to provide advice and assistance to the RAP Team
- to implement public outreach activities
- to liaise between the Canadian and U.S. Niagara River RAPs.

The PAC achieves input into the RAP through various sub-committees, which meet on a regular or " as required" basis. These are:

1) The International Advisory Committee (IAC)
2) The Technical Sub-committee
3) The Communications and Editorial Sub-committee
4) The Land-use Sub-committee.

In addition, the PAC provides direct input through participation of 2 representatives on the RAP team.

1.6.6 The International Advisory Committee (IAC)

The IAC is composed of 5 PAC members and 5 members of the Niagara River Action Committee (NRAC) of the U.S. RAP, including the PAC Chair and the NRAC Co-chair. The IAC acts as a forum for the exchange of information, discussion of common concerns, and the development of joint activities between the two RAPs on the Niagara River. The IAC meets each month, with the meeting venue alternating between Ontario and New York State. The host country chairs the meetings and records the minutes. Agenda items are discussed and agreed upon for each of the meetings.

The IAC has provided a forum for review of the RAP Stage 1 documents. The NRAC members were provided with copies of the draft RAP Stage 1 (Ont.) document. Comments from the NRAC were directed to the PAC in a letter, and these comments were reviewed by the PAC before being submitted to the RAP Team. The Canadian IAC members and the Technical Sub-committee are presently reviewing the draft chapters of the U.S. RAP Stage 1 document. Their comments and requests for further clarification on some issues were discussed at the November 1991 IAC meeting. The PAC will convey its comments to the NRAC through a letter via the IAC when the complete draft RAP Stage 1 has been reviewed.

To date, joint activities undertaken by the PAC and NRAC via the IAC have included a boat tour of the upper Niagara River, and the establishment of repositories containing reports on pollution in the Niagara River. The NRAC repository is housed in the Buffalo office of the N.Y. Department of Environmental Conservation. The PAC's Niagara River Repository is housed at the Niagara Falls Public Library.

1.6.7 The Technical Sub-committee

The Technical Sub-committee acts as an advisory and technical review body to the PAC. It meets between PAC meetings as required to review and provide comments and suggestions on material of a technical nature. The Technical Sub-committee facilitates PAC decisions on various issues presented for consideration during the RAP process. Any issues arising from PAC meetings that require further consideration are usually referred to the Technical Sub-committee. On several occasions the Technical Sub-committee has made recommendations to the PAC for discussion or endorsement.

Response to the RAP Stage 1 draft document by the PAC has been provided primarily by the Technical Sub-committee. It reviewed the RAP Stage 1 (Ont.) report and presented detailed written comments to the PAC for discussion before submission to the RAP Team. The Technical Sub-committee is presently reviewing the draft chapters of the NRAC RAP Stage 1 (U.S.) report. Comments will be conveyed to the IAC members, who will in turn present and discuss these issues at the IAC meetings.

Most recently, in Stage 2 of the RAP, the Technical Sub-committee has reviewed and discussed in detail the preliminary identification of remedial options compiled in a technical options, discussion document. Comments from this review have been brought to PAC meetings for discussion and clarification, and subsequently directed to the RAP Team for integration into the technical options report.

1.6.8 The Land-use Sub-committee

The Land-use Sub-committee was established to address concern expressed by the PAC on various land-use issues in the AOC. To date the sub-committee has commented on the need for a discussion on tourism.

1.6.9 The Communications & Editorial Sub-committee

The Communications & Editorial Sub-committee was established to design, develop and implement public outreach activities. These activities inform the public of the RAP process and provide an avenue for receiving suggestions, comments, etc., from the public.

One of the first accomplishments of the sub-committee was the production of a slide-show and script, which explains the environmental problems in the Niagara River AOC, the Niagara River RAP and the PAC's involvement in the RAP process. The slide-show and a portable display system has enabled the PAC to provide extensive information to the general public at various events, such as:

1990:
- Environment Day, City of Niagara Falls, June 1990
- Niagara Falls University Women's Club, October 1990.

1991:
- Brock University's 'Two Days of Canada' Conference, February 1991
- High Schools, A.N. Myer's Global Awareness Day, May 1991
- Niagara South Board of Education's Environmental Conference, May 1991
- Environment Day, City of Niagara Falls, June 1991
- Canada Day exhibit in Optimist Club, Niagara Falls, July 1991
- Christ Church, River Road, Niagara Falls, October 1991
- Niagara Square Shopping Mall, November 1991
- RAP Stage 1 Media Familiarization Tour of the main points of interest in the AOC, November 1991.
- Maclean-Hunter Cable Television Interview, December 1991.

During the summer and fall of 1991 the display system was exhibited at Niagara Falls, St.Catharines, Welland and Fort Erie public libraries.

Factsheets on the Niagara River and the RAP program are available as handout material to the general public. Also, a business card with details of the PAC office address, telephone and fax numbers is available.

Through the sub-committee, the PAC has recently produced a document entitled "The Niagara River - How did we get to this Stage?" This report has been produced at the initiative of the PAC and under the collaborative direction of the PAC, RAP Team and the Canada-Ontario Agreement (COA) Steering Committee. It was prepared to present the problems, both real and perceived, to the public in the AOC. This report includes a tear-off strip, which has been designed by the PAC to solicit comments from the general public or requests for further information or slide-show presentations.

Also, the PAC has produced a newsletter "Current" which contains up-to-date information on the RAP and activities within the AOC.

These documents are available to the general public in both English and French, and are being actively distributed through networks of local citizens.

A recent public outreach campaign was held to publicize the Stage I activities and the work of the PAC during the week of November 4, 1991 and included the following:

- RAP Familiarization Tour of points of interest in the AOC for the media, November 5, 1991.
- CJRN Radio Talk-show on which the PAC Chair and the NRAC Co-chair were guests to provide information about the RAP process and public involvement, and they responded to questions telephoned in by the listening public.
- Niagara Square Shopping Mall, November 7 & 8, 1991. The slide-show and display system were exhibited and Factsheets were available for the general public.

1.6.10 PAC Activities

The PAC has been instrumental in establishing a pollution report repository. The establishment of the repository was recommended by the PAC to be available as reference material to the citizens of the community. The bibliography contains over 550 entries, and acquisition of the items commenced in September 1991.

To date the PAC has held 2 workshops for PAC members, the RAP Team and the general public to discuss the issues. In each case, the PAC scheduled a Saturday session, from 9:00 a.m. to 5:00 p.m., for which a Facilitator was employed to conduct the workshop, consolidate all comments and to provide a report of the proceedings.

The first workshop was held in January 1990, when the PAC identified impaired uses of the Niagara River, such as fishing, swimming and boating. From the report of the workshop, the PAC initiated the development of its goals.

The second workshop was held in February 1991 to review and comment on the RAP Stage 1 (Ont.) report. All comments from the PAC were considered by the RAP Team. Where appropriate, this report contains the PAC's recommendations and suggestions.

Since the January 1990 workshop, the PAC has been developing goals and objectives so that it might accomplish the mission it established at its inception "to protect and maintain the integrity of the ecosystem for the Niagara River." The PAC is presently going through the exercise of linking those goals and objectives.

The PAC has also been consulted and asked to either comment on or endorse special projects within the AOC. These have included the following:

1) Atlas Specialty Steels dredging project in the Welland River to remediate areas of sediment contamination.

   Members of the PAC sit on the Welland River Liaison Committee to provide continuity of concern in the RAP process. The PAC provided suggestions during the design and initiation of the demonstration project. With support from the PAC, the project received funding from Environment Canada's Federal Great Lakes Clean-up fund.

2) Infrastructure Needs Study by the Regional Municipality of Niagara. After a presentation about this study and discussion of its application to Stage 2 of the RAP, the PAC endorsed this project.

3) The PAC was presented with information on the proposed remediation by Cyanamid of its landfill sites in the north end of the City of Niagara Falls.

1.6.11 The Ontario PAC Council

Networking among the RAPs in Ontario is achieved via the Ontario PAC Council, which is comprised of representatives from each of the 16 PACs. The Chair of the Niagara River PAC represents the PAC at the PAC Council meetings. The PAC Council meets biannually at different AOCs. To date meetings have been held at the Bay of Quinte (October 1990, establishment of the PAC Council), Toronto (April 1991) and Hamilton (October 1991).

1.6.12 New initiatives for Public Involvement

The Niagara River PAC encourages involvement of all sectors in the community in the RAP process, including student participation. Student interest in the RAP has resulted in the discussion of a possible "student club" associated with and under the direction of the PAC. The student club is carrying out a "hands on" activity within the AOC in February 1992 to complement input to the RAP by the PAC.

1.6.13 Reports by the PAC

1) Niagara River RAP/PAC workshop to define water quality problem and use goals. Workshop Report January 27 1990.

2) Niagara River RAP/PAC Stage 1 Report Workshop Report February 2 1991.

3) "Niagara River - How did we get to This Stage." Joint RAP/PAC Report.

4) "Current" Newsletter, Fall 1991 Volume 1 No. 1.

5) "Au Courant" Newsletter, Automne 1991.

6) "La riviére Niagara - Comment en est-on arrivé lá ?" Jan. 1992.

2.0 DESCRIPTION OF THE AREA

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The complete Great Lakes area which drains into the Niagara River is 227,000 square kilometres (88,000 square miles) and encompasses the entire drainage basins of the four upstream Great Lakes: Superior, Huron, Michigan and Erie, as well as the Ogoki and Long Lake Diversion north of Lake Superior. The Niagara River "Area of Concern" (AOC) involves only that portion of the drainage area between Lakes Erie and Ontario (Figure 1.1).

The Niagara River is the major interconnecting waterway between Lake Erie and Lake Ontario (Figure 2.1). Flowing northerly from the former to the latter, the Niagara River drops some 100 metres (330 feet) in water elevation over a distance of 58 kilometres (37 miles). The river includes one of the seven natural wonders of the world, Niagara Falls (one of the world's major waterfalls), which physically divides the river into an upper and a lower section. More than half of the drop (56 m or 182 ft) in the Niagara River occurs over the Niagara Falls.

The border between Canada and the United States of America lies down the middle of the Niagara River. The west bank and tributaries on the west side of the river are the jurisdictions of Canada and the Province of Ontario. The east side is under the jurisdiction of the United States and the State of New York.

2.1 Physical Characteristics

On a regional scale, the Niagara River Area of Concern extends the entire 58 kilometre length of the Niagara River and, in Ontario, encompasses the Welland River drainage basin. The Welland River basin extends some 70 kilometres westward from the Niagara River to its headwaters in the agricultural area south of Hamilton. This Niagara-Welland drainage basin is predominantly agricultural in nature; a few urban centres are found in the area, notably the cities of Welland and Niagara Falls (Ont.) and the urban areas of the Towns of Fort Erie and Niagara-on-the-Lake. These centres are primarily residential, with a limited number of secondary industries.

At the head of the upper Niagara River (Figure 2.2), the flow is divided. Since the water flows very swiftly down the uppermost section between Fort Erie and Buffalo, the Black Rock Canal was built along the U.S. shore. This canal lies between Squaw Island (U.S.) and the New York State mainland. The canal extends upriver into Lake Erie towards Buffalo Harbour and downstream from Squaw Island towards Tonawanda. Water Levels in the Black Rock Canal are maintained by a set of locks beneath the International Railroad Bridge. The west bank of the canal is formed by the mass of Squaw Island extended by a concrete reinforced seawall which separates the canal from the river itself. The Canal was built to allow small cargo vessels to navigate this portion of the river, access docks on the New York side in Tonawanda, North Tonawanda and Niagara Falls and feed into the Erie Barge Canal in Tonawanda. Two bridges cross this section of the river, The Peace Bridge between Fort Erie and Buffalo permits road and pedestrian traffic between the countries. The International Bridge further downstream between Fort Erie and the north end of Buffalo via Squaw Island allows rail traffic across the river.

Below the fast-flowing section, a number of islands separate the river's flow. At a distance of 8 kilometres (5 miles) downstream from Lake Erie, sand-based Strawberry Island (U.S.) divides the upper river into two channels: the Chippawa Channel to the west and the Tonawanda Channel to the east. The channels are further separated by Grand Island (U.S.), the largest island in the Niagara River, which lies immediately downstream of Strawberry Island. Two bridges span the Tonawanda Channel from the U.S. mainland to Grand Island. The bridge to the north crosses to Niagara Falls (N.Y.); the one to the south

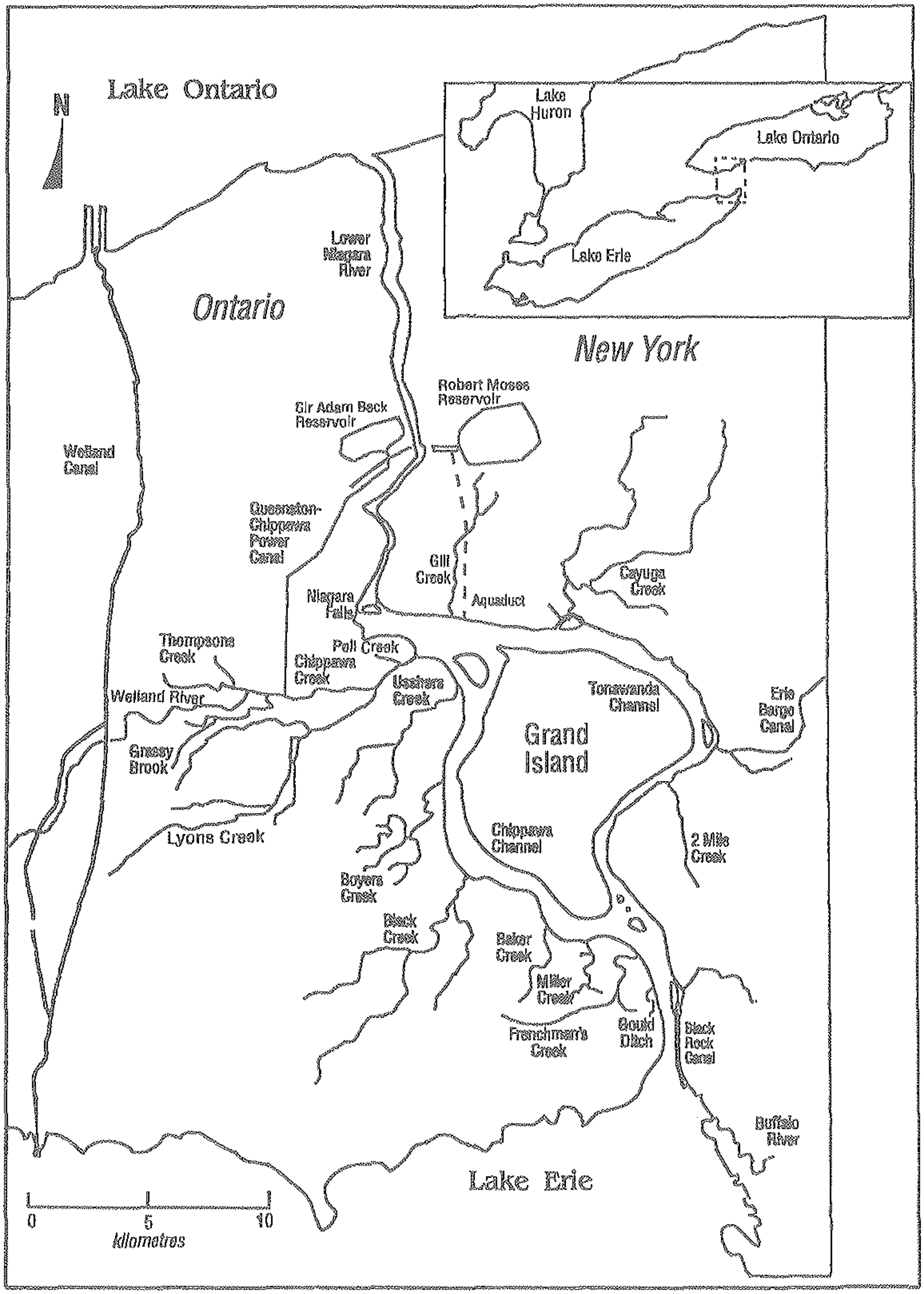


Figure 2.1 ***The Niagara River and Its Tributaries***

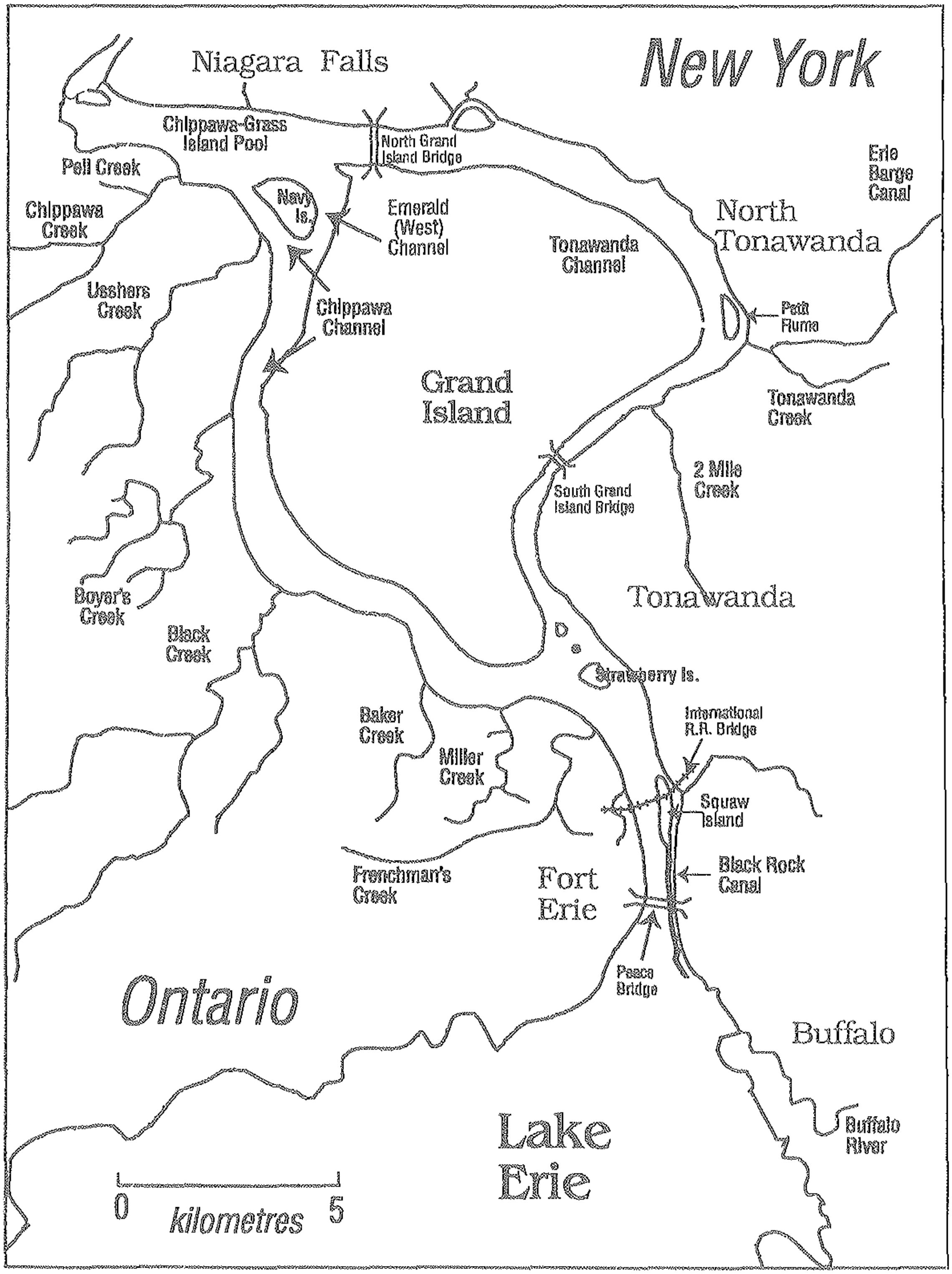


Figure 2.2 ***Upper Niagara River***

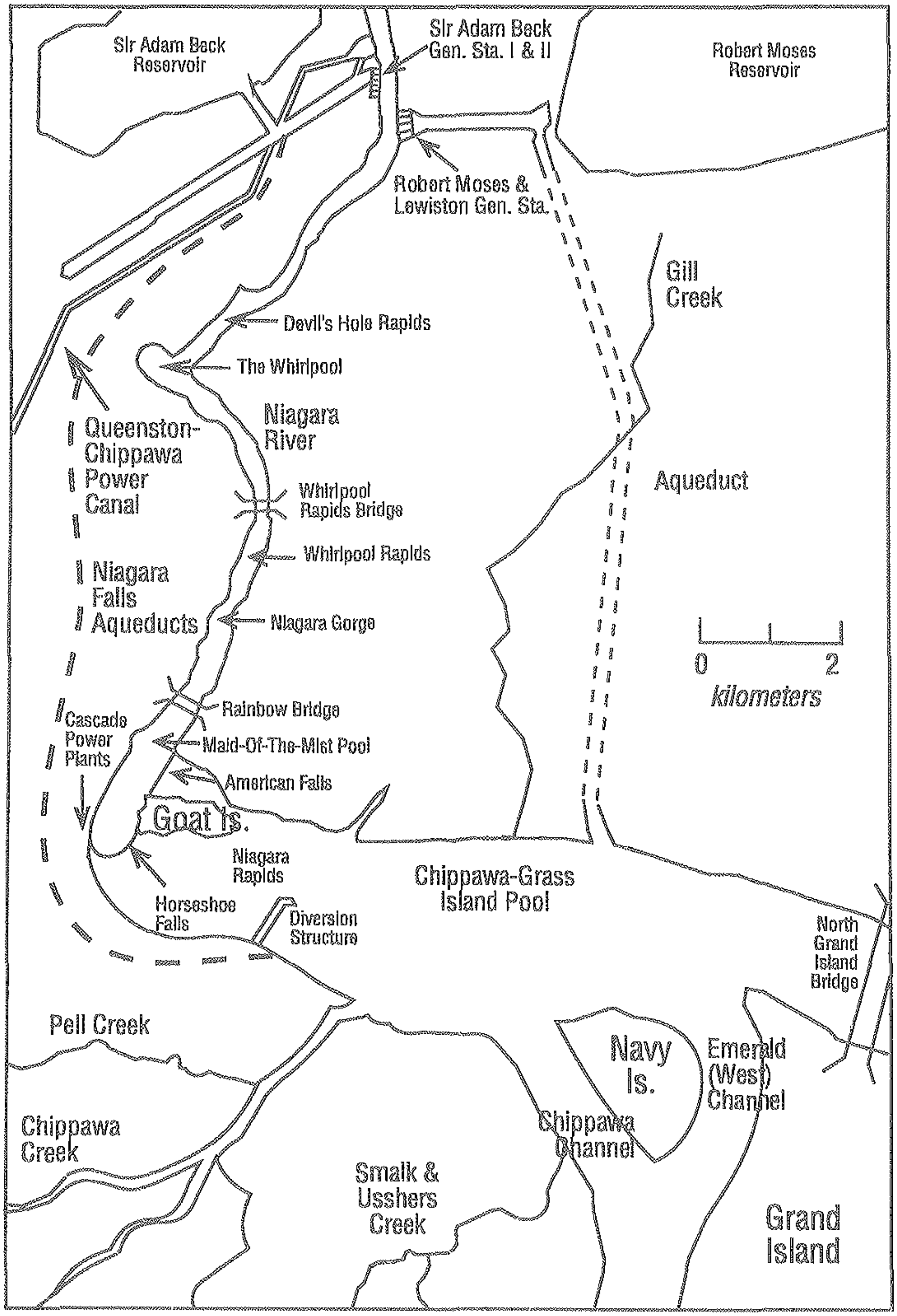


Figure 2.3 ***Niagara River - Niagara Falls***

links Grand Island to Tonawanda. Both bridges are part of U.S. Interstate 190. The Canada/U.S. border passes to the west of Grand Island in the Chippawa Channel. The 18 kilometre (11 mile) long Chippawa Channel, carrying about 57% of the flow, is a transborder waterway; the 24 kilometre (15 mile) long Tonawanda Channel, which carries the remaining 43% of the upper river flow, is completely in U.S. territory.

At the northwest corner of Grand Island (Figure 2.3), the Chippawa Channel is further divided into the Chippawa and Emerald (West) Channels by Navy Island (Can.). The international border passes down the Emerald Channel between Navy Island and Grand Island. Beyond (north) Grand and Navy Islands, the three channels recombine in a widening of the Niagara River known as the Chippawa-Grass Island Pool. This pool is a source of water for hydro-electric power generation. Water is diverted from the pool to generating stations at Lewiston (N.Y.) and Queenston (Ont.) as permitted by the 1950 Niagara Diversion Treaty. Between the control structure at the downstream end of the Chippawa-Grass Island Pool and the falls at Niagara Falls, a 1.5 kilometre (1 mile) reach of the river known as the Niagara Rapids provides a spectacular whitewater section with many rock ledge outcrops.

At the brink of the Niagara Falls, Goat Island (U.S.) divides the falls into two parts: the principal Horseshoe Falls between Goat Island and the Canadian mainland and the smaller American Falls between Goat Island and the U.S. mainland.

Downstream from Niagara Falls, the lower Niagara River (Figure 2.3) flows through a 50 metre (160 foot) deep gorge. The gorge extends some 12 kilometres to the Niagara Escarpment at Queenston. This Niagara Gorge area is virtually inaccessible except for a few Ontario Hydro access points, commercial (tourist) access points and other trails created by enterprising fishermen. At the base of the Niagara Falls, the water plunges into a one kilometre long, deep river section known as the Maid-of-the-Mist Pool, which lies between the falls and the Rainbow Bridge. The Rainbow Bridge spans the Niagara Gorge over the Maid-of-the-Mist Pool. This bridge provides vehicular and pedestrian traffic between Niagara Falls, Ontario and Niagara Falls, New York.

Downstream from the Maid-of-the-Mist Pool, the river enters a fierce whitewater section known as the Whirlpool Rapids. The Whirlpool Rapids presents some four kilometres of 3 to 5 metre standing waves. This set of rapids ends at a sharp dogleg in the Niagara River known as the Whirlpool. The Whirlpool is a deep decreasing concentric whirlpool in the mainstream of the river. Immediately downstream from the Whirlpool lies another set of whitewater rapids known as the Devil's Hole Rapids. This set of rapids, with shorter and choppier waves than the Whirlpool Rapids, is still not navigable. They extend some 4 kilometres downstream through the Niagara River Gorge to the bend at Bloody Run Creek where it recombines with the discharges of the hydro-electric plants at Queenston and Lewiston. A drop in the river of 23 metres (75 feet) occurs over the length of the Whirlpool Rapids and the Devil's Hole Rapids.

At Queenston, where the river exits the Niagara Gorge (Figure 2.4), the recombined flow of the Niagara River is still very turbulent. The underlying rock formations crop out at this point in the east-west lying Niagara Escarpment. The water flows rapidly northwards from this point some 10 kilometres where it discharges into Lake Ontario. The portion of the lower river from Lake Ontario to Queenston is extensively used for fishing and boating. Most of the riverbank north of the escarpment is parkland; shoreline access along this portion is largely unrestricted.

The focal point of the Area of Concern is the mouth of the Niagara River between Niagara-on-the-Lake, Ontario and Youngstown, New York. Water passing this point accounts for 83% of the total tributary flow to Lake Ontario.

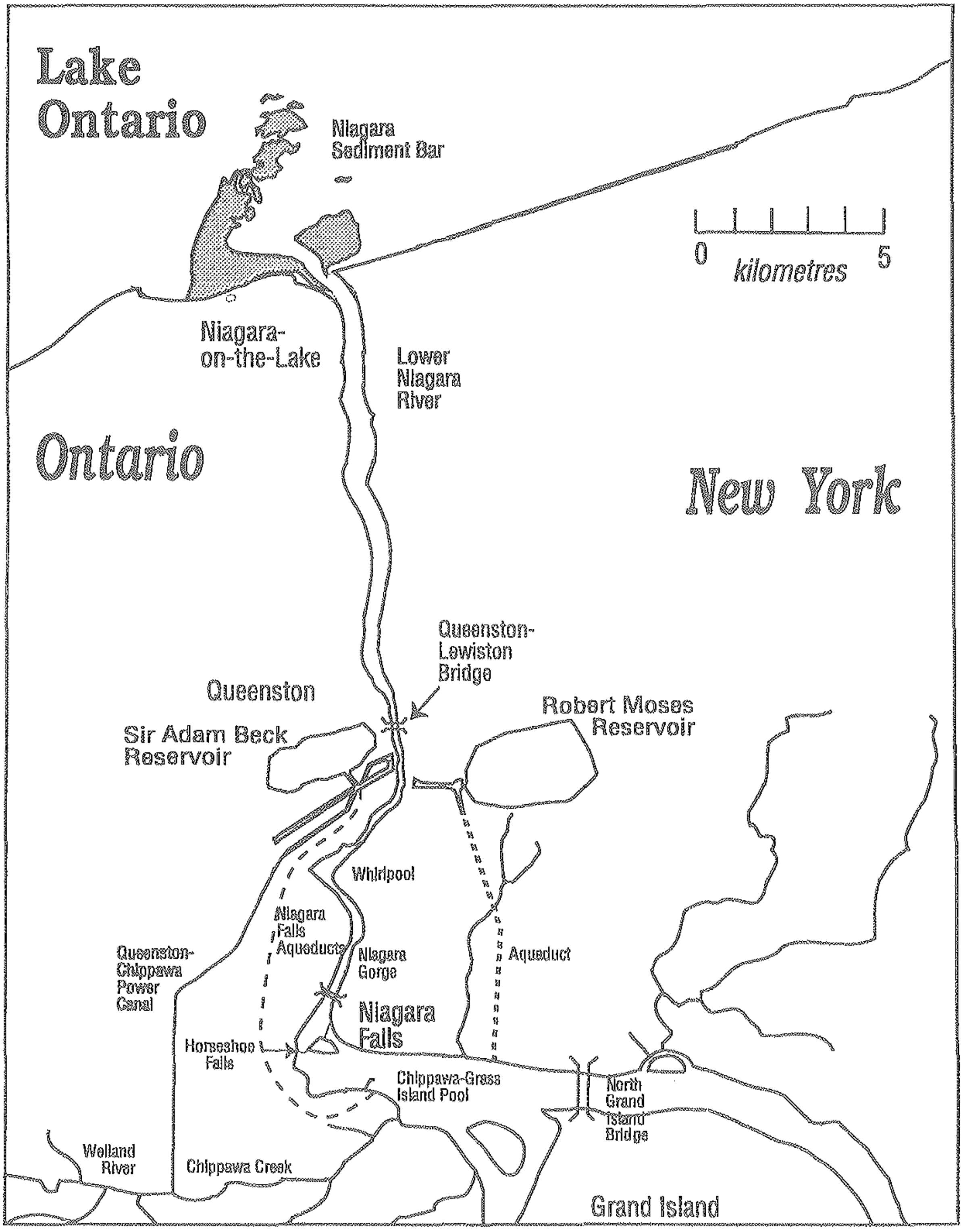


Figure 2.4 **Lower Niagara River**

2.2 Development along the Niagara River

In the early 1900's, a highly industrialized area was created along the banks of the Niagara River, particularly on the U.S. side. This development involved steel, petrochemical and chemical manufacturing complexes which located on the Niagara Frontier as a result of readily available cheap electrical power and vast quantities of water for use in industrial processes. Cheap sources of power became available at that time because the hydro-electric generation potential of the hydraulic head at Niagara Falls was exploited by power authorities in Ontario and New York State.

Treaties were signed in 1909 and 1950 which provided for the diversion of waters around Niagara Falls. The 1950 Niagara River Treaty was signed to preserve the scenic spectacle by providing a guaranteed flow over the Niagara Falls and to make more efficient use of the river for power generation purposes. As a result, Ontario Hydro and the New York Power Authority constructed a control structure at the lower end of the Chippawa-Grass Island Pool. The structure consists of eighteen gates extending from the Canadian shore about half way across the river and into U.S. territory, terminating at Tower Island. The structure is operated by the two power entities under the direction of the International Joint Commission's International Niagara Board of Control.

The majority of the flow in the Niagara River, a long term average of 5810 m^3/s[280], (Figure 2.5) is now diverted for use by the power authorities. The 1950 Treaty requires that a minimum flow of 2,832 m^3/s (100,000 cfs) be maintained over the falls during the daylight hours of the tourist season from May through October. At all other times, the flow over the falls must be at least 1,415 m^3/s (50,000 cfs). Operation of the control structure permits a relatively quick shift between daytime and nighttime operation. The structure also creates an in-stream storage reservoir in the Chippawa-Grass Island Pool. Current procedures call for the water level in the pool to be maintained as close as practical to its long-term average elevation. Operation is permitted over the range of +/- 0.46 m from the long-term mean pool elevation of 170.99 m. Fluctuations in the water levels and velocities in the Chippawa, Emerald (West) and Tonawanda channels extend as far upstream as Strawberry Island.

On the Ontario side, there are five hydro-electric plants, four of which continue to use the share of diverted water allocated to Canada. Three older facilities: Canadian Niagara, Toronto Power and Ontario Power (known as the Cascade Plants), are situated around the brink and at the base of the Horseshoe Falls. The Toronto Power Plant was retired in the 1970's. The two plants remaining in operation are now used if flow available for power generation exceeds about 4700 m^3/s and have the capability to pass 520 m^3/s. The major power plants on the Canadian side are Ontario Hydro's Sir Adam Beck Generating Stations I and II at Queenston with a combined capacity of 2500 m^3/s.

Water is directed to the cascade plants by a series of submerged channels and seawalls along the Canadian shore. It is also transported from the Chippawa-Grass Island Pool to the Sir Adam Beck stations via two aqueducts beneath the City of Niagara Falls, Ontario and via the Queenston-Chippawa Power Canal. Total Canadian diversion capability is 2,350 m^3/s (84,000 cfs). Total U.S. diversion capability (to the Robert Moses and Lewiston Hydro-electric generating stations) is 3,115 m^3/s (110,000 cfs).

The Queenston-Chippawa Power Canal flows northward from the Welland River at a point 6 kilometres west of the junction with the Niagara River. The entire flow of the Welland River is also diverted at this point through the Power Canal and discharges to the Lower Niagara River via the tailraces of the power plants at Queenston. The operation of the Power Canal and the Control Structure cause the section of the Welland River between Chippawa and the Queen Elizabeth Way (locally known as Chippawa Creek) to flow westward (upstream) as water is diverted from the Niagara River to the Power Canal. Water is also stored in a large artificial reservoir adjacent to the Sir

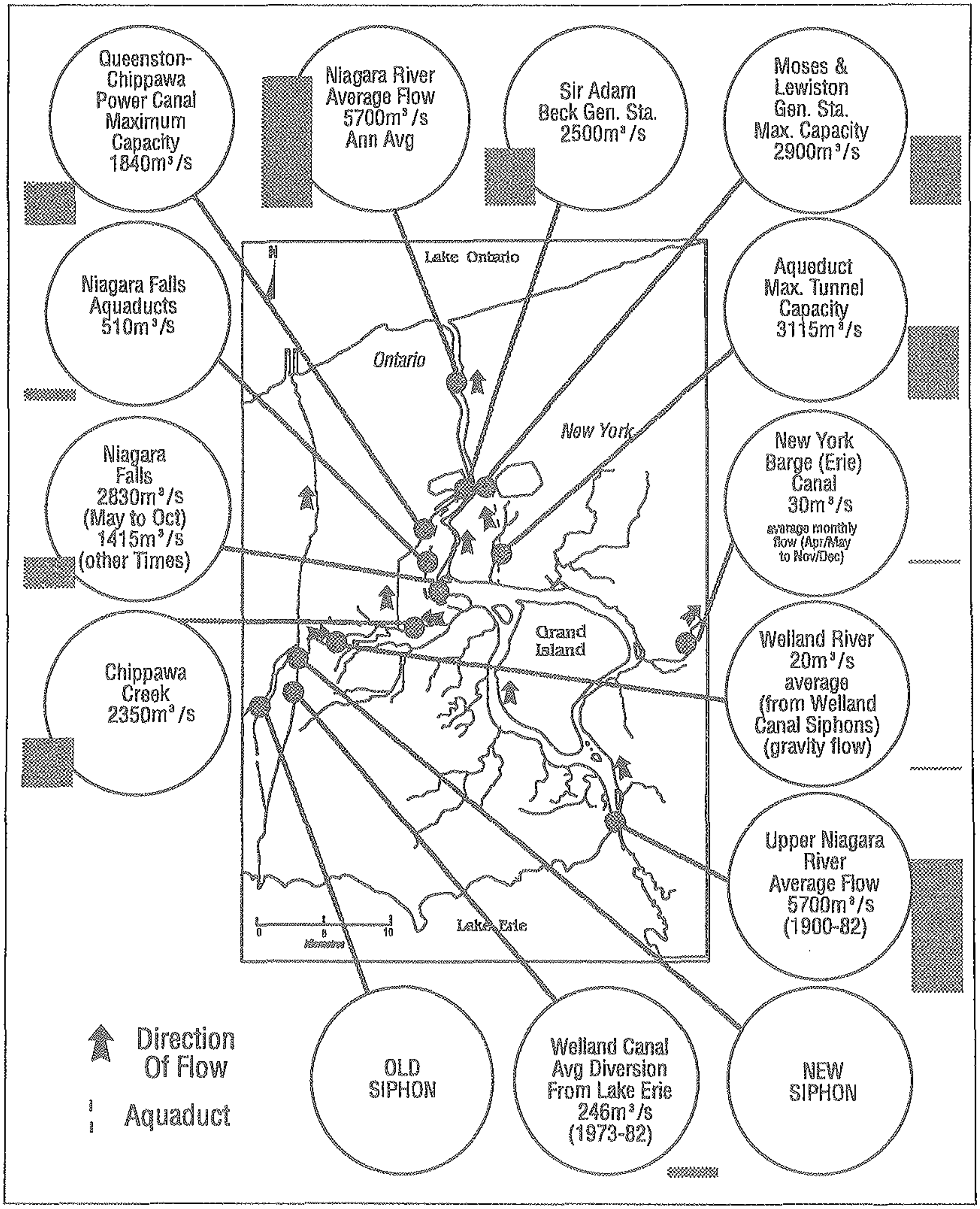


Figure 2.5 ***Water Flow Distribution***

Adam Beck plants at Queenston for ready use when additional power is needed or when the diversion of water must be reduced to ensure guaranteed flow over the Falls. Discharge from the turbine tailraces of the Sir Adam Beck stations back to the Niagara River occurs immediately upstream of the Queenston-Lewiston Bridge. On the U.S. side of the river, the New York Power Authority operates a diversion from the river to the Robert Moses Station, the Lewiston Pumping Generating Station and the Robert Moses Reservoir.

The Grass Island Pool upstream from the falls provides very limited storage. During periods of low energy demand, some water in excess of that necessary for flow maintenance over the falls and for diversion for power generation and storage can be stored in the Chippawa-Grass Island Pool. However, most flow in excess of diversion flow (ie. to generation facilities in New York State and Ontario) passes over the Falls. During daylight hours of high power demand, the stored supply is converted to hydro-electric power by release through the penstocks and turbines at the Queenston and Lewiston plants. Diversion flows are reduced when required to maintain minimum flows over the Falls.

The Niagara River, while providing a connecting channel between Lakes Erie and Ontario, also presents a physically insurmountable barrier to navigation between these lower two Great Lakes. Consequently, a canal and series of locks were constructed around the Niagara Falls. The Welland Ship Canal, between Port Weller on Lake Ontario and Port Colborne on Lake Erie, is the fourth and current route by-passing the Niagara River and represents a second interconnecting channel between Lakes Erie and Ontario. It is used by both recreational and commercial vessels including ocean-going ships. Operation of the canal (by the St. Lawrence Seaway Authority) occurs predominantly during the Great Lakes navigation season (April to December).

2.3 Watershed Characteristics

The Niagara River carries an annual average flow of 5,700 cubic metres per second from Lake Erie to Lake Ontario. The vast majority of the flow comes from the basins of the four Great Lakes upstream of the Niagara River; the Niagara-Welland basin contributes less than 0.1% of the total flow.

In itself, the Niagara River has a relatively small drainage basin on the Canadian side. This basin, between Fort Erie and Chippawa, extends inland up to 10 kilometres. This is an undeveloped area drained by several small creeks which discharge along the length of the Chippawa Channel of the Niagara River. The drainage area on the west side of the Niagara between Chippawa and Niagara-on-the-Lake comprises a narrow strip of land extending generally less than one kilometre inland. The central portion of the drainage basin consists of the Welland River Basin, which covers a drainage area of about 1050 square kilometres. The agricultural nature of this basin predominates, with the City of Welland being the largest urban centre in the basin. The river flows eastward on a very low gradient from headwaters located south of the City of Hamilton.

The terrain above the escarpment is generally flat and dominated by the laminated glaciolacustrine clay overburden of the Haldimand Clay Plain which overlays Halton Clay Till. This tight laminated layer generally exceeds 25 metres in thickness and exhibits an extremely low water permeability of 10^{-7} to 10^{-8} m/s. The upper 5 metres is generally highly weathered and has much higher permeabilities. The overburden overlies dolomitic bedrock of the Guelph-Lockport formation.

The portion of the basin north of the Escarpment has a lacustrine silt and clay overburden generally up to 30 metres thick, which overlies a fine-grained sand stratum immediately over bedrock. This bedrock is red shale of the Queenston Formation in the northern section and sandstones and dolostones in the portion immediately below the escarpment. The clay units here are relatively tight with a hydraulic conductivity of 10^{-6} m/s; that of the shale bedrock is typically 10^{-5} m/s.

The topography and the high clay composition of the soils in both basins result in a very slow ground water movement, with some increase in flow rate in the shallow weathered zones. Ground water recharge and base flow in these basins is therefore not a large contributor to surface flows on a volumetric basis. The nature of the soils promotes surface runoff rather than infiltration during precipitation events. Within the Welland River basin, agricultural activities, in the presence of fine-grained, low permeability surface materials, contributes surface runoff that adds to river water degradation through both contaminant migration and erosion. This runoff carries with it suspended fine clay particles; hence, the waters of the Welland River appear murky most of the time due to these suspended materials. The same effect is noticed to a lesser extent in the Niagara River during spring runoff.

The fast-flowing waters of the Niagara provide little in the way of depositional areas. Along its length, only a handful of backwaters create areas for sedimentation. The bottom of the Niagara River, particularly in mid-channel, is generally scoured clean. Materials suspended in the water column of the river are deposited outside the river mouth in Lake Ontario where a bar of predominantly sandy material (the Niagara River Bar) is an extensive feature.

2.4 Ground Water Movement

Under natural conditions, ground water flows from areas with high water levels to areas with low water levels. When the water in a well is lowered, the hydraulic potential is changed. The water level is lowered locally and water from the surrounding water bearing zone flows towards the well. This action is known as drawdown.

Three types of grond water zones are commonly referred to in the discussion of hydrogeology: aquifers, aquitards and aquicludes, based on their ability to yield water. Aquifers yield water in usable quantities[5]. Those layers which are sufficiently permeable to permit vertical water movement to or from the aquifer, but not horizontal movement, are known as aquitards. Layers through which virtually no water moves are called aquicludes.

Previous investigations of the ground water resources of the Niagara Peninsula[12] have lead to the conclusion that ground water divides generally coincide with the surface water divides. A second conclusion is that ground water movement is toward ground water discharge areas which usually are topographically low areas (for example, in the shallow ground water system, regional ground water discharge is to Lake Ontario in the north; Lake Erie in the south; and the Welland and Niagara Rivers in the central and eastern parts of the study area, respectively).

Detailed studies[10] indicate that the water table fluctuates over the weathered/fractured upper 2-3 metres of the glaciolacustrine silts and clays comprising the overburden aquitard. Consequently, precipitation causes an immediate response or flow in this shallow zone when the weathered fractures quickly fill with water. After the weathered overburden is filled, a large portion of the remainder of the precipitation becomes surface runoff. A small portion of the remainder penetrates to depth to recharge the ground water system. During periods of no precipitation, the water table drops just below the level of surface swales. This results in the stoppage of surface water recharge and promotes deep ground water flow from the water table through the overburden aquitard into the bedrock aquifer.

Hydraulic head information within the bedrock aquitard is limited. Deep boreholes have been drilled by Ontario Hydro and Environment Canada to establish a geological and hydrogeological data base on the Canadian side of the Niagara River in the vicinity of the Niagara Gorge. These data indicate[27] that very high hydraulic heads occur at the base of the Lockport Formation.

Hydraulic heads measured below the Lockport Formation are higher than the ground level due to confined water pressure in these formations. These extreme pressures would prevent vertical ground water movement downward from the shallow ground water system. Ontario Hydro[28] determined that large vertical gradients occur in the deep formations across the less permeable horizons such as the Rochester Formation. This indicates a strong potential for downward movement of ground water below the Clinton Group (see table 2.2).

The influence of the Niagara Escarpment on the deeper hydraulic heads in the gorge and escarpment areas is not clear. Both areas may be influenced by dewatering effects close to the scarp face. Further studies are required to determine the hydraulic head distribution below the bedrock aquifer in the areas away from the influence of the gorge or escarpment.

Ground water movement in the Niagara area is generally slow and deliberate. Although surface contamination may be taken to depth, this is an unlikely occurrence due to both the nature of ground water movement and the scarcity of contaminant sources in the area. The potential for contamination of deeper ground water systems is dependent on a number of factors: the nature of the source, the thickness and permeability of the confining units, prevailing hydrolic gradients and the presence of fractures in otherwise impermeable units. Although feedlot and landfill sources may create localized ground water problems, the low permeability nature of the rock and soils in the Canadian Area of Concern sufficiently confine contaminant migration so that ground water problems are not widespread.

The hydrogeology of the area protects the ground water resource; however, this results in heightened inputs to the surface waters.

2.4.1 Hydrogeology

Hydrogeology is the study of ground water with emphasis on its chemistry, movement and relation to the geographic environment[3]. With the increasing demand for water by society, ground water continues to be an important resource. This is particularly true in areas where surface water supplies are not readily available. The Niagara Peninsula is surrounded by an abundance of surface waters which supply a considerable portion of the water used in the area. However, some people, particularly those in rural areas located inland in the peninsula, rely on ground water as a source of potable water or for livestock use.

The ground water resources of the Niagara Peninsula are based mainly in a geologic formation known as the Guelph aquifer. In order to understand the limitations of ground water resources in general and this aquifer in particular, it is necessary to understand a few of the basics of hydrogeology.

The term ground water is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated. Ground water is more than a resource. It is an important feature of the natural environment; if polluted, it can lead to environmental problems; alternatively, it may in some cases offer a medium for environmental solutions[4].

2.4.2 Hydrogeologic Units

Geologic land masses are clustered together into horizontal units which have a similar capacity to transmit water. The generalized hydrostratigraphy of the Niagara-Welland basin is presented in Table 2.1. The landmass in this basin is generally composed of clay or clay-till soils overlying limestone bedrock. The soils are collectively referred to as overburden.

TABLE 2.1

Hydrostratigraphy of the Niagara Peninsula

Hydrostratigraphic Unit	Geological Units
Overburden Aquifer	Post-glacial deposits
	St. Davids Gorge deposits
	Fonthill Kame complex
Overburden Aquitard	Upper glaciolacustrine
	Halton Till
	Lower glaciolacustrine
	Lower till complex
Bedrock Aquifer	Basal granular deposits
	Weathered bedrock
Bedrock Aquitard	Unweathered and weathered bedrock

The hydraulic conductivities of the geologic units in the area are listed in Table 2.2.

2.4.2.1 Overburden Aquifer

Where overburden aquifers exist within the Niagara-Welland basin, the aquifer is generally located within near-surface granular deposits. Such deposits are found at Niagara Falls, and to the east of Welland. Other deposits are located in close proximity to the basin at Fonthill and St. Davids. These are the only significant areas of overburden deposits in the Niagara Peninsula that are used as sources of water supply. Hydraulic conductivities of the sands and gravels are typified by the Fonthill and St. Davids deposits and are generally in the order of 10^{-4} m/s (Table 2.2).

2.4.2.2 Overburden Aquitard

The surface soils over much of the Area of Concern consist of glaciolacustrine clays and tills which act as an aquitard. The reported hydraulic conductivities of these soils are less than 10^{-7} m/s. Where these materials are weathered, they contain numerous interconnected fractures that can transmit very small amounts of ground water. A number of studies conducted on silt and clay materials[6,7,8,9] confirm that weathering is generally a surface feature, the extent of weathering and frequency of fractures decreasing with depth. The hydraulically active part of the weathered zone has been estimated to extend to a maximum depth of about 5 m with the average, for the most part, being 2 to 3 m deep[10].

Where weathering has not occurred, hydraulic conductivities of less than 10^{-9} m/s have been measured (Table 2.2). Below the weathered zone, ground water movement is dominated by the porosity of the materials. A number of tests have shown that the total or bulk porosity of the materials tends to be the same as the intergranular porosity[7,9,10,11].

In areas of sandy silt till higher hydraulic conductivity rates are found[10] (Table 2.2). These higher permeabilities have been attributed to sand and gravel layers reported to be present in the till at some locations[12].

2.4.2.3 Bedrock Aquifer

The bedrock generally consists of dolomitic limestone of the Lockport formation above (south of) the escarpment and Queenston Shale below (north of)

TABLE 2.2

Hydraulic Conductivity of the Geologic Units in the Niagara Peninsula

Geologic Unit	Hydraulic Conductivity Range (m/s) ***	# of Tests **	Hydrostratigraphic Classification	Remarks
Near-Surface Granular				
Gravel	1 x 10-5	1	Overburden Aquifer	Found at Fonthill
Sand	2 x 10-5 to 2 x 10-4	2	Overburden Aquifer	Found in St.David's Gorge
Upper Glaciolacustrine				
Silt	2 x 10-9 to 3 x 10-6	11	Overburden Aquitard	Higher Values from Sandier Materials
Silt Clay	2 x 10-10 to 7 x 10-7	10	Overburden Aquitard	
Clay (weathered)	2 x 10-9 to 7 x 10-7	37		Includes Fractured Clay
Clay (unweathered)	5 x 10-11 to 1 x 10-9	57		
Silt Till (Halton)	1 x 10-10 to 7 x 10-5	40		Higher Values from Sandy/granular Wentworth Till
Shallow Bedrock				
Onondaga	No Data	0	Bedrock Aquifer	No data Available for this formation
Bois Blanc	6 x 10-7 to 1 x 10-6 *	3	Bedrock Aquifer	
Bertie	9 x 10-8 to 2 x 10-6 *	18		
Salina	1 x 10-5 to 6 x 10-4 *	2		
Guelph	3 x 10-11 to 1 x 10-5 *	45		
Lockport	5 x 10-9 to 4 x 10-3 *	52	Dolostone	
Deep Bedrock				
Clinton Grp.	4 x 10-11 to 5 x 10-6	88	Bedrock Aquitard	Higher values from Irondequoit/Decew Formations
Cataract Grp.	7 x 10-12 to 2 x 10-7	31	Bedrock Aquitard	Higher values from Whirlpool Formation
Queenston	6 x 10-12 to 1 x 10-8	31	Bedrock Aquiclude	Does not include weathered Queenston Formation to the north of the Niagara Escarpment

NOTES:
* - weathered bedrock is generally more permeable than the underlying bedrock
** - slug tests, constant head tests and pump tests
*** - data sources: MOE, OWMC, Env. Cda. and Ont. Hydro.

the escarpment. Both of these formations exhibit highly variable hydraulic conductivities. Water moves through these rocks primarily via horizontal breaks known as bedding planes and through vertical routes such as joints, fractures and solution cavities (in carbonate rocks).

It is recognized that limestone bedrock generally has higher hydraulic conductivities than underlying shales (Table 2.2). A large number of closely spaced fractures provide increased permeability.

The uppermost part of a bedrock formation generally has a higher hydraulic conductivity than the same formation at depth due to weathering of the bedrock surface. This generality is supported by water well record data [13,14,15]. These data indicate that most water wells completed in the bedrock obtain their water from the uppermost part of that bedrock.

2.4.2.4 Bedrock Aquitard

The underlying shale bedrock formations exhibit significantly lower hydraulic conductivities than the limestone formations above (about one to three orders of magnitude lower)[12].

Hydraulic conductivities ranging from 1×10^{-9} to 5×10^{-6} m/s, representing the upper permeable limits, have been estimated for the carbonate and sandstone formations. The estimated low range hydraulic conductivities for the remaining formations are generally from 7×10^{-12} to 1×10^{-8} m/s.

2.4.2.5 Bedrock Aquiclude

The hydraulic conductivity of the Queenston Shale is highly variable, particularly in the upper surfaces, and ranges from 6×10^{-12} to 1×10^{-8} m/s. Table 2.2 shows values for deep boreholes drilled near the Niagara River. All but one of the measured hydraulic conductivity values are less than 1×10^{-10} m/s. Although it is possible to obtain a water supply from the upper weathered bedrock surface of the Queenston Formation, the generally low hydraulic conductivities and significant thickness of the formation potentially classifies this formation as an aquiclude or barrier to deep ground water flow.

2.4.3 Water Well Yields

Water well yields are dependent on the hydrogeologic properties of the materials in which the wells are completed. Generally, within the Niagara-Welland basin, wells completed in the bedrock aquifer are higher yielding. The water well data indicate that some of the bedrock wells located in the basin produce in excess of 2 L/s (Table 2.2).

Overburden wells that are high yielding are generally completed in granular materials overlying, and hydraulically connected to, the uppermost bedrock formation. These basal granular materials are restricted in the extent of their occurrence throughout the Niagara-Welland basin. High yielding overburden wells have been identified[12] in the following materials:

- the basal sands of the headwaters area of the Welland River basin from Mount Hope to Caistor Centre,
- the basal sands of the south-central part of the Welland River basin north of Dunnville,

- the kame deposits of the Fonthill area adjacent to the basin to the northwest of Welland,

- the valley fill deposits adjacent to the basin in the vicinity of Niagara Falls and St. Davids.

2.4.4 Ground Water Levels

The water table is the upper surface of the ground water in an unconfined aquifer. The water table fluctuates in response to both, the water infiltrating from the ground surface through the unsaturated zone toward the ground water, and to the depletion of the aquifer. These water level fluctuations can be measured in water wells.

The variation in levels that can be expected in the ground water of the Niagara-Welland basin is shown in the hydrograph of the bedrock observation well located within the basin at Wainfleet and the bedrock observation well located outside the basin at Grimsby (Figure 2.6). Both wells are completed into the bedrock aquifer through the overburden aquitard.[16,17,18,19,20,21,22,23,24] The data indicate a cyclical pattern where maximum ground water recharge occurs in the spring months and minimum water levels occur in the late summer/fall corresponding to a period of water table drawdown contributed to by a period of maximum depletion of infiltrating water by vegetation and evaporation. Deviations to this general pattern occur when precipitation exceeds evaporation during the growing season, or when infiltration does not occur because of frozen ground conditions or lack of precipitation.

Flowing wells have been reported adjacent to the basin in the St. Davids area, along the Onondaga Escarpment near Lake Erie and in the Pelham area northwest of Fonthill[25].

2.5 Biological Characteristics

The fish and wildlife of an area depend on many factors. Habitat can be defined as any area where fish and/or wildlife spend part of their life cycle. The habitat available determines the abundance and diversity of wildlife in any given area. The provision of diverse and well-mixed habitat types allows for a variety of animals to obtain food, water and shelter from the elements and to escape from predators[78].

The detrimental effects of urban land uses on habitat, particularly fish habitat, have been documented[79]. The damage to fish habitat may be attributed to five changes that occur with land conversion: increased erosion/sedimentation, removal of vegetation, increased human intrusion, introduction of toxic material, addition of nutrients to the stream, and disruption of streamflow characteristics. Wetlands currently make up less than 0.1% of land use in the Niagara River and its tributaries (Table 3.2).

The re-introduction and maintenance of vegetative buffer strips along watercourses can significantly reduce the effects of urbanization on water quality. Buffer strips reduce stream bank erosion, decrease sediment input, increase the aesthetic quality, reduce water temperature variations, provide cover and food for wildlife, fish and insects.

Buffer strips along watercourses provide quality habitat and travel corridors for wildlife species such as birds, mammals, reptiles, and amphibians. Improving the water quality of an area, partially through buffer strips, will help move towards a quality environment for all species. Future integrated resource management has the potential to provide the largest positive effect on wildlife if the needs of wildlife are considered during land use planning activities.

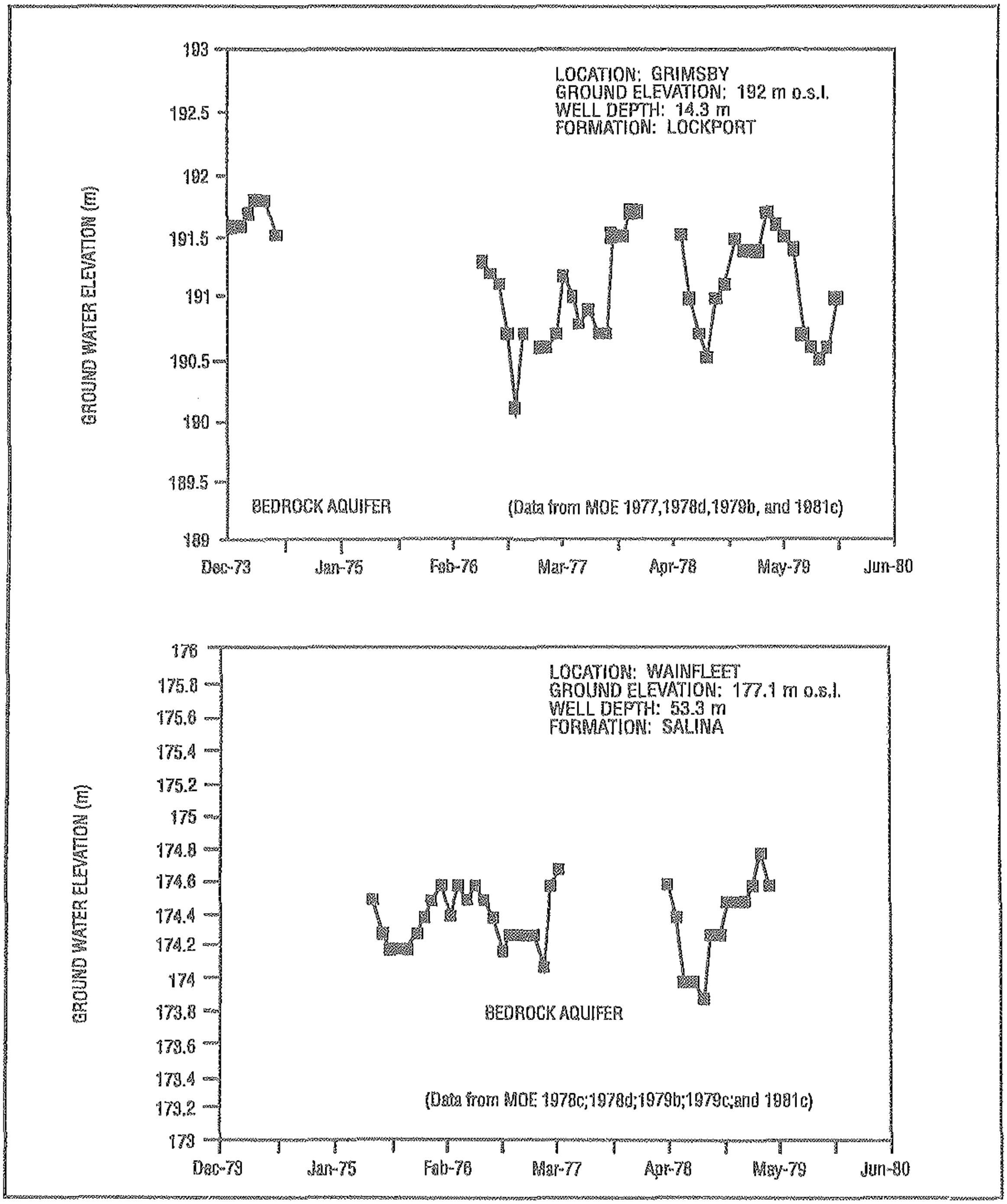


Figure 2.6

Observation Well Hydrographs
Typical of Niagara-Welland Basin

2.5.1 The Niagara Fishery

The Niagara River contains an impressive array of fish species which in turn generates a diverse and enthusiastic sport fishery. Adding to the diversity in the river are migrating fish runs from each of two Great Lakes giving distinct identities to both the upper and lower rivers. The Niagara River watershed also includes various tributaries including the Welland River.

The fisheries of the Niagara River watershed can generally be divided into three areas; the upper Niagara River and inlet from Lake Erie, the lower Niagara River and mouth into Lake Ontario, and the numerous warm water tributaries. The tributaries can be subdivided into those entering the Niagara River directly and those which drain into the Welland River, which subsequently flows into the Chippawa Power Canal and ultimately enters the Niagara River via the Sir Adam Beck generating station.

The dominant species, harvest estimates and pressure estimates discussed in the following sections were determined using creel data collected in 1983-84 by the Ontario Ministry of Natural Resources[80].

2.5.1.1 Fish Distribution

The fish species historically recorded in the watershed are listed in Table 2.3. The upper and lower Niagara River support different types of fisheries with varied community structure. The upper river is similar to Lake Erie with angler harvest dominated by smallmouth bass, yellow perch, rock bass, and rainbow smelt, when total numbers of fish are considered. If total weight of harvest is used muskellunge is in the top four species. Seasonal migrations of walleye (yellow pickerel), white bass, and rainbow smelt occur on the upper river. Moderate runs of rainbow trout, brown trout, coho salmon, and chinook salmon also occur. An economically important commercial baitfish harvest, consisting primarily of emerald shiners, exists on the upper river.

The lower Niagara River is considered to be a cold water fishery similar to Lake Ontario with angler harvest, by weight, dominated by rainbow trout, lake trout, coho salmon, and white bass. Other important angler catches include yellow perch, freshwater drum, and rockbass. The lower river has heavy runs of rainbow trout in the spring, and lake trout, brown trout, coho salmon, and chinook salmon in the fall. There is some influx of fish from Lake Erie to the lower Niagara River, including golden and palamino trout, (genetic variants of rainbow trout introduced exclusively by the state of Pennsylvania).

The walleye harvest currently amounts to about 1/3 of 1 % of the total harvest by number of fish from the Lower Niagara River[204]. This would not seem to be a very significant contribution to the fishery at present although fishing patterns may change in the future.

The species composition of fish in the river is constantly changing due to various factors including water quality, loss of habitat, over-harvest, and introduction of foreign species. The grass pickerel and lake sturgeon, now considered rare in the area, were once abundant in the upper river[81]. There have been introductions of many foreign species into the Great Lakes Basin, many of which have developed into viable self-sustaining populations. These include rainbow trout, rainbow smelt, alewife, goldfish, carp, white perch, coho salmon and chinook salmon. All these species with the exception of the salmons are self-sustaining populations[82]. Though some natural reproduction has been reported, the coho and chinook salmon have been maintained by annual stocking since 1966. A highly successful salmon sport fishery has developed though restrictive consumption guidelines exist for coho and chinook salmon greater than 55 and 65 cm, respectively[83], in the lower river.

TABLE 2.3

Fish Species of the Niagara River and Its Tributaries

Species	Scientific Name	Species	Scientific Name
Sea Lamprey	Petromyzon marinus	Lake Sturgeon	Acipenser fulvescens
Longnose Gar	Lepisosteus osseus	Bowfin	Amia calva
Alewife	Alosa pseudoharengus	Gizzard Shad	Dorosoma cepedianum
Brown Trout	Salmo trutt	Lake Whitefish	Coregonusclupeaformis
Coho Salmon	Oncorhynchus kisutch	Chinook	Oncorhynchus tshawytscha
Rainbow Trout	Oncorhynchus mykiss	Lake Trout	Salvelinus namaycush
Central Mudminnow	Umbra limii	Smelt	Osmerus mordax
Grass Pickerel	Esox americanus vermiculatus	Chain Pickerel	Esox niger
Northern Pike	Esox lucius	Muskellunge	Esox masquinongy
American Eel	Anguilla rostrata	Goldfish	Carassius auratus
Carp	Cyprinus carpio	Carp-Golfish, Hybrid	
Central Stoneroller	Campostoma anomalum	Hornyhead Chub	Nocomis biguttatus
River Chub	Nocomis micropogon	Golden Shiner	Notemigonus crysoleucas
Emerald Shiner	Notropis atherinoides	Common Shiner	Notropis chrysocephalus
Common Shiner	Notropis cornutus	Blacknose Shiner	Notropis heterolepis
Spottail Shiner	Notropis hudsonius	Spotfin Shiner	Notropis spilopterus
Sand Shiner	Notropis stramineus	Mimic Shiner	Notropis volucellus
Bluntnose Minnow	Pimephales notatus	Fathead Minnow	Pimephales promelas
Creek Chub	Semotilus atromaculatus	Longnose Dace	Rhinichthys cataractae
Quillback Sucker	Carpiodes cyprinus	White Sucker	Catostomus commersoni
Lake Chubsucker	Erimyon sucetta	Northern Hog Sucker	Hypentelium nigricans
Redhorse Sp.	Moxostoma sp.	Shorthead Redhorse	Moxostoma macrolepidotum
Greater Redhorse	Moxostoma valenciennesi	Silver Redhorse	Moxostoma anisurum
Golden Redhorse	Moxostoma erythrurum	Black Bullhead	Ictalurus melas
Brown Bullhead	Ictalurus nebulosus	Yellow Bullhead	Ictalurus natalis
Channel Catfish	Ictalurus punctatus	Brook Silverside	Labidesthes sicculus
Trout-perch	Percopsis omiscomaycus	Tadpole Madtom	Noturus gyrinus
Stonecat	Noturus flavus	Banded Killifish	Fundulus diaphanus
Three-spined Stickleback	Gasterosteus aculeatus	Brook Stickleback	Culaea inconstans
White Perch	Morone americana	White Bass	Morone chyrsops
Rock Bass	Ambloplites rupestri	Pumpkinseed	Lepomis gibbosus
Bluegill	Lepomis macrochiru	Smallmouth Bass	Micropterus dolomieui
Largemouth Bass	Micropterus salmoide	White Crappie	Pomoxis annularis
Black Crappie	Pomoxis nigromaculat	Yellow Perch	Perca flavescens
Walleye	Stizostidion vitreum	Blue Pike	Stizostdion vitreum glaucum
Rainbow Darter	Etheostoma caeruleum	Iowa Darter	Etheostoma exile
Johnny Darter	Etheostoma nigrum	Fantail Darter	Etheostoma flabellare
Tesselated Johnny Darter	Etheostoma olmstedi	Greenside Darter	Etheostoma blennoides
Logperch	Percina caprodes	Freshwater Drum	Aplodinotus grunniens
Mottled Sculpin	Cotus bairdi		

References used: Hamilton 1987; E. Crossman 1989; ANON 1989; Lewies et al. 1985; OMNR 1974; Spotila et al. 1979.

The species composition of angler harvest in the tributaries of the Niagara River was dominated by what are considered "coarse" fish. These species are more tolerant to adverse conditions such as high suspended sediment and chemical pollutant concentrations[84].

Dominant in the harvest are bullheads, rock bass and crappie, suckers, sheephead, carp, and catfish. The percentage of cyprinids in the population is hard to accurately state with the information available. Commercial harvest of baitfish in the tributaries generally occurs in the evening when fish from the Niagara River move into mouths and a hardier catch can be obtained[85]. Population estimates have not been done in Niagara District and extensive stream surveys have not been conducted since 1972. Several tributaries of the Niagara River are designated as having provincially significant warm water fisheries[33].

The harvest on the Welland River is difficult to determine from the creel as the Welland River results are included in the inland waters category. The catch from gill netting, done at four sites on the Welland River by a graduate student at Brock University, was dominated by 'coarse' fish; including brown bullhead, channel catfish, freshwater drum, crappies, and carp[86].

The effects of adverse conditions in the river on the distribution of fish species is unknown. One can presume, however, that when aquatic plants disappear so will some fish species. Work by researchers at Brock University[87] indicated that industrial effluent discharge to the Welland River caused an impact zone where no aquatic plants survived and plant diversity recovered with increasing distance downstream of the effluent source. Aquatic habitat degradation has been linked to changes in fish species composition and decreases in fish diversity[85], leading to more 'coarse' fish including bullheads, catfish, freshwater drum, and carp.

2.5.1.2 Fishery Productivity

The productivity of the Niagara River has never been determined directly since its size presents physical hazards to conducting such surveys.

The effects of water quality degradation on spawning beds in the Area of Concern are not likely to be ascertainable. On the Niagara River itself very little information exists on the precise location or condition of spawning beds since they are suspected to be in locations inaccessible to man such as backwater areas of the whirlpool and rapids or the talus around the foot of both falls. Investigations of these areas are prohibitively difficult and dangerous.

Angler use of the Niagara River is extensive. Estimates of angler use of both New York and Ontario waters (1976-77, 1983-84, and 1989-90) ranged from 53,000 to 515,700 angler days per year with an annual harvest between 85,000 and 2.4 million sport fish[68].

Sport fish harvest estimates from creel data of 8.84 and 39.45 kg/ha/yr for the upper and lower river, respectively, indicate a very productive system. When baitfish harvest is included in the upper river harvest, the value increases to 61.27 kg/ha/yr. Table 2.4 shows historical baitfish harvest values. Harvest depends on both relationships with fish populations in the adjacent Great Lake and the angler effort. The estimated annual angler hours on the upper and lower river were 96,000 and 97,500 respectively.

Individuals surveyed for a questionnaire in the 1989 "Guide to Eating Ontario Sport Fish" (Table 2.5) ranked the Niagara River ninth in popularity among Ontario rivers fished.

TABLE 2.4

Niagara Area Commercial Baitfish Harvest			
Year	Niagara District Harvest (gallons)	Niagara River Harvest (gallons)	River Harvest as % of Total
1969	9054.3	4727.3	52.2%
1970	12054.2	10114.2	83.9%
1971	19117.4	14864.2	77.8%
1972	11298.8	5418.8	48.0%
1973	106160.3	100735.4	94.9%
1974	47610.0	24105.4	50.6%
1975	84552.7	43370.6	51.3%
1976	80780.7	62181.4	77.0%
1977	60868.4	44844.0	73.7%
1978	4414.6	2581.6	58.5%
1979	4683.2	291.1	6.2%
1980	11658.4	8338.1	71.5%
1981	N/A	N/A	N/A
1982	22600.2	N/A	N/A
1983	16328.1	N/A	N/A
1984	7825.8	6827.5	87.2%
1985	17065.0	13414.5	78.6%
1986	30023.0	21376.0	71.2%
1987	9633.7	6833.0	70.9%
1988	16332.4	N/A	N/A
Average	30400.0	18501.2	60.9%

Individuals surveyed for a questionnaire in the 1991 Guide to Eating Ontario Sport Fish (Table 2.5) ranked the Niagara River ninth in popularity among Ontario rivers fished.

In the Ontario portion of the Niagara River, fishing pressure comprises approximately 25 percent of the total for the entire Niagara District, which includes portions of Lakes Erie and Ontario and most of the inland portion of the Niagara Peninsula[80]. This must be considered in assessing the productivity of the Niagara River because most sport fish species are migratory: fish produced in the river may be caught in nearby areas of Lakes Ontario or Erie or vice-versa. In fact, for some species it may not be possible to separate the productivity of the Niagara River from the entire lake basins of Erie and Ontario.

Historical data indicates a relatively stable catch per unit effort (CUE) in the upper river (0.38 and 0.55 in 1980 and 1983) and an increasing CUE (0.08 and 0.32 in 1977 and 1983) in the lower river. The increasing CUE in the lower river may be due to changes in harvest, being increasingly dominated by species that are only seasonal migrants, spending most of their lives in Lake Ontario.

In 1983, the inland waters of the Niagara Peninsula had higher CUEs (0.82) than those found on the Niagara River; however, the survey did not distinguish between areas in and out of the Niagara River watershed. Twenty percent of the angler effort in the district occurs on inland waters. The harvest from these waters is mainly 'coarse' fish.

The impact of changes in the ecosystem upon species productivity is hard to assess.

If reproductive success is considered, observable behaviour of salmonids and the physiological changes that they undergo in the Niagara River suggests that spawning does occur but there does not seem to be much evidence of spawning success for most salmonid species. There are however other resident species in the river such as smallmouth bass, northern pike and muskellunge which also must spawn in or near the river. They do appear to have success because they continue to persist in the face of heavy fishing pressure. The bass use gravel areas of the river such as may occur in the whirlpool and rapids and which do occur around Navy Island. Muskellunge

TABLE 2.5

Relative Popularity of Angling Areas and Fish Species*

	Most Frequently Fished Lakes and Rivers.		Most Frequently Caught and Consumed Sport Fish.	
	Lake/River	Relative Popularity (%)	Species	Relative Popularity (%)
a) Ten Most Popular Angling Areas				
	1. Lake Ontario	19.5	1. Walleye	18.7
	2. Lake Huron/Georgian Bay	19.3	2. Smallmouth Bass	15.9
	3. Lake Erie	13.5	3. Yellow Perch	12.1
	4. Lake Simcoe	10.0	4. Northern Pike	11.2
	5. Credit River	7.1	5. Largemouth Bass	9.7
	6. Grand River	6.9	6. Rainbow Trout	9.2
	7. Trent River	6.5	7. Lake Trout	7.8
	8. Lake Scugog	6.4	8. Brook Trout	6.1
	9. Lake Nipissing	5.8	9. Chinook Salmon	4.9
	10. Saugeen River	5.0	10. Coho Salmon	4.4
		100.0		100.0
b) Inland Lakes				
	1. Lake Simcoe	23.9		
	2. Lake Scugog	15.3		
	3. Lake Nipissing	13.7		
	4. Rice Lake	11.7		
	5. Buckhorn Lake	9.8		
	6. Pigeon Lake	7.6		
	7. Balsam Lake	6.3		
	8. Sturgeon Lake	5.8		
	9. Stony Lake	4.5		
	10. Chemung Lake	1.4		
		100.0		
c) Rivers				
	1. Credit River	13.6		
	2. Grand River	13.3		
	3. Trent River	12.4		
	4. Saugeen River	9.7		
	5. Ottawa River	9.5		
	6. Thames River	9.3		
	7. French River	8.6		
	8. Ganaraska River	8.3		
	9. Niagara River	7.7		
	10. Rideau River	7.6		
		100.0	* - Data from 1989 survey of Anglers	

spawning areas are generally found on the American side of the river such as at Strawberry Island and may possibly occur also around Grand Island and Navy Island. Northern pike are known to come up the various tributaries on the Ontario side of the river such as Black, Frenchmans, Lyons and Tee Creeks and the Welland River to spawn. These may be affected by man-made alterations of the habitat but specifics are generally not very well known.

There appears to be no impairment of fish and wildlife habitat in the Niagara River and along its banks but this conclusion is difficult to support with positive information; this conclusion is based mostly on the lack of evidence to the contrary in this Area of Concern. U.S. based information from the New York side of the river would not seem to support that conclusion for the river as a whole. Netting work by Ontario MNR to collect fish from the Welland River for contaminant analysis showed very little in catch for the effort expended. This suggests quite a depressed population for this major tributary to the Niagara River which may be attributable to habitat degradation or a number of other factors.

The cause of reductions in a species is difficult to determine and is probably the result of a number of factors, which include stresses imposed due to loss of habitat areas and poor water quality.

Loss of habitat occurs in various ways. Shoreline development and urbanization along the water course generally means loss of forest cover, edges and wetlands. Wetlands act as spawning and nursery areas for many species. Southern Ontario has already lost more than 70 percent of its original wetlands[88]. Table 2.6 summarizes known spawning and nursery areas on the Niagara River. Spawning and nursery areas on the Welland River and other tributaries are very sparse. In the spring of 1989, a pike spawning assessment was started in the Niagara District by the Ministry of Natural Resource (MNR)[89]. The spawning areas within the watershed can be seen in Figure 2.7. The information on spawning and nursery areas is incomplete and additional surveys are needed to fill the gaps in the current knowledge.

In the past, during summer dry periods, low water flow in the upper Welland River basin has had detrimental effects on the lower Welland River and its fish population. High contaminant levels combined with high temperatures and low oxygen levels have probably stressed the aquatic population and may have lowered productivity in the Welland River as a whole.

Water quality encompasses an enormous number of factors including physical, chemical and biological elements. Physical alterations, which alter the natural temperature regime of the ecosystem, can affect fish productivity in various ways including altering spawning activities[91]. High levels of suspended sediment and sedimentation have been shown to decrease productivity[92,93].

Habitat can also be lost through siltation; clogging of gravel beds with settleable material means loss of spawning areas and possible smothering of eggs. The introduction of foreign species can aggravate the problem of lost habitat and productivity. For example, carp are aggressive feeders; they uproot vegetation and increase turbidity while foraging in the sediment[90].

The focus of current efforts appears to be moving towards fisheries habitat conservation, restoration and development. A White Paper on wetlands policy has been developed by the Ontario Ministries of Natural Resources and Municipal Affairs and is currently being reviewed by the public.

2.5.1.3 Fishery Areas

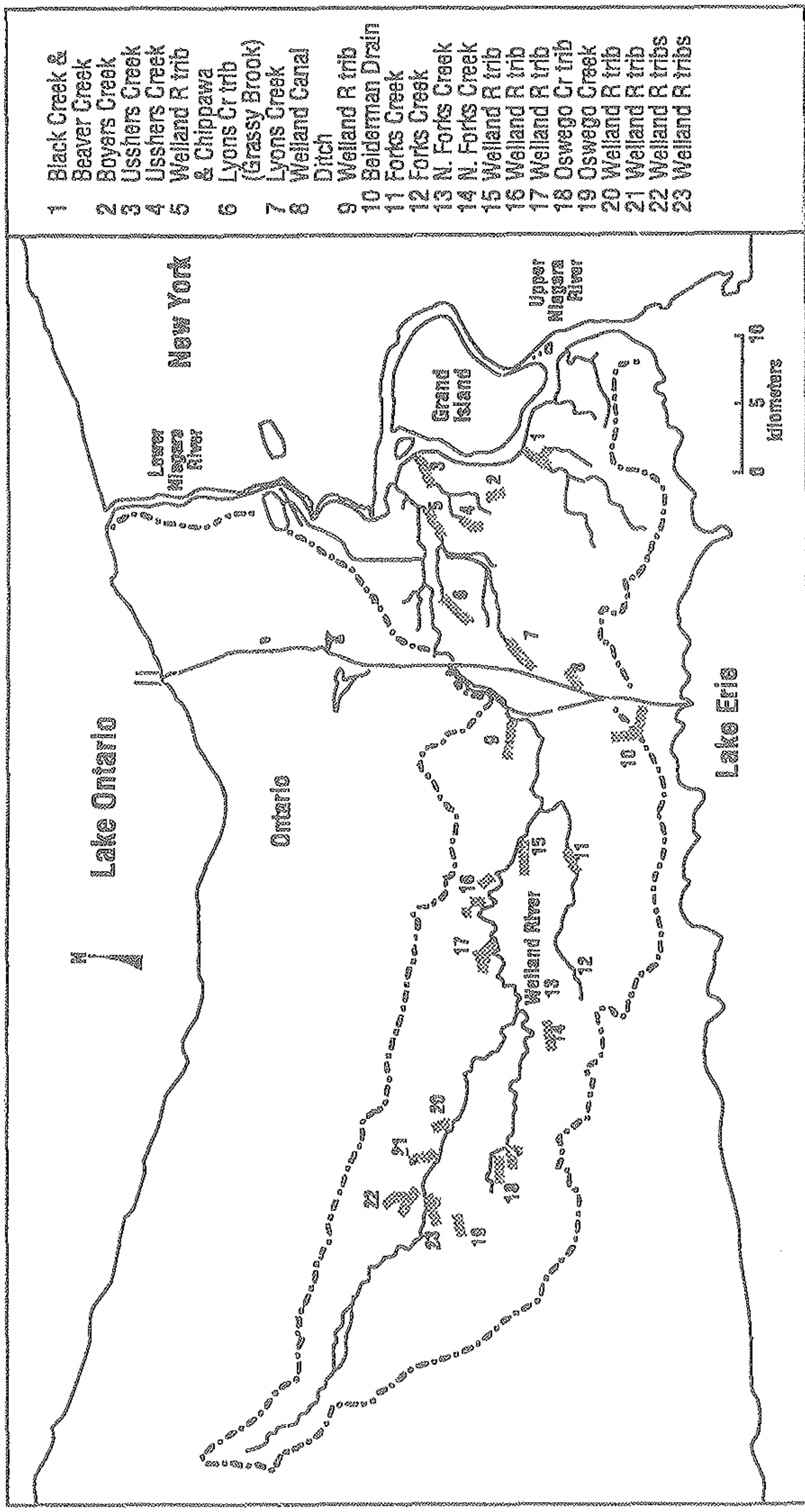
The fishery of the Niagara district is economically important to the area. Fishermen spend money on equipment, food and accommodation. With the introduction of resident fishing licences in 1986, to complement the non-resident licence, the revenues have increased.

TABLE 2.6

Species With Known Spawning and Nursery Areas on the Niagara River			
Species	**Loc.**	**Evidence**	**Date**
Lake Sturgeon	UNR	spawn	(1891) disappeared around 1890
Longnose Gar	UNR	young	late 1920's
Lake Herring	LNR	Adult spawners	1878
Rainbow Trout	LNR	Adult spawners	(1973)
Atlantic Salmon	LNR	Adult spawners	until late 1800's
Rainbow Smelt	UNR	Adult spawners	1959 first seen run
Northern Pike	UNR	Adult spawners	until 1960's in main river, now mainly in tributaries and Black Rock Canal (1978)
	LNR	Adult spawners	(1977)
Muskellunge	UNR	Adult spawning	two major spawning areas (1978)
Carp	UNR	Adult spawners	(1929,1968)
	LNR		
Emerald Shiner	?	young	late 1920's
Blackchin Shiner	?	Adult spawners	(1929)
Blacknose Shiner	UNR	Adult spawners	(1929)
Spottail Shiner	UNR	young	(1979)
White Sucker	UNR	young	(1980)
Greater Redhorse	trib	young	(1929)
Catostomid spp.	UNR	Adult spawners	(1860-1898)
Threespine Stickleback	LNR	young	late 1920's
Trout-Perch	?	young	late 1920's
White Bass	?	young	late 1920's
Rock Bass	UNR	Adult spawners	four shoals (1978)
Smallmouth Bass			
Largemouth Bass	UNR	Adult spawners	Strawberry, Motor and Grand Islands (1979)
Bass spp.	UNR	Adult spawners	Grand and Navy Islands and Chippawa Creek (1977, 1860-98)
	LNR	Adult spawners	Queenston (1860-98)
Yellow Perch	UNR	Adult spawners	(1967)
		young	(1929)
Walleye	UNR	Adult spawners	(1860-98)
		young	(1929)

UNR - Upper Niagara River
LNR - Lower Niagara River

- from Goodyear, C.D., T.H. Edsall, D.M.O. Dempsey, G.D. Moss and P.E. Polanski. 1982. Atlas of the Spawning and Nursery Areas of the Great Lakes Fishes Volume X - Niagara River, 1982, U.S. Fish and Wildlife Service, FWS/OBS-82/52: 15p.



Not all inclusive, but what has been documented to date by observation or hear-say evidence. Likely any creek with adequate spring flooding will have pike spawning.

O.M.N.R. - Niagara District Office Records - unpublished

Figure 2.7
Niagara River Area Of Concern - Spawning Areas

Various favourite fishing spots are present in the Niagara River watershed. These 'hot spots' will change with season, fish abundance and community structure. In the last decade the numbers of salmonids in the lower river have increased. Fishing pressure at the mouth of the river and at the whirlpool for salmons has paralleled this increase. Contaminant levels in the salmonids does not appear to deter fishermen. The percentage of anglers who consume these fish is unknown and may be worth determining. It is believed by some community agencies that anglers in lower income brackets are consuming all they catch.

Fishing also occurs in the Sir Adam Beck Generating Station Reservoir and forebays on Ontario Hydro land. The water level in the reservoir fluctuates and can have an influence on fishing success.

On the upper river, fishing occurs upstream of the Welland River mouth. The shoreline on the Canadian side is owned by the Niagara Parks Commission so there is continuous access to the river. Fishing at the inlet from Lake Erie is popular and there are numerous boat launching facilities along the river. Care must be taken on this river due to the rapid current and hazard of the falls. A map of "Upper Niagara River Fishing Hot Spots" has been published by the Urban Waterfront Advisory Committee in Buffalo, New York. A book, "Fishing in Niagara" has also been published[94].

Fishing also occurs on the tributaries, especially the mouths. The siphons on the Welland River at Port Robinson and in the city of Welland are popular fishing spots.

2.5.2 Wildlife

Wildlife in The Niagara Peninsula have not been studied in depth. Most efforts in documenting species and numbers have come through the efforts of organized groups of individuals.

The geological nature of the Niagara Escarpment was a major factor in its being declared a biosphere reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO) on April 4, 1990. The wildlife of the Niagara Escarpment, with its wide diversity of birds, mammals, reptiles and amphibians, including a number of rare or endangered species, was a contributing factor to the UNESCO decision.

Although few members of the wildlife community appear affected by the water quality of the Niagara River, the entire Niagara area environment may play a part in its makeup.

2.5.2.1 Avian Wildlife

The Niagara Peninsula has a wide diversity of bird species, with 341 species being identified (Table 2.7 located at the end of this chapter). Of these, 152 species breed in the area. Of the 302 species in the peninsula, (exclusive of species considered to be in the area accidentally) 123 species of birds occur on the river or in aquatic habitat closely related to the river[95]. Twelve of the peninsula species are considered rare, threatened or endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or the Ontario Ministry of Natural Resources.

The Niagara River is an important area for staging and migration of waterfowl. Thirty-six species have been recorded in the peninsula with many species using the area for winter habitat. The numbers of birds in any area varies between years but the average number of birds counted on the river, using nine years of mid-winter waterfowl counts usually conducted on the first weekend of January by the Peninsula Field Naturalists and the Niagara Falls Nature Club in co-operation with the Ontario Ministry of Natural Resources (1977-87), is 9,700. Declines in the population are hard to determine, as numbers in the area depend partially on weather and ice conditions.

TABLE 2.7

Birds of the Niagara Peninsula					
Species	Status	Species	Status	Species	Status
Common Loon	M.	Barrow's Goldeneye	Ra.	American Woodcock *	
Artic Loon	A.	Bufflehead	A.	Common Snipe *	M.
Red-throated Loon	OM.	Oldsquaw	WV.	Whimbrel	M.
Red-necked Grebe	OM.	Harleqin Duck	O.WV.	Upland Sandpiper *	
Horned Grebe	M.WV.	Common Eider	Ra.	Solitary Sandpiper	M.
Western Grebe	A.	King Eider	WV.	Spotted Sandpiper *	
Eared Grebe	Ra.M.	White-winged	M.WV.	Willet	Ra.M.
Pied-billed Grebe *		Surf Scoter	M.	Greater Yellowlegs	M.
Wilson's Petrel	A.	Common Scoter	M.	Lesser Yellowlegs	M.
White Pelican	A.	Ruddy Duck *1	M.	Knot	M.
Brown Pelican	A.	Hooded Merganser *	M.WV.	Purple Sandpiper	WV.
Gannet	A.	Common Merganser	M.WR.SV	Pectoral Sandpiper	M.
Double Crested Cormorant	OM.WV.	Red-breasted Merganser	M.WR.SV	White-rumped Sandpiper	M.
Great Blue Heron *		Smew	A.	Baird's Sandpiper	M.
Green Heron *		Turkey Vulture *	SR.	Least Sandpiper	M.
Little Blue Heron	A.	Black Vulture	A.	Curlew Sandpiper	A.
Black-crowned Night Heron *		Goshawk	OM.WV.	Dunlin	M.
Yellow-crowned Night Heron	Ra.	Sharp-shinned Hawk *2	M.WV.	Short-billed Dowitcher	M.
Wood Stork	Ra.SV.	Gryfalcon	V.Ra.	Long-billed Dowitcher	Ra.M.
Cattle Egret	Ra.SV.	**Cooper's Hawk *1**	M.WV.	Stilt Sandpiper	O.M.
Common Egret	SV.	Red-tailed Hawk *	PR.	Semipalmated Sandpiper	M.
Snowy Egret	A.	**Red-shouldered Hawk *1**	SR.	Western Sandpiper	Ra.M.
Least Bittern *		Broad-winged Hawk	M.	Buff-breasted Sandpiper	Ra.M.
American Bittern *		Rough-legged Hawk	WR.	Marbled Godwit	Ra.M.
Glossy Ibis	A.	Golden Eagle	Ra.OM.	Hudsonian Godwit	O.M.
White-faced Ibis	A.	**Bald Eagle *1**	Ra.M.	Sanderling	M.
Sandhill Crane	Ra.M.	Northern Harrier *	SR.WV.	American Avocet	Ra.M.
Tundra Swan	A.	**Osprey**	M.	Red Phalarope	O.M.
Mute Swan	Ra.	**Peregrine Falcon**	Ra.M.	Wilson's Phalarope	O.M.
Whistling Swan	M.	Merlin	OM.	Red-necked Phalarope	Ra.M.
Canada Goose *	M.OW.	American Kestrel *	PR.	Long-tailed Jaeger	Ra.M.
Brant	OM.	Ruffed Grouse *	PR.	Parasitic Jaeger	Ra.M.
Snow Goose	OM.	Bobwhite	Ra.PR.	Pomarine Jaeger	Ra.M.
Blue Goose	OM.	Ring-necked Pheasant *	PR.	Glaucous Gull	WV.
Mallard	PR.	Gray Partridge	PR.	Iceland Gull	WV.
Black Duck	PR.	Wild Turkey	PR.	Great Black-backed Gull *1	WV.SR.
Gadwall *	OM.WV.	King Rail	O.SR.	Lesser Black-backed Gull	Ra.M.
Pintail	M.WV.	Virginia Rail *		Herring Gull	PR.
Green-winged Teal *2	M.	Yellow Rail	Ra.SV.	Thayer's Gull	Ra.M.
Blue-winged Teal *		Sora *		California Gull	A.
European Widgeon	A.	Purple Gallinule	A.	Ring-billed Gull *	PR.
American Widgeon *	M.O.SR.WV	Common Moorhen *		Mew Gull	A.
Shoveler *	OM.	American Coot *	WV.	Sabine's Gull	Ra.M.
Wood Duck *		American Oyster-catcher	A.	Black-headed Gull	Ra.WV.
Redhead*	M.WR.	Semipalmated Plover	M.	Laughing Gull	Ra.WV.
Ring-necked Duck	M.WV.	Piping Plover	M.	Franklin's Gull	Ra.M.
Canvasback	M.WV.	Killdeer *	WV.	Bonaparte's Gull	WR.
Greater Scaup	M.WR.	American Golden Plover	M.	Little Gull	Ra.WV.
Lesser Scaup	M.	Black-bellied Plover	M.	Ivory Gull	A.
Common Goldeneye	M.WR.SV.	Ruddy Turnstone	M.	Black-legged Kittiwake	Ra.WV.
Forster's Tern	Ra.M.	Purple Martin *		Yellow Warbler *	
Common Tern *		Black-billed Magpie	A.	Magnolia Warbler	M.
Caspian Tern *	O.M.	Blue Jay *	PR.	Cape May Warbler	M.
Black Tern *		Common Crow *	PR.	Black-throated Blue Warbler	M.

TABLE 2.7 (con't)

Birds of the Niagara Peninsula

Species	Status	Species	Status	Species	Status
Roseate Tern	A.	Black-capped Chickadee *	PR.	Myrtle Warbler	M.O.WV.
Arctic Tern	A.	Boreal Chickadee	O.WV.	Black-throated Green Warbler *1	M.
Razorbill	Ra.M.	Tufted Titmouse *	O.WR.	Cerulean Warbler *	
Thick-billed Murre	A.	White-breasted Nuthatch *	PR.	Blackburian Warbler *1	M.
Black Guillemot	A.	Red Breasted Nuthatch *	M.O.WV.	Chestnut-sided Warbler *2	M.
Rock Dove *	PR.	Brown Creeper *	M.O.WR.	Bay-breasted Warbler	M.
Mourning Dove *	PR.	House Wren *		Blackpoll Warbler	M.
Yellow-billed Cuckoo *		Winter Wren *2	M.WV.	Pine Warbler	O.M.
Black-billed Cuckoo *		Carolina Wren *	O.	Yellow-throated Warbler	A.
Barn Owl *	O.PR.	Bewick's Wren	A.	Prairie Warbler	O.M.
Great Grey Owl	Ra.WV.	Marsh Wren *		Worm-eating Warbler	Ra.
Eastern Screech Owl *	Ra.	Sedge Wren *		Palm Warbler	M.
Great Horned Owl *		Rock Wren	A.	Ovenbird *	
Snowy Owl	WV.	Mockingbird *	PR.	Northern Waterthrush *2	M.
Long-eared Owl *	O.WR.	Catbird *		Louisana Waterthrush *2	M.
Short-eared Owl *	O.PR.CWR	Brown Thrasher *		Kentucky Warbler	O.M.
Boreal Owl	O.WV.	Sage Thrasher	A.	Connecticut Warbler	O.M.
Saw-whet Owl *	WV.	Robin *	WV.	Mourning Warbler *	M.Ra.SR.
Hawk Owl	Ra.WV.	Wheatear	Ra.	Yellowthroat *	Ra.WV.
Whip-poor-will *	M.	Wood Thrush *		Yellow-breasted Chat *	O.
Common Nighthawk *		Hermit Thrush	M.O.SV.	Hooded Warbler *2	Ra.M.
Chimney Swift *		Swainson's Thrush	M.	Wilson's Warbler	M.
Ruby-throated Hummingbird *		Gray-cheeked Thrush	O.M.	Canada Warbler *2	M.
Belted Kingfisher *	O.WV.	Veery *		American Redstart *	
Yellow-shafted Flicker *	PR.	Varied Thrush	A.	House Sparrow *	PR.
Pileated Woodpecker	PR.	Eastern Bluebird *		Bobolink *	
Red-bellied Woodpecker *	O.	Blue-gray Gnatcatcher *	O.SR.	Eastern Meadowlark *	WV.
Red-headed Woodpecker *	PR.	Golden-crowned Kinglet	M.WV.	Western Meadowlark	O.SR.
Yellow-bellied Sapsucker	M.	Ruby-crowned Kinglet	M.O.WV.	Yellow-headed Blackbird	A.
Hairy Woodpecker	PR.	Water Pipit	M.	Red-winged Blackbird *	WV.
Downy Woodpecker	PR.	Bohemian Waxwing	Ra.WV.	Orchard Oriole *	O.
Northern Three-toed Woodpecker	A.	Cedar Waxwing *	PR.	Northern Oriole *	
Eastern Kingbird *		Townsends Solitaire	A.	Rusty Blackbird	M.O.WV.
Western Kingbird	A.	Northern Shrike *	WV.	Common Grackle *	O.WV.
Scissor-tailed Flycatcher	A.	Loggerhead Shrike *	O.WV.	Brown-headed Cowbird *	O.WV.
Great Crested Flycatcher *		Starling *	PR.	Summer Tanager	Ra.V.
Eastern Phoebe *		White-eyed Vireo *2	O.M.	Western Tanager	A.
Yellow-bellied Flycatcher	O.M.	Yellow-throated Vireo *	O.SR.	Scarlet Tanager *	
Acadian Flycatcher *	O.	Solitary Vireo	M.	Cardinal *	PR.
Willow Flycatcher *		Red-eyed Vireo *		Blue Grosbeak	Ra.
Alder Flycatcher *		Philadelphia Vireo	O.M.	Rose-breasted Grosbeak *	
Least Flycatcher *		Warbling Vireo *		Indigo Bunting *	
Eastern Wood Pewee *		Black-and-White Warbler	M.	Dickcissel	O.WV.
Olive-sided Flycatcher	O.M.	Prothonotary Warbler *1	O.SR.	Evening Grosbeak	WV.
Horned Lark *	PR.	Golden-winged Warbler *	SR.	Purple Finch *	M.WV.
Tree Swallow *		Blue-winged Warbler *	Ra.SR.	Pine Grosbeak	WV.
Bank Swallow *		Tennessee Warbler	M.	Hoary Redpoll	A.
Rough-winged Swallow *		Orange-crowned Warbler	O.M.	Common Redpoll	WV.
Barn Swallow *		Nashville Warbler *	M.	Pine Siskin *	M.WR.
Cliff Swallow *		Parula Warbler	O.M.	American Goldfinch *	PR.

TABLE 2.7 (con't)

Birds of the Niagara Peninsula

Species	Status	Species	Status	Species	Status
Red Crossbill	M.WV.	Vesper Sparrow *		White-crowned Sparrow	M.O.WV.
White-winged Crossbill	M.WV.	Lark Sparrow	A.	White-throated Sparrow *	M.O.WV.
Green-tailed Towhee	A.	Slate-colored Junco	M.WV.	Fox Sparrow	M.WV.
Rufous-sided Towhee *	WV.	Oregon Junco	O.WV.	Lincoln's Sparrow *	O.
Savannah Sparrow *		Tree Sparrow	M.WV.	Swamp Sparrow *	M.O.WV.
Grasshopper Sparrow *	O.SR.	House Finch *		Song Sparrow *	PR.
Le Conte's Sparrow	A.	Chipping Sparrow *		Harris's Sparrow	O.SV.
Henslow's Sparrow	O.SR.	Clay-coloured Sparrow	Ra.SR.	Lapland Longspur	WV.
Sharp-tailed Sparrow	O.M.	Field Sparrow *	O.WV.	Snow Bunting	WV.
Ruff	A.	Lark Bunting	Ra.V.		

Legend:	PR.	Permanent Resident, breeding in summer.
	*	Breeds in the region in summer, may also migrate through the region
	M.	Migrant
	O.	Occasional
	OM.	Occasional Migrant
	SR.	Summer Residentt, no breeding evidence
	Ra.	Rare
	SV.	Summer Visitor
	WR.	Winter Resident
	CWR.	Common Winter Resident
	WV.	Winter Visitor
	A.	Accidental (birds which are out of their normal range in the region and for which there are few records).
	bold	= Species considered rarethreatened or endangered by COOSEWIC or MNR
	From:	Niagara Peninsula Conservation Report Volume I 1972 Atlas of the Breeding Birds of Ontario - 1987 Birds of the Niagara River - Buffalo Ornithological Society - 1989 Wildlife of the Niagara Escarpment Planning Area - 1978
	1=possible sighting 2=probable sighting rest are confirmed nesting sightings in Atlas or other reference.	

The Niagara River is an internationally recognized area among naturalists for numbers and diversity of gulls. The maximum number of species of gulls documented on the river at one time is thirteen including rare species. Bonaparte's Gulls are seen by the thousands with a record of 60,000 at one time[95]. Birders come in busloads to observe along the Niagara River, particularly during November.

Re-introductions of rare, endangered or extirpated species have been attempted in the area, including peregrine falcons, wild turkeys and bald eagles. A very enthusiastic effort was made in 1986-87 to re-introduce 19 peregrine falcons into the area by a local naturalist club. Two pairs of bald eagles were introduced west of Cayuga between 1986 and 1987. Wild turkeys were first reintroduced to the Niagara Region in 1984. Since that time, turkeys have been trapped and transferred to additional areas. Nesting platforms are currently being erected in an attempt to encourage nesting of osprey in the area.

2.5.2.2 Mammalian Wildlife

There are 44 mammalian species found in the Niagara Peninsula (Table 2.8 located at the end of this chapter), with 22 considered common. The detrimental effects of the environmental quality of the area on these populations are hard to determine. A limited amount of work has been done on the status of mammalian populations, primarily white-tailed deer using aerial surveys and jacklight surveys to determine population, sex ratio, and fawning rate. Differences in the condition between Navy Island and mainland deer[107] were thought to be mainly due to overpopulation on Navy Island. A population of about 116 deer/km^2 (300 per square mile) was found on Navy Island as a peak level prior to the 1981 controlled hunt that was used to reduce the population to a sustainable level. The highest population density found on the mainland in Niagara was 18 deer/km^2 (47 per square mile) in the Wainfleet bog during 1989.

Population surveys of other species are virtually nonexistent and the use of harvest data to determine other mammalian population trends has several drawbacks. Harvest is dependent on trapper effort and experience, pelt prices and demand, and habitat quantity and quality[108]. Also trappers are not presently required to record specifically where within a trapping unit the pelt was taken.

2.5.2.3 Reptilian and Amphibian Wildlife

Thirty-four species of amphibians and reptiles occur in the Niagara peninsula (Table 2.9 located at the end of this chapter). These species include 13 snakes, 8 turtles, 10 frogs and toads, and 7 salamanders and newts[110]. The recent discovery of local specimens of dusky salamander in the Niagara River area is the only known population in Ontario. Sampling of rare or endangered species is discouraged, as the act of sampling itself could have significant detrimental effects on population levels.

The status of the populations of reptiles and amphibians in the area is not well documented. These animals are generally small and secretive in their behaviour. Little is known about their distribution, abundance, habitat requirements, breeding behaviour, hibernation and other aspects of their life cycles[110]. The Ontario Field Herpetologists document sightings of species but little is known about the numbers and reproductive success. Six species in the area are considered rare, threatened or endangered. Depletion of wetlands, urban development and physical disturbances, along with contaminant problems, probably contribute to declines in numbers. Freshwater wetlands are important as habitat for aquatic reptiles and amphibians and the distribution and abundance of these organisms is controlled by several major factors including wetland size and location, water quality, flooding regime, substrate and vegetation structure[111].

TABLE 2.8

Mammalian Species of the Niagara Peninsula	
COMMON NAME	SCIENTIFIC NAME
Northern Short-tailed Shrew	Blarina brevicauda
Little Short-tailed Shrew	Cryptosis parva
Smoky Shrew	Sorex fumeus
Masked Shrew (Common) *	S.cinereus
Pigmy Shrew	Microsorex hoyi
Star nosed Mole *	Condylura cristata
Hairy-tailed Mole (Brewer's Mole)	Parascalops breweri
Meadow Vole *	Microtus pennsylvanicus
Gapper's Red-backed Vole	Clethrionomys gapperi
Woodland Vole (Pine Vole)	Microtus pinetorum
White-footed Mouse *	Peromyscus leucopus
Meadow Jumping Mouse *	Zapus hudsonius
Deer Mouse *	Peromyscus maniculatus
House Mouse *	Mus musculus
Norway Rat *	Rattus norvegicus
Silver Haired Bat	Lasionycteris noctivagans
Red Bat	Lasirus borealis
Hoary Bat	Lasirus cinereus
Keen's Myotis (Eastern Long-eared Bat)	Myotis keenii
Least Bat	Myotis subulatus
Little Brown Bat *	Myotis lucifugus
Big Brown Bat *	Eptesicus fuscus
Eastern Pipistrelle	Pipistrellus subflavus
Southern Bog Lemming	Synaptomys cooperi
Woodchuck *	Marmota monax
Muskrat *	Ondatra zibethicus
American Beaver	Castor canadensis
American Mink	Mustela vison
Long-tailed Weasel	Mustela frenata
Ermine	Mustela erminea
White-tailed Deer *	Odocoileus virginianus
Bobcat	Lynx rufus
Eastern Cottontail *	Sylvilagus floridanus
European Hare *	Lepus europaeus
American Red Squirrel *	Tamiasciurus hudsonicus
Gray or Black Squirrel *	Sciurus carolinensis
Southern Flying Squirrel	G. volans
Eastern Chipmunk *	Tamias striatus
Striped Skunk *	Mephitis mephitis
Raccoon	Procyon lotor
Virginia Opposum *	Didelphis virginiana
Red Fox *	Vulpes vulpes
Gray Fox	Urocyon cinereoargenteus
Coyote (Brush Wolf) *	Canis latrans

-from Niagara Peninsula Conservation Report Volume 1 1972 and The American Society of Mammalogists - Species monographs

* indicates common species

-species identified in bold are currently considered rare, threatened, or endangered in Ontario or Canada

Table 2.9

Niagara Peninsula Herpetofaunal Summary	
Common	**Scientific Name**
Mudpuppy	Necturc maculosus
Red-spotted Newt	Triton vert
Jefferson Salamander	Ambystoma jeffersonianum
Yellow-spotted Salamander	Ambystoma masculatum
Dusky Salamander *	Desmognathus fuscus
Four-toed Salamander	Hemidactylium scutatum
Eastern Redback Salamander	Plethodon cinereus
American Toad	Bufo americanus americanus
Woodhouse's Toad	Bufo woodhousei
Spring Peeper	Hyla crucifer
Tetraploid Gray Treefrog	Hyla versicolor
Striped Chorus Frog	Pseudacris triseriata
Wood Frog	Rana sylvatica
Northern Leopard Frog	Rana pipiens
Pickerel Frog	Rana palustris
Green Frog	Rana clamitans melanota
Bullfrog	Rana catesbeiana
Common Snapping Turtle	Chelydra serpentina
Stinkpot	Sternotherus odoratus
Painted Turtle	Chrysemys picta
Blanding's Turtle	Emydoidea blandingii
Spotted Turtle	Clemmys guttata
Eastern Box Turtle*	Terrapene carolina
Spiney Softshell	Trionyx spiniferus
Five-lined Skink *	Eumeces fasciatus
Common Garter Snake	Thamnophis sirtalis
Eastern Ribbon Snake	Thamnophis sauritus
Northern Water Snake	Nerodia sipedon
Redbellied Snake	Storeria occipitomaculata
Brown Snake	Storeria dekayi
Smooth Green Snake	Opheodrys vernalis
Ringneck Snake	Diadophis punctatus
Eastern Hognose Snake*	Heterodon platyrhinos
Rat Snake	Elaphe obsoleta
Fox Snake*	Elaphe vulpina
Milk Snake	Lampropeltis triangulum
Massassauga*	Sistrurus catenatus
Timber **Rattlesnake****	Crotalus horridus

-from Distribution and Status of the Herpetofauna of Central Region, August 1989 (Plourde et al. 1989)
-bolded species are currently considered rare, threatened, or endangered in Ontario or Canada
-bolded first letters indicate species currently under review for status
-* indicates the species is considered rare in the area
-**species probably expirated from Niagara R. watershed

3.0 USE OF THE RESOURCE

3.0 USE OF THE RESOURCE

The potential of the Niagara River has long been recognized. The waters of the Niagara River itself were used for potable water by Native Peoples for centuries before Niagara Falls was first visited by Father Hennepin. Today, the river continues to serve as a potable water source for the public and for industrial facilities. However, the Niagara River area is primarily used for hydro-electric power generation and for tourism and recreation.

3.1 Water Uses

Lake Ontario is the source of drinking water for approximately 4 million residents of the Province of Ontario and 1 million residents of the State of New York. In addition, it serves a myriad of recreational uses for residents and visitors to the Lake Ontario area. Such uses include: swimming, diving, boating, windsurfing, fishing and hunting (waterfowl).

The Niagara River itself serves as a source of drinking water for the City of Niagara Falls, Ontario via a filtration plant at the junction of the Niagara River and Chippawa Creek in Chippawa. Most of the urban areas in New York State between Buffalo and Youngstown are also serviced by plants that draw water from the Niagara River.

The river is also used for many of the same primary recreational activities as Lake Ontario. On the lower river, fishing takes place from boats and from the shoreline for such species as: american eel, yellow and white perch, rainbow trout, walleye, muskellunge, pike, coho salmon, rock and smallmouth bass, suckers and smelt. In the upper river, smelt, yellow perch, rainbow trout, smallmouth bass, suckers and walleye are extensively fished. Lake trout and brown trout are also caught in Lake Erie near the head of the river off Fort Erie.

Marinas for both sail and power boats exist at Fort Erie, Chippawa and Niagara-on-the-Lake as well as several locations along the Chippawa Channel and in Chippawa Creek.

The extensive parkway belt along the Canadian shoreline of the Niagara River provides a habitat for a wide range of amphibians, birds, mammals and reptiles. Habitat for most of these species is also found in areas not normally accessible to humans, such as: Navy Island, emergent areas in the Niagara Rapids and through the Niagara Gorge.

For the most part, the fast-flowing Niagara River is too dangerous for bathing. However, bathing beaches are found at Niagara-on-the-Lake, Chippawa and Fort Erie.

The spectacle of the Niagara Falls panorama, the Niagara Rapids, Whirlpool Rapids and Devil's Hole Rapids, the Niagara Gorge and the Whirlpool, historical attractions such as Fort George, Queenston Heights and Old Fort Erie and recreational attractions such as the Spanish Aero Car, the Shaw Festival, the Maid-of-the-Mist and the Cave of the Winds bring millions of tourists to the Niagara area each year from all over the world.

The extensive park lands along the Niagara River are also popular for bicycling, hiking, picnicking, sightseeing, camping and photography.

3.2 Land Uses

The drainage area associated with the Canadian side of the Niagara River can be divided into two parts: the Niagara River proper (and its minor tributaries) and the Welland River (and its tributaries) having associated drainage areas of approximately 230 and 1,050 km^2, respectively (Table 3.1).

Land use can have a dramatic influence on water quality within a drainage area. A survey of the land use in the Niagara-Welland watershed has not been done directly. The agencies responsible for collection of land use data work on a geographic township-by-township basis. Statistics for each regional municipality are available for varying time periods. The values reported in Table 3.2 and in the following sections were estimated using land use maps of the regional municipalities of Niagara (1980), Haldimand-Norfolk (1982) and Hamilton-Wentworth (1980).

The following sections discuss the various land uses in the area and how they can affect environmental quality, particularly water quality. Niagara district agricultural statistics quoted are from the Ministry of Agriculture and Food[29].

3.2.1 Agricultural Lands

Agriculture is an important industry in the Niagara Peninsula. In 1986, the Niagara region had 3,147 farms reporting some farm income, with 2,619 farms reporting income greater than $2,500 per year[29]. These farms covered 95,887 hectares, with 70,964 hectares under crops. The total value of the agricultural products produced in the Niagara Peninsula was over $250,000,000. Unfortunately, the data are not reported in such a manner as to make it practical to identify the income from the agricultural operations within the Niagara-Welland watershed.

The soils of the area are primarily clay, and the slope is low. This implies that the drainage of the area is naturally poor. Portions of the area have been tile drained, with fruit production areas highly drained. However, tile drainage in areas that are flat and have a high clay content is ineffective. In the Niagara Peninsula, there were 71,000 hectares of cropland, of which 21,000 hectares are systematically or randomly drained[29]. The drains are, however, concentrated below the escarpment in fruit production areas which are outside the Niagara-Welland watershed.

The Niagara Peninsula is acknowledged as one of the country's leading fruit production areas. The Niagara River watershed does not include a large proportion of these orchards and vineyards; these are primarily located between the Niagara Escarpment and the Lake Ontario shoreline. Some fruit production does occur along the northwest shore of the Niagara River and near Fonthill. This makes up approximately 1,000 hectares, or less than 1 percent, of the land in the watershed.

A breakdown of the different crops grown in the Niagara River area can be seen in Table 3.2. Row-crops (corn, soybean) and cereal grains (winter wheat, barley, oats) make up a large percentage of the crops of the area. The acreage of each crop varies from year to year depending on crop rotation and current market value. In the last five years the amount of soybean planted in the area has increased dramatically.

Livestock produced in the area includes cattle, poultry, sheep, and pigs. There is no livestock access directly to the Niagara River, but livestock do have access to the tributaries, and this contributes to localized bank erosion problems. Manure storage and application is a source of bacterial/nutrient problems and is not strictly regulated or enforced. Spills of liquid wastes from poultry or livestock operations can produce immediate and significant fish kills.

TABLE 3.1

Watershed Areas of the Niagara River			
Sub-watershed	Area sq. km	Sub-watershed	Area sq. km
Niagara River (total)	229.9	Welland River (total)	919.6
Direct Drainage	2.9	Direct Drainage	351.3
Frenchman Creek	17.2	West Wolf Creek	14.0
Miller Creek	8.3	Buckhorn Creek	23.9
Beaver Creek	34.9	Elsie Creek	34.3
Baker Creek	3.2	Oswego Creek	169.1
Black Creek	70.3	Little Wolf Creek	10.0
Bayer's Creek	13.5	Wolf Creek	13.8
Usshers Creek	19.6	Mill Creek	19.7
		Moores Creek	13.0
		Wilson Creek	5.9
Chippawa Cr./Power Canal		Beaver Creek	39.3
(total)	130.2	Black Ash Creek	13.6
		Parkers Creek	19.7
Chippawa Creek		Little Forks Creek	14.3
Direct Drainage	8.5	Big Forks Creek	27.2
Lyons Creek	47.5	Sucker Creek	9.9
Tee Creek	30.1	Mill Race Creek	80.1
Grassy Brook	13.7	Coyle Creek	40.0
Hunter's Drain	3.8	Drapers Creek	11.5
Queenston/Chippawa		Thompsons Creek	13.8
Power Canal	26.6		

Tree nursery areas are usually kept bare between the trees, leading to erosion problems on a continual basis. Herbicides are generally used to control weed growth. Sod farms similarly are left bare at cutting times and erosion can also be a problem at these times. Herbicides are also used on the grass for weed control.

Agriculture in the area includes nursery areas and sod farms. Farmers in Ontario are encouraged to test their soils before application of phosphorus, nitrogen and potash fertilizers. The soils of this area generally have low levels of phosphorus and are high in potash content. The pH is low, between 5-6 without the application of lime. It is believed that farmers in the area are generally not over-applying fertilizers. Possible exceptions exist for livestock operations, particularly poultry, where large amounts of waste are being spread over small areas. Application of livestock wastes at the wrong time of the year appears to be a larger problem and is not regulated. Application of large amounts of manure during the spring run-off period can result in serious contamination of surface waters. The crop planted also has specific requirements; for instance, the increase in soybean acreage leads to an overall decrease in the application of nitrogen fertilizer.

The amounts of herbicides, fungicides and pesticides applied in the Niagara peninsula is unknown. Until recently, farmers and other users were not required to obtain a permit or to record volumes used. These chemicals can influence water quality and wildlife especially if they are not applied according to specifications. There is a course available on proper chemical application but it is not required by law. Organic farming is gaining popularity in the peninsula.

Past and present agricultural practices are not always beneficial to the environment or the farmer in the long term. Recent awareness of the effect of agricultural land use practices on environmental quality, particularly the effects of sediment and phosphorus loading, has led to the introduction of programmes that encourage changes in farming practices. These programmes include: SWEEP (Soil and Water Environmental Enhancement Program), Rural Beaches Programs, Land Stewardship Program and Tillage 2000. However, these are usually short-term programmes. Time and resources are needed to initiate substantial change.

TABLE 3.2

Land Use in the Niagara River Watershed				
Land Use Type	**Niagara R. & Tribs.**	**Power Canal & Chippawa Cr.**	**Welland R. & Tribs.**	**Total**
Area (ha)	23000	13000	92000	100%
Agriculture				
(orchards & vineyards)	2.7%		0.4%	< 1%
(vegetables & berries)	0.3%			
mixed	8.1%			
rowcrops	0.4%			
corn-wheat	12.0%			
cereal grains	1.1%			
hay	5.6%			
pasture, grazing	2.4%			
nursery, sod	0.3%			
Abandoned land				
(orchards...idle agriculture and scrubland)	23.2%			
Forested	15.5%			
Recreation	1.7%			
Urban... Rural Residential & Transportation	23.0%			
Wetland	0.1%			
Extraction	1.0%			

* estimates based on land use maps from Niagara, Haldimand-Norfolk, and Hamilton-Wentworth Districts (1980, 1982, and 1980)

Government grants for farmers willing to initiate changes are scarce. Encouragement in the use of crop rotation, buffer strips, grassed waterways, green belts, restricted cattle access, proper manure management, improved construction practices, proper chemical application methods and discouragement of wetland draining will help to eliminate the detrimental effects of agriculture.

The small farm appears to be a thing of the past. Recently there has been a move to larger, more efficient farms. Urban development, especially along the escarpment and the Lake Ontario shoreline, is threatening fruit production in these areas of Niagara, which for the most part are outside the study area. There is also concern with the potential groundwater contamination arising from rural strip housing, particularly in the upper Welland River basin.

3.2.2 Urban and Rural Centres

The main Ontario urban centres with water and sewage services in the Niagara River drainage area are: Fort Erie (pop. 23,486), Niagara Falls (pop. 72,107), Niagara-on-the-Lake (pop. 12,050) and Welland (pop. 44,569). The population figures in parentheses are 1988 estimates. These centres are all situated along the Niagara River or its tributaries and make up only a small percentage of the land in the drainage area. The sewage treatment plants for these urban centres are currently in various stages of improvements, but inputs of nutrients and contaminants are still significant.

3.2.3 Industrial Sites

The extent of industry on the Canadian side of the Niagara River is considerably less than that on the U.S. side. Many of the companies situated on the river have been identified historically as point sources of pollution[30]. Some degree of clean-up activity is currently underway at the plant sites of most point sources. In the upper reaches of the Welland River there are no significant industries.

There are, however, industries in the cities of Welland and Niagara Falls. During storm events, contaminants from these properties are carried into the Welland River which in turn flows into the Power Canal and eventually into the Niagara River through the Sir Adam Beck generating station.

Industrial properties in Fort Erie and Niagara Falls also contribute contaminated storm water runoff into minor tributaries or into the Niagara River directly.

3.2.4 Abandoned Lands

The percentage of the land in the Niagara-Welland basin considered abandoned agricultural land, including abandoned pasture, orchards and scrubland is considerable. These lands are considered important areas for wildlife habitat. Often these lands are held for future development by speculators.

3.2.5 Landfill Sites

Seventeen landfill sites have been identified in the area[31]. Of these sites, five are currently certified and still operating, and twelve are closed. Five landfill sites were considered possible problem areas in 1984[30]. Since then, further investigations into the sites have initiated remedial action and only one site remains a possible problem. These five landfills are discussed in more detail in section 5.6. There may exist other abandoned sites that have not been identified since landfill sites have only been required to be licensed since 1971. Leachate collection is not practised at any of the five sites.

TABLE 3.3

Conservation Authority Holdings on the Niagara River and Its Tributaries

Name	Area (ha)
Binbrook Conservation Area	396
Canboro	6
Chippawa Creek Conservation Area	148
E.C. Brown	6
Hedley Forest	17
Humberstone Marsh	82
Oswego	6
Port Davidson	0.2
Ruigrok Tract	76
Stevensville	49
United Empire Loyalist	22
Willoughby Marsh	231
Total Holdings	**1039.2**

3.2.6 Recreational and Forested Areas

Recreation and forested areas also make up a considerable portion of the land in the Niagara and Welland River basins. The Niagara Peninsula Conservation Authority now owns over 1,800 hectares of land, consisting of 34 conservation areas in the peninsula. Of this land area, 1,039.2 hectares lie within the Welland and Niagara watersheds directly (Table 3.3). These areas are used for various recreational activities and provide important wildlife habitat.

The Ontario Ministry of Natural Resources owns three tracts of land in the Niagara River watershed. The Wainfleet Bog acquisition, in the City of Port Colbourne, is probably the most ecologically significant. This 207 hectare piece of land is part of a class 1 wetland and was acquired to preserve this habitat and prevent the expansion of the peat extraction practices in the bog. There are two acquisitions in the City of Fort Erie; the Nigh (29.1 hectare) and Bowen Road (8.9 hectare) properties. These properties are used for reforestation projects and are considered wildlife areas.

3.2.7 Wildlife Areas

All land and water has the potential to be wildlife habitat using the most basic definition. Planning can make it possible for wildlife to coexist with most, if not all land use.

The Niagara Peninsula is considered part of the Carolinian life zone and southern Ontario has the only area of this type in Canada. Therefore many species that occur in this area are provincially or nationally significant. These include many of the rare vascular plants listed in Table 3.4 (located at the end of this chapter).

Wetlands in the past have been randomly and continuously drained and filled. It is now realized that wetlands have economic, water-related, ecological and social benefits in Southern Ontario[32]. These include tourism, renewable resource production, flood reduction, ground water recharge and flow augmentation, water quality improvements, diversity of ecological habitat, education, research and aesthetic value[32]. The realization of the importance of these areas has led to an attempt to protect the remaining wetland areas. The Provincial Wetland Policy statement was approved in May 1992. Its goals are: to ensure that wetlands are identified and adequately protected through the land use planning process and to achieve no loss of provincially significant wetlands. Table 3.5 (located at the end of this chapter) lists the wetlands of the Niagara River watershed which have been evaluated by the Ministry of Natural Resources. Many of these areas are small in size but all the wetlands are Provincially significant (Classes 1, 2, or 3). All these wetlands merit protection as required by the Provincial Wetland Policy statement.

TABLE 3.6

Natural Areas of the Niagara Region Within the Niagara River Watershed

(Regional Municipality of Niagara... 1985)

Areas Associated With Escarpment	**Forested Recreation Areas**
Niagara River Gorge *#	Stevensville Conservation Area #
Queenston Heights *#	
	Wet Forests
MNR Classified Wetlands	Cyanamid Corners *
Wainfleet Marsh *#	Forks Creek Woods *#
Wainfleet Wetlands *#	Comfort's Bush *
Lyons Creek Wetlands #	Sucker Creek *
Willoughby Marsh *#	Silverdale Woodlot *
(Clay Plain Muck Basin Forest)	(South St. Anns Slough Forest)
Humberstone Marsh *#	Fletcher Woodlot *
Mud Lake *#	Chambers Corners Clay Plain
Moulton East Wetland	Marshville Station Clay Plain
	Bartell's Bush *
Additional Wetlands	Bismarck Bush *
Ridgeville Swamp	Hardy's Wood *
Welland River #	Garber's Grove *
South St. Anns Slough Forest *	Pot's Woodlot *
	McCready's Bush *
Important Fisheries and Waterfowl Habitat	Ruigrok *#
Niagara River	(Caistor-Canborough Slough Forest)
Boyer's Creek	**Unusual Landforms**
Usshers Creek #	Ridgemount Quarry
Black Creek #	Humberstone Quarry
Miller Creek	
Frenchman Creek	**Other Sites of Rare Flora and Fauna**
Woodlots	Miller Creek
Summer Street Woodlot *	Usshers Creek Mouth #
Chippawa Creek Con. Area *#	Garner Road Woodlot
Navy Island	Cream and Welland Streets

* - ESA in Brock University ESA Report

\# - ESA in Regional Policy Plan... Municipality of Niagara

3.2.8 Environmentally Sensitive Areas

An environmentally sensitive area (ESA) is designated by a natural feature satisfying at least four of the following nine criteria[33]:

1) unusual and distinctive landform;
2) ecological functions (eg. water storage or recharge, wildlife stopover or concentration point);
3) unusual/distinctive plant and/or animal communities;
4) unusual/distinctive habitat;
5) high diversity of biological communities;
6) habitat for rare or endangered indigenous species;
7) large potential habitat for species requiring expanses;
8) amenable to scientific research and conservation education purposes;
9) high aesthetic value where alteration results in loss of amenity.

The Regional Municipality of Niagara recognizes 90 natural areas, 42 of which are designated as ESAs in the Regional Niagara Policy Plan[33]. The watershed of the Niagara River contains 39 of the 90 natural areas (Table 3.6). Hamilton-Wentworth region has 1 ESA within the Welland River watershed[34]. There are 3 ESAs within the Haldimand-Norfolk jurisdiction of the watershed[35].

The identification of natural areas or ESAs assists in the review of development plans for all regions. The intent is to ensure that development does not adversely affect the ESA. This does not necessarily mean restricted development within the ESA, but protection as determined through preparation of environmental assessments (EAs). In many cases, all or large portions of ESA areas may need to be protected.

The ESAs may also be identified by other programmes such as Areas of Natural and Scientific Interest (ANSIs) (Table 3.7), Niagara Parks Commission, Niagara Escarpment Commission, and MNR Wetland Classifications.

TABLE 3.7

Areas of Natural and Scientific Interest on the Niagara River and Its Tributaries
Life Sciences
Niagara Gorge
Caistor-Canborough Slough Forest
Attercliffe Station Slough Forest
Wainfleet Peat Basin Heath
Humberstone Muck Basin Swamp Forest
Lyons Creek Flood Plain Wetlands
Willoughby Clay Plain Muck Basin Forest
Navy Island
Earth Sciences
Niagara River Bedrock Gorge
Humberstone Quarry
Ridgemount Quarry

TABLE 3.8

Composition of the Regional Municipality of Niagara				
Municipality	**Status**	**Population (1986)**	**Growth (%) 1975-86**	**Area Sq. Km.**
St. Catharines	City	123455	2.5	94.4
Niagara Falls	City	72107	6.2	212.0
Welland	City	45054	0.2	81.2
Fort Erie	Town	23253	0.8	168.3
Port Colborne	City	18281	-10.1	122.8
Grimsby	Town	16956	9.0	68.1
Thorold	City	16131	9.8	84.6
Lincoln	Town	14391	1.0	163.4
Niagara-on-the-Lake	Town	12494	0.9	131.1
Pelham	Town	12137	23.4	124.5
West Lincoln	Township	9918	6.2	382.9
Wainfleet	Township	5955	0.4	217.4
Total		370132	3.2	1850.9

source: 1986 census data (see ref 852)

3.3 Socio-economic Perspective

The Niagara River Area of Concern includes a major portion of the Niagara Peninsula. Niagara is not a peninsula in the traditional sense although it is bounded by water on three sides. Because the Niagara River no longer forms a barrier to the east, the Niagara area serves as a corridor or gateway between Canada and the United States. A corresponding major water transportation corridor through the Niagara between Lake Erie and Lake Ontario makes Niagara a transportation crossroads. The demography, social patterns and development are strongly associated with the transportation routes which transect this area[855]. Although the AOC does not include the potential corridor along the Queen Elizabeth Way north of the Niagara Escarpment, a number of urban centres and considerable agricultural areas make up the population in the Area of Concern.

The historical panorama of Niagara Falls, combined with the existence of cheap electrical power has led to concentrated development along the banks of the Niagara River and particularly in the vicinity of Niagara Falls. The majority of the Niagara River area lies within the municipal boundaries of the Regional Municipality of Niagara. Small portions of the Region of Hamilton-Wentworth and the Region of Haldimand Norfolk are included in the agricultural headwaters of the Welland River to the south and east of Mount Hope and to the east of Cayuga and Dunnville.

The socio-economic fabric of the Niagara Region, involving population and money, effects the populace's ability to support remedial measures in the AOC, particularly if there is a direct cost to the individual or economic sector or to a municipality as a whole.

3.3.1 The Regional Municipality of Niagara

In 1969, the region of Niagara was the first area in the province to undergo full-scale regional reorganization. The Regional Municipality of Niagara Act reorganized four cities, five towns, three villages, fourteen townships and the counties of Lincoln and Welland into the Regional Municipality of Niagara and twelve area municipalities[924] (Table 3.8). The Regional Municipality of Niagara is a more powerful unit of government than the two counties it replaced. Within the Niagara River Area of Concern lie the cities of Niagara Falls and Welland, the Town of Fort Erie, significant portions of the towns of Pelham and Niagara-on-the-Lake and the townships of West Lincoln and Wainfleet, and small portions of the City of Port Colborne and the Town of Thorold. The City of St. Catharines and the towns of Grimsby and Lincoln are outside of the Area of Concern; however, due to the mobility and regional nature of the labour force, residents of these areas work within the AOC and some residents of the AOC work outside the area. Their socio-economic picture is directly or indirectly related to the Region as a whole[929].

The Region is responsible for activities which benefit more than one area municipality or which require a large scale to be most effective or economical[925], including: health, welfare, police and social services subject to Provincial control. In other areas such as planning and public works, the Region and local municipalities have split-jurisdiction, both having responsibilities in these areas. In water and sewer areas, the local municipalities supply water and provide sewage collection but the Region manages all water filtration plants and water pollution control plants as well as main trunks and pumping stations[925]. Within the Region, residential, commercial and industrial assessments have steadily increased over the past 5 years to support the municipalities in these programs[851].

The population of the Region of Niagara is currently estimated at 385,400 (1991 assessment)[854], up some 15,000 from the 1986 census of 370,130 (a population density of 200/km^2.). In another source, provincial population projections[662] were 381,680 for the year 1991 and 415,110 for the year 2011. For the year 2000, the projected population is 399,010 (51% female) with 53% of the entire population between 25 and 64 years of age[662]. These projections also show the median age of both men and women in Niagara increasing from 32.0 (1987) to 38.9 (2011) for men and from 34.5 (1987) to 42.2 (2011) for women. These figures are extrapolations based on the 1986 census.

Trends[851] indicate that the population grew steadily in the sixties and seventies (2400/yr.) but levelled off during the late seventies and early eighties (470/yr.)[852]. Population projections based on assessment indicate that between 1985 and 1991 the population has again started to expand (3050/yr.)[850]. The 1991 assessment roles show a 4.1% increase in population since the 1986 census[854] (Table 3.8). For the most part, this population expansion has occurred in municipalities along the QEW transportation corridor.

3.3.2 The Economy of the Niagara Peninsula

The readily accessible high-speed transportation corridor of the QEW is a significant factor in the Peninsula's development over the past 4 decades. It places most of the Area of Concern within one hour's drive of Metropolitan Toronto or Buffalo and Western New York. The four road bridges over the Niagara River are the busiest border crossings between Canada and the United States. They place Niagara within one day's trucking of 56% of the U.S. industrial market and more than 120,000,000 consumers[855].

The economy of the Niagara Peninsula has involved three sectors, since the development that occured at the turn of the century. Although modern trends change the balance of these three, they co-exist throughout the Peninsula. These economic mainstays are agriculture, manufacturing and tourism. The area is caught between the economies of its major neighbouring communities[923]. To the east, Niagara and Erie Counties in the U.S. have suffered severe periods of economic decline over the past three decades. To the west, the expanding metropolis of the "Golden Horseshoe" Toronto and Hamilton is "suburbanizing" the western portions of the Niagara Peninsula. The economy of the Niagara Peninsula is reflected in the regional assessment base. Tax assessments reflect growth and decline in both residential and industrial sectors. Table 3.9 shows a levelling off of growth between 1985 and 1988 with a slight growth indicated between 1989 and 1990. The 1990-1992 recession is expected to halt the weak growth pattern once again as indicated in the marginal assessment increase between 1889 and 1990.

TABLE 3.9

Niagara Regional Assessment Base (1986-1990)

Regional Assessment (Million $)

Year	Regional Total	Industrial	Residential
1986	895	309	587
1987	910	311	599
1988	926	310	616
1989	1013	371	642
1990	1045	379	654

source: NRDC (see ref 851)

The development of Niagara mirrors the development of Canada on a smaller scale. Until the second half of this century, Niagara, like Canada, was viewed as vast land area with limitless resources. In the 1970's, people started coming to the realization that these resources are both limited and fragile; these limits have been reached and in some cases are diminishing. As in the rest of Canada, there is a strong dependency between these resources and our activities to the extent that they are often in conflict[923]. Regional and Municipal Official Plans attempt to resolve these conflicts but the pressures remain. One of the most serious and potentially far-reaching conflicts in the 1990's is the development (and loss) of farmland throughout the peninsula (particularly those operations involving tender fruit production).

Within the Niagara River (Ont.) AOC, the 1985 income per household was $33,938[855]. Based on Revenue Canada information, there was a 25.5% increase in this income between 1985 and 1988. Using a figure of 8.0% increase in income per family/unattached in Ontario for 1988-89 and a 10.1% increase in the consumer price index between 1989 and 1991, the estimated income per household in Niagara for 1991 is $50,600[850].

3.3.3 Agriculture

Niagara has been known for many years for the production of grapes and tender fruit for markets provincially and across the country. Although most of this fruit-growing area is outside the Niagara River Area of Concern, a portion is found inside, along the northern edge of the AOC. The vast portion of the agricultural area of the Welland River basin is more diverse than the area below the escarpment, extending into all aspects of agriculture, especially row crops and livestock. Agricultural development grew to importance in the late 1800's and peaked in 1911 when an estimated 340,000 acres was in agricultural production. This acreage had declined to approximately 307,000 acres by 1941, predominantly through loss of field crop area in the former Welland County. Since 1941, the acreage has generally continued to decline (272,000 in 1951, 239,000 in 1961, 211,000 in 1971 and 219,000 in 1981)[927,928]. The 1991 census is not yet available; however, indications are that the decline has continued and that the major impact has been in the acreage under tender fruit crop.

The number of farms in the peninsula has also continually declined from 5,828 in 1941 to 3,512 in 1981[927]. The trend to fewer and larger farms is also likely to continue through the 1991 census. The decline in both acreage (29%) and number of farms (40%) reflects the agricultural trends country-wide. The decline in the number of farms has not been as great in Niagara as nationally; this has been attributed to the high proportion of part-time farming in Niagara which is less influenced by fluctuations in the general economy than full-time farming[923]. The changes in agriculture are not simply associated with urbanization but are the result of a complex interaction of socio-economic factors. The reduction in acreage of improved land, market gardens, orchards and field crops of 20 to 30 percent resulted in the removal of some 88,000 acres from production between 1941 and 1981[923]. In contrast the acreage under grape production, greenhouse operations and feedlot operations increased during the same period. Intensive livestock operations form the largest part of the agricultural economy in the peninsula, particularly pork and poultry and to a lesser extent, beef. These operations are often part-time and frequently are connected with field crop production as the manure generated forms a prime source of fertilizer for the crops.

The global 'greenhouse effect' may have contributed to a changing climate in the Niagara Peninsula, a climate already mild compared to the remainder of Canada. The mild climate benefits both livestock and greenhouse operations, in reducing heating costs, a large portion of operating costs for these operations. This temperate climate has resulted in a four-fold expansion of the greenhouse industry in Niagara between 1961 and 1981 to 0.57 million square metres (6.1 million square feet)[923]. This rapid expansion, more than double the provincial average, has occurred predominantly north of the escarpment (towards Lake Ontario) and reflects the intensification of Niagara's agricultural industry. This activity is specialized, capital and labour intensive.

Fruit and grape production receive the most attention in Niagara. They account for about 80% of Canada's grape area, almost 90% of Ontario's peach acreage and 75 to 85% of the province's cherries, pears and plums[928]. Nevertheless, the fruit industry in Niagara has been declining over the past two decades and the industry has shifted in the varietals used and the methods employed for planting and harvesting. Peach production is likely to continue to be stable; however, other tender fruits will likely continue to decline. Grape acreage stabilized in 1971, but, changes over the next decade, in varieties, planting density and harvesting methods significantly increased production. By 1983, the number of vines in production increased to some 14 million and new varieties accounted for 42% of the harvest[928]. Some of the crop surpluses that have resulted have been purchased by government to protect the industry.

Agriculture is traditionally susceptible to price fluctuations in the marketplace, variable interest rates and the cost-price squeeze on the producer. In addition, a reduction in processing facilities and the resultant decline in food processing capacity has affected the tender fruit industry by reducing the available market[923] for the industry's products. Trade policies, including the GATT and the Free Trade Agreement with the United States, have altered tariff levels and the degree of protection permitted, which in turn is having a serious impact on the agricultural industry. The differences in climate between Canada and the United States also contribute to an imbalance in the grape and fruit production capabilities which is now being further stressed by the ongoing tariff changes. Additionally, the sale of subsidized European wine has depressed wine prices and contributed to the grape surplus in recent years[923].

An additional factor in the decline of farmland is the development of agricultural land as residential or industrial. This occurred rapidly in the 1950's when agricultural land was considered as undeveloped urban area rather than as a resource. Although official plans now restrict this activity somewhat, the development of farmland still continues and is a substantial issue in this decade. While the loss of land to urbanization is serious, urban encroachment through severances and the introduction of alien uses may be more significant by raising property values, making future expansion difficult and often resulting in costly changes in farming practices or crop losses.

Competition also occurs within the agricultural community as vineyards displace orchards and greenhouse operations displace both. In the area south of the escarpment within the northern portions of the Area of Concern, grapes have already displaced corn and grain in some operations.

There has long been recognition of the significance of, and the need for, protecting Niagara's agriculture, particularly the less stable fruit, grape and general agriculture. This protection did not occur until the 1970's with the development of the Region of Niagara's Official Plan, supported by citizen interest and the Provincial Ministry of Agriculture and Food.

The well-being of Niagara's agriculture relies on the continued support of the various levels of government but the future use of the land for agriculture is not guaranteed. The well being also relies on the farmers having an opportunity to make a reasonable living in this business. The competition for available land is slanted towards developers who can afford to pay more than farmers for the same parcel. There is increasing concern in 1991 that the squeeze between high investment cost and low return is creating a serious problem for the farmer. This is being further aggravated by the removal of tariffs on foreign produce and the elimination of protection for domestic production to the point where agriculture is becoming non-viable in this area.

There is still opportunity for agricultural growth in the Niagara area, even in grape and peach production which can be compatable with urban and industrial growth. Niagara's agriculture is changing, it is intensifying and specializing in response to social and economic change. The maintenance and expansion of farming can continue, but only under suitable economic conditions, a reasonable certainty of future viability and a respectable financial return. If these factors do not occur, the agricultural industry will disappear.

3.3.4 The Manufacturing Industry

The manufacturing industry in Niagara was initially established around the availability of cheap electrical power, the major land and water transportation routes and rail corridors[855]. Over recent decades, these factors have decreased in importance. Cheaper electricity has disappeared with the equalization of rates across the province. The Welland Canal is now a route rather than a destination on the St. Lawrence

TABLE 3.10

Comparison of Unemployment Rates in Niagara

	Percent Unemployment		
Year	Niagara CMA*	Ontario	Canada
1981	9.7	6.6	7.6
1982	13.8	9.8	11.0
1983	15.8	10.4	11.9
1984	11.1	9.1	11.3
1985	11.1	8.1	10.6
1986	9.9	7.0	9.6
1987	9.4	6.2	9.1
1988	6.5	5.1	7.7
1989	7.2	5.2	7.5
1990	7.4	6.3	8.1
1991 (to July 1991)	12.2	9.7	10.7

source: Stats Can Cat.71-001P
*CMA - Canadian Manufacturing Association

Seaway system and other modes of transportation have replaced the railways in Southern Ontario. Where the QEW once was the only high speed corridor in the province, many such corridors now exist, each representing a major competing axis of provincial development. Changing technologies and economic conditions have changed lifestyles over the past three decades; education and training facilities along with recreation and leisure facilities have become more important to society as a whole.

Since 1945, there have been seven recessions in Canada, the seventh currently underway. In the sixth such recession in the early 1980's, Niagara was more deeply affected[927] with unemployment levels 4 to 5 percentage points higher than either the provincial or national average (Table 3.10).

The rate of recovery in the Niagara area also seems to be greater; in 1984, it was led by a strong rebound in the automotive sector which accounted for 25.1% of the manufacturing jobs in 1989 (Table 3.11).

TABLE 3.11

Major Manufacturing Sectors (1989)

Sector	Proportion
Automotive	25.1%
Metal Fabricating	14.4%
Food and Beverage	8.9%
Primary Metal	8.7%
Transportation (Marine/Aerospace)	6.8%
Machinery	5.5%

source: RMON (see ref 851)

Employment in Niagara has traditionally relied on the transportation equipment and related products industries[923]. Niagara's industry closely follows that of the neighbouring communities of Buffalo and Hamilton which rely on large-scale manufacturing operations established at the turn of the century to take advantage of regional features which are no longer applicable. These industries include transportation equipment, iron and steel and metal fabricating, abrasives, paper products and chemical manufacturing. Most of these industries are now experiencing massive structural economic change involving partial or complete shutdowns and restructuring. Although this post-industrial transformation is having a significant effect on the economy of the Niagara area, it is necessary for the long-term viability of industry in the area. This change is towards tertiary (small business) and quaternary (service industry) economic activities[851].

This past reliance on a narrow manufacturing segment in a mature industrial base has been an unstable factor in the demand and supply of labour in the peninsula. The employment picture is further destabilized by the seasonal employment nature of the region's agriculture, tourism and water transportation industries. Niagara is attempting to diversify its manufacturing and develop a more competitive manufacturing base. The short term costs are reflected in high unemployment[851] (Table 3.10); however, it is hoped that this natural and necessary transformation will be to Niagara's long-term economic benefit.

As the nature of industry changes, the workforce is also undergoing change. The local workforce is becoming very mobile, often working in one community and living in another (from 24 to 74% depending on the community)[923]. As employment opportunities are redistributed throughout the area, displaced workers are able to secure new and often different positions. The workforce can be considered as a regional workforce based in a number of interdependent communities. There is also a portion of the workforce living in and around Fort Erie which works in the Buffalo area of New York State.

The economic development "megatrend" of a shift towards tertiary industry such as community services, small business, retail and wholesale trade and other commerce has been experienced in the Niagara area during the last four decades. Between 1951 and 1989, a major trend has appeared in an increasing rate of job creation in the tertiary sector. In 1981, the service sector surpassed the manufacturing sector in the percentage of the workforce employed in the Niagara area (Table 3.12).

TABLE 3.12

Service Industry Base (1989)

Service Industry Type	Employment
Legal Services	743
Architectural/Engineering	1464
Accounting	626
Customs Brokerage	546
Computer Services	169

source: RMON (see ref 851)

TABLE 3.13

Size of Niagara's Manufacturing Industries Based on Employment

	Number of Employees				
Year	<50	51-100	101-200	>200	Total
1980:					
# Firms	528	51	37	42	658
# Jobs	7009	3589	4775	31840	47213
1985:					
# Firms	669	59	38	36	802
# Jobs	8672	4164	5438	25615	43889

Data showing the switch from large scale manufacturing to small business also reveals that virtually all of the net job creation over the period 1980-1985 occurred in businesses with less than 50 employees (Table 3.13). This movement results in smaller scale plants with more capital-intensive manufacturing. The number of small businesses in Niagara increased in the early 1980's while the number of larger manufacturers decreased over the same period (Table 3.14).

Goods and services produced in Niagara are also exported to other areas. These contribute to the region's income and employment.

The trend towards expansion in tertiary industry appears to have continued during the 1980's[851]; however, a new phenomenon, "cross-border" shopping by the residents of the Niagara area, may be having a profound effect on Niagara's tertiary business industries, particularly during the 1990-92 recessionary period. This exodus of money, spent in New York rather than Ontario, may be severely impairing Ontario business, particularly in the Niagara Peninsula and may seriously damage the small business sector if the trend continues.

TABLE 3.14

Number of New Manufacturing Industries in the Niagara Region

Year	# of New Industries	# of New Jobs	Total # of Jobs
1986	27	502	45690
1987	32	728	45089
1988	26	283	47726
1989	17	324	49149
1990	12	230	47228
1991*	6	83	45243

* to 2nd Quarter 1991
source: Summer 1991 Business Directory Update

3.3.5 Tourism and Development

Since the turn of the century, the Falls at Niagara have attracted millions of tourists each year into the Niagara Region. Today, tourism in the area has reached more than ten million visitors per year, making Niagara Falls THE largest tourist attraction in Ontario and one of the largest in North America. An important fact is that tourism worldwide has been one of the growth industries in recent years and tourism is big business. The trend towards expansion of tourism is related to a number of social and economic factors: increased leisure time, a large population of senior citizens, more disposable income, improved transportation, higher levels of education and a greater interest in our surroundings.

The primary attraction for almost every visitor is the combination of the Horseshoe and American Falls[923]. The majority of people (70%) make day trips to the Niagara Falls and stay an average of four hours. The majority of these visitors to Niagara Falls (44%) are from the United States; 43% are from Ontario. Most tourists (80%) are repeat visitors coming from Ontario, New York State, and Pennsylvania. The population in the Great Lakes basin is expected to stabilize over the next two decades and therefore the market of the future either will be in other areas or more will have to be done to attract the existing market.

Niagara Falls annually receives as many visitors as Disney World in Orlando, Florida. While most tourists come to see the Falls, many visitors who stay in Niagara Falls at least overnight also participate in a wider range of activities while in the area (golfing, shopping, dining, etc.). However, the Niagara Falls visitors do not stay as long or spend nearly as much money as Orlando tourists do. Only 30% of Niagara tourists stay more than one day compared to 90% of Orlando tourists[926]. These overnight visitors are likely to be any age from 15 to over 60[851]. Generally, these people have had to travel farther than single day visitors and their trips are usually motivated by general pleasure and sightseeing. Of these long-term visitors, the average length of stay in Niagara is 1.5 nights whereas the average length of stay in Orlando is just under 6 nights. In Niagara Falls, $22 is spent during the average day trip while $116 is spent during the average overnight trip; hence, it is easy to understand why the tourist industry is working to increase the visitor's length of stay. Accordingly, if 90% (rather than 30%) of Niagara Falls' visitors were to stay the typical 1.5 nights, it would double annual visitor spending to almost one billion dollars. The focus for promotion of Niagara tourism has to be split between attracting people who have not been here before and keeping visitors longer in the Niagara area[853].

There are a number of factors which influence the tourism market. The makeup of society is changing. Most tourists in the traditional sense are in the older age groups. With decreases in the average family size, a considerable number of holidays are organized trips, oriented less to children and are taken in the 'shoulder-seasons'; fall and spring. In addition, with many families having two working parents, vacations are more weekend getaways due to the difficulty of both people getting away at the same time. The most important factor is that people demand value for money. Particularly in tough economic times, the consumer demands high standards of service. If people are not satisfied, they will not come back nor will they recommend the area to others; in fact, if dissatisfaction is high, they may recommend against the area.

The majority of single day visitors to the Niagara area spend their time enjoying the area and facilities around the Falls. Typical single day tourists to Niagara Falls tend to be aged 40 or older and their trips are much more likely to be motivated by personal errands (ie. shopping, visiting friends or family, etc.) than a specific trip to the Falls.

It is easy to understand how the community of Niagara Falls could be overwhelmed by tourism when more than ten million people visit annually. In the past, tourism was largely taken for granted by the average Niagara Falls resident and has even been a point of some aggravation to some. Only recently, as tourism has stagnated in the Niagara Region, or even declined, has the community begun to fully realize the beneficial economic impact that tourism has had on the Niagara area in general and on the Niagara tourist industry in particular. A deeper understanding of tourism, based on a shift in the Niagara work force towards the service industry, seems to be lending itself to an increased spirit of cooperation between the community and the tourist industry. The city and the citizens of Niagara Falls stand to benefit from this cooperation[853], as tourist revenues subsidize the costs of many municipal services to the community. Every motel/hotel room generates as much income for the municipality as a three bedroom bungalow.

A report prepared by the Ministry of State for Tourism has established[926] a classification system for Canada's tourist attractions based on uniqueness, competitiveness and stage of development. Categories are:

A) unique or superior world-class attractions

B) quality attractions competitive with similar North American attractions

C) attractions competitive within Canada

D) local recreation attractions.

Development categories are:

Immature -a primitive attraction with lack of service infrastructure

Developing -developed attraction needing secondary visitor services

Developed -fully-serviced attraction needing maintenance

Declining -attraction, infrastructure and services have deteriorated due to lack of maintenance or a failure to address changing market requirements and major revitalization is required.

In 1985 this report positioned Niagara Falls in category A - **Declining**[926]. Such areas are "on the downside of their product cycle. Indeed, substantial development or restoration is required, including new or renovated hotels and restaurants, additional visitor services and new recreational activities or changes in product availability, to enable them to attract and satisfy the number of visitors they have accommodated in the past."

Tourism has a profound economic effect on both the Niagara Peninsula and the entire Province. Tourists spend half a billion dollars annually in the Niagara area, of which over four hundred million comes from outside of Ontario[853]. More than 300 million dollars of this money is retained in the area and reinvested locally in capital expenses and operating costs including: employee wages, goods, services and taxes which in turn are spread throughout the community as workers and support industries purchase goods and receive services. This economic trickle-down effect is vast and complex and is central to the economy of the entire Niagara Falls area.

Every year, tens of millions of tourist dollars also flow through Niagara Falls to the rest of Ontario, leaving the local economy in the form of payment for goods/services not generated locally in Niagara Falls[853]. In addition to these direct economic impacts, there exist numerous indirect benefits to industries which support and/or complement Niagara tourism. It is estimated that this tourist trade generates an additional 175 million dollars annually outside of Niagara Falls. In addition, spinoff tourism revenues in other parts of the Province are directly influenced by people drawn to Ontario by Niagara Falls who remain to enjoy the many other attractions[926] that the Province has to offer. Some of these are in neighbouring areas of the Peninsula. The tourist industry and government have attempted to develop the Welland Canals as a major tourist initiative over the decade of the 80's. It is most beneficial to link tourism with other segments of Niagara society. The introduction and promotion of blossom festivals, winery tours, grape and wine festivals, peach festivals and pick-your-own activities not only contribute to Niagara's tourism, they also support Niagara's agriculture industry.

While "tourism" generally equates to holidayers, it does not exclusively refer to this segment of society. Tourism should also incorporate people who come to the Niagara area for recreational enjoyment of the river. This includes not only visitors from out-of-town but also local citizens and regional residents who come to enjoy the river. Most of these people do not come for the view from Table Rock but for other things that the river has to offer.

Residents and visitors make considerable use of the river's resources; the Niagara is widely known and used for fishing and bird watching. These individuals and parties make considerable use of the river's resources and contribute significantly to the industry and economy of the Niagara area. There is concern over the ability of these river users to access the resource; provision must be made to address this in long-term planning.

The lands surrounding the Falls of Niagara on the Canadian side are publicly owned. Since 1885, some 60 hectares of parkland next to the Horseshoe Falls have been maintained and developed by the Niagara Parks Commission (NPC), a self-supporting agency, now part of the Ontario Ministry of Tourism and Recreation. The NPC has also accumulated shoreline lands from Fort Erie to Niagara-on-the-Lake and currently manages more than 1200 hectares of parkland including a number of significant natural and historical sites. These sites augment the spectacle of Niagara Falls in attracting visitors to the Niagara area. The Niagara Parks Commission as well as being the majority property holder, in trust for the citizens of the Province, is also one of the largest employers in the area.

Over the past few years, the tourism industry in Niagara has started to address the concerns presented in the Ministry of State for Tourism report. The hotel industry has undergone and continues to undergo renovation and expansion of accommodation and ancillary services. The City of Niagara Falls is working with the Niagara Parks Commission and the Regional Development Commission to improve Niagara's image and promote their attractions. More and varied attractions are being added to draw the tourist to Niagara. The season has been extended into the winter period with the Festival of Lights.

In 1988, the NPC prepared a long-term plan[606] which presented its views on tourism and the direction of future development in the parklands it administers. The NPC's strategy is to provide facilities which enhance the Niagara Falls panorama in attracting tourists to the area and more importantly in prolonging their visit to Niagara. The NPC is working with the City of Niagara Falls and the Towns of Niagara-on-the-Lake and Fort Erie, to get more tourists to enjoy a longer stay in the Niagara area. Currently, many visitors to the parks system only journey here to view the Falls from Table Rock. The NPC hopes to make Table Rock just one of many highlights along the Niagara River.

The Niagara Parks Commission's plan involves the creation of a series of points of interest along the Niagara River upstream and downstream of Table Rock[606]. To create these points, the NPC intends to revitalize and/or enhance existing parklands and attractions, in addition to developing and acquiring new attractions. These points would consist of interpretive displays, focusing on local natural and geological history, local prehistory and the history of man in Niagara. These would be linked by a promenade to create a discovery trail, intended to guide and promote the flow of pedestrian traffic. Within the discovery trail area, the commission would incorporate tourist information centres which could promote other attractions in the region. This promenade could also be designed to encourage tourists to visit other attractions within the City of Niagara Falls. Outside of the discovery trail, the Commission would like to enhance tourism to Fort Erie and Fort George. The intent of the NPC is to maximize the use of these and other historical sites within its care.

The NPC's stated objective is to maintain the world's perception of Canada as a place of natural beauty, largely untouched and unspoiled by human development. The current plan for the future of the

Niagara Parks system attempts to strike a balance between nature and development, while maintaining its mandate of self-funding[606].

There is concern in the local environmental community, especially among members of the Niagara River PAC that development of Niagara Parks Commission property is not reflecting the desires nor the concerns of Niagara-area residents. The plan, as outlined, has been strongly criticized by PAC members as an engineered spectacle where most attempts to improve use by tourists results in "manicuring" of the environment in the interests of attracting tourists. This "engineered environment" is felt by the local public to detract, in some cases strongly, from the natural environment along the Niagara River. Strong exception has been taken to the creation of an artificial ecosystem on NPC parkland. While artificial environments may be the only reasonable development in high traffic areas, there is concern over the use of artificial landscaping in all areas. PAC members feel that too much of the area which could and should either be allowed to regenerate naturally or be cultivated with native species, is not being allowed to do so, nor is such a consideration being actively considered by the NPC.

There is increasing concern over the need to preserve existing aspects of Niagara which are part of the image which attracts tourists. Development of shorelines, the Niagara Escarpment, the Canal corridor and the fruit belt in an inappropriate fashion could seriously affect these resources. Continued urban expansion will likely encroach on the fruit belt; industrial development along the Welland Canal could reduce its potential for a landscaped parkway; residential development along the escarpment could reduce the attractiveness of the Bruce Trail; and water pollution can destroy the assets of lakeshore and river locations. These issues must be seriously considered in the development of the Niagara area. In most cases, Official Plans or Government Commissions control development of sensitive areas. The concerns of the public must be considered in the deliberation of development proposals to ensure that developing Niagara's resources does not result in a less desirable attraction for the people.

In some cases, development for tourism purposes has been detrimental to the physical and aesthetic beauty of the Niagara River. Examples include the construction of modern-design pedestrian bridges over all tributaries to the Niagara and the blasting of considerable quantities of bedrock into the Niagara Gorge to construct a new restaurant. The resultant "rock fall" was smoothed over and subsequently paved to make a parking lot in the Niagara Gorge.

Concerns have been identified by PAC members over the proposed removal of the upper levels of gorge face and replacement by glass, steel and concrete "skybox" observation facilities immediately north of Table Rock.

The NPC is attempting to work together with the Niagara municipalities in the setting of environmental and development standards for the areas near the Falls. However, the major part of this activity involves developmental compatibility rather than environmental concerns. It should be noted that during the environmental deliberations by the NPC in developing its plan, the federal and provincial environment and resource agencies were not consulted. The environmental impact on the Niagara River has not been considered during development by the Niagara Parks Commission, the area municipalities (especially Niagara Falls and Welland) and area industry.

The issue of service quality directly impacts the tourism industry. A high standard of service reflects well on the area and visitors are likely to return or to recommend the experience to others. Similarly, a low level of service reflects poorly and is equally well remembered by visitors when choosing not to return. The tourist expects fair exchange rates, high quality cuisine, reasonable costs and friendly, efficient service[853].

Tourists are also part of the problem faced by the Niagara River. Increased tourism also increases the demand for additional tourist and municipal services. The redevelopment of the commercial core of Niagara Falls has resulted in a much higher accommodation density than previously existed. This increase in commercial development for tourist purposes could result in considerable environmental problems, particularly for the Niagara River. Existing sewage services were inadequate to meet the demands of the 1970's. The inadequacy of Niagara Fall's combined sewer system is seen in the continuous and intermittent discharge of untreated sewage to the Niagara River both above the Falls and to the face of the Niagara Gorge. Consequently, there is already a need for upgraded water mains, storm and sanitary sewers and other utilities. The projected higher density use creates an even more urgent need for upgrading of these existing municipal services. The planning and upgrading of utilities must precede tourist development or the impact on the environment could be tremendous.

The tourist industry in Niagara Falls is reasonably healthy, although some sectors of the industry are experiencing difficulty. Niagara Falls would also like to increase tourism in the winter months. At present, three quarters of the tourism occurs between April and September. The Niagara Parks Commission plan incorporates this desire by including ideas for winter facilities, programs and attractions intended to spread the concentration of tourists throughout the year[606].

Development within Areas of Concern is itself a concern. Society continues to grow and the demand for services and housing continues in Niagara Region as in the rest of the Province. There is increasing public concern over the environmental impact of development of all types. This includes transportation and utility corridors, residential, institutional and industrial construction and development of open spaces. All development should be self-sustaining and have no net impact on the environment. There is a growing demand for development to be conducted with minimal environmental impact, indeed, for environmental mitigation to be an integral part of any development. Development that provides a net gain to the environment is preferable from the perspectives of both the environmental agencies and the general public. Before these types of judgement can be made, much more specific and detailed plans are required for all development, particularly adjacent to the Niagara River. This planning process should undergo review by appropriate government agencies and have extensive community-based support.

TABLE 3.4

Rare Vascular Plants In the Niagara Region			
Common Name	Scientific Name	Common Name	Scientific Name
Hemlock Parsley	Conioselinum chinense	Red Mulberry	Morus rubra
Harbinger-of-spring	Erigenia bulbosa	Yellow Pond-lily	Nuphar advena
Hairy-jointed Meadow Parsnip	Thaspium barbinode	Black Gum	Nyssa sylvatica
Creeping Fragile Fern	Cystopteris protrusa	Biennial Gaura	Gaura biennis
Cherry Birch	Betula lenta	Many-fruited False Loosestrife	Ludwigia polycarpa
Yellow Gromwell	Lithospermum incisum	Sundrops	Oenothera fruticosa
American Gromwell	Lithospermum latifolium	Meadow Sundrops	Oenothera pilosella
Virginia Cowslip	Mertensia virginica	Rugulose Grapefern	Botrychium rugulosum
Hairy-forked Chickweed	Paronychia fastigiata	Moss Phlox	Phlox subulata
Wild Potato-vine	Ipomoea pandurata	Halberd-leaved Tear-thumb	Polygonum arifolium
Field Dodder	Cuscuta campestris	Erect Knotweed	Polygonum erectum
Buttonbush Dodder	Cuscuta cephalanthi	Hills Pondweed	Potamogetum hillii
Sedge	Carex emmonsii	Hairy Bedstraw	Galium pilosum
Glaucescent Sedge	Carex glaucodea	Mosquito Fern	Azolla caroliniana
Willdenow's Sedge	C. willdenowii	Woodland Fern-leaf	Aureolaria pedicularia
Wild Lupine	Lupinus perennis	Branching Bur-reed	Sparganium androcladum
Chestnut	Castanea dentata	Marsh Valerian	Valeriana sitchensis
Pin Oak	Quercus palustris	Goose-foot Corn-salad	Valerianella chenopodiifolia
Shumard Oak	Quercus shumardii	Green Violet	Hybanthus concolor
Yellow Harlequin	Corydalis flavula	Early Blue Violet	Viola palmata
Pignut Hickory	Carya gladra	Bird's-foot Violet	Viola pedata
Big Shellbark Hickory	Carya laciniosa	Stemless Yellow Violet	V. rotundifolia
Tapered Rush	Juncus acuminatus	Spotted Wintergreen	Chimaphila maculata
Grass-leaved Rush	Juncus marginatus	American Water Willow	Justica american
Purple Giant Hyssop	Agastache scrophulariifolia	Green Dragon	Arisaema dracontinum
Taper-leaved Bugleweed	Lycopus rubellus	Hop Tree	Ptelea trifoliata
Oswego Tea	Monarda didyma	Downy False Foxglove	Aureolaria virginica
Bent Trillium	Trillium flexipes	Virginian Bartonia	Bartonia virginica
Winged Loosestrife	Lythrum alatum	Common Greenbrair	Smilax rotundifolia
Tulip Tree	Liriodendron tulipifera	Wedge Grass	Sphenopholis nitida
Cucumber Tree	Magnolia acuminata	Deerberry	Vaccinium stamineum
Swamp Rose Mallow	Hibiscus moscheatos		

-from Rare Vascular Plants of Ontario - 1987, National Museums of Canada, and the Endangered Species Mapping Project, OMNR, 1989.

TABLE 3.5

Wetland Evaluations on the Niagara River and Its Tributaries				
Wetland	Class	Area (ha)	TDS mg/L	Year assessed
Niagara River Watershed				
Beaver Creek	2	113.6	629	1988
Black Creek	2	37.2	266	1986
Frenchman Creek	3	4.5	1121	1986
Humberstone Marsh	2	62.8	170.5	1984
Miller Creek	3	17.1	688.4	1985
Lyons Creek	1	150.5	261.5	1984
Lyons Creek Woodlot #13	3	17.2	123	1988
#26	3	31.5	---	1988
#36	3	5.0	820	1988
#43	3	4.1	450	1988
#44	3	4.7	419	1988
Navy Island	3	25.8	250	1987
Niagara Falls Woodlot 1	3	128.1	790.6	1986
Tee Creek	2	15.8	325	1980
Welland River Watershed				
Abingdon (Northwest)	3	10.5	406.3	1987
Abingdon (Southwest) Mill Ck	3	8.9	532.5	1987
Attercliffe Station Slough Forest	2		254	
Balfour Sumbler Road Woodlot	3	13.4	56.4	1987
Beaver Creek (West Lincoln)	1	61.3	405	1988
Big Forks Creek	2	61.5	337.8	1986
Binbrook CA	1	90.9	318.3	1985
Bismark (Northwest) Beaver Ck	3	23.4	166.5	1987
Bismark (Northwest)	3	9.7	95.1	1987
Parker's Creek Headwaters				
Caistor Centre (SE woodlot)	3	12.2	60	1987
Moores Creek Tributarie Caistor Centre (SW woodlot)	3	25.5	113.2	1987
Moores Creek				
Caistor Centre (SW woodlot)	3	48.5	78	1987
Mills Creek Tributaries				
Caistor Centre (SE woodlot)	3	14.3	100	1987
Mills Creek Woodlot				
Caistor Centre (NE woodlot)				
Area #1	3	5.1	122.1	1987
Area #2	3	19.6	157.5	1987
Area #3	3	6.3	68.3	1987
Area #4	3	14.8	190.5	1987
Area #5	3	22.4	306	1987
Caistor Centre (NW woodlot)	3	12.2	352.2	1987
Moores Creek				
Caistor Centre (NW woodlot)	3	26.2	96.6	1987
Mills Creek				

TABLE 3.5 (con't)

Wetland Evaluations on the Niagara River and Its Tributaries				
Wetland	Class	Area (ha)	TDS mg/L	Year assessed
Caistor-Canborough Slough				
Forest East	2	72.2	92.6	1986
Centre	2	79.5	92.6	1986
West	2	35.6	92.6	1986
Chambers Corners Clay Plain	3	5.7	200	1985
Chippawa Creek CA	1	62.6	121	1985
Clement Tract	2	66.4	839.7	1987
Ellsworth Drain Woodlot	3	----	700	----
Fish Carrier Tract #1	3	7.2	393.3	1987
Fish Carrier Tract #2	2	10.4	461.5	1987
Fish Carrier Tract #3	2	15.0	300	1987
Fish Carrier Tract #4	3	5.2	140	1987
Grassy Brook	3	7.9	890	1988
Highland Golf Course Woodlot	2	20.4	525.0	1987
Little Forks Creek	2	11.6	332	1989
Little Forks Creek Woodlot	3	37.5	252	1987
Marshville Station Swamp (W)	3	15.9	303	1988
Marshville Station Swamp	2	28.1	152.3	1985
Mill Creek	3	33.1	825.7	1987
Mud Lake	3	50.7	308.1	1989
Niagara Falls Woodlot 25		49.4	320.2	1986
36		69.7	288	1986
Old Welland Feeder Canal	2	40.4	409.2	1985
Ontario Waste Managment Area	3	9.3	264.4	1987
Oswego Creek	2	85.0	224.7	1986
Parker's Creek Headwater	2	23.6	92.6	1987
Port Robinson Woodlot	1	9.1	693.8	1987
Ridgeville Swamp	3	3.6	267.5	1985
Silverdale: Lot 2 Con. 5	3	20.6	316.7	1988
St. Anns Slough Forest	2	37.5	88.7	1985
Vaughan Woodlots	2	16.1	107	1987
Wainfleet Marsh (Bog)	1	1526.4	253.4	1983

TABLE 3.5 (con't)

Wetland Evaluations on the Niagara River and Its Tributaries				
Wetland	Class	Area (ha)	TDS mg/L	Year assessed
Welland River #1	1	36.4	403	1985
#2	1	34.7	429.7	1985
#3	2	30.8	605.1	1986
#4	2	104.5	292.6	1987
#5	2			
Welland Swamp	2	17.8	230	1985
Willoughby Marsh	1	62.8	170.5	1984
Winslow Area #1	3	12.1	92.5	1987
Winslow Area #2	3	15.7	39.8	1987
Winslow Area #3	2	16.9	209.9	1987
Wolf Creek	2	23.2	213.0	1987
Young Tract #1	1	384.7	49.2	1984
#2	3	34.5	58.7	1984
#3	3	7.9	65.2	1984
#4	3	16.4	60.9	1984
#5	2	116.4	64.7	1984
#6	3	13.2	218.9	1984
(Young Tracts 1,2,3,5, and 6 are within the ANSI known as the North Cayuga Slough Forest)				

4.0 DESCRIPTION OF ENVIRONMENTAL CONDITIONS

4.0 DESCRIPTION OF ENVIRONMENTAL CONDITIONS

The environmental condition of the Niagara River is greatly influenced by human activities in the Niagara Peninsula. Although the regenerative powers of the river are immense, given its physical characteristics, decades of abuse have left a poor legacy for current and future generations. The upper Niagara River appears to be in relatively good condition on the Ontario side; however, chemical contamination from point and non-point sources has significantly deteriorated the conditions in the lower Niagara River.

In addition, agricultural activities, combined with industrial development have strained the assimilative powers of the Welland River to a point where it has been necessary to divert riparian flows from the Welland Ship Canal. Poor water quality during low flow conditions in the Welland River has been compounded by excessive sediment load from the agricultural areas upstream. Siltation, combined with chemical contamination, has altered the aquatic habitat of the lower Welland River.

4.1 Public Perceptions

Residents in communities in the Niagara Peninsula are well aware of the water quality problems in the Niagara River and Lake Ontario. A 1983 public attitudes survey conducted by Environment Canada[36] quantitatively provided the levels of public awareness and degree of concern about the problems.

About 75% of the 569 survey respondents in Fort Erie, Niagara Falls (Ont.) and Niagara-on-the-Lake considered water pollution to be a serious problem in their communities and were aware that the city water treatment plants do not remove all toxic chemicals from drinking water supplies. The concern and awareness were broad-based, distributed evenly across major social factors such as occupation, education, income and age.

The survey also showed that most of the respondents (60%) believed that drinking water from the Niagara River and Lake Ontario is a health hazard. There was strong public support for stricter controls on industrial dischargers and waste disposal activities. About 72% of the survey respondents expressed a willingness to pay more taxes for better water quality. Since 1983, it is believed that public opinion has strengthened on the desire for an improved environment; however, it is not known whether or not the public would still support additional taxation for environmental cleanup.

The question over toxics is not new or localized, many people in Ontario are concerned over chemicals in their drinking water. Public perception generally is that the chemicals are there and therefore the water is unfit to drink. Little consideration is generally given by the public at large to drinking water criteria. This is particularly true of the Niagara River where chemicals of all types have been identified for many years on a random basis and at very low levels; however, the public perception is of a highly contaminated "toxic soup". Many residents have opted for bottled water rather than drink the river's water because they believe it is of better quality. Occasional occurrences, such as the algal die off in late 1991, leading to smell and taste problems in municipal water supplies in the Niagara Peninsula, sustain the public's perception of poor water quality.

There are similar concerns over the quality of the mist at Niagara Falls. These anxieties remain, despite the fact that the mist has been tested and no chemicals detected.

There is also a perception of pollution associated with the water's colour. During spring runoff, with the fine clay soils suspended in the water column, the water over the falls takes on a tan colour. Immediate public reaction, particularly from tourists, associates the brown water with toxic chemicals despite the actual cause. This apprehension over colour extends year-round to the brown foam in the maid of the mist pool. This foam, natural in origin, and coloured by the same fine clay soils is aesthetically displeasing, is very visible and is often misinterpreted as evidence of chemical pollution of the Niagara.

The evidence of chemicals in the Niagara River has led to a concern over the same chemicals being present in the sports fish from the Niagara River. Although bioaccumulation of chemicals in larger sports fish species has led to fish consumption advisories, there is also some belief that all Niagara River fish flesh is tainted. For all the years of record, there is only one complaint of taste or odour (tainting) for fish from the lower Niagara River and none from the upper Niagara River.

Newspapers and magazines were the major sources of information on water quality for 55% of the respondents. A content analysis of four newspapers[37] showed that on both sides of the river, newspapers have been providing a wide range of information about toxics issues including spills, contaminated dump sites, health concerns and so on. As a whole, the media message seemed to be that the situation was quite serious and out of control. Despite progress in cleaning up the Niagara River ecosystem, a lot of doubt and scepticism remains. These perceptions will take considerable time and effort to dispel before an unbiased and accurate view of the Niagara problem is widely held by the general public.

4.2 Surface Water Quality

Annually between 1967 and 1982, and periodically thereafter, the Ontario Ministry of the Environment conducted surveys of water quality in the upper and lower reaches of the Niagara River. Since 1975, Environment Canada has also routinely collected surface water quality samples at a permanent monitoring station at the downstream end of the river where it enters Lake Ontario at Niagara-on-the-Lake. In 1983, Environment Canada added an upstream station to monitor Lake Erie's input to the river at Fort Erie.

In addition to surface water quality monitoring of the ambient river, the Ministry of Environment also conducts routine monthly sampling in the Chippawa Power Canal and Welland River. The Ministry of the Environment also carried out intensive surveys to monitor tributary inputs in 1983 and 1988/89. During the summer months, the Niagara Regional Health Unit samples for fecal coliform bacteria at three beaches on the river (Figure 4.1).

Ongoing monitoring of drinking water, upstream/downstream river water (continuous), tributaries (1988-89) and cross-river transects (1988) will provide additional data during the development of the RAP to aid in the selection of appropriate remedial measures and chart the progress of existing and future abatement programmes.

4.2.1 Conventional Pollutants

Fecal Coliform bacterial contamination has been greatly reduced in all areas of the river since having been detected during early surveys of the river water (1960's-1970's)[38]; however, elevated levels were still detected in the 1980's close to the mainland shores of the Chippawa and Tonawanda Channels and at Niagara-on-the-Lake[39]. Levels of fecal coliform bacteria in the Power Canal at the Whirlpool Road monitoring station, located a short distance downstream of the Niagara Falls W.P.C.P. outfall, were also elevated above the Provincial Water Quality Objective (PWQO) (100 orgs./100 mL) during the years 1980 to 1982[38]. The PWQO for fecal coliform has also been exceeded at the Princess Street, King's Bridge and Dufferin Islands beaches (Figure 4.1) in recent years (1985-1987). In 1992, no beach closures occurred due to bacteriological contamination, based on the new provincial protocol for E. coli bacterium. The elevated levels of

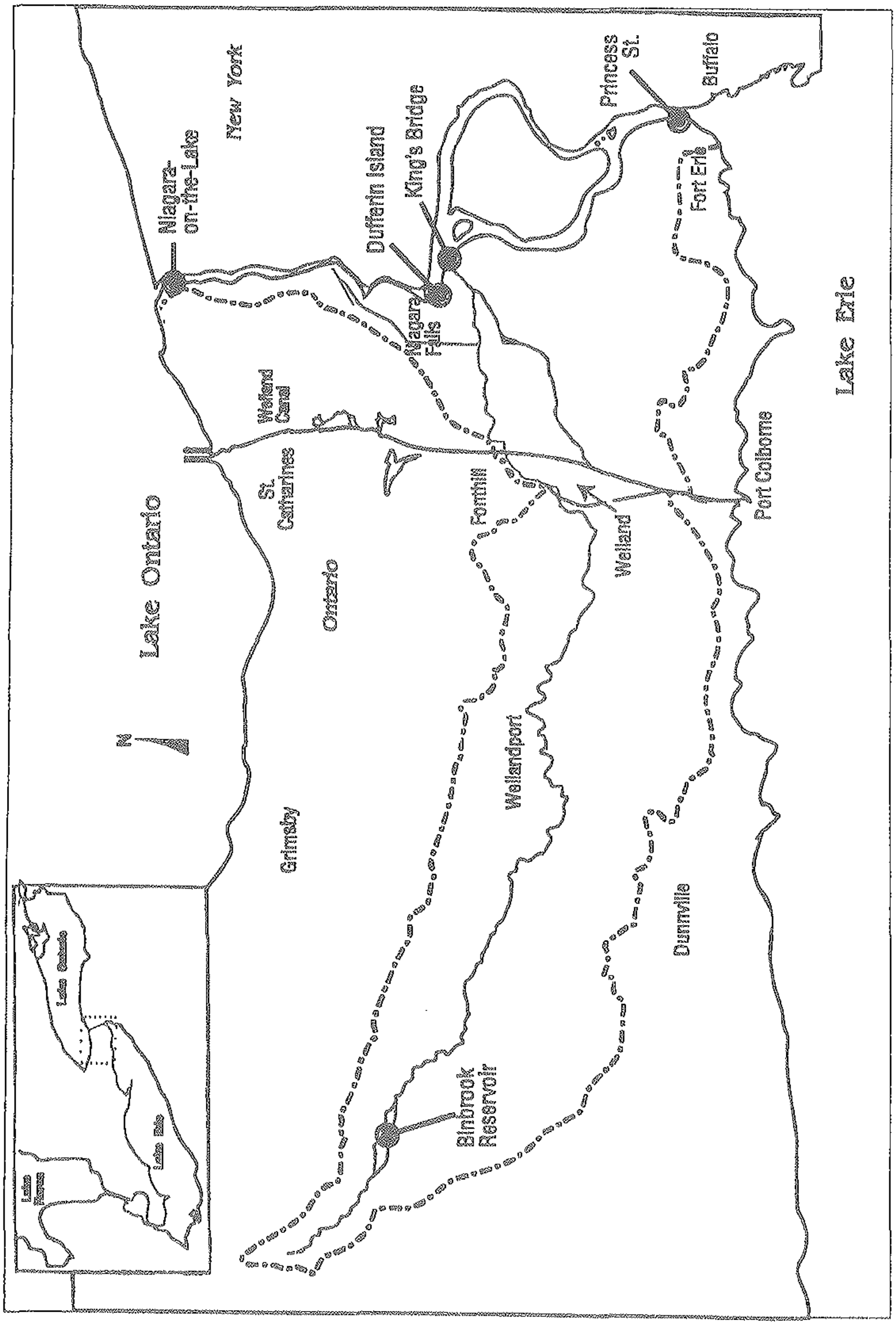


Figure 4.1
Niagara River Beaches Monitoring

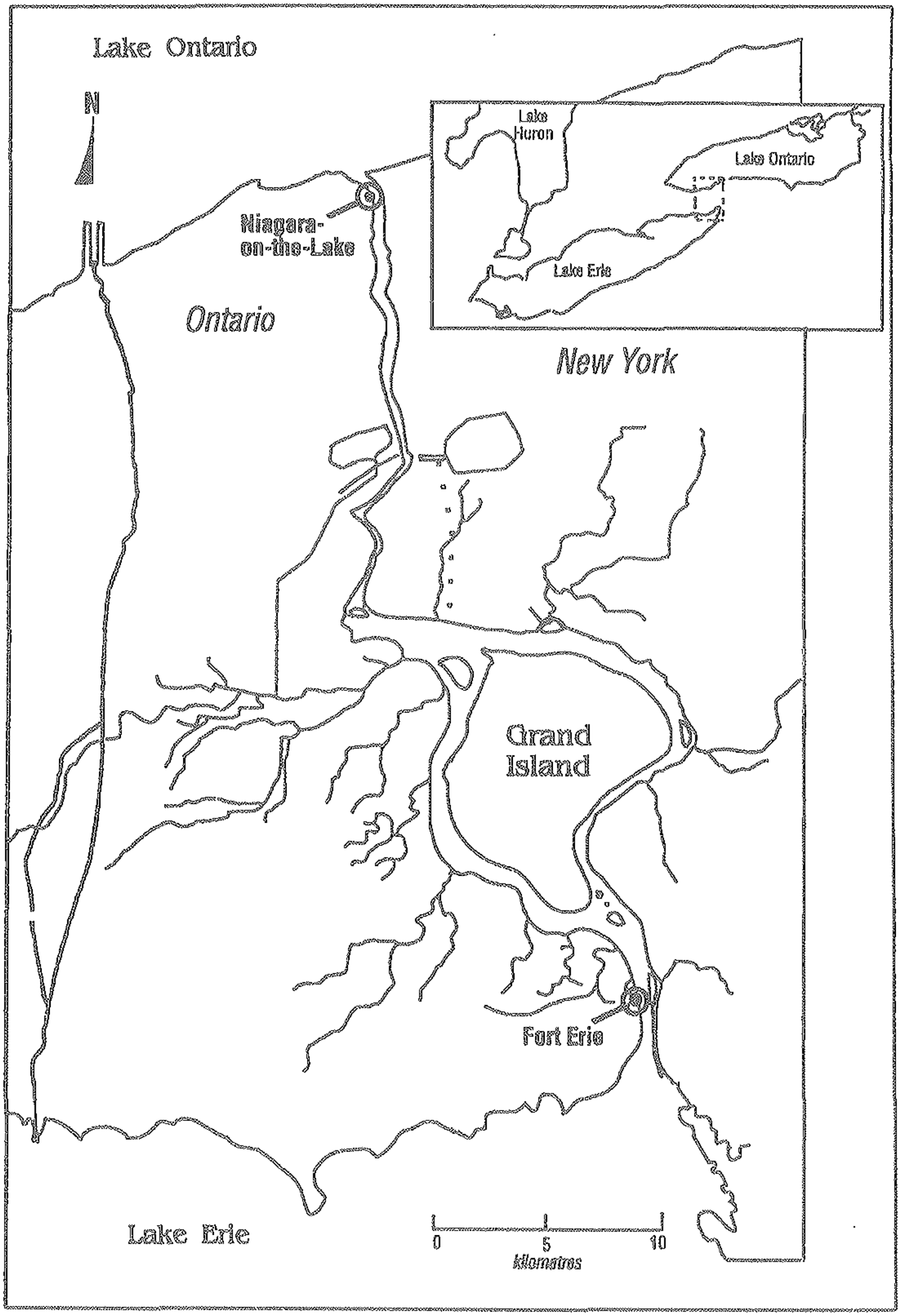


Figure 4.2 ***Upstream-Downstream Monitoring Stations***

fecal coliform bacteria pose adverse health effects to the people who use these areas for swimming during the summer months.

Phosphorus levels in the Niagara River have gradually been decreasing since control measures were established in the 1972 Great Lakes Water Quality Agreement[40]. Concentrations of total phosphorus in the Niagara River have declined at a rate of 0.001 mg/L/year since 1967[41]. Reductions in phosphorus loadings to the Great Lakes through phosphate detergent bans and upgrading treatment at water pollution control plants has resulted in a slow but steady decrease in phosphorus concentrations and reduced eutrophication in Lake Erie and Lake Ontario[42].

Nitrate and nitrite nitrogen concentrations have been increasing in the Niagara River since 1967 at a rate of 0.013 mg/L/year[41]. No specific impacts have been identified with the increasing levels, although nitrate is an important plant nutrient which can enhance eutrophication[40]. Environment Canada data for 1984 and 1985 at upstream and downstream monitoring stations indicated that point sources located on the Niagara River and/or non-point sources in the basin could be contributing to the higher levels[40]. Presently, no impairment of uses in the Niagara River are attributed to the increasing nitrate and nitrite levels.

4.2.2 Persistent Toxic Substances

The major cause for concern in the Niagara River is the presence of toxic and persistent compounds, particularly heavy metals and chlorinated organic chemicals.

In 1984, the Niagara River Toxics Committee (NRTC) produced a report[30] which identified the Niagara River as a significant source area of a number of these toxic substances. In studying the ambient conditions (water, sediment and biota) in the Niagara River, the NRTC identified 267 separate chemicals. Of these 267 chemicals, iron, sulphur, cholesterol, vanillin and silicon were determined to be of natural origin and of minimal toxicological concern. The remaining 261 chemicals were considered to be ones which warranted further investigation to determine whether or not they require remedial action.

In the NRTC studies, some organic substances and metals were occasionally found to exceed the most stringent water quality standard amongst the agencies involved. In the nearby area of Lake Erie, and in the Fort Erie and lower river sections, the following contaminants were found to exceed the standards:

aluminum	cadmium	copper
lead	silver	phenolics.

In the Fort Erie area, chromium, alpha-BHC, aldrin and dieldrin were also were found to exceed the standards, while in the lower river, alpha-BHC and PCBs exceeded the standards.

Chromium exceeded the standard in some instances in Lake Erie.

The MOE conducted an intensive survey of ambient water quality in transects across the river during 1980 to 1982 and found that a substantial reduction in the levels of total phenolics was noted from 1971. In earlier years, up to 100% of the samples from the Niagara River exceeded the provincial water quality objectives for phenolics (1 ug/L) (Table 4.1). The concentration of total phenolics in samples taken at various locations along the river[39] during 1980-1982 ranged from meeting the PWQO to exceeding the PWQO by up to 34%. Phenolic compound levels in Lake Erie also exceeded water quality criteria in some instances. Over the three year period from 1980 to 1982, levels of copper, iron and silver were also frequently found in excess of the provincial objectives.

TABLE 4.1

Exceedences of the PWQO for Total Phenolics in the Niagara River Chippawa Power Canal and Welland River

River Portion	Location	Year	% at or above PWQO	Number of Samples
Niagara River	Transect Mile 1.3	1980	25	N/A
	Transect Mile 19.3	1971	74	N/A
		1980	10	N/A
	Transect Mile 20.5	1980	8	N/A
	Transect Mile 26.7	1980	8	N/A
	Transect Mile 37.7	1971	66	N/A
		1980	1	N/A
Chippawa Power Canal	Whirlpool Rd.	1980	9	12
		1981	0	11
		1982	9	11
Welland River	Montrose Bridge	1982	27	11
		1983	8	11
		1984	9	11
		1985	36	11
		1986	50	14

Analyses for PCBs and organochlorine pesticides during 1980, 1981 and 1982 indicated that the majority of samples did not contain concentrations above the PWQOs[39]. PCBs exceeded the objective (0.001 ug/L) in the upper river only, in less than 10% of the samples. Levels of gamma-BHC (Lindane), heptachlor epoxide, endrin and dieldrin occasionally (< 10%) exceeded Provincial Water Quality Objectives, primarily in the Tonawanda Channel, although detections of organochlorine compounds were observed throughout the river. Of fifty-two additional compounds analyzed for in 1982, only six (toluene, ethylbenzene, dichloromethane, dichloroethane, 1,2-dichloropropane, and 1,1,2-trichloroethylene) were identified in Niagara River water, with concentrations just above the analytical detection limits.

For many substances, particularly organics, there still exists a scarcity of information on the effects on the ecosystem. Likewise, for a number of these chemicals, no guideline or criterion has been established either for protection of aquatic life or for human consumption. This lack of "effect" data makes it difficult to determine the relative environmental significance of some substances. This is particularly true for long-term or "chronic" effects.

In 1984, NRTC scientists screened each chemical of concern, based on their judgement of the available information in three areas:

- Existence of a water quality standard for that chemical.
- Chemical and toxicological information.
- Environmental occurrence information.

The concentrations of each of these chemicals monitored in the Niagara River were compared with this screening information and the chemical was assigned to a "group" with chemicals of a similar level of concern. These groups are presented in Table 4.2 located at the end of this chapter.

Since 1984, studies have concentrated on the chemicals of highest concern in NRTC groups I, IIA and IIB. These chemicals were those that had some indication of environmental or human health concern at that time. The listings of the group I, IIA and IIB chemicals are presented in Table 4.3 located at the end of this chapter.

In 1988, the Coordinating Committee for the Niagara River Toxics Management Plan (NRTMP) asked for a reappraisal of the chemicals of concern in the Niagara River based on more recent information. An ad hoc committee was charged with developing a mutually accepted list of persistent chemicals of concern for which loading reductions of 50% should be required by 1996. That committee was responsible for establishing a procedure through which persistent chemicals of concern could be identified and then, using this procedure, develop a list of chemicals to be considered for 50% loading reduction. The committee considered those chemicals which were both persistent and toxic. The master list of chemicals considered by this committee included the NRTC group I and IIA chemicals (Table 4.3), the IJC Water Quality Board's 1985 list of critical pollutants (Table 4.4) and the list of chemicals currently being monitored by the ongoing Niagara River ambient water quality monitoring programme (Table 4.5). The U.S. EPA Priority Pollutants list (Table 4.6) was also used. Tables 4.5 and 4.6 are located at the end of this chapter.

TABLE 4.4

IJC Water Quality Board, Chemicals of Concern (1985)
Polychlorinated biphenyls (total)
Mirex
Hexachlorobenzene
Dieldrin
DDT and metabolites (DDD/DDE)
2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)
2,3,7,8-tetrachlorodibenzofuran (TCDF)
Benzo(a)pyrene
Lead (alkylated)
Toxaphene
Mercury

There are many ways of identifying persistent toxic chemicals of concern. Each has its advantages and disadvantages and there is no clearly superior method. Consequently, one methodology was adopted based on the best information available at that time.

Persistent and toxic chemicals were identified by considering bioconcentration in and toxicity to fish, and carcinogenicity to mammals. Fish were chosen as representatives of the aquatic ecosystem because of their place in the aquatic food chain, their socio-economic importance and their role as environmental vectors of chemicals to man. While considerable data may be found for toxicity, not all chemicals have been tested. In addition, measurements of persistence (residence time in aquatic media or in particulates in real or artificial systems) are scarce.

Consequently, bioconcentration factors (BCFs) for fish were used as surrogates for persistence. Acute lethality (LC_{50}) to rainbow trout, bluegills and fathead minnows was used as a surrogate for aquatic toxicity. Carcinogenicity and mutagenicity were also taken into account because of concern for human consumption of water and fish from the river.

BCFs are associated with slow rates of metabolism and excretion of chemicals by fish. A chemical that is "lost" slowly will accumulate and "persist" in fish to a greater degree than one which passes through the digestive system quickly.

There is a relationship between the structure or properties of a chemical and its toxicity, bioconcentration or other environmental behaviour. The most useful measure of these properties is the partitioning coefficient for octanol and water. This coefficient, K_{ow}, is a measure of a chemical's relative affinity for lipid (fats) and water. The higher the K_{ow} value, the higher the relative affinity for lipids. Highly polar compounds dissolve primarily in the water phase and therefore cannot readily bioconcentrate (low K_{ow}). In contrast, non-polar compounds dissolve more readily in organic material, such as n-octanol, than in water. Since these non-polar compounds prefer fatty tissue (lipophilic), they are the ones that readily bioaccumulate. K_{ow} is determined by placing a chemical in an octanol-water mixture and determining the ratio of concentrations of that chemical in each phase. K_{ow} models have been developed to define the uptake of chemicals by fish from water across gill lipid membranes.

The master list was sorted into compound class and each chemical within that class was ranked according to its K_{ow} value. A BCF, carcinogenicity and LC_{50} were defined for each of these chemicals. The link between chemical properties and environmental behaviour means that ranking by the K_{ow} values is also an indication of their relative hazard. The chemicals and their determinations are presented in Table 4.7 located at the end of this chapter.

In cases where the scientific data were inconclusive or insufficient, the committee considered water quality standards or guidelines in a comparison with measured levels of these compounds.

4.2.3 Chemicals of Concern

Concern over chemical contamination of the Niagara River ecosystem has led to a detailed review of which chemicals, specific to the Niagara area, are causing the problems the river is facing.

The 1988 NRTMP revision[769] included a preliminary categorization of 92 toxic chemicals present or potentially present in the Niagara River. The secretariat identified[769] fifteen Niagara River Toxics which were present in the Niagara River/Lake Ontario ecosystem at unacceptably high levels. Ten of these fifteen

NRTMP 1988 Priority Toxic Chemicals

Chemicals of Concern Scheduled for 50% Reduction		Other Priority Toxics	
benz(a)anthracene	(IA)	chrysene	(IA)
benzo(a)pyrene	(IA)	chlordane	(IA)
benzo(b)fluoranthene	(IB)	dieldrin	(IA)
benzo(k)fluoranthene	(IB)	octachloro-styrene	(IB)
tetrachloroethylene	(IA)		
mirex	(IA)	DDT and metabolites	(IA)
hexachlorobenzene	(IA)		
PCB's	(IA)	() indicates NRTMP category	
mercury	(IB)		
2,3,7,8-TCDD (dioxin)	(IA)		

priority toxics had significant Niagara River sources and were therefore scheduled for 50% reduction by the year 1996.

The most recent assessment[374] of chemicals in the Niagara River was completed in 1990 by scientists from all four environmental agencies with responsibility for the Niagara River, as a review of the chemicals identified in previous assessments.[30,769,474] The Categorization Committee has reported[374] to the Secretariat of the Niagara River Toxics Management Plan the results of this review.

The Categorization Committee used the previous listing of 92 priority chemicals and data collected between 1976 and 1989[304,307,310,524,552,203,83,604,389,829,713] to recategorize 342 chemicals.

The chemicals are categorized in two groups (each with sub-categories) as follows:

Category I - Chemicals with Available Ambient Data	
Sub Category	**Description**
IA	Exceeds an enforceable standard
IB	Exceeds a more stringent unenforceable criterion
IC	Equals/less than the most stringent criterion
ID	Detection limit too high to categorize
IE	No criterion available
Category II - Chemicals with No Available Ambient Data	
Sub Category	**Description**
IIA	Evidence of presence in or input to the river
IIB	No evidence of presence in or input to the river

The categorization above was applied to the 15 priority chemicals identified in 1988. These chemicals all appear in categories IA or IB. The categories (as determined in 1990) are indicated in the listing table following the chemical name. In addition to the 11 category IA chemicals identified in the 1988 priority toxic chemical table, the following eight chemicals were also classified as category IA.

Chemicals assigned to Category IA not identified in the above table.

hexachlorocyclohexane (BHC (total))
cadmium
heptachlor
heptachlor epoxide
iron
lead
photomirex

In addition to the four category IB chemicals identified in the 1988 priority toxic chemical table, the following nine chemicals were also classified as category IB.

Chemicals assigned to Category IB not identified in the above tables.

aldrin
aluminum
arsenic (total)
copper
endosulfan(total)
pentachlorobenzene
1,2,3,4-tetrachlorobenzene
1,2,4,5-tetrachlorobenzene
toxaphene

The numbers of chemicals in the remaining categories are presented in the following table.

Toxic Chemicals in Catergory IC through IIB

Category	Number of Chemicals
IC	31
ID	1
IE	14
IIA	342
IIB	not applicable

4.2.4 Upstream/Downstream Programme

An upstream/downstream monitoring programme was initiated by Environment Canada in 1983. The purpose of the programme was to estimate input loadings of contaminants entering the Niagara River from Lake Erie at Fort Erie and output loadings leaving to Lake Ontario at Niagara-on-the-Lake (Figure 4.2).

Loadings rather than concentrations of contaminants were considered because of the vast quantities of water, in the order of 7,000 cubic metres per second, (240,000 to 250,000 cubic feet per second (cfs)) moving through the Niagara River. At these discharge rates, even minute concentrations of a contaminant can translate to large inputs to Lake Ontario over the course of a day or a year. For example, a concentration of 2.8 nanograms/Litre (ng/L) of a chemical at Niagara-on-the-Lake represents a daily loading to Lake Ontario of 1.56 kg and an annual loading of 555.36 kg. The difference between downstream and upstream loadings (the differential load) was taken to represent the combined input of contaminants from point and non-point sources along the course of the river. The programme originally involved bimonthly collection of water and suspended sediment at two permanent monitoring stations located at the head (Fort Erie) and mouth (Niagara-on-the-Lake) of the Niagara River. The frequency of sampling for this program was increased to bi-weekly in 1984.

Results from the period December 1984 to March 1986 were released in a four party report in October 1986[43]. Due to uncertainties in sampling methods, analytical procedures and quality assurance and control practices, only the most conservative interpretations of this data set were possible.

Effective April 1986, the programme was modified in an effort to improve the reliability of future data sets. Modifications included:

- increasing the sampling frequency from bi-weekly to weekly;
- extending the sampling period from single grab samples to 24 hour composite samples;
- improvements in extraction methods;
- incorporation of agreed to analytical and quality control/quality assurance protocols; and
- development of improved statistical methods to deal with the data.

The large difference between present methods and those used prior to April 1986 makes direct comparison with the earlier data sets inappropriate. Consequently, the following discussion will focus on Niagara River water and suspended sediment data obtained in the latest studies reported for the period April 1986 to March 1987[307] and April 1987 to March 1988[310].

Contaminants which were present at statistically significant higher ($p > 0.1$) concentrations at Niagara-on-the-Lake than at Fort Erie, in either the water or suspended sediments fraction, or in both fractions, in 1986-87[307] and 1987-88[310] respectively, are presented in Table 4.8. From Table 4.8, it can be seen that concentrations of twenty-two contaminants (16 organics and 6 metals) were significantly higher (statistically) in both years.

TABLE 4.8

Contaminants Showing an Increase in Concentrations At Niagara-On-The-Lake (Compared to Fort Erie) in 1986-87 and 1987-88 (+)				
Chlorinated Organics and PAHs				
	1986-87 Data		1987-88 Data	
Contaminant	Water	Sedi-ments	Water	Sedi-ments
mirex		+		+
PCB's (Total)		+		+
BHC		+		+
lindane (-BHC)				+
methoxychlor			+	
hexachlorobutadiene	+	+	+	+
1-2-dichlorobenzene	+	+	+	+
1-3-dichlorobenzene	+	+	+	
1-4-dichlorobenzene	+	+	+	
1-2-3-trichlorobenzene	+	+	+	+
1-2-4-trichlorobenzene	+	+	+	+
1-3-5-trichlorobenzene	+	+	+	+
pentachlorobenzene	+	+	+	+
hexachlorobenzene	+	+	+	+
benzo(a)pyrene		+		
benz(a)anthracene				+
benzo(b)fluoranthene		+		
benzo(k)fluoranthene		+		
chrysene	+		+	+
fluoranthene	+	+	+	+
pyrene	+	+	+	+
1-2-3-4-tetrachlorobenzene	+	+	+	+

TABLE 4.8 continued

Contaminants Showing an Increase in Concentrations At Niagara-On-The-Lake (Compared to Lake Erie) in 1986-87 and 1987-88		
Trace Metals		
Element	Recombined 1986-87 Data	Whole Water 1987-88 Data
aluminum	+	+
arsenic	+	+
chromium	+	+
iron	+	+
manganese	+	+
nickel		+
zinc	+	+
strontium	not analyzed	+
vanadium	not analyzed	+
barium	not analyzed	+

Higher concentrations of these chemicals at the downstream station indicate that they originate from sources along the river. The specific sources of these chemicals cannot be determined from the upstream/downstream data alone. The relative contribution from "non-point sources" can be crudely estimated using the differential loadings from the upstream/downstream study and point source loading data from Canadian and U.S. point source monitoring programmes. However, inconsistencies in sampling and analytical methods, together with inadequate numbers of samples, make any such estimates of relative point/non-point source contribution unreliable.

It is noteworthy that the following seven chemicals were detected only at Niagara-on-the-Lake:

- 1,3-dichlorobenzene
- 1,3,5-trichlorobenzene
- 1,2,3,4-tetrachlorobenzene
- pentachlorobenzene
- hexachlorobenzene
- hexachlorobutadiene (suspended sediment fraction only) and
- mirex (suspended sediment fraction only).

Since these chemicals were only encountered at the downstream station, it appears that they originate exclusively from sources along the Niagara River.

Contaminant concentrations in Niagara River water were compared to several sets of water quality criteria, standards or guidelines. Water quality criteria adopted by the United States Environmental Protection Agency, the New York Department of Environmental Conservation, Environment Canada, and the Ontario Ministry of Environment, along with the IJC Specific Objectives, are summarized in Table 4.9 located at the end of this chapter.

As a result of the four-agency deliberations on monitoring data, it was decided to report contaminant concentrations for 'Recombined Whole Water' (RWW). In sampling and preserving samples taken from the Niagara River, the suspended sediment is removed from the water by centrifugation. This results in two distinct samples: a solid sediment phase and a "filtered" water phase. These are analyzed using completely different procedures. The results are then combined to produce the total RWW loading in the river. Mean RWW contaminant concentrations for those chemicals at Fort Erie and Niagara-on-the-Lake in 1986-87[307] and 1987-88[310], respectively, which exceeded the most stringent water quality criteria are listed in Table 4.10.

TABLE 4.10

Contaminant Concentrations Exceeding Strictest Water Quality Criteria at Fort Erie and Niagara-on-the-Lake

Contaminant	Criterion	Fort Erie 1986-87	Fort Erie 1987-88	NOTL 1986-87	NOTL 1987-88
benz(a)anthracene	0.002(NY)			2.58 (12)	2.26 (15)
benzo(b)flouranthene	0.002(NY)			2.35 (6)	
benzo(k)flouranthene	0.002(NY)			2.43 (6)	
benzo(a)pyrene	0.002(NY)			1.59 (7)	
chrysene	0.002(NY)	2.61 (12)		3.30 (18)	2.82 (25)
PCBs	0.001(MOE)	3.90 (26)	2.18 (45)	1.66 (28)	2.89 (43)
tetrachloroethylene	0.7(NY)		973.60 (6)		
Aluminum		294.5	243.2	459.1	343.2
Iron		459.7	380.4	833.1	659.3

NOTE: All concentrations in ug/L. Numbers in brackets indicate the number of times water quality criteria were exceeded. Criteria may be for water phase, solids phase, or Recombined Whole Water (RWW).

For the 1986-87 database[307], mean RWW concentrations of chrysene, total PCBs, aluminum and iron exceeded the strictest water quality criteria at Fort Erie. At Niagara-on-the-Lake, water quality criteria were exceeded for benz(a)anthracene, benzo(b)flouranthene, benzo(k)flouranthene, chrysene, PCBs, tetrachloroethylene, aluminum and iron.

The 1987-88 data[310] show that water quality criteria for PCBs, aluminum and iron were exceeded at Fort Erie and those for benz(a)anthracene, chrysene, PCBs, aluminum and iron were exceeded at Niagara-on-the-Lake. Water quality criteria were exceeded more frequently at Niagara-on-the-Lake than at Fort Erie.

Exceedence of water quality criteria for chrysene at Fort Erie and Niagara-on-the-Lake is, in part, indicative of the quality of water entering the Niagara River from Lake Erie. However, statistically significant differential loads for this chemical were determined, suggesting that there were input sources of this chemical along the river. The 1987-88 data indicate that chrysene was measured almost exclusively in samples collected at Niagara-on-the-Lake.

Although aluminum and iron exceeded water quality criteria at both Fort Erie and Niagara-on-the-Lake, concentrations of these metals were considered to reflect natural levels in surface waters rather than the result of local source inputs. Since there was a statistically significant difference between total PCB concentrations measured at Fort Erie and Niagara-on-the-Lake, sources must exist along the Niagara River; however, water quality exceedences for these contaminants at both stations are more a reflection of water quality in the Eastern Basin of Lake Erie than of excessive loading to the Niagara River.

In 1989, the Coordinating Committee for the Niagara River and Lake Ontario Toxic Management Plans formed a Chemical Categorization Committee to continue the work of the ad hoc committee. The ad hoc committee had recommended that the universe of chemicals be broadened and a mechanism be established to develop, review and update a more comprehensive list of chemicals of concern for the Niagara River.

4.2.5 Drinking Water

With the knowledge that a wide number of toxic chemicals were present in the Niagara River, the people living along the shores of the river became concerned with the quality of the water they were drinking.

There are a number of water treatment plants that serve the residents in the Niagara area. These are operated by the Regional Municipality of Niagara. The Rosehill Treatment Plant in Fort Erie draws water from Lake Erie, approximately 5 kilometres west of the convergence of Lake Erie and the Niagara River. The plant serves a population of about 24,000 in the communities of Ridgeway, Fort Erie, Crystal Beach, Stevensville and Douglastown.

The Niagara Falls Treatment Plant is located in Chippawa. It draws water from the east end of Chippawa Creek. This water is drawn from the Niagara River's Chippawa Channel as it is being diverted to Queenston for power generation purposes. A population of approximately 155,000 is served by this plant over an area of 70 square kilometres.

The Niagara-on-the-Lake Treatment Plant was removed from service in 1982 due to its inability to service the needs of a rapidly expanding community. Niagara-on-the-Lake, along with the nearby communities of Virgil and Queenston, are now served by the Region of Niagara by pipeline from its main plant at DeCew Falls in St. Catharines. The DeCew Falls plant treats water taken from Lake Erie via the Welland Ship Canal.

The Welland Ship Canal also provides a water source to the central peninsula area via water treatment plants in Welland, Port Robinson and Port Colborne.

Rural residences between Fort Erie and Chippawa have their own shore wells for providing potable water. Individual treatment systems vary.

In 1984, in response to the NRTC list of chemicals of concern, the Ontario Ministry of the Environment supplanted the existing water treatment plant monitoring programme in the Niagara Peninsula with a detailed monitoring of the 139 chemicals of concern that were present in the ambient water environment, along with 15 general chemistry parameters. The results of that monitoring were presented in a report entitled "Drinking Water Survey of Selected Municipalities in the Niagara Area and Lake Ontario". The water treatment plants in Niagara Falls, Fort Erie, Welland, St. Catharines, Hamilton, Oshawa and Toronto (R.L. Clark) were involved in the programme. Of particular concern was the Niagara Falls (Ont.) Water Treatment Plant, the only remaining plant on the Canadian side of the Niagara River.

The report[46] indicated that the drinking water at all of these plants meets all Ontario Drinking Water Objectives for those compounds referenced in the NRTC report. The data also show that the drinking water quality meets World Health Organization drinking water criteria for these compounds.

The levels of the metals and inorganic chemicals found in this study were consistent with those found in treated water supplies in Southern Ontario. The levels of organic chemicals (large number of non-detected values) is consistent with historical databases for these compounds. With the exception of Alpha-BHC (0.003 to 0.006 parts per billion), no chlorinated pesticides or PCBs were found to be present. This level is well below the Objective of 4 parts per billion for Lindane, which is a mixture of BHC isomers. Three trihalomethanes, which are chlororganic compounds traditionally formed in the drinking water treatment process, were detected at levels well below the ODWO for trihalomethanes. Only five other organic chemicals were found above the detection limit, these are listed in Table 4.11. Currently, ODWOs do not exist for these compounds. A water quality criterion for chlorinated aromatics as a group has been proposed by the U.S. EPA at a level 5,000 times higher than those measured in this study.

TABLE 4.11

Other Organic Chemicals Above Detection Limits (1984)

Compound Name	Number of Locations
1-3-5-trichlorobenzene	1
1-2-4-5-tetrachlorobenzene	2
2-4-5-trichlorotoluene	2
hexane	3
bis(2-ethylhexyl)phthalate	3

In 1985, the COA (Canada-Ontario Agreement Respecting Water Quality) Review Board released a report on trace organics in Ontario drinking water along the Niagara River[47]. This report was prepared for COA by a group of scientists from the Ontario Ministry of the Environment, Environment Canada and Health and Welfare Canada. That report made a number of conclusions and recommendations relating to drinking water on the Niagara River. It evaluated primarily the chemicals identified by the NRTC and compared these with chemicals which had been detected in raw or treated drinking water at plants in the Niagara area.

Thirty seven chemicals were detected in Niagara area drinking water (Table 4.12); 16 of these appear on the NRTC's Group I, IIA or IIB lists. Eleven of the 37 chemicals have established drinking water guidelines. It was concluded that none of these guidelines was exceeded and consequently, there appeared to be no immediate concern regarding their impact on human health.

Recommendations coming from this report for more extensive monitoring resulted in the implementation of the Drinking Water Surveillance Programme (DWSP). This programme, which initially incorporated most Niagara area water treatment plants, is now a province-wide drinking water monitoring programme.

TABLE 4.12

Trace Organic Chemicals in Niagara Area Drinking Water	
Chemicals with Drinking Water Guidelines	
Chemical	**Guideline**
Benzene	WHO
Bromoform	MOE/CAN
Carbon tetrachloride	WHO
Chlorodibromomethane	MOE/CAN
Chloroform	WHO
1,4-Dichlorobenzene	MOE/CAN
Dichlorobromomethane	MOE/CAN
Lindane	MOE/CAN/WHO
Heptachlor epoxide	MOE/CAN/WHO
Tetrachloroethylene	WHO
Trichloroethylene	WHO
Chemicals Without Drinking Water Guidelines	
Chemical	**Chemical**
Acetone	Hexane
Benzaldehyde	Isopropanol
BHC-(alpha) *	Methyl ethyl ketone
Butanal	Methylene chloride *
t-Butanol	Pentane
Chlorotoluene	Styrene *
Dibromomethane	Tetrahydrofuran
Dichloroiodomethane	Toluene
Diethyl ether	1,1,4-Trichlorobutadiene
Dimethyl disulphide	1,1,1-Trichloroethane
Ethylbenzene *	Trichlorophenol *
Heptanone	m-Xylene
Hexanal	o- or p-Xylene
* - denotes chemical on NRTC List I, IIA, or IIB.	

The quality of the drinking water for Niagara Falls (Ont.) is protected by filtration and disinfection processes; however, some dissolved organic and inorganic chemicals may not be removed during this treatment. Contaminants bound to particulate matter are, for the most part, filtered out and recent data on treated water show that no drinking water quality objectives are exceeded at the water treatment plant in Niagara Falls[48].

Chlorine disinfection is widely used at water treatment plants, including the one at Niagara Falls (Ont.), to destroy bacterial contaminants and pathogenic material. Most raw water samples taken at the Niagara Falls Water Filtration Plant contain some coliform bacteria, although the Provincial Water Quality Objectives for recreational use of water (1,000 org./100 mL total coliforms and 100 org./100 mL fecal coliforms) have not been exceeded[49]. Chlorination of drinking water is known to create trihalomethanes and these compounds do appear in finished drinking water at most communities which are served by water treatment plants with chlorine disinfection.

In 1986, the Canadian Public Health Association (CPHA), in cooperation with the Ontario Ministry of the Environment and Health and Welfare Canada, released a report on Great Lakes drinking water. The CPHA found that available data indicated that applicable standards and guidelines were only rarely exceeded. Because the frequency and extent of these guideline exceedences were low and overall exposure was below guideline values (based on a review of relevant toxicological data) the health implications were considered to be negligible. However, it was noted that there was a lack of information on exposure to and health effects of several of the compounds identified. Where information was available, food appeared to be a more significant route of exposure than water.

The CPHA report also concluded that epidemiological studies on populations surrounding the Great Lakes have not suggested that ingestion of water from these sources contributes significantly to cancer or other health risks. It also concluded that while treatment processes differ among water treatment plants, the data clearly show that the overall effect of the in-place water treatment facilities is a significant and beneficial effect on drinking water quality.

Although specific areas within the Great Lakes basin are not discussed, data used are presented in Volume II of the CPHA report. A summary of the data from the Niagara River area of concern is given in Table 4.13 located at the end of this chapter.

This data shows that there is no significant contamination problem in the municipal water supply of Niagara Falls. Although some trihalomethanes are generated in the disinfection process, these are well below the drinking water standards.

In 1987, the Ontario Ministry of the Environment released a report on monitoring at the Niagara Falls Water Treatment Plant on Macklem Street in Chippawa, as part of the DWSP studies. The Niagara Falls (Ont.) plant is designed to supply 145,500 m³/day to the City of Niagara Falls and a small part of the Town of Niagara-on-the-Lake. This report gave the results of 15 samplings of raw and treated water during the year 1986. Chemical analysis was conducted for six chemical groups and the results are presented in Table 4.14.

A value indicated as positive is one that is greater than the statistical limit of detection and is quantifiable.

The data reveals that for metals, inorganic ions and bacteriological parameters, raw water values are frequently in the detectable range; levels of metals and organics are also found in the treated water. The concentrations of metals, inorganic compounds and bacteria are consistent with those found in other water supplies in the Province of Ontario.

Most concentrations of organic compounds were below detection limits, even though the most sophisticated equipment available was employed in the chemical analysis.

For those parameters with Ontario Drinking Water Objectives (ODWOs), none exceeded the Objectives with the exception of organic nitrogen. ODWOs have not been established for some of the compounds analyzed; for these few compounds, reference was made to appropriate guidelines established by other agencies. No levels exceeded any drinking water guideline or objective set by other jurisdictions, such as the U.S. EPA, the World Health Organization, and Health and Welfare Canada. The results of these analyses were also consistent with those obtained in other areas of the Great Lakes.

TABLE 4.14

Chemical Compounds Monitored at Niagara Falls Water Treatment Plant

Drinking Water Surveillance Program _ 1987 Summary

	Raw Water		Treated Water	
Chemical Scan	**# of Tests**	**# of +ves**	**# of Tests**	**# of +ves**
Bacteriological	48	47	48	13
Field Chemistry	36	36	71	71
Lab Chemistry	225	180	225	159
Metals	242	123	243	113
Chloroaromatics	143	0	156	1
Chlorophenols	12	0	6	0
PAHs	51	0	51	0
Pesticides & PCBs	275	0	297	0
Phenolics	11	0	11	1
Specific Pesticides	161	0	155	0
Volatile Organics	339	2	339	47

4.3 Ground Water Quality

Field sampling and chemical analysis of ground water have been undertaken by a number of parties[10,17,50,51,52,53,54,55]. Table 4.15 shows the results of ground water analysis from these studies and may be considered as representative of background conditions. Most of the analyses represent water samples from the bedrock aquifer. The overburden aquifer, because of its limited areal extent in the vicinity of Niagara Falls, St. Davids and Fonthill, is only represented by four analyses.

Traditionally, general ground water quality is measured by consideration of concentrations of a small number of conventional chemical parameters and a few metals. Detailed chemical analyses of ground water for heavy metals, organics, pesticides or herbicides are not conducted, except in the case of known or suspected ground water contamination.

One of the traditional parameters is specific electrical conductance. This is a measure of the concentration of ions in water and historically has been used as a qualitative measure of overall ground water quality. A drinking water criterion has not been established for this parameter; however, the closest applicable measure of water quality using this parameter comes from criteria which have been produced for irrigation waters in the State of California[56] as shown in Table 4.16.

TABLE 4.15

Health and Aesthetic Related Water Quality Parameters Exceeded in Niagara Peninsula Ground Waters	
Health Related Parameters	
Fluoride	The concentration of fluoride in ground water was found to exceed the Provincial Drinking Water Objective (DWO) on one occasion in a deep monitoring well near the Niagara River.
Sodium	There is no objective for sodium; however above 20 mg/L restricted diets should consult their physician(*). Sodium concentrations exceeded the 20 mg/L level significantly in most samples.
Aesthetic Quality Parameters	
Total Dissolved Solids	The DWO for total dissolved solids (TDS) was exceeded consistently by about six times.
Hardness	The DWO for hardness was exceeded by about three to five times.
Sulphate	The DWO for sulphate was exceeded by about three to five times.
Iron	The DWO for iron was exceeded by two to ten times.
Chloride	The DWO of 250 mg/L for chloride was exceeded infrequently.
* see references -96	

TABLE 4.16

Ground Water Quality Rating Based on Electrical Conductance			
Class Designation	**Specific Electrical Conductance Limits (uS)**	**Sub-class Limits (uS)**	
Class I (suitable under most conditions)	<1000	<250	(excellent)
		250 - 750	(good)
		750 - 1000	(permissible)
Class II (suitability dependent on soil, crop, climate, etc.)	1000 - 3000	1000 - 2000	(permissible)
		2000 - 3000	(doubtful)
Class III (unsuitable under most conditions)	>3000	>3000	(unsuitable)

4.3.1 Overburden Aquitard

A number of studies[6,10,11,57] conducted in the Haldimand Clay Plain have indicated very high concentrations of major ions in the shallow ground waters in the upper part of the overburden aquitard. In shallow (<9 m) ground water monitors, the specific electrical conductance ranges from 3,400 to 9,680 uS. Below this depth, specific conductance readings decline rapidly and reach levels of about 700 uS at a depth of 25 m. High concentrations of ions are associated with the dissolution of readily available constituents in the highly weathered portion of the near-surface silt and clay materials by downward percolating water[10]. The decrease in the major ion concentrations with depth is attributable to the slow downward movement of ground water and diffusion of dissolved constituents from the shallow (poor quality) overburden aquitard mixing with the better quality ground water in the deeper overburden bedrock aquifer[10].

4.3.2 Bedrock Aquifer

The specific electrical conductance of ground water from bedrock wells in the Niagara River area of concern is shown on Figure 4.3. Values range from 643 to 4,800 uS. The distribution generally suggests that the specific electrical conductance of ground waters in the bedrock is slightly higher than in the overburden. Well water from most of the bedrock wells is classified unsuitable as irrigation waters (Class III). Very few wells in the area have suitable Class I or Class II ratings as shown on Table 4.16.

The bedrock of the Niagara Peninsula south of the Niagara Escarpment is predominantly calcareous and comprised of glaciated carbonate and shale bedrock with a high content of soluble gypsum. Large quantities of absorbed chloride and sulphate salts are retained by these formations[58]. Because of this, ground waters are generally rich in chloride and sulphate which suggests a slow rate of ground water movement. This provides for the dissolution of significant amounts of minerals from the rock. The ground waters found in the bedrock in the

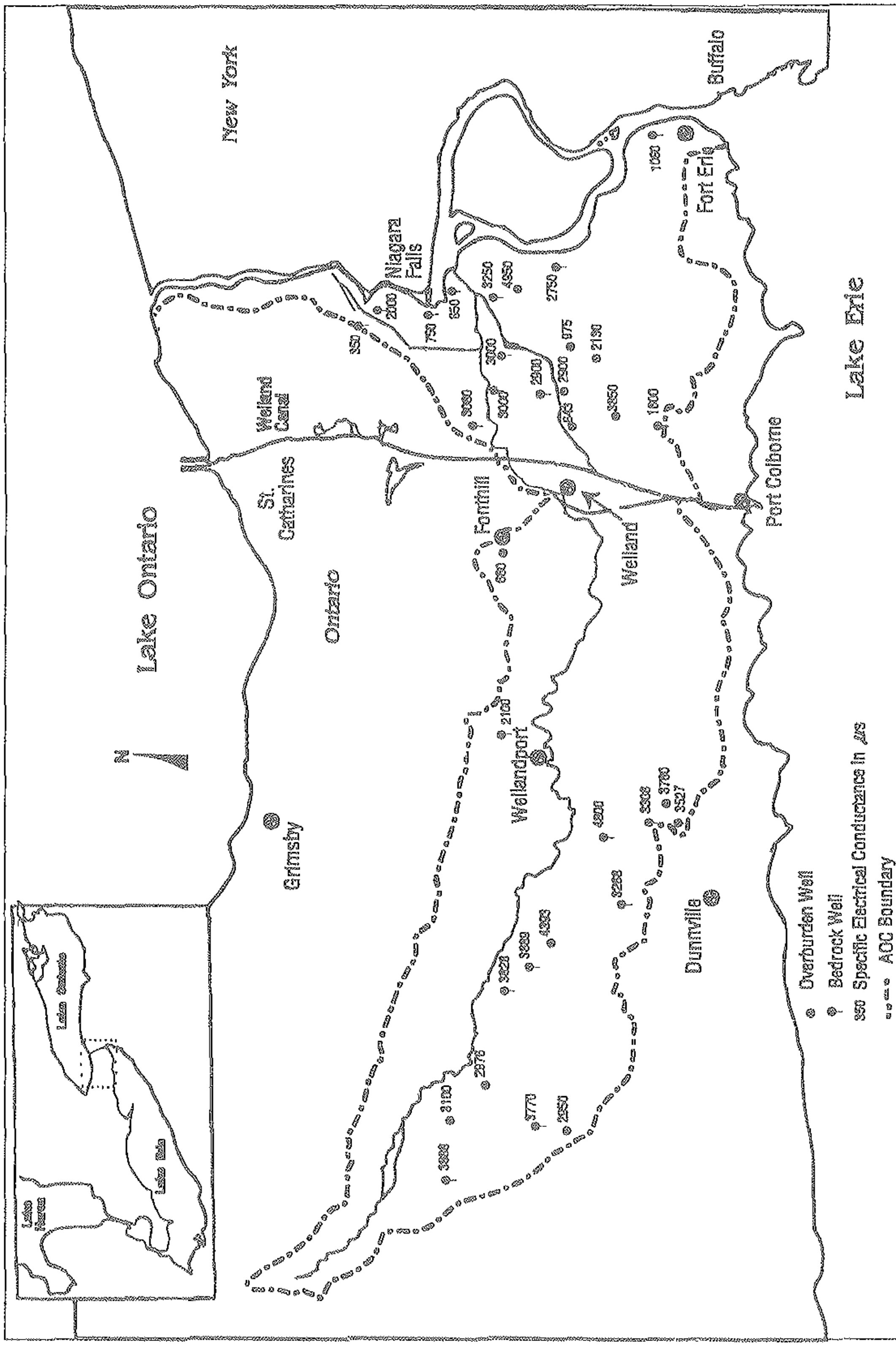


Figure 4.3
Electrical Conductance in Niagara Peninsula Groundwaters

Niagara Peninsula were classified in the mid-1950's[59]. Most of the ground water samples are classed as sulphate waters.

Bicarbonate type waters are similar in composition to rain water and appear only to be present in ground water in those areas where rapid infiltration occurs, usually where the overburden aquifer is found.

Those chemicals exceeding Ontario Drinking Water Objectives[60] in the Niagara area are identified in Table 4.15.

The high concentrations of chloride and sulphate in the ground waters limit their usability without extensive pre-treatment. Although, as indicated above, this chemical composition is entirely natural, derived from solution of natural minerals, it still prevents the ground water from being used in large quantities in the area. Bedrock ground waters do not appear to be contaminated by man's activity nor do they appear to be widely affected by man's requirements.

4.3.3 Ground Water Susceptibility

The Ontario Ministry of the Environment has prepared a series of maps detailing ground water susceptibility to contamination. These were produced in response to the widespread occurrence of potential contamination sources in Ontario, ranging from waste disposal sites (landfills) to accidental spills of chemicals. These maps evaluate the susceptibility of ground water to potential sources of contamination. Ground water susceptibility maps have been produced for the Niagara River (Ontario) area of concern[12]. The maps are also used to flag environmental concerns with respect to ground water contamination when a specific land use development is being considered. Due to the general nature of these maps they should not be used alone to determine site-specific susceptibility of ground water contamination from specific sources. Site-specific investigations must be carried out to determine actual, local hydrogeological conditions and to relate these to specific potential contaminant sources.

Ground water susceptibility is based on the three hydrogeological factors which play the largest part in determining the movement of contaminants into the ground water system: the permeability of near-surface materials, ground water movement and the presence of major shallow aquifers.

4.3.3.1 Overburden Aquifer Susceptibility

The major shallow aquifer of concern in the Niagara Peninsula is the Fonthill Kame Complex which lies outside the Welland River basin to the southwest of St. Catharines. The protection of this overburden aquifer is extremely important because of its potential for generating high yields and the widespread use of this aquifer as a water supply. If this aquifer were to become contaminated, the contaminants would likely move to depth because of the moderate to high relief and because of the deeper water table in this area.

There are also three localized areas where other water-bearing overburden zones, based in permeable glaciolacustrine sands are susceptible to contamination. These areas are located in the vicinity of Niagara Falls, north and east of Dunnville, and along the south shore of Lake Ontario, the latter two being outside the Niagara-Welland basin. The ground water movement in these localized areas is slow due to the low hydraulic gradient imposed on the ground water by the relatively flat topography. Therefore, although these areas are susceptible to contamination (should it occur) the contaminants would not spread as rapidly as at Fonthill.

4.3.3.2 Overburden Aquitard Susceptibility

The soils of the southern portion of the Niagara Peninsula, above the Niagara Escarpment, are comprised of relatively impermeable glacial deposits of clay, till and silt. Waters in these deposits are not generally useful as a source of water due to the low permeability of the rock and soil material. In some areas, low yields of water are obtained from these tight soils by the slow collection of ground waters in large-diameter bored or dug wells. The potential for any contaminant movement over appreciable distances in these deposits is small. The need to include susceptibility for contamination can be greatly enhanced by presence of vertical fractures which provide pathways for contaminant movement especially those greater than water.

4.3.3.3 Bedrock Aquifer Susceptibility

The limestones and dolostones in the Niagara area are unique because of their widespread use for water supply. Areas of the Niagara Peninsula where the bedrock aquifer is within 10 m of ground surface are considered to be the most susceptible to ground water contamination. Such shallow bedrock areas are located in the eastern part of the study area: along the north shore of Lake Erie, along the Niagara River between Fort Erie and Chippawa and west of Niagara Falls. Two small areas of shale bedrock also subcrop below the Niagara Escarpment but, since the shale is not used as a major source of water, its susceptibility to contamination is considered to be less than that of the carbonate bedrock above the Niagara Escarpment. While groundwater is used for some rural water supplies, most urban centres use surface water supplies.

4.3.4 Risk of Contamination from Ground Water

The available information supports the hypothesis that ground water within the Niagara-Welland basin is relatively slow moving with a low risk of being contaminated. Situations exist that could lead to ground water contamination, for example extensive bedding plane fracutres, but in general, such contamination would not migrate to the Welland and Niagara rivers and contribute to surface water contamination.

4.3.5 Contaminated Ground Water

Contaminated ground water, leachate and surface water runoff can each adversely affect the water quality in the Niagara and Welland Rivers. Of these inputs, the contribution from ground water is the hardest to determine. Pollutant loadings from ground water are not well known due to the complexity in determining the exact movement of contaminants beneath the earth's surface.

Before the influence of contaminated ground water can be defined, it must be determined if the ground water itself can be or has been contaminated. In Section 2.4, the physical surface layers were described in detail. The massive clay plain which overlies most of the Area of Concern provides excellent protection for the ground water from contaminants which are deposited on the ground surface.

Investigations undertaken in a number of locales within the Area of Concern have shown that the water-bearing units have remained free of contamination from human activities. Although the high mineral nature of the bedrock has made the aquifer high in dissolved minerals, these dissolved chemicals will not adversely affect the surface waters in the Area of Concern, were they to be discharged to the surface waters. The high mineral content of this water inhibits potability but can easily be removed through conventional water treatment processes.

In Section 4.3.3, several areas are identified where the overburden consists of more permeable materials or the clay layer is thin and the potential for ground water contamination is greater. Ground water has been contaminated in a number of these isolated pockets in the Area of Concern. These are located where an insufficient thickness of clay soils overlies the ground water. The sites of these occurrences: in the Fort Erie area, along the side of the Niagara Gorge and along the Niagara Escarpment, are associated with waste disposal sites and chemical spills.

Remedial activities have been underway within Ontario to correct each of these problem sources of pollution as they have arisen. In the 1970's, abatement activities centred around conventional pollutants such as Biochemical Oxygen Demand (BOD), suspended solids, phosphorus, oil and grease. In the late 1970's the significance of excessive levels of heavy metals became well known and abatement of sources of these contaminants was undertaken by the respective agencies on a case-by-case basis.

In the 1980's, great concern arose over the impact of toxic wastes buried at hazardous waste sites such as the Love Canal in Niagara Falls (N.Y.) and nation-wide and international attention was focused on the Niagara River. The majority of the contaminated ground water problem lies with hazardous waste dumpsites on the U.S. side of the Niagara River.

Abatement activities with respect to ground water contamination on the Canadian side of the Niagara River have been expanded to include the control and remediation of toxic metals and organic pollutants. Investigations and remediation of this contamination is continuing with the respective federal and provincial agencies.

A study recently completed for the MOE[178] has involved an evaluation of Canadian waste disposal sites identical to one conducted for the EPA in 1988. This study identified many data gaps in the varied studies conducted on all sites. It was determined that a "best estimate" total of 30.5 kg/day of toxic contaminants have the potential to be discharged from Canadian waste disposal sites to the Niagara or Welland Rivers. Of this total, 26.4 kg/day is attributed to contaminated ground water; consisting of 26.4 kg/day of inorganic contaminants and 0.01 kg/day of organic contaminants.

The largest portion of the potential loading, 25.8 kg/day of one inorganic chemical (cyanide) comes from one location, the disposal sites surrounding the Cyanamid plant in Niagara Falls (Ont.). The loading estimate considers the cyanide to be completely in the form of free cyanide (the toxic component). The cyanide is also treated in the report as a conservative substance (i.e. no degradation). In fact, cyanide, although toxic, is not persistent and readily degrades biologically and photochemically. Actual measurements from this area at ground water monitors on the perimeter indicate elevated levels of the breakdown products in the nitrogen cycle (NO_3, NO_2, NH_3 and organic nitrogen) but no evidence of either free or complexed cyanide. A remediation plan for this site has been submitted to the Ministry of the Environment and will be presented to the public in the spring of 1992. If the plan is accepted, remediation will start in 1993.

There is no evidence of contamination of ground water by chlorinated organics on the Canadian side of the Niagara River, including the entire drainage basins of the Welland River and all the small tributaries to the Niagara River between Fort Erie and Niagara-on-the-Lake.

4.4 Contaminants in Biota

Since aquatic biota are in continuous contact with their environment, contaminant levels observed in tissues are a primary indication of water-borne contaminant levels. Aquatic biota also integrate contaminants over time, thereby reflecting those contaminants which are introduced sporadically into the environment or occur in water at levels below current analytical detection limits. Determination of contaminant levels in resident aquatic biota is thus a useful tool for identifying areas of contamination and the relative degrees of contamination in various segments of the river.

The measurement of inorganic and organic contaminants in the lower trophic levels of the ecosystem also provides information on biological availability and potential for biomagnification. These data are essential in the determination of ecosystem contaminant dynamics.

A wide variety of plants and animals may be used as biological monitors of contaminant levels. The choice of a biological monitor is dependent on the chemical of interest (organic or inorganic contaminants), the trophic level and what portion of its lifecycle the organism spends in a specified region.

Aquatic biota can also be introduced to an area as a biological monitor. The accumulation of contaminants by introduced aquatic biota is valuable for investigations where a resident population cannot be sustained. The ability to place a biological monitor at a specific location for a pre-determined period of exposure is also an advantage in that variability due to movement, age or size and contaminant body-burden at the start of the exposure period can be controlled.

4.4.1 Biota - Algae

Attached filamentous algae (Cladophora glomerata) can serve as a useful biomonitor of contaminant source areas due to its growth habits, proliferation throughout the Niagara River and its non-mobile nature. Since this algae grows attached to rocky substrates, obtaining all its nutrient requirements from the ambient water, any increase in its contaminant concentrations can be directly related to uptake from the water column.

Cladophora is frequently used as an indicator of trace metal pollution rather than as a monitor of organic contaminants. Cladophora responds to metals in solution, whereas trace organics exhibit a higher degree of association with particulate matter. Therefore, biomonitoring of Cladophora for metals complements other studies of the aquatic ecosystem.

Since 1980, the Ontario Ministry of the Environment has annually monitored PCB and elemental concentrations in Cladophora at shoreline sites in the Niagara River. The Niagara River Toxics Committee[30] reported the following based on a summary of existing data at that time:

Cladophora specimens taken from the Niagara River at Fort Erie, the Chippawa Channel and the lower river all exhibited higher levels of the following contaminants than the Lake Erie specimens:

lead	selenium	zinc
PCBs	chromium	copper
nickel		

The Fort Erie specimens exhibited higher levels of mercury and the lower river specimens showed elevated concentrations of mercury, cadmium and arsenic.

In a source investigation study carried out by the Ontario Ministry of the Environment in 1987[61], the following sites had the highest mean values, of a total of 34 sites surveyed on both sides of the Niagara River, for the elements indicated. See Figures 4.4 at the end of the chapter.

Canadian side:

- Boyers Creek (aluminum)
- Lyons Creek (barium, cobalt & nickel)
- & Usshers Creek (titanium, magnesium)

American side:

- Occidental's sewer 003 (arsenic & total Kjeldahl nitrogen)
- 2-mile Creek (beryllium, manganese & phosphorus)
- Landfill North (boron)
- Bloody Run Creek (cadmium)
- Love Canal (chromium & mercury)
- Pettit Flume (copper, iron & lead)
- Gill Creek area (selenium & zinc)

Although there are exceptions, a general pattern of gradually increasing downstream levels was seen on the Canadian side of the Upper Niagara River for the following elements: aluminum, barium, cobalt, chromium, copper, iron, magnesium, nickel and titanium. For these elements, the highest results were found at tributaries Boyers Creek and Lyons Creek[61].

Studies undertaken by the Ministry of the Environment from 1980 to 1987 have shown mercury levels in Cladophora from specific sites in the mid-Niagara area and in the St. Clair River to be the highest levels found in the Great Lakes. The Niagara sites: Love Canal (0.85 - 2.35 ug/g) and Gill Creek (0.45 - 1.09 ug/g), are both situated on the American side of the river. Elevated levels of mercury (above 0.05 ug/g) during the same period have been found in samples from the upper river on the Canadian side at levels ranging from less than 0.01 to 0.13 ug/g. Overall, it is apparent that the Niagara River Cladophora mercury levels were found to be higher in the early 1980's and lower in the late 1980's. This trend is most evident in the lower river on the Canadian side and in the middle of the river on the American side[62].

PCB levels in samples taken at Gill Creek (U.S.) (2200 - 16000 ng/g) during 1982-87 studies have been identified as the highest levels in the Great Lakes sampling. Elevated levels (above 200 ng/g) in Cladophora at Love Canal (152 - 442 ng/g), Landfill North (120 - 578 ng/g) and Bloody Run Creek (<20 - 1810 ng/g) were also recorded on the American side of the river only.

The Niagara River (17 - 57 ug/g at Gill Creek) and St. Clair River samples had the highest overall lead levels in the 1982 to 1987 Great Lakes surveys (MOE data report in press). No clear trends are evident however the data suggests decreasing levels on the Niagara River. These decreases may be due to the variability of sampling and/or weather induced factors which affect the bioavailability of lead in the environment.

4.4.2 Biota - Fish

Fish accumulate chemical substances from water and from the aquatic food chain. Consumption of contaminated fish provides a major route of exposure for numerous organic compounds to man as well as other fish-eating organisms (e.g. gulls, mergansers and mink). Biomonitoring for contaminants in fish is carried out under two programmes within the Ontario Ministry of the Environment: young-of-the-year spottail shiner collections and the sport fish programme conducted in cooperation with the Ontario Ministry of Natural Resources.

High levels of phenols can lead to tainting of fish flesh. Levels of phenols have been recorded over the water quality objective in Frenchman's Creek, however, little work has been done to relate concentrations in the organisms to effects on the population[63].

4.4.2.1 Spottail Shiners

Young-of-the-year spottail shiners (Notropis hudsonius) have proven to be sensitive biomonitors for organochlorines and metals. Accumulated residues of these substances reflect the most recent water quality conditions and bioavailability of contaminants for a given locality. Due to their restricted habitat, young-of-the-year spottail shiners have useful applications in compliance monitoring and the detection of recently introduced persistent contaminants from land-based sources.

In accordance with the long-term biological monitoring recommendations of the NRTC report, yearly sampling of young-of-the-year spottail shiners has been continued by the Ministry of the Environment since 1975. Table 4.17 (located at the end of this chapter) summarizes the findings at several locations on the Canadian side of the Niagara River.

Although residue levels of PCBs in spottail shiners are significantly lower than comparable residue accumulations of the mid-1970's the downward trends identified in earlier collections have moderated considerably in the 1980's. PCB residue levels during a four year period (1979-1983) showed little change at Niagara-on-the-Lake. Residue concentrations for PCBs in 1985 were generally lower than concentrations in the 1984 collections; and remained consistent in 1987 and 1988. Concentrations decreased considerably in 1989 but then increased significantly ($p<0.05$) in 1990. Sampling by the New York State Department of Environmental Conservation between 1981 and 1987 indicated an 86% decline in total PCBs in the Niagara River, a significant reduction when combined with Suns' (1985) data[64]; however, 1990 samples showed PCB concentrations were significantly higher ($p<0.05$) than samples from 1988 and 1989 at all sites in the lower Niagara River. The highest concentrations were found in shiners collected from the New York State shoreline at Lewiston.

The most pronounced PCB residue reductions in 1985 samples, in absolute terms, were noted at the Pettit Flume in North Tonawanda and at Wheatfield (both upper Niagara River locations) in New York State. The 1985 PCB levels (127±38 ng/g) still exceeded the IJC's Great Lakes Water Quality Objective for whole fish of 100 ng/g. In 1987, one of three sites sampled in the Niagara River was in excess of the 100 ng/g objective.

Total DDT residue fluctuations remain largely unexplained, although residue increases at Niagara-on-the-Lake in 1981 and 1982 were investigated and appeared to be related to agricultural runoff with high DDT content[65]. DDT residues consisted largely of the metabolite DDE and have not exceeded the 1,000 ng/g IJC's Great Lakes Water Quality Agreement whole fish objective. Samples collected in 1985 by the Department of Environmental Conservation in the Buffalo River had the highest concentrations of p,p'-DDD of all their Great Lakes sites (mean 34 ng/g, min. 29 ng/g, max. 40 ng/g)[64]. None of the 1987 collections by the Ministry of the Environment exceeded the total DDT (and congeners) objective of 1,000 ng/g[62]; however, concentrations increased in 1989 and 1990 at several locations.

Although temporal trends in the concentration of mirex in the Niagara River remain undefined due to the extreme fluctuations in residue concentrations, mirex levels in recent spottail shiner collections were clearly lower than residue concentrations in comparable samples from the mid-1970's. The decline is likely associated with the discontinuation of mirex packaging operations at Niagara Falls, New York during the mid-1970's. The guideline for the protection of aquatic life requires that mirex be "substantially absent" in the biota[66]. In 1990 mirex was detected in samples taken from the Canadian side of the Niagara River both at

Niagara-on-the-Lake and at Queenston. All samples taken downstream of the 102nd Street landfill on the New York side had measurable mirex concentrations in 1990.

A considerable decline in mercury concentrations was observed at Niagara-on-the-Lake between 1977 and 1980; however, recent mercury residue levels indicate a levelling off of this decline. Mercury residues in all MOE Great Lakes spottail shiner collections were found to be below the Aquatic Life Guideline of 500 ng/g[67].

Generally, there are no indications that significant changes are taking place in total DDT, mirex, total BHC, hexachlorobenzene or octachlorostyrene residues that may be construed as trends.

TABLE 4.18

Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) Residues in Young-of-the-Year Spottail Shiners from Selected Sites in the Niagara River

Site #	Sampling Site	2,3,7,8-TCDD					
		1981		1982		1983	
		N	pg/g	N	pg/g	N	pg/g
46	Fort Erie			1	ND		
47	Frenchman's Creek	1	15	1	ND		
49	Wheatfield, N.Y.					1	ND
50	102nd St. Niagara Falls, N.Y.	2	8				
51	Cayuga Creek, N.Y.	2	59				
52	Search & Rescue Stn., N.Y.			1	ND	1	ND
53	Ussher's Creek			1	ND	1	ND
58	Peggy's Eddy, N.Y.	2	7				
59	Niagara-on-the-Lake	2	14				

Detection Limit - 3 pg/g
ND - Non detectable
N - Number of samples; Each sample is a composite of 20 fish.

Table 4.19

Polychlorinated Dibenzofuran Residues in Young-of-the-Year Spottail Shiners from Selected Sites in Niagara River - 1983

	Congener Mix % to Total						
Sampling Site	**N**	**4Cl**	**5Cl**	**6Cl**	**7Cl**	**8Cl**	**PCDF-pg/g**
Wheatfield N.Y.	1	24	17	38	20	1	3179
Search & Rescue Stn. Niagara Falls, N.Y.	1	56	23	17	4	0	646
Ussher's Creek Ont.	1	99	1	0	0	0	232
Niagara-on-the-Lake	1	57	19	16	8	0	680

N = number of sampling periods
4Cl = tetrachlorodibenzofurans
5Cl = pentachlorodibenzofurans
6Cl = hexachlorodibenzofurans
7Cl = heptachlorodibenzofurans
8Cl = octachlorodibenzofuran
PCDF = polychlorodibenzofurans (sum of congeners)

Tables 4.18 and 4.19 present results of residue analysis for tetra-chlorodibenzo-p-dioxin (2,3,7,8-TCDD) and polychlorinated dibenzofurans from selected Canadian and U.S. sites on the Niagara River.

Data from the 1990 collections at Cayuga Creek N.Y. and Niagara-on-the-Lake show that dioxin availability has decreased. The mean concentration of 2,3,7,8-TCDD which was 59 pg/g (parts per trillion) in the 1981 Cayuga Creek collection, showed only 8 pg/g (8.8 pg/g of 2,3,7,8-TCDD equivalents) in the 1990 collection. These results are in agreement with results published by NYDEC. DEC investigations show that fish contaminant levels decreased by 22-80% following clean-up activities in the Cayuga/Black/Bergholtz Creek system associated with the remediation of the Love Canal. 2,3,7,8-TCDD concentrations in shiners taken from Niagara-on-the-Lake have similarly reduced from 14 pg/g in 1981 to not-detected in 1990.

4.4.2.2 Sport Fish

The Niagara River has been monitored since 1978 as part of the Ontario Sport Fish Contaminant Monitoring Program because it is a popular angling location. This programme is a co-ordinated undertaking of two Ontario Ministries; the Ontario Ministry of Natural Resources, whose staff is responsible for collecting fish flesh and the Ministry of the Environment, whose staff analyses the fish for various contaminants, using skinless, boneless, dorsal fillet samples. Consumption advisories for Ontario anglers are then provided for various sizes of each species tested. The advisories are based on human health protection advice provided by medical specialists in the Ministry of Labour, and on Health and Welfare Canada guidelines for commercially marketed fish. Consumption advice on Niagara River sport fish as well as sport fish from over 1,600 Ontario locations is provided to the public in the annually updated "Guide to Eating Ontario Sport Fish".[485]

A number of sport fish species have been sampled from both the upper and lower Niagara River. In the upper Niagara River (Table 4.20), only freshwater drum over 35 cm and white suckers over 45 cm are not suitable for unlimited consumption. The drum are restricted due to PCB values above the 2.0 ppm criterion, while mercury levels above the 0.5 ppm criteria are causing the consumption restrictions on white suckers. In the lower Niagara River (Table 4.21), the following species have consumption restrictions due to PCB/mirex values above the federal guidelines:

American Eel > 55 cm
Rainbow Trout > 65 cm
White Perch > 25 cm
Lake Trout > 25 cm
Channel Catfish > 65 cm
Chinook Salmon > 65 cm
Coho Salmon > 55 cm.

It must be noted that some species, particularly sport fish are nomadic in nature. Those caught in the Niagara River will have spent considerable time in the adjacent Great Lake (Erie or Ontario). Exposure to chemicals outside the Niagara River may have contributed to the levels detected.

For all these species, women of childbearing age and children under 15 should not consume these fish. For adult males and women not in the childbearing age category, consumption should be limited to one to two meals per month. As well, yellow perch, while suitable for unlimited consumption at sizes below 30 cm, have consumption restrictions due to mercury levels of between 1.0 and 1.5 ppm in sizes above 30 cm. Lake trout (which tend to accumulate the highest organic contaminant levels among Lake Ontario sport fish) sampled near the mouth of the river were restricted above 25 cm due to elevated PCB and mirex levels.

Mirex has been acknowledged as the contaminant most limiting to sport fish consumption in Lake Ontario. Three potential sources of Mirex to Lake Ontario have been identified: the Niagara River, the Oswego River and the Credit River. Recent work by Ontario and New York indicate that inputs from the Oswego River are lessening and that no impact from the Credit River has been detected.

Mirex was not detected in the upper Niagara in any of the yellow perch and white suckers sampled. Nor was it detected in any of the rainbow trout sampled except one. For these same species in the lower Niagara, mirex was detected in almost all the sport fish samples, with maximum values above the 100 ppb federal government guideline in white sucker and rainbow trout. As well, lake trout were sampled in the lower Niagara, and all samples were above the 100 ppb guideline. These results indicate a definite source of mirex in the Niagara River. Table 4.22 shows the comparative mirex results for sport fish sampled in the upper and lower Niagara River in 1986.

Mean mirex levels in lower Niagara River white sucker and yellow perch increased slightly throughout the early 1980's (Table 4.23), which further indicates a continuous input from the Niagara River.

Mean mirex values in white sucker and yellow perch from Lake Ontario do not exceed the 100 ppb consumption guideline; however, the concentration did not decline between 1982 and 1986, also suggesting continuing input from the Niagara River. Mirex levels in lake trout and rainbow trout are more than double the 100 ppb guideline, indicating severe contamination of these species. While the 1986 mean mirex level in rainbow trout is substantially less than the guideline (Table 4.23), any rainbow trout over 65 cm in length will exceed the guideline, therefore significantly impairing the utilization of these fish for food. Although mirex is present in substantial conThe

TABLE 4.20

Consumption Advisories for Sport Fish from the Upper Niagara River

Fish Size in Centimetres

Water Body	Fish Species	15-20	20-25	25-30	30-35	35-45	45-55	55-65	65-75	>75
Upper Niagara River (Fort Erie)	Rainbow Smelt	[outline fish]								
	Freshwater Drum		[outline fish]	[outline fish]	[outline fish]	[lower-half shaded fish]	[solid fish]			
	Yellow Perch	[outline fish]								
	Rock Bass	[outline fish]	[outline fish]							
	White Bass	[outline fish]								
	Smallmouth Bass	[outline fish]	[outline fish]	[outline fish]	[outline fish]					
	Rainbow Trout				[outline fish]	[outline fish]				
	Redhorse Sucker	[outline fish]	[outline fish]	[outline fish]	[outline fish]	[outline fish]	[outline fish]	[outline fish]		
Miller Creek	Smallmouth Bass		[outline fish]	[outline fish]	[outline fish]	[outline fish]				
	Yellow Perch	[outline fish]	[outline fish]	[outline fish]						
	White Sucker		[outline fish]	[outline fish]	[outline fish]	[outline fish]	[spotted fish]			
	Rainbow Trout			[outline fish]	[outline fish]	[outline fish]				
Upper Niagara River Between Fort Erie and Dufferin Island	Yellow Perch	[outline fish]	[outline fish]	[outline fish]						
	Rainbow Trout				[outline fish]	[outline fish]	[outline fish]			
	White Sucker	[outline fish]	[outline fish]	[outline fish]						
		15-20	20-25	25-30	30-35	35-45	45-55	55-65	65-75	>75

Consumption Guidelines for Fish Caught by Anglers

Consumption Frequency	Advisory Level				
	[outline fish]	[spotted fish]	[banded fish]	[lower-half shaded fish]	[solid fish]
Long-term Consumption	no restrictions	0.2 kg.wk.	0.1 kg/wk.	1-2 meals/mo. 0.5 kg/mo.	none
One Week Vacation	no restrictions	10 meals 2.3 kg.	7 meals 1.5 kg.	1-2 meals 0.5 kg.	none
Two Week Vacation	no restrictions	5 meals/wk. 1.3 kg./wk	4 meals/wk. 0.8 kg./wk.	1-2meals/wk 0.5 kg./wk.	none
Three Week Vacation	no restrictions	4 meals/wk. 1 kg./wk.	3 meals/wk. 0.6 kg./wk.	1-2meals/wk 0.5 kg./wk.	none

Children Under 15 and Women of Childbearing Age Should Eat ONLY FISH IN CATEGORY [outline fish]

Source: The Guide to Eating Ontario Sport Fish, February 1990

TABLE 4.21

Consumption Advisories for Sport Fish from the Lower Niagara River

Water Body	Fish Species	Fish Size in Centimetres: 15-20	20-25	25-30	30-35	35-45	45-55	55-65	65-75	>75
Lower Niagara River (Queenston to Whirlpool)	American Eel						no restrictions	1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.
	Rainbow Trout			no restrictions	no restrictions	no restrictions	no restrictions	no restrictions	1-2 meals/mo.	1-2 meals/mo.
	Yellow Perch	no restrictions	no restrictions	no restrictions	0.1 kg/wk.					
	Walleye						no restrictions			
	Muskie							no restrictions		
	Northern Pike						no restrictions	no restrictions	no restrictions	no restrictions
	White Sucker			no restrictions	no restrictions	no restrictions	no restrictions			
	Coho Salmon							1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.
	Rock Bass	no restrictions	no restrictions							
	Smallmouth Bass	no restrictions	no restrictions	no restrictions	no restrictions	0.2 kg/wk.				
	White Perch		no restrictions	1-2 meals/mo.	1-2 meals/mo.					
	Brown Bullhead			no restrictions	no restrictions					
	Redhorse Sucker			no restrictions	no restrictions	no restrictions	no restrictions			
	Rainbow Smelt	no restrictions								
	Lake Trout						1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.	
	Channel Catfish				no restrictions	no restrictions	no restrictions	no restrictions	1-2 meals/mo.	
	Freshwater Drum		no restrictions	no restrictions	no restrictions	0.2 kg/wk.				
	White Bass			no restrictions	no restrictions					
	Chinook Salmon						no restrictions	no restrictions	1-2 meals/mo.	1-2 meals/mo.
Lake Ontario, Niagara-on-the-Lake to Port Weller	Lake Trout			1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.	1-2 meals/mo.		
	Rainbow Smelt	no restrictions								
		15-20	20-25	25-30	30-35	35-45	45-55	55-65	65-75	>75

Consumption Guidelines for Fish Caught by Anglers

Consumption Frequency	Advisory Level				
Long-term Consumption	no restrictions	0.2 kg.wk.	0.1 kg/wk.	1-2 meals/mo. 0.5 kg/mo.	none
One Week Vacation	no restrictions	10 meals 2.3 kg.	7 meals 1.5 kg.	1-2 meals 0.5 kg.	none
Two Week Vacation	no restrictions	5 meals/wk. 1.3 kg./wk	4 meals/wk. 0.8 kg./wk.	1-2meals/wk 0.5 kg./wk.	none
Three Week Vacation	no restrictions	4 meals/wk. 1 kg./wk.	3 meals/wk. 0.6 kg./wk.	1-2meals/wk 0.5 kg./wk.	none

Children Under 15 and Women of Childbearing Age Should Eat ONLY FISH IN CATEGORY

Source: The Guide to Eating Ontario Sport Fish, February 1990

TABLE 4.22

Mirex in Niagara River Sport Fish

Sampling Location	Species	#	Length		Mirex Concentration	
			Mean (cm.)	Range (cm.)	Mean (ppb)	Range (ppb)
Upper Niagara River	Yellow Perch	17	18.4	15.2 - 25.8	ND	ND
	White Sucker	6	33.5	15.8 - 44.8	ND	ND
	Rainbow Trout	12	36.4	31.0 - 47.0	ND	ND-12
Lower Niagara River	Yellow Perch	20	23.5	19.9 - 35.0	7	ND-134
	White Sucker	20	39.3	28.4 - 51.7	24	ND-160
	Rainbow Trout	20	58.2	40.0 - 90.5	60	ND-218
	Lake Trout	20	66.6	56.1 - 72.8	251	114-540

LEGEND: # - number of fish analyzed
ND - not detected (detection limit = 5 ppb)

NOTE: for ND, the detection limit value was used in calculating the mean

TABLE 4.23

PCB and Mirex levels* (ppb) in sportfish 1978-1984 Lower Niagara River (Queenston-Whirlpool)	PCB (guideline = 2000ppb)				
Species	'84	'82	'81	'80	'78
Lake Trout	3284	-	-	-	-
Rainbow Trout	-	1075	-	-	-
White Sucker	-	1081	692	505	-
Yellow Perch	-	222	194	86	-
White Perch	-	1394	-	-	-
Rock Bass	-	146	270	-	-
Smallmouth Bass	-	-	366	-	-
Eel	-	-	-	2928	-
Coho Salmon	-	-	-	-	2094
	MIREX (guideline = 100 ppb)				
Species	'84	'82	'81	'80	'78
Lake Trout	269	-	-	-	
Rainbow Trout	-	70	-	-	
White Sucker	-	27	20	-	
Yellow Perch	-	8	5	-	
White Perch	-	39	-	-	
Rock Bass	-	7	16	-	
Smallmouth Bass	-	-	15	-	
Eel	-	-	-	-	
Coho Salmon	-	-	-	142	

* - mean concentrations based on a minimum of 9 fish per sampling

TABLE 4.24

Contaminants in Fish Data Summary (1984)

Location: (Lower) Niagara River (Queenston-Whirlpool) Regional Municipality of Niagara

Species of Fish:		Lake Trout	Rainbow Trout	Coho Salmon	Brown Trout	Freshwater Drum
Sample Size:		19	6	3	2	1
Length (cm)	Mean	62.8	52.2	47.3	39.2	40.5
	Min	55.0	29.2	41.5	36.3	-
	Max	69.9	75.4	53.5	42.0	-
Weight (gm)	Mean	2351	2276	1415	1155	900
	Min	1500	352	909	694	-
	Max	3500	4175	1762	1615	-
Hg (ppm)	Mean	0.37	0.19	0.07	0.06	0.49
	Min	0.28	0.04	0.06	0.05	-
	Max	0.47	0.50	0.08	0.06	-
PCB (ppb)	Mean	3284	1362	297	1305	2190
	Min	1710	187	261	1120	-
	Max	5320	3610	367	1490	-
Mirex (ppb)	Mean	269	154	8	59	91
	Min	ND	10	ND	54	-
	Max	490	385	14	64	-
Cu (ppm)	Mean	0.54	0.47	0.34	0.49	0.29
	Min	0.28	0.31	0.20	0.48	-
	Max	1	0.78	0.61	0.49	-
Ni (ppm)	Mean	<0.42	<0.39	<0.58	<0.39	<0.39
	Min	<0.36	<0.38	<0.40	<0.38	-
	Max	0.62	<0.41	0.92	<0.39	-
Zn (ppm)	Mean	3.2	4.4	4.7	5	6.3
	Min	2.2	3.2	4	4.2	-
	Max	4.8	7.8	5.7	5.7	-
Pb (ppm)	Mean	0.59	<0.59	<0.61	<0.59	<0.59
	Min	0.53	<0.59	<0.60	<0.58	-
	Max	0.66	<0.61	<0.61	<0.59	-
Cd (ppm)	Mean	<0.039	<0.039	<0.040	<0.039	<0.039
	Min	<0.035	<0.038	<0.040	<0.038	-
	Max	<0.044	<0.040	<0.040	<0.039	-
Mn (ppm)	Mean	<0.39	<0.39	<0.41	<0.39	<0.39
	Min	<0.35	<0.38	<0.40	<0.38	-
	Max	0.44	<0.41	<0.41	<0.39	-

centrations in rainbow trout throughout Lake Ontario, concentrations are higher in locations nearer to the Niagara River.

The mirex in the Niagara River is chiefly from U.S. sources and has been found to have an impact on sport fish from all parts of Lake Ontario from Hamilton Harbour in the west to the Bay of Quinte in the east and includes such species as lake trout, rainbow trout, chinook salmon, white perch and walleye.

In the five sport fish species listed above, and in other species not listed here, mirex is found at detectable and quantifiable levels. Mirex is not a detectable contaminant in fish from any other of the Canadian Great Lakes or from inland waters in Ontario.

PCB levels were higher in the lower Niagara River species; however, only one white sucker and one rainbow trout sample were above the 2,000 ppb guideline. Significant PCB levels were detected in lake trout and rainbow trout which were temporarily resident in the Niagara River in the 1982-1986 period. The lake trout exhibited considerably more PCB contamination than the rainbow trout. Lake Trout are subject to a consumption advisory because of PCB levels in the fish flesh.

Other organic contaminants were occasionally detected in the lower Niagara yellow perch, white sucker and rainbow trout, and were more elevated in the lake trout samples, but not at levels of concern.

Analysis of upper and lower Niagara River sport fish for arsenic and selenium did not indicate any elevated levels.

Although a number of contaminants are detected in fish flesh, the only organochlorine contaminants which result in sport fish consumption advisories for the lower Niagara River (Table 4.24), are mirex and PCBs.

Even though this Remedial Action Plan is restricted to identifying and providing remedial alternatives for Canadian sources of contamination, the effect of contaminants originating on either side on migrating fish is a concern felt equally on both sides of the river.

Fish consumption advisories, particularly for mirex and PCBs, are based on the concept of "tolerable daily intake". The ideal intake of persistent toxic chemicals such as these, is zero, since they have no useful purpose in the human body.

4.4.2.3 Fish Pathology

Greater than anticipated incidences of lesions and neoplasia in several species of fish in the Niagara River drainage system have been documented[69]. Among the causes known to produce these phenomena are chemical contaminants, particularly PAHs. Researchers have been successful in producing dermal neoplasia on brown bullheads with periodic painting of extracts of PAH-contaminated sediments from the Buffalo River[69].

Researchers from Brock University have studied[70] gonadal neoplasms in wild carp-goldfish hybrids from the Welland River. Higher incidences of tumors in carp-goldfish hybrids and lower species richness occur in the lower Welland River compared to the upper Welland River. This has been correlated to deteriorated water quality in the lower Welland River[71].

In addition, 80% of the mature hybrids in the portion of the Welland River with the worst water quality (lower portion) had neoplasms[70]. No neoplasms were found in juvenile fish.

Recent investigations into mutageneticity of this hybrid have shown that the neoplasms are genetically related rather than associated with contaminant effects. The variations in percent occurrence of neoplasms is now thought to be linked with the abundance of this hybrid and the difficulty in differentiating carp from carp-goldfish cross rather than conditions in various reaches of the Welland River. The non-incidence of carcinomas in juvenile carp-goldfish appears to be related to age. As the hybrid ages, the neoplasms start to increase.

Other biological manifestations seen in areas of high contaminant levels but not found in the Niagara River (Ontario) area of concern, include high incidences of liver and gonadal neoplasms, lip papillomas, spinal curvatures, reduced fecundity and condition, and reduced egg survival and hatchability. The exact cause of these symptoms is unknown in most cases.

4.4.3 Biota - Benthos

Benthic invertebrates have been recognized for their value as indicators of environmental quality due to their abundance, low mobility and habitat preference. They usually remain in a localized area for their entire life-cycle, which may vary from six months to two years, and thereby indicate past as well as present environmental conditions.

In a study conducted in 1983 to assess the relative abundance and distribution of benthic invertebrates in the Niagara River, a variety of benthic invertebrate community types were observed[72]. The distribution of community types was largely governed by the physical environment (i.e. depth, current speed, bottom substrate composition and the presence of aquatic plants).

In 1983, some local areas along the Niagara River shoreline in the Buffalo area exhibited a slower water velocity and numbers of invertebrates traditionally regarded as "pollution sensitive" were identified[72]. The sediments deposited there were severely contaminated and appeared to have resulted in some impairment of these invertebrate communities.

In the Chippawa Channel, benthic communities were healthy in spite of fairly high levels of arsenic and cadmium in the sediments. In the lower river and adjacent parts of Lake Ontario, a small number of sites had communities which were apparently impaired by contamination.

Benthic invertebrate communities appeared to be somewhat healthier in 1983 in the Tonawanda Channel and the lower river compared to a previous survey carried out in 1968 by the Ministry of the Environment's predecessor, the Ontario Water Resources Commission[73]. Some of this difference may be due to changes in sampling methodology and interpretation techniques.

A study in the early 1980's regarding contaminant levels in benthic invertebrates in Lake Ontario (western basin) and Lake Erie (eastern basin) was conducted to determine differences based on Niagara River contaminant inputs[74]. Significantly higher levels of organic contaminants were found in <u>Pontoporeia affinis</u>, an amphipod, in samples collected at the mouth of the Niagara River compared to those collected in Lake Erie (Table 4.25)

NOTE: For PCBs, DDE, dieldrin, heptachlor epoxide, oxychlordane, mirex alpha-chlordane and hexachlorobenzene, the data reported in Whittle and Fitzsimmons (1983) has been checked and monitored annually for QA/QC and is fully acceptable.

For photomirex, tri-, tetra- and penta-chlorobenzenes, alpha- and beta hexachlorocyclohexane (BHC) and trans-nonachlor, the data reported is fully acceptable although it has not been checked and monitored annually for QA/QC.

TABLE 4.25

PCB and Organochlorine Concentrations in Pontoporeia affinis				
	Lake Erie (Eastern Basin)		Lake Ontario (Western Basin)	
Number of Samples	5		5	
Percent Lipid	20.3	(0.3)	24.1	(1.4)
Mean Contaminant Concentrations (ng/g dry weight) and Standard Error ( )				
p.p'-DDE	58	(18)	292	(17)
total DDT	110	(31)	440	(43)
total PCBs	560	(40)	1378	(100)
Dieldrin	62	(23)	226	(21)
Chlordane	35	(15)	64	(14)
Mirex	ND		228	(4)
LEGEND:	ND - not detected ( ) - standard error of the mean			

For DDD and DDT, results should be interpreted with caution.

Mirex was detected in samples from the Lake Ontario site (mean 228 ng/g, dry weight) while all Lake Erie samples were below the 10 ng/g detection limit. All other organic contaminants measured were significantly greater in the Lake Ontario samples.

Pontoporeia also had significantly higher mean concentrations of mercury, arsenic, copper and zinc (Table 4.26)[74]. The results of this study confirmed that the Niagara River, as the single largest tributary to Lake Ontario, is a major source of organic contaminants and trace metals.

4.4.4 Biota - Mussels

Freshwater mussels (Elliptio complanta), obtained from a clean location with low background concentrations, have been shown to accumulate trace contaminants following exposure to a known source area[76,77]. Since mussels are filter feeders, the accumulation of contaminants is from food, from solution and from the ingestion of inorganic particulate material. The ability of mussels to respond to these three routes of contaminant uptake provides additional information on environmental conditions and sources in a given area.

TABLE 4.26

Inorganic Contaminant Mean Concentrations in Pontoporeia affinis				
	Lake Erie (Eastern Basin)		Lake Ontario (Western Basin)	
Number of Samples	5		4	
Contaminant Concentrations (ug/g dry weight) and Standard Error ( )				
Mercury	0.09	(0.00)*	0.40	(0.05)
Arsenic	3.10	(0.10)*	7.43	(0.24)
Copper	85.60	(0.40)*	98.50	(2.08)
Zinc	60.0	(1.00)*	89.75	(1.89)
Lead	2.90	(0.40)	4.50	(0.75)
LEGEND:	( ) - standard error of the mean *- significant difference at $p<0.05$			

Environment Ontario has been conducting biomonitoring studies using introduced (caged) mussels in the Niagara River since 1980. Results from these studies have shown that, except for BHCs detected in the Chippawa Channel, most areas of contaminant sources in the river are located along the mainland shore in the upper river on the American side. The table, "Areas of Elevated Contaminants", shows levels above background Lake Erie levels.

The locations of elevated levels of contaminants in mussels agreed with known sources in the river and also correlated with the spatial differences observed in indigenous biota (Cladophora, and young-of-the-year fish).

The data collected in 1981 and 1983 (Table 4.27) show considerable within-year variability in contaminant concentrations and when compared to 1987 results, no clear long-term trend was evident. Mean concentrations of some contaminants however, were much higher than in previous years (e.g. mirex at OCC Sewer 003; 1,2,3,4-tetrachlorobenzene and pentachlorobenzene at Pettit Flume, Love Canal & OCC Sewer 003, hexachlorobenzene at Pettit Flume, octachlorostyrene at Gill Creek). PCB and hexachlorobenzene levels were lower in 1987 at the Niagara-on-the-Lake station than in 1980-83.

Areas of Elevated Contaminants	
Buffalo River mouth	**Bloody Run Creek (Hyde Park)**
PCBs	PCBs
Chlordanes	hexachlorobenzene
Gill Creek mouth	**Wheatfield**
PCBs	PCBs
hexachlorobenzene	Chlordanes
octachlorostyrene	heptachlor epoxide
hexachlorobutadiene	hexachlorobenzene
Pettit Flume	**S & N Area Occidental sewer 003**
PCBs	PCBs
BHCs	mirex
Chlordanes	hexachlorobutadiene
hexachlorobenzene	1,2,3-tetrachlorobenzene
1,2,3,4-tetrachlorobenzene	pentachlorobenzene
pentachlorobenzene	
Niagara Falls, New York	
PCBs	dieldrin
BHCs	endrin
Chlordanes	arsenic
heptachlor epoxide	copper
hexachlorobenzene	zinc

Dioxin and furan levels were monitored at selected sites in the Niagara River in 1985 and 1987 by Environment Ontario. The Pettit Flume site in Tonawanda, (N.Y.) was found to be an active source of dioxins (including the most toxic form, 2,3,7,8-TCDD) and furans. Maximum 1985 levels of 2,3,7,8-TCDD were 3.6 ng/g in sediment and 0.02 ng/g in caged mussels. In 1987, samples taken at the same site reached 9 ng/g in sediment and 0.2 ng/g in the mussels. In 1989, measured sediment concentrations of 2,3,7,8-TCDD at the Pettit Flume decreased to between 0.52 to 1.10 ng/g. This variation in undisturbed sediments likely indicated localized variability in sediment concentrations. These concentrations are still high and the findings indicate that the source is continuing to release dioxin to the Niagara River and that 2,3,7,8-TCDD is still available for uptake by the Niagara River biota.

4.4.5 Biota - Avian Wildlife

The status of the avian populations of the area is unknown. The general opinion of long-term bird watchers indicates that the number of birds is declining. The actual cause for this perceived decline is hard to determine but is suspected to be the culmination of many factors including toxic contaminants, loss of habitat, and physical disturbances. Birds tend to be sensitive indicators of environmental toxicant problems due to their small liver size, rapid food uptake, and high body temperature[96]. Many birds ultimately depend on aquatic food chains, whether they eat fish directly, aquatic vegetation, or insects that emerge. Water quality objectives for the protection of fish-eating birds are exceeded in the cases of PCBs and organochlorine pesticides in some locations along the river.

Monitoring of spatial and temporal trends in wildlife in the Great Lakes basin has been underway by the Canadian Wildlife Service since 1974. The Niagara River programme has been centred on contaminant levels in Herring Gull and Black-crowned Night-Heron eggs. Contaminant levels in indigenous and introduced biota in the Niagara River also have provided a good indication of sources and bioavailability in the Niagara River.

Herring gull eggs have been collected almost yearly by the Canadian Wildlife Service (CWS) for contaminant analysis from an island just above the falls. In April 1989, 37 nests were counted. Black-crowned night-heron (BCNH) eggs are also periodically collected from the island. In April 1989, 153 BCNH nests were counted on this island and 43 nests were counted on two smaller islands upstream. The location of these islands prevents revisiting of the colonies to determine hatch success and rate of deformities; the disturbance would cause the chicks to retreat to the water and be swept over the falls. The results (Table 4.28) from these collections and some done in 1971 on Lake Erie suggest a reduction in organochlorine contaminant levels between 1971 and 1986 in Herring Gulls. Fish-eating birds have generally been found to accumulate higher residue levels than carnivores feeding on terrestrial mammals or birds[97].

TABLE 4.27

Contaminant Concentrations in Mussels Exposed in Niagara River										
Station	Year	Total PCB	BHC	Mirex	HCB	1,2,3,4,CB	QCB	HCB	OCS	% Lipid
Lake Erie -	1980	*	7+/-1	*	NA	NA	NA	Tr.	NA	1.3+/-0.2
Thunder Bay	1981	Tr.	Tr.	*	NA	NA	NA	Tr.	*	0.9+/-0.2
	1983	*	1+/-3	*	*	*	*	*	*	NA
	1987	*	*	*	*	*	*	*	*	1.0+/-0.3
Chippawa Ch. -	1980	23+/-4	7+/-1	*	NA	NA	NA	ND	NA	1.3+/-0.4
Chippawa	1981	*	11+/-3	*	NA	NA	NA	2+/-3	*	NA
	1983	*	Tr.	*	2+/-4	*	*	*	*	NA
Tonawanda Ch.	1980	NA	NA	NA	NA	NA	NA	NA	NA	NA
Petit Flume	1981	58+/-21	11+/-2	*	NA	NA	NA	14+5	*	NA
	1985	*	*	*	3+/-4	*	*	3+4	*	0.9+/-0.2
	1987	35+/-25	4+/-5	*	10+/-3	246+/-50	171+/-242	558+/-85	2+/-1	1.1+/-0.3
Tonawanda Ch.	1981	212+/-49	1+/-0	*	NA	NA	NA	3+/-2	*	1.0+/-0.3
- Love Cannel	1983	107+/-74	2+/-3	*	*	80+/-60	4+/-1	5+/-2	*	NA
		47+/-8	*	*	*	*	Tr.	2+/-0	5+/-1	1.4+/-0.1
		*	*	*	*	*	Tr.	*	*	
		*	3+/-5	*	1+/-2	*	23+/-39	19+/-34	2+/-2	NA
		*	*	*	*	*	*	3+/-1	*	NA
	1987	110+8	4+3	*	1+1	291+206	343+211	58+5	2+1	1.5+0.4
Tonawanda Ch.	1980	78+/-8	14+/-3	*	NA	NA	NA	4+1	NA	1.5+0.3
Nia.Falls, NY	1981	161+/-37	8+/-2	8+/-2	NA	NA	NA	3+1	*	NA
	1983	152+/-209	1+/-2	*	4+/-4	*	11+/-6	5+/-1	*	1.4+/-0.1
Tonawanda Ch.	1983	*	Tr.	3+/-4	20+/-21	30+/-51	36+/-15	12+/-10	7+/-11	NA
S & N Site		183+/-158	*	8+/-7	2+/-1	*	41+/-28	72+/-61	4+/-3	0.9+/-0.2
(outfall 003)		73+/-127	*	*	35+/-8	*	12+/-21	110+/-119	2+/-2	NA
		224+/-83	*	*	64+/-34	*	124+/-33	280+/-103	*	NA
		*	*	*	5+/-4	*	11+/-1	2+/-2	*	NA
	1987	322+/-102	2+/-3	167+/-49	3+/-2	162+/-207	204+/-260	20+/-6	4+/-4	1.4+/-0.1
Tonawanda Ch.	1981	722+/-164	12+/-3	Tr.	NA	NA	NA	10+/-8	3+/-1	0.9+/-0.2
Gill Creek	1983	825+/-454	*	*	43+/-48	Tr.	5+/-9	11+/-12	*	NA
		1192+/-367	3+/-1	*	ND	Tr.	2+/-3	12+/-2	*	1.0+/-0.1
		1974+/-1736	1+/-5	*	43+/-45	*	24+/-17	15+/-18	*	NA
		268+/-130	1+/-3	*	40+/-6	*	Tr.	4+/-2	*	NA
		Tr.	2+/-4	*	*	*	129+/-204	5+/-2	*	NA
	1987	935+/-133	7+/-5	*	77+/-58	6+/-9	11+/-13	44+/-16	82+/-51	1.1+/-0.2
Low. Niagara R	1983	*	*	*	6+/-1	*	40+/-5	35+/-5	14+/-11	NA
Bloody Run Cr		122+/-102	1+/-1	4+/-3	*	18+/-12	38+/-22	49+/-32	*	1.2+/-0.1
(Hyde Park)		117+/-202	ND	*	18+/-15	84+/-72	138+/-30	196+/-182	*	NA
		86+/-76	1+/-1	*	52+/-7	*	138+/-21	98+/-13	*	NA
		*	10+/-14	*	ND	*	276+/-17	171+/-13	*	NA
	1987	*	9+/-4	*	19+/-23	4+/-5	32+/-26	51+/-19	1+/-1	1.0+/-0.2
Low. Niagara R	1980	94+/-11	2+/-3	*	NA	NA	NA	Tr.	NA	0.8+/-0.4
Niagara-on-	1981	48+/-14	11+/-2	Tr.	NA	NA	NA	3+/-4	3+/-3	NA
the-Lake		73+/-20	5+/-1	*	*	*	*	1+/-0.5	Tr.	NA
		115+/-38	6+/-1	*	*	*	*	2+/-1	1+/-0.4	NA
		74+/-28	3+/-2	*	*	*	*	3+/-2	Tr.	NA
		69+/-7	5+/-1	*	*	*	*	1+/-1	*	NA
	1983	*	Tr.	*	*	*	7+/-3	3+/-2	*	NA
	1987	*	*	*	*	*	*	*	*	1.1+/-0.2
Method Detection Lim		20	3	5	1	1	1	1	1	
Note: 1) NA = Not Available 2) * = not detected at MDL										

TABLE 4.28

Contaminant Concentrations in Herring Gull and Black-Crowned Night Heron Eggs from the Niagara Peninsula

Species	Year	Total Mean	Total DDT*	Total Mean	Total PCBs*	Number of Samples
Herring Gull	1971	10.4	(14.5)	74	(87)	21
	1979	4.2	1.334	50.5	22.51	10
	1982	3.73	1.143	45.5	----	11/1
	1986	2.73	1.106	22.55	10.52	10
Black-crowned	1971	7.82	(24.1)	27	(70)	13
Night Heron	1971a		(2.6)		(27)	10
	1971b		(6.3)		(18)	3
	1982	5	----	18.9	----	1
	1986	3.44	----	33.4	----	1

LEGEND: * - refers to sum of DDT and metabolites (DDE and DDD)
SD - standard deviation (numbers in brackets are ranges)

NOTE: Eggs taken in 1971 were by independent researchers from the north shore of Lake Erie.
Eggs taken after 1971 were by Canadian Wildlife Service from colonies on the Niagara River above the falls.

Analyses of Niagara River Black-crowned Night-Heron eggs from the Canadian Wildlife Services's 1982 collection[2] indicated elevated levels of dieldrin, mirex, beta-HCH and the four chlorobenzenes over the eggs from colonies in Lakes Erie and Huron.

The Niagara River was ranked the lowest in terms of quality when compared to the other 4 sites monitored (in Lakes Erie, Huron, and Ontario). An increase in trans-nonachlor and PCB levels in eggs from 1982 to 1986 appears to be indicated by the data collected.

The Canadian Wildlife service has monitored dioxin levels in the eggs of herring gulls from sites in the Niagara River since 1981. Dioxin and dibenzofuran results are presented in Table 4.29. Levels in 1986 appear to have declined somewhat since the initial sampling studies, although there is no indication of a significant downward trend.

Organochlorines (PCBs, dieldrin, and DDE) were implicated as the cause of death of ring-billed gulls in 1969 and 1973. Levels of organochlorine in the brain were significantly higher in birds found dead compared to those collected by gun-shot[98]. Recent colonial bird contaminant work deals exclusively with egg levels; tissue concentrations in most bird species is unknown.

TABLE 4.29

Concentrations of selected chlorinated dioxins and dibenzofurans in herring gull eggs from sites in Lake Ontario and the Niagara River 1981-1986. (Single pools of 10 eggs per site per year).

		Dibenzodioxins (ppt)		Dibenzofurans (ppt)	
Location	**Year**	**2,3,7,8-TCDD**	**Other***	**2,3,7,8-TCDF**	**Other****
Niagara River	1981	87	39	-	-
	1982	69	29	-	-
	1983	19	24	-	-
	1984	41	35	2	40
	1985	41	28	<2	19
	1986	40	25	2	38
Lake Ontario					
Snake Island	1981	185	33	-	-
	1982	129	39	-	-
	1983	90	51	-	-
	1984	101	54	<2	24
	1985	67	22	<2	<14
	1986	65	26	<2	<14
Muggs Island	1984	60	44	2	28
	1985	39	22	<2	<10
	1986	49	23	<2	<12
Scotch Bonnet Island	1981	50	36	<2	33
	1982	42	25	<2	<12
Hamilton Harbour	1984				
	1986				

Source: Canadian Wildlife Service, Ottawa, Ontario.

* Includes 1,2,3,7,8-penta 1,2,3,6,7,8-hexa and octa-chlorodibenzo-p-dioxins. No heptachlorodioxins were found.

** Includes 1,2,4,7,8-penta. 2,3,4,7,8-penta. 1,2,3,4,7,8-hexa. and 1,2,3,6,7,8-hexachlorodibenzofurans. No hepta or octachlorodibenzofurans were found.

Some studies have been completed on PCB and DDE concentrations in waterfowl by the New York State Department of Environmental Conservation[75], the results of which are summarized in Table 4.30

Studies by NYDEC (1984-85) on one waterfowl species - goldeneye (Bucephala angula), that overwinter on the Niagara River, involved the measurement of the relative uptake of an array of chemicals during their period of residence on the river. Goldeneye are migrants from northern Canada, thus were expected to contain low levels of chemicals prior to migration to the Niagara River system. Results indicated that although these ducks arrived with elevated levels of contaminants, significant accumulations of several contaminants (PCBs, Dieldrin, HCB, Heptachlor epoxide) occurred during their residence in the area (Table 4.31). DDT concentrations remained stable but the rate of occurrence increased by a factor of

TABLE 4.30

PCB and DDE Concentrations in Waterfowl from the Niagara Frontier and Eastern Lake Ontario and Eastern Lake Ontario/St. Lawrence Flyways

		Concentration in ng/g of tissue* Niagara Frontier	
Waterfowl Species	**Compounds**	**Fat**	**Muscle**
Mallard	PCB	1.2 +/-1.1	0.07+/-0.04
	DDE	1.58+/- 1.70	0.03+/-0.02
Bufflehead	PCB	6.73+/-11.33	0.10+/-0.14
	DDE	0.82+/- 1.16	<0.01
Scaup	PCB	1.0 +/- 0.8	0.1 +/-0.2
	DDE	0.3 +/- 0.34	0.01+/-0.01
Black Duck	PCB	0.6 +/- 0.2	<0.01
	DDE	0.67+/- 0.75	0.01+/-0.01
Canada Goose	PCB	0.01+/- 0.04	<0.01
	DDE	0.04+/- 0.02	0.03+/-0.005
Wood Duck	PCB	0.20+/- 0.1	<0.1
	DDE	0.13+/- 0.08	<0.1
Common Goldeneye	PCB	31.6 +/-23.7	NA
	DDE	5.57+/- 7.84	NA

* - Arithmetic Mean +/- standard deviation
NA - Not Analyzed
Source: New York State 1983

six between December 1984 and February/March 1985. Goldeneye feed primarily on crustaceans and gastropods and constitute a link between contaminants that occur in prey species residing in sediments and water and uptake by wildlife.

Tissue contaminant level in waterfowl were determined for goldeneye collected just below Grand Island upon arrival for the winter in 1984 and just before migration to breeding grounds in the spring[99]. Mean organochlorine levels in the duck fat increased at least 1.5 times during their stay on the river; however, the fat content of the ducks was not determined. Comparison of contaminant levels in hatching-year and adult male ducks indicate a significant body burden of contaminants already in adult birds upon arrival on the river.

Ten oldsquaw ducks were collected from the river near Niagara-On-The-Lake in 1980 for contaminant analysis. Unpublished results[100] indicate very high levels of PCBs in the breast muscle (>1 ppm total PCBs wet weight) and males contain higher levels than females. The low numbers of ducks sampled at the same stage of maturity and sex limits the statistical confidence of the results. These results cannot be directly compared with those found in the goldeneye as different tissue was measured.

Mallards were collected in 1988 around the Welland River for contaminant analysis but results have not yet been released.

The levels of organochlorines and PCBs in waterfowl of the Niagara River need further investigation and may warrant the need for consumption advisories. CWS is currently investigating the possibility of consumption advisories for waterfowl harvested from specific sites in Canada. In 1990/91, an intensive survey was conducted in Ontario; samples were collected from Niagara AOC. Breast muscle was analyzed for organochlorines, metals and selected samples were analyzed for dioxins/furans. The residue data are now undergoing assessment by Health and Welfare Canada. Guidelines do exist in New York State and the State of Wisconsin. Twenty-six percent of duck hunters in the Niagara District hunt exclusively on the river[101].

Work on contaminants in birds of the Niagara River is very limited and restricted to levels. Background levels of contaminants need to be determined in relatively "clean" areas and compared with the levels found in the area of concern. There is a definite need for studies which determine the relationship between tissue burden level and chronic effects on the populations. Possible sub-lethal effects can be categorized into physiological, behaviourial, and genetic and morphological responses[102].

Egg shell thinning and embryonic mortality, due to levels of DDT and its metabolites, were responsible for the decline of several North American avian species in the past including peregrine falcons, bald eagles, and osprey. Recent work indicates that Bald Eagles living near the Great Lakes have lower breeding success and survival than those farther away[103]. Bald eagles are opportunist feeders, with fish comprising a large portion of the diet. Organochlorines have also been implicated in mortality leading to the decline in Great Horned Owls near the Hudson River and Lake Ontario[104].

Current research indicates contaminant burden reproductive failure is due not only to egg shell thinning but also abnormal incubation behaviour, abnormal thyroids[96], deformities, decreased weight at birth[104] and changes in sperm characteristics[105]. Studies done that involved feeding an organochlorine mixture to ringdoves[106] indicated changes in breeding behaviour and fledgling success. These effects could alter reproductive success in the wild.

4.4.6 Biota - Mammalian Wildlife

Monitoring of contaminant levels in mammals has been very limited in the past. Some work[109] indicates that organochlorines and PCB levels in mink in the Lake Erie area are extremely high (0.6-7.37 ppm wet weight body homogenate) and are probably high enough to reduce reproductive success since mink appear to be sensitive to PCBs. PCB levels of 5 ppm in adult mink and 1 ppm in kits (in liver or muscle tissue)

TABLE 4.31

Occurrence of PCB and organochlorine pesticides in common goldeneye overwintering on the Niagara River winter 1984-85.

	Concentration (ug/g wet weight)			
	December 1984		February/March 1985	
Chemical	**Brain**	**Fat**	**Brain**	**Fat**
PCB*	0.2	23.5	0.3	35.1
	0.1-0.2	18.2-30.4	0.2-0.4	25.9-47.6
Total DDT	0.024	3.39	0.03	4.89
	0.019-0.031	2.51-4.59	0.022-0.041	3.44-6.98
Dieldrin*	1.013	0.228	0.014	0.71
	0.010-0.017	0.163-0.317	0.010-0.019	0.48-1.05
HCB*	0.003	0.101	0.003	0.157
	0.0026-0.0035	0.078-0.132	0.0025-0.0036	0.115-0.215
Oxychlordane	0.003	0.24	0.0025	0.25
	0.0026-0.0032	0.18-0.31	0.0022-0.0028	0.19-0.35
Heptachlor Epoxide*	<0.025	0.13	<0.025	0.23
	-	0.091-0.17	-	0.16-0.34
Mirex	ND	0.109	ND	0.107
	-	0.067-.18	-	0.058-0.19
Endrin	<0.025	0.006	<0.025	0.005
	-	0.004-0.006	-	0.005-0.007
Heptachlor	0.0026	NC	0.0028	NC
	0.0023-0.0028		0.0025-0.0032	

ND = Not detected
NC = Not calculated
* - Significant change ($p<0.05$) between collection periods.
For each item - first row is the Mean and second row is the range.
SOURCE: New York State Department of Environmental Conservation.

have been shown to cause mortality[104]. There are indications that the numbers of mink living near Lake Ontario are reduced although the exact reason is presently unknown.

Correlations between contaminant levels in mammals and sub-lethal, or lethal effects are not well known. In many cases, very little monitoring occurred in the area. The major problem with case histories is determining the toxic agent as many environmental contaminants are found in the affected species and their concentrations are often correlated.

4.4.7 Biota - Reptilian and Amphibian Wildlife

Little work has been done on contaminant levels of amphibians and reptiles in the area. Recent sampling of 3 snapping turtles from the Welland River indicates moderate levels of total PCBs in muscle (mean 0.12 ppm wet weight). However, the age and sex of the turtles has not yet been determined and the effect of these levels on the biota was not investigated. Recent work on laboratory hatched eggs indicates that embryonic development of snapping turtles may be sensitive to organochlorine residues[112].

4.4.8 Biota - Other

Due to the highly developed area bordering the Niagara River and the precipitous terrain of the lower Niagara River, the habitable area for other resident wildlife of potential value as contaminant indicators is very limited. Sample sizes necessary to provide reliable indicators of changes in contaminant load or as a measure of current contamination levels would severely affect local wildlife populations. Therefore, there is no routine monitoring of wildlife species.

4.5 Sediment

Sediment is a significant factor in the environmental problems in the Niagara River (Ontario) Area of Concern.

Soils and other materials from natural processes (erosion and snowmelt) and human activities (agriculture, waste disposal and residential/industrial land development) gradually accumulate in bottom sediments along with much of the load of organic and inorganic contaminants associated with these materials. The predominance of sedimentation and burial as a pathway is due, in part, to the strong affinity of many contaminants for particulate matter. The transport of contaminants from their point of entry to the river system to their final burial in depositional areas is a complex cycle of deposition and resuspension, which is further complicated by the incorporation of contaminants within the biota.

Contaminants in sediment can be available to bottom-dwelling members of the biotic community and can be converted to soluble forms through biological and/or microbiological processes. In addition, contaminants in sediment that have been deposited in shipping channels can be remobilized as a result of propeller activity and the pressure waves created by passing ships. Contaminants can also be remobilized during dredging and disposal operations, which are essential to the maintenance of navigation channels and harbours and to the excavation of new channels and harbour facilities.

The Niagara River has very limited depositional areas in the main channel due to high velocities. An extensive side-scan sonar survey by Environment Canada has shown that virtually the entire river is swept clean of any fine sediments.

Most sediments in the Niagara River are suspended while in the river and carried to an area in Lake Ontario known as the Niagara River Bar (at the mouth of the Niagara River north of Niagara-on-the-Lake) which is the main depositional area for the sediment-borne contaminants from the Niagara River.

A minor depositional area, particularly for suspended sediment which originates in the Welland River is the reservoir at the Sir Adam Beck generating stations, which provides a relatively quiescent area in which a partial deposition of suspended sediments can occur. Over the years, there has been a significant accumulation of sediments in this reservoir. In addition to accumulation, these may also be resuspended and discharged to the lower river.

Surficial bottom sediments (top 3 cm) in the Sir Adam Beck Reservoir were found[113] to be contaminated with arsenic, cadmium, chromium, copper, iron, lead, nickel, silver and zinc at levels in excess of the MOE guidelines for open water disposal of dredged sediments. The mobility of the reservoir sediments and the availability of their associated contaminants has been investigated[763].

This sedimentation within the reservoir has created problems for Ontario Hydro. The utility has implemented mitigative measures to minimize the resuspension of contaminants. Precautions are now required during construction activities or changes in operation of the reservoir to prevent the resuspension and mobilization of the contaminated sediments[760].

Some sediment deposition also occurs within the Area of Concern, particularly at the mouths of Niagara River tributaries and throughout the lower portions of the Welland River. In many of these areas, habitat and biota loss through sediment deposition is a far greater concern than chemical contamination, although both may occur.

In addition to contamination that exists on sediment particles prior to suspension in water, the suspended sediment in the Niagara River tends to sorb contaminants from the water column, particularly heavy metals and organics, during its passage to Lake Ontario.

4.5.1 In-Situ Sediment Contamination

A number of studies were undertaken between 1980 and 1982 during the NRTC investigation to assess bottom sediments in the Niagara River. The findings have been reported in the NRTC final report of 1984.

On the Ontario side of the upper Niagara River, the Fort Erie and Chippawa segments were relatively uncontaminated, showing only some metal contamination and no PCBs in excess of NRTC screening levels. These two segments along with background control areas in Lake Erie were also less contaminated than the lower river segment. The NRTC determined that pollutant levels were higher in the Lake Erie control area than in either the Fort Erie or Chippawa segment.

On the U.S. side of the upper river, contaminated sediment removed by the U.S. Army Corps of Engineers from the navigation channels in the Niagara River, harbours and tributaries to the river, is deposited at a dumping ground in Lake Erie off Buffalo Harbour near the head of the Niagara River. By virtue of its location and the prevailing currents, this ground may be a source of contaminants to the river, especially if persistent organic substances are remobilized from the dredgeate.

The lower Niagara River was classified by the NRTC as having an intermediate level of pollutants (similar to Lake Erie), although elevated levels of hexachlorobenzene and chlorinated aromatics were noted. Levels of zinc, mercury, p,p'-DDT, alpha-endosulfan, BHCs, mirex, PCBs and heptachlor epoxide in the lower river also exceeded average Lake Ontario levels.

The results of the NRTC study were, in general, confirmed by a Ministry of the Environment sediment survey in 1983[900]. Three sediment samples were collected at each of over 120 sites along the Canadian and American sides of the river. Each set of three samples was homogenized to provide a single sample.

The Ontario Ministry of the Environment has recently produced a series of draft provincial sediment quality guidelines (PSQGs)[901]. These guidelines are biological-effects based to protect those organisms which are directly impacted by contaminants in sediment (benthos). The guidelines establish three levels of ecotoxic effects for a number of metals, nutrients and organics. These levels are:

NOEL:No-Effect Level at which no toxic effects have been observed on aquatic organisms.

LEL: Lowest Effect Level at which a level of sediment contamination can be tolerated by most (95%) aquatic organisms.

SEL: Severe Effect Level at which a level of sediment contamination is detrimental to most (95%) aquatic organisms.

Development of the guidelines has progressed through three drafts and are currently being applied in a number of areas, including the lower Welland River. The guidelines themselves are now supported by a development document[903] for ten of the metals and an applications consideration document[902].

Concentrations of metals in sediment collected on the Canadian side of the upper river were generally lower than for those collected on the American side. In addition, exceedances of the draft Ontario Provincial Sediment Quality Guidelines[901] "lowest effect level" (LEL) and "severe effect level" (SEL) were rare on the Canadian side. The single exception was arsenic which exceeded the LEL concentration on the Canadian side at Fort Erie and in the Chippawa Channel. Exceedances of these criteria occurred frequently on the American side of the river.

Sediment collected from the lower river in 1983 had higher concentrations of phosphorus, nitrogen and metals than sediment collected in the Chippawa Channel and at Fort Erie. Exceedances of the LEL were more common on the lower river than on the Canadian side of the upper river. As a comparison, there were several sites in the Tonawanda Channel that had concentrations of metals higher than those found in the lower river.

Contaminant concentrations on both sides of the lower river were similar, due primarily to the strong mixing effects of the falls, the rapids and the power plant discharges. Exceedances of the LEL for arsenic, cadmium, zinc, chromium, copper, lead and mercury occurred equally on both sides with the exception of chromium which was present at Youngstown, N.Y. and not at Niagara-on-the-Lake and arsenic which was higher near Queenston than near Lewiston. Lead concentrations peaked on both sides of the river below Queenston-Lewiston.

The Ministry of the Environment has also studied contaminant levels in bottom sediments in the reservoir at the Sir Adam Beck generating stations[113]. It was found that surficial bottom sediments (top 3 cm) in the reservoir were contaminated with nine heavy metals at concentration levels in excess of Ministry of the Environment guidelines for open water disposal of dredged sediments. However, only cadmium, iron, lead and nickel concentrations in some samples exceeded the proposed Ministry guidelines for unrestricted land use of dredgeate; in one sample, the concentration of iron exceeded the guideline for restricted land use.

PCBs were detected in about half of the samples collected from the reservoir but at levels close to the detection limit. DDT and its metabolites were the only organochlorine pesticides detected in the reservoir sediments. These findings suggest relatively recent upstream input of contaminants. The origin of these contaminants is not known at this time and may warrant investigation. Ontario Hydro has proposed mitigative measures to prevent the reservoir from becoming a future source of contaminants[760].

In 1983, The Ministry of the Environment conducted a survey at the mouths of eleven Ontario tributaries to the Niagara River[134]. This survey included the collection of bottom sediments samples, some of which were found to contain metal concentrations at levels in excess of the Ministry guidelines for open water disposal of dredged materials. Chlorinated compounds and phenoxy herbicides were also detected in some of the bottom sediment samples.

Contaminated sediments and a coal tar deposit were identified in 1983 by the Ministry of the Environment following public complaints of chemical burns to bathers in Chippawa Creek. Subsequent investigations revealed a 10 by 20 metre deposit of material on the bottom of the Chippawa Creek. Tests revealed the material to contain high levels of coal tar and naphtha residue including 26 different types of polycyclic aromatic hydrocarbons (PAHs). The material was also determined to contain ng/L levels of dioxins and furans; however, 2,3,7,8-TCDD was not detected. The source of these materials was determined to be historical and the location was linked to the area currently occupied by the Norton Company. The possibility existed of migration of the deposits as a result of continual scouring action in this part of the river system along with the possibility of continued direct exposure to swimmers; therefore, clean-up operations were required.

In 1986, the Ministry of the Environment and Norton subsequently undertook a joint program to remove this deposit from the bottom of Chippawa Creek. The coal tar mass was removed using a barge-mounted clamshell dredge and hydraulic removal. A total of 500 cubic metres of sediment were removed from the creek bed and temporarily stored in a settling basin located near the site. The dredged sediment was disposed of at a certified landfill site, after on site treatment. This process was conducted between the fall of 1986 and the fall of 1987. Local residents that swim in the area were prohibited from swimming during the remediation period. Removal activities were completed in 1987.

4.5.1.1 Welland River Sediments

Contaminated sediments may also represent a problem in the lower sections of the Welland River. The typically slow-flowing areas of the river lead to deposition of suspended sediment (approximately 10 mg/L loss) during most of the year. Fine soils, eroded from the agricultural basin, may contain nutrients and pesticides. Industrial activities in Welland also add heavy metals to the suspended load. Dredging has not occurred in the Welland River because spring run-off tends to remove this bed-load from these depositional areas to a large extent.

In 1990, a study of the environmental condition of the lower Welland River was conducted for the Ontario Ministry of the Environment[916]. This study concentrated on the surficial bottom sediments of the Welland River between Welland Airport and Chippawa (25 stations) with the intent to develop a database for the assessment of remedial options and to determine the significance of this area in the overall contamination problem in the Niagara River Area of Concern.

This study determined that sediment quality was quite variable throughout the study area. The concentrations of lead, chromium, nickel, zinc, cadmium, copper, arsenic, iron, mercury, nitrogen, phosphorus, PCBs, PAHs, oil and grease exceeded MOE open water disposal guidelines at some locations. No organochlorine pesticides were detected.

The area of severest contamination was the reach of the Welland River between the old and new Welland Canals. Between the upper syphon and the Welland sewage treatment plant outfall, sediment quality was degraded by several metals, oil and grease, cyanide and PAHs. Many of these parameters were also at elevated levels in the area east of the Welland Ship Canal. A number of industrial, municipal and stormwater discharges are located in these areas, as well as several landfill sites, although no attempt was made to link sources to contaminated sediments in this study.

The sediments in the portion of the Welland River known as Chippawa Creek were determined[916] to be generally uncontaminated although the fast moving current tends to inhibit sedimentation.

4.5.1.2 The Atlas Reef

Studies by Brock University researchers in the mid-1980's[904,905] revealed a heavily contaminated sediment deposition area in the Welland River in the City of Welland. Results of the initial sediment sampling and chemical analysis indicated an area of heavy metal contamination in the Welland River in the vicinity of the Atlas-Mansfield sewer outfall on the east bank of the river between Almond and Bruce Streets in Welland. Further testing showed a reef-type deposit of heavy metals adjacent to the sewer outfall with chromium and nickel the major contaminants. During low flow conditions, portions of this sizable deposit are exposed above the water level and have formed a hard rock-like crust which resembles an unsightly "reef" in the Welland River.

Brock researchers have also investigated the aquatic life in the vicinity of the reef[906,907] and discovered that parts are devoid of macrophytes and benthos. There is also a defined zone of lesser impact and various recovery zones which extend at least to the Welland water pollution control plant outfall, approximately 800m. downstream.

The deposit has been associated with the discharge of Atlas Specialty Steels of Welland, Ontario, which has released contaminated effluents into the Welland River for approximately 50 to 60 years. Over the past several years, Atlas has undertaken efforts to eliminate or minimize the impact of its Welland operation on the surrounding environment. Atlas and its parent company Sammi Steel have recognized corporate and community responsibility in the contamination of river sediments and, in 1987, committed to clean-up the river contamination. Atlas' plant discharges have, in the past, consisted of granular and oily industrial wastes which contain heavy metals and solvent extractables (oil and grease); some of these were discharged as instantaneous contaminant batches which were identified as causes of "shock" to the ecosystem.[908]

Process modifications and construction of wastewater treatment facilities at its north and south plants during the past decade and a half have improved the quality of Atlas' discharge. While some heavy metal contamination remains, solids, oil and grease have been largely removed at the plant. Further modifications towards a closed-loop system should reduce the contaminant load further.

Atlas has committed itself to undertaking a clean-up of the contaminated sediment deposits and, as a result, has implemented investigations which included a complete definition of the limits and nature of the contamination, characterization of the reef deposits and an assessment of appropriate clean-up technologies. These investigations were conducted during the summer/fall of 1989[909,910] and again in the spring of 1990[911] and have established the presence of three distinct deposits in the Welland River. The three reefs are located between the Regional Municipality of Niagara (RMON) Welland Water Treatment Plant at the south end of Meritt Island and the RMON Welland Water Pollution Control Plant approximately 2km. downstream. The reefs are known as:

1. Atlas-Mansfield Reef
2. Downstream Reef
3. McMaster Reef

The reefs are composed of a black coarse granular metallic material, occasionally interlayered with soft, black clay, sand or silt, overlying the natural reddish-brown, stiff clayey till river bottom. The granular material is generally compact (35-65% relative density)[909] while underwater. Upon its exposure to air, the material undergoes oxidation to a 30-50 mm. thick, orange, easily broken crust. Both wet and dry forms give off an oily odour, as well as an oily sheen and texture. In the downstream reef, the black granular material is not always present and contamination was sometimes observed as soft, black, silty-clay sediment.[912] In the vicinity of the reefs, natural sedimentation also occurs. This material is generally a soft to firm mixture of clay and silt with traces of sand. Occasionally this sediment may also contain more sand and minor amounts of gravel.

The sediment investigations in and around the Atlas Reefs have shown that the main reef deposits contain copper, chromium, iron, lead, manganese, nickel and zinc at levels exceeding Ontario's draft PSQG "severe effect levels". Analyses for PCBs and trichloroethylene showed concentrations near or below detection limits[912]. Reef material was also analyzed for base/neutral extractable organics including PAHs. These showed some compounds detectable at trace levels or low ug/g range[912]. All organics, with one exception are below PSQG "lowest effect levels" indicating that organic contamination is not a factor in the reef sediments.

A fairly large area of contamination, approximately 1300m. in length, has been delineated, concentrated mostly on the east side of the Welland River but in some locations migrating across the full width of the river[910,911]. Generally, concentrations of metals on the west side are similar to upstream (background) metal concentrations and significantly less than metal concentrations in the reef deposits. A statistical analysis of sediment data by Acres[910] has generated an estimate of 30,000 cubic metres of contaminated sediment requiring removal.

As part of the investigation, Atlas confers with the public through a Liaison Committee. The committee raised the issue of potential contamination of the floodplain, in addition to the bottom sediments. Acres has conducted preliminary east bank floodplain investigations[911] and detailed investigations are underway. The preliminary investigations revealed elevated levels of heavy metals, oil and grease contamination in the top two surface strata in the eastern floodplain. These strata (up to 3m. thick) have a strong oily sheen and odour and covers a layer of sandy septic material (1.6m. thick). Contamination of the floodplain is still under investigation[913].

Atlas intends to implement a remediation project which uses state-of-the art dredging and sediment treatment technologies. Prior to its implementation, the potential environmental effects of the proposed project and the mitigative measures required to minimize its impact will be identified. They have determined that the dredge method which is most cost-effective and environmentally acceptable is the "suction dredge method". In partnership with Environment Canada, under the Great Lakes Action Plan, Atlas conducted a sediment removal and treatment demonstration project in the fall of 1991[914]. During this time, 500 to 1000 m^3 of sediments were removed. If this demonstration project is successful (ie. meets all government operational and performance standards, and meets all government regulatory requirements for remediation of the Welland River), it will be applied on a much larger scale to the entire Atlas Reef deposits.

4.5.2 Suspended Sediment Contamination

In a fluvial system, sediments are continually resuspended, transported and deposited in other areas. This is particularly true of fine-grained sediments. In the Niagara River, with its high rate of flow, the transportation of sediments and deposition at the Niagara Bar area in the western basin of Lake Ontario has been well documented[46,114,115]. Due to the water velocity, accumulation of any particles that are less than 63 um in size is rare, although occasionally a small quantity of fine-grained sediment becomes entrapped within the coarser bottom sediments[114]. Research in the 1970's estimated that fifty percent[115] of the silt and fine-sized grain material load to Lake Ontario, or 4.56 million tonnes per year, was contributed by the Niagara River[116]. In 1983, this load was estimated at 1.54 million tonnes of silt and fine-sized grain material per year[117]. Most of the material is believed to come from Lake Erie[46].

Substantial quantities of contaminants enter Lake Ontario from the Niagara River on the suspended sediment fraction because of the propensity of organic and inorganic contaminants to bind (or adsorb) to fine-grained particulate matter[118]. It was estimated that the river contributes a significant proportion of the sediment-bound lead (46%), copper (68%), zinc (86%) and PCBs (33%) to Lake Ontario[46].

Niagara River bottom sediment study results[46] suggested that resuspension of contaminated sediment is probably insignificant throughout most of the river's channel. Concentrations of organics in the bottom sediments were greater than those in Lake Erie sediments. It was concluded that organic contaminants from different sources also become associated with coarse grained bottom sediments in the river.

Niagara River suspended sediment collections[46] contained levels of inorganic and organic contaminants greater than those measured at Fort Erie with the exception of DDT. For example: lead, copper and zinc measurements at Fort Erie were 43, 25 and 76 ug/g respectively, while measurements at Niagara-on-the-Lake were 133, 102 and 350 ug/g. This is equivalent to the levels found in the bottom sediments in the western basin of Lake Ontario.

In summary, while there is a large sediment load flowing through the Niagara River, very little of the quantity is thought to originate from sources in the river itself or from resuspension of bottom sediment. The quality of the suspended particles however, can be attributed to sources along the river and the ability of both inorganic and organic contaminants to adsorb onto the fine-grained fraction.

4.5.3 Siltation and Erosion

Sediment itself must also be considered a pollutant when it interferes with beneficial use of the water[119]. In 1970, pollution was the most serious water problem in the Niagara peninsula[120]. One of the main pollutants of the inland rivers was sediment. Water having suspended sediment concentrations in excess of 5 mg/L was considered unsuitable for drinking, whereas swimming waters having levels greater than 10 mg/L lead to complaints[119]. In 1970, the recreational potential of the inland rivers of the Niagara Peninsula was considered seriously curtailed due primarily to low flows and sediment pollution[120].

There are many contributors to increased erosion and siltation. One of the major contributors is poor land management practice, including excessive removal of vegetative cover, channelization, cultivation close to the bank, and field erosion[121,122]. Field and streambank erosion problem areas were mapped in 1970[120] and indicate the upper Welland River as a problem area for the watershed. Suspended sediment in the water has been related to land use; levels increase with cropland and decrease in areas of woodland and improved grassland[123].

There are many problems associated with high erosion and siltation. The clarity of the waters in the Welland River is poor due to the high sediment load. Suspended sediment in the water column can adversely affect water quality in various ways. High sediment load can increase water temperature and decreases light penetration, which lead to a decreased photosynthetic rate[84,125,126,127]. Low light can also reduce feeding activity of fish that are visual feeders[84]. High loadings of nutrients associated with sediment can cause increased eutrophication, which leads to decreased oxygen levels[84].

In portions of the Welland River, sediment has settled out of the water column. This has resulted in changes to the characteristics of the bottom, covering it with a layer of silt. This degrades invertebrate populations by removing substrate, causing increased drift, and clogging filtering devices[84,128]. Fish populations are similarly affected by the changing of spawning areas, resulting in decreasing fish egg survival, abrasion of fish gills which leads to increased susceptibility to disease, changing of food sources and feeding rates, changes in distribution in the water column which could affect adult fish survival, possible interference with migrations and changes in blood physiology at high levels[71,84,121,125,127,129,130].

The net effect of increased sediment is change to the composition and diversity of aquatic species. Species composition usually moves from sensitive species to more tolerant ones; this means a movement from original fish species like bass, perch, and walleye, to carp, catfish, and freshwater drum and from filter feeding invertebrates such as caddisflies and mayflies to sediment dwellers such as worms and chironomids[84,131,132].

Sediment loading has a negative economic effect on the system by reducing numbers of desired high value sport and commercial fish and by reducing recreational activities. The waterbody, in general, is not as aesthetically pleasing to man. The economic effect of soil loss from agriculture must also be considered[119]. Sediment can also cause navigational problems and indirectly cause drinking water limitations[133].

Generally, the "no effect level" for suspended sediment levels is considered to be 25 mg/L. This is the maximum acceptable concentration of nonfilterable residue in Manitoba. The European Inland Fisheries Advisory Commission (1965) set 25 mg/L as the maximum concentration of suspended solids for a high level of protection with no harmful effects on fisheries. Levels higher than 80 mg/L indicate a low level of protection and the system is unlikely able to support a good fishery[71].

Suspended sediment levels on the Welland River are higher than those in the Niagara River, due predominantly to the basin soils. The main soil type in the Welland River basin is clay. Fine grained cohesive materials, such as clay particles, are hard to erode but once in the water column, remain suspended for longer periods[120] and will travel farther downstream. The Welland River is very turbid, year round, from the headwaters at Mount Hope to a point just east of Port Robinson, after the river passes under the Welland Ship Canal. Flow augmentation from the canal at this point dilutes the suspended sediment concentration in the river causing a change in the water colour. Even with flow augmentation from the canal, the average suspended solids concentration at the confluence with Chippawa Creek is 28 mg/L.

Levels of suspended solids are determined monthly at various sites along the Welland River by filtration. Average levels in mg/L at the Sinclairville bridge and Montrose bridge sampling sites are 86 and 28 respectively, with maximums, over a nine year period (1980-1988), of 542.4 and 451.7. In 1970, suspended sediment concentrations in the Welland River, downstream of Warner, exhibited levels lower, but within the range, of current levels at the Sinclairville bridge[120]. The maximum levels of suspended solids occur at peak flows, which may last from several days to weeks.

Suspended sediment levels found in the Welland River (and on occasion in the Niagara River tributaries) are above the level which provides a high level of protection to fisheries (25 mg/L). Although these suspended solid levels are not directly lethal to fish it has been shown that at levels greater than 100 mg/L growth rate and feeding response is slower, and with levels greater than 300 mg/L fish are displaced, oxygen uptake is increased, and toxicant tolerance is decreased[125].

Sediment loading to the Welland River can be estimated using average annual suspended sediment concentrations and flows. The continuous flow gauge for the Welland River is located at Caistor Corners, well upstream from the confluence with the Queenston-Chippawa Power Canal. No water quality sampling is undertaken at this location but flows from the gauge, together with flow figures of water diversions from the Welland Canals, provided by the St. Lawrence Seaway Authority are used by the Ministry of the Environment to estimate flows at Montrose where suspended sediment concentrations are monitored.

These load estimates are based upon average annual suspended solids estimates; therefore, they tend to underestimate the inputs at peak flows. Estimates made in the Welland River Report[84] are approximately 25 percent of those determined here. The annual flow used in the former study is lower than that determined by the MOE (1989). Other methods of estimating sediment load are available but there is a lack of flow-related data for the Welland River and other tributaries.

Measurements along the Welland River indicate that the average suspended sediment concentration decreases downstream from Sinclairville. This suggests that siltation rates could be higher in the upper reaches or that dilution is occurring as more water enters the stream.

Dissolved solids are operationally defined as material that passes through a 0.45 ug pore-size filter. Average levels of dissolved solids (filterable residue) in the Welland River at the Sinclairville bridge and Montrose sampling sites are 490 and 235 mg/L with maximums of 1,270 and 386 mg/L over a nine year period (1980-1988). These values were determined from monthly water sampling. Sampling results from 1970 show similar results for the Welland River and levels of 400-560 mg/L for Forks, Coyle, and Oswego Creeks[120]. Dissolved solids in the Niagara River and tributaries[134] were not monitored.

Dissolved solids determine the ionic strength of the water and are involved in complexations and precipitation processes with trace metals[125]. They also provide nutritionally important ions to phytoplankton[138]. The composition and concentration of dissolved solids are important in determining the variety and abundance of aquatic plants and fauna. Major changes in the quantity or composition of total dissolved solids will influence the function and structure of the local aquatic ecosystem[125].

Total dissolved solids are correlated to eutrophication. One researcher suggested a relationship between the morphoedaphic index (total dissolved solids/mean depth) and total yield to fishing. If mean depth is held constant, total dissolved solids (TDS) is related to yield and as TDS increases there is a change in species composition from salmonids to cyprinids. Therefore, high levels of TDS indicates eutrophication and an effect on the fisheries of the water body[139].

The biological impact of sedimentation is significant. It has been reported that a silt deposit rate of 1.0 mm/day can be associated with 97% mortality in pike eggs[71]. In an ecosystem study, sedimentation was reported to be the major habitat factor in the viability of smallmouth bass population[93] in Iowa streams. Other researchers confirm that increased sedimentation leads to decreased fish production[92].

The total dissolved solids levels found in the Welland River are well above the optimum range of dissolved solids for walleye (40-80 mg/L)[140]. Therefore, walleye may be impaired by the high level of dissolved solids in the Welland River but it is only one of several possibilities. Walleye used to be present in the Welland River but now are gone. Rehabilitation seems unlikely unless dissolved solids are reduced, suspended solids are reduced, possible blockages to migration corrected, and siltation cleaned off possible spawning areas.

Very little information is available on suspended sediment levels in the tributaries of the Welland and Niagara Rivers. In 1970, suspended sediment levels were determined on Forks and Oswego Creeks, tributaries of the upper Welland River. Levels ranged from 80-180 mg/L.

A 1983 tributary study[134] estimated suspended sediment loadings (Table 4.32); however, these estimates were based on flow values from one day and, on

TABLE 4.32

Suspended Sediment Concentrations and Loadings for the Niagara River and its Tributaries

Waterbody	Suspended Concentration (mg/L)	Sediment Load (t/yr)	Water Flow (cms)	Date Gauged
Niagara River #	10	1,700,000	6400	1979-81
Welland River *	28	30,100	34.1	1980-88
	20.5-38.3	26,200	40.6	June 10/83
Frenchmans Creek	13.9-17.6	N/A	0.084	June 7/83
Miller Creek	12.0-34.4	21.6	0.020	May 1/83
Baker Creek	10.5-29.7	N/A	N/G	N/G
Black Creek	26.9-93.4	5,000	1.691	June 8/83
Boyers Creek	15.7-42.8	N/A	N/G	N/G
Usshers Creek	3.0-5.8	2.2	0.012	June 9/83
Pell Creek	17.3-66.7	12.6	0.023	June 9/83
Lyons Creek	7.3-12.0	1,600	4.358	June 11/83
Chippawa Creek	4.5-6.0	N/A	N/G	N/G
Thompsons Creek	25.8-29.4	2,300	0.132	June 11/83

LEGEND:
- Average flow calculated from hourly flow at Queenston
- suspended sediment sampled bi-weekly April 1979 - Dec. 1981
* - Flow calculated from gauge at Merritt's Church
- suspended sediment sampled monthly 1980 - 1988
N/A - not available
N/G - not gauged

average, three suspended sediment sampling dates. Concentrations ranged from 3.0-93.4 mg/L with the highest concentrations found in Black Creek[134]. Results extrapolated from such limited data are generally unreliable. Given the sediment load pattern of the Welland River much higher loads from these tributaries are very possible.

Suspended sediment levels for the Niagara River are determined weekly at Fort Erie and Niagara-on-the-Lake by centrifugation over a 24 hour period. Average levels at Niagara-on-the-Lake are approximately 10 mg/L with a recorded maximum, over a ten year period (1979-88), of 53.7 mg/L.

Estimates of sediment loadings from the Niagara River and its tributaries to Lake Ontario can be made using average annual suspended sediment concentrations, as determined on a weekly basis by centrifugation, and flow data from the gauge at Niagara-on-the-Lake. This provides only an estimate of loading and will be underestimating the actual load, as peak suspended sediment concentrations and water flows coincide and the majority of the load occurs during peak events[135]. Estimated suspended sediment loads can be seen in Table 4.32.

A comparison of the suspended sediment and water flow values determined at Fort Erie with those from Niagara-on-the-Lake indicates the loads leaving the river at Niagara-on-the-Lake are slightly higher than those entering at Fort Erie. These results indicate that the majority of the suspended sediment in the Niagara River originates from Lake Erie. This is supported by the fact that suspended sediment concentrations at Niagara-on-the-Lake can be correlated with storm events on Lake Erie. Erosion and sedimentation on the Niagara River itself are primarily due to erosion at the gorge face, as the bottom of the river is predominantly bedrock. Deposition will occur in areas of increased channel capacity or decreased gradient; bends in the river and deep holes[136].

The estimate provided indicates that, even though the suspended sediment concentrations in the Welland River are much higher than those in the Niagara River, the impact of the Welland sediment load is minimal due to the large relative difference in the volumes of flow in the two rivers. However, the plume of water discharged from the Sir Adam Beck power generating stations is visible in the Niagara River, most likely as a result of this higher suspended sediment levels associated with the Welland River water that discharges through the power plant.

The suspended sediment load in the Niagara River represents the major portion of the sediment loading to Lake Ontario. Over 1.6 million tonnes of sediment are discharged annually with much of this load being deposited on the Niagara Bar at the mouth of the Niagara River. The fine gravels and sand deposited on the Canadian portion of the bar are mined for construction aggregate by a company holding a license for dredging operations.

The biological effects of the deposition and mining of the sand and gravel from the Niagara Bar are not fully understood. It may be assumed that the deposition will change the bottom topography. Resuspension during dredging in Denmark has been reported[137], with concentrations of up to 5,000 mg/L; however, such concentrations are likely associated with fine grained clays and silts. The course material in the Canadian portion of the Niagara Bar would not resuspend solids to the same level, nor would the materials contain significant amounts of adsorbed chemical contaminants. Currently, there is no evidence to suggest that organic chemicals are being resuspended into the water column as a result of the dredging activities on the Canadian portion of the Niagara Bar.

The most heavily contaminated areas of sediment involve the fine clays and silts which are carried out further from the mouth of the river and deposited in U.S. waters on the western portion of the Niagara Bar. Presumably, the levels of suspended solids reported in the Danish study might be achieved if dredging were to be carried out on such fine grain contaminated sediments. In such a case, the subsequent increase in the proportion of fine sediments could have further detrimental effects to Lake Ontario, both by increasing contaminant concentrations in the water column and by depositing a layer of highly contaminated fines over a larger area.

4.6 Aesthetics

The majestic setting of the Niagara River has made it a major attraction for millions of people, tourists and residents alike. However, for many people, the beauty of Niagara Falls is compromised by the presence of invisible toxic contaminants.

There are also a number of visible contaminants that detract from the aesthetics of the Niagara River; however, these are not necessarily associated with human activities and are also not necessarily associated with toxic contaminants. In the spring period, snowmelt and erosion carry soils into the surface waters throughout the Great Lakes Basin. Many of the larger soil particle settle out in river mouths and lake basins. Many of the very fine particles, especially the clays of the Lake Erie basin, remain in the water column and are delivered to the Niagara River. These soils cause the Niagara River to take on a light tan colour, during the spring period. Many viewers associate this discolouration with chemical pollution but there is no indication that this association occurs. Contaminant levels measured at Niagara-on-the-Lake show no significant increase during this period.

In late summer, algae blooms and dies in Lake Erie causing discolouration of the Niagara River similar to the spring sediment discolouration. This problem has been reduced significantly over the past two decades with the pollution control measures that have been implemented in the Lake Erie basin; however, a stronger than normal algal bloom in Lake Erie during the late summer and early fall of 1991 and subsequent die-off has been associated with taste problems in municipal water supplies in the Niagara River.

Excessive growth of aquatic macrophytes or plants has created aesthetic problems in many inland lakes and rivers. Although concerns over this problem may be valid for tributaries in localized portions of the watershed, this is not a major concern in the Niagara River in that due to its fast-flowing, turbulent nature, it is not affected by abundant weed growth.

Aesthetics concerns have also included air quality in the Maid-of-the-Mist Pool and the associated quality of the mist at the brink of the Horseshoe Falls. Reports[159,160] on air quality investigations have failed to provide evidence of mist related contamination that could be a problem.

One of the most recognized aesthetic concerns in the Niagara River is the year-round appearance of a brown foam or "scum" in the Maid-of-the-Mist Pool. Investigations have shown that, although this foam affects the aesthetics of the immediate Niagara Falls area, it is caused by the plunging of the water at the Horseshoe Falls and comprises mainly decayed vegetation and the tan-coloured clay particles mentioned above. The foam rapidly dissipates downstream from the falls.

4.6.1 Aquatic Vegetation

Aquatic plants form an important component of the environment in a lake or river by providing shelter and feeding areas for many fish and wildlife species. Some researchers have reported[200] at least 603 species of aquatic animals feeding on aquatic plants. Some species of fish, such as yellow perch and muskellunge, spawn in shallow vegetated areas of lakes and streams. Many species of birds and mammals utilize vegetated areas.

Excessive growths of aquatic plants can have detrimental effects on biological diversity and production and on aesthetic and recreational values. The most productive wetlands are those which have generous interspersions of open-water areas that are interconnected by channels. These channels serve as travel corridors for fish and other aquatic animals. Water currents through these channels serve to keep the wetland fresh and clean. Infilling of wetlands by cattail or other dominant species reduces the biological diversity and limits productivity and the number of animal species utilizing the wetland. Excessive submergent aquatic growth in otherwise open-water areas interferes with fishing and pleasure boating. Perhaps more importantly, during the winter, decomposition of these plants can deplete the oxygen content of the water under the ice causing high winter mortality of fish and other organisms that are dependent on dissolved oxygen.

4.6.1.1 Niagara River

Very little research work has been done on the Niagara River aquatic plant community. Excessive weed growth to the point where it would be considered a nuisance, is not common on this waterway. Examination of 1989 aerial photographs of the river indicated limited areas along the shore and around islands as potentially suitable for vascular plant growth. In the Ontario waters of the Niagara River there are perhaps fifty to fifty-five hectares available in areas protected from the severe current and shallow enough for plant growth. Much of this area may, however, be bedrock suitable only for filamentous algae.

Aquatic vegetation is generally associated with wetlands, few of which exist on the Niagara River. Navy Island has a wetland area of 25.8 hectares, of which 69 percent are marshes bordering the river at the northern and southern tips. The remaining 31 percent is swamp to the upland side of the northern marsh, running back into the interior of the island.

The Navy Island marsh species in order of dominance, include grass species, sedge, cattail species, purple loosestrife, water milfoil, coontail, and pondweed.

4.6.1.2 Welland River

The Chippawa Creek portion of the Welland River drainage basin is slightly more hospitable to the production of aquatic macrophytes than the Niagara River proper, with some growth occurring along its banks and in backwater areas. The Welland River itself, west of the Power Canal is a slow-moving waterbody. This low velocity, combined with an area of deep sediments provides a habitat that is much more amenable to plant growth. There is a well-established plant community along both banks of the Welland River, even through the urban area of Welland. Suspended solids concentrations in the Welland River tend to restrict light penetration and consequently the growth of weeds in mid-channel; however, zebra mussels have recently entered the lower Welland via the diversions at the Welland Canals and it has not yet been determined whether these organisms will have an effect on light penetration and macrophyte growth.

The total wetland area along the Welland River (excluding that on tributaries) is 206.6 hectares. Of this, 191.6 hectares is marsh and only 15 hectares is swamp. Swamp areas are mainly restricted to the upper reaches of the river with 13.6 of the 15 hectares found between Attercliffe and Binbrook.

Plant species diversity of both the marshes and swamps increases along the Welland River from mouth to source, as the river depths become more suitable for plant growth. Between the Niagara River and the old Welland Canal in Welland, 19 plant species contribute significantly to the marsh communities in either a dominant or sub-dominant role. Other species are not present in significant numbers. Between the old Welland Canal and Attercliffe the number of significant marsh species increased to 22; from Attercliffe to Binbrook the number increased to 40. Table 4.33 lists the marsh and swamp plant species in order of dominance.

Although the physiography of the Welland River west from the power canal lends itself to macrophyte growth, that growth appears to be abundant but not excessive. This may be due, in part, to reduced water clarity in the lower portions, which reduces the productive zone in the river.

TABLE 4.33

Estimated Order of Dominance of Plant Species in the Wetlands of the Welland River Basin

I. Marshes (191.6 Ha.)

#	Species	#	Species	#	Species
1	Cattail	18	Purple Loosestrife	35	Water Starwort
2	Arrowhead	19	Sw. Rose	36	Wild Grape
3	Grass sp.	20	White Elm	37	Ferns
4	Burreed	21	Buttonbush	38	Nightshade
5	Coontail	22	Water Milfoil	39	Black Walnut
6	Willow (low)	23	Arrow Arum	40	C. Scullcap
7	Yellow Waterlily	24	Blue Flag	41	Sw. Cinquefoil
8	White Waterlily	25	Jewelweed	42	Wild Celery
9	Sedge	26	White Ash	43	Bindweed
10	Bulrush	27	Willow (tree)	44	Black Ash
11	Dogwood	28	Giant Reedgrass	45	Hawthorn
12	Sw. Milkweed	29	Manitoba Maple	46	Highbush Blueberry
13	Spatterdock	30	Sw. White Oak	47	Red Ash
14	Willow (tall)	31	Winterberry	48	Red Maple
15	Pickerelweed	32	Red Oak	49	Shagbark Hickory
16	Potomogeton	33	Horsetail		
17	Smartweed	34	Nettle		

II. Swamp (15.0 Ha.)

#	Species	#	Species	#	Species
1	Willow (low)	11	Dogwood	21	Southern Arrowwood
2	Willow (tree)	12	Red Maple	22	Sw. Rose
3	Willow (tall)	13	White Ash	23	Burreed
4	Grass sp.	14	Beggar's Tick	24	Red Elderberry
5	Buttonbush	15	Cattail	25	Red Elm
6	Black Ash	16	Jewelweed	26	Arrowhead
7	Winterberry	17	Ferns	27	Sw. Milkweed
8	Sedge	18	White Elm	28	Manitoba Maple
9	Highbush Blueberry	19	Coontail	29	Nettle
10	Sw. White Oak	20	Shagbark Hickory	30	Nightshade

NOTE:

This is not a comprehensive listing of all plant species within the wetlands but is a listing of the dominant and more frequent subdominant plant species.

4.6.2 Algal Growth

Documentation of algal growth in the Niagara River appears to be very limited. Virtually all of the information available is qualitative in nature, as no formal algal population studies have been done for the river itself. Literature on the eastern basin of Lake Erie and the western section of Lake Ontario is more extensive, and some of that information is presented in an attempt to draw inferences to conditions in the Niagara River.

4.6.2.1 Eutrophication

Eutrophication is defined as the process of fertilization that causes high productivity and biomass in an aquatic ecosystem[141]. Eutrophication can be a natural process or it can be a cultural process accelerated by increased nutrient loadings from human activity. Advanced or accelerated eutrophication is characterized by an increasing abundance of algae and other aquatic plants to nuisance levels, increased turbidity and chlorophyll levels, oxygen depletion of waters at depth and undesirable shifts in fish community structure and total production[141]. The variables that determine the biological productivity of a body of water are: substrate, temperature, light, depth, volume and the amount of nutrients received from the environment.

Lake Erie was the first of the Great Lakes to demonstrate a serious eutrophication problem because it is the shallowest, warmest and most naturally productive[141]. As of 1987, Lake Erie also received more effluent from sewage treatment plants than any of the other Great Lakes, since about one-third of the total Great Lakes population lived within the drainage area of this lake[141]. In the 1950's, massive algal blooms, increased turbidity, and depletion of oxygen (indicative of eutrophication) began to occur as a result of unabated loadings of nutrients. Cladophora, a filamentous blue-green algae which thrives under eutrophic conditions, became the dominant nearshore algae and covered beaches in green slimy masses[141]. Government actions in the 1970's resulted in major reductions of nutrient discharges to the Great Lakes. The results were visible, most notably in Lake Erie. Nuisance conditions occurred less frequently, dissolved oxygen levels improved and algal mats disappeared as nutrient levels declined.

The following represent evidence of improvements in water quality problems associated with eutrophication in Lakes Erie and Ontario[142]:

- reductions in blue-green algal biomass in Lake Erie between the mid-1960's and late 1970's;
- reductions in total phytoplankton biomass and a shift in phytoplankton composition toward more oligotrophic species in Lake Erie between 1970 and 1980;
- reductions in the amount of algae washed up on bathing beaches on Lake Erie between the mid-1960's and late 1970's;
- a decreasing chlorophyll trend in the eastern basin of Lake Erie between 1968 and 1980; and
- a shift in the Lake Ontario phytoplankton community structure and composition toward more species indicative of meso- and oligotrophic conditions between the late 1960's and late 1970's.

Although evidence exists to support the claim that the trophic status of all the Great Lakes is improving toward more oligotrophic characteristics, no research is available to confirm if this is also the case in the Niagara River. Only inferences can be made based on other factors.

Traditionally, measurements of phosphorous and chlorophyll a have been analyzed over time to determine the trend in the trophic status of the Great Lakes. If levels of either of these decreased, then the algae population correspondingly decreased and the trophic status of the lake improved. This situation was observed in all of the Great Lakes during the 1970's.

The most comprehensive data which may shed light on the trophic status of the Niagara River is also phosphorous level trends[143]. A study by Environment Canada[144] in the mid-1970's indicated that phosphate levels increased with passage though the Niagara River (indicating the presence of active input sources). A mean level of 16 ug/L (total phosphorus as P) at the eastern end of Lake Erie was found, whereas the water leaving the Niagara River averaged 20 ug/L phosphorous[144]. However, these levels, as well as levels in Twelve Mile Creek, the Welland Canal, and the Chippawa Power Canal were all better than the phosphorous objective level of 20 ug/L (0.020 ppm) during 1976 to 1978. Trend analysis[145] indicates that year to year concentrations of phosphorous in the Niagara River decreased significantly overall, at the rate of approximately 1 ug/L per year over the period 1967 to 1981. This resulted in associated loading decreases from about 8,100 tonnes in 1968 to 3,400 tonnes in 1981[145].

This, then, would tend to indicate that the Niagara River, like the Great Lakes during this time period, enjoyed a period of trophic improvement. Caution must be exercised with this conclusion though; more recent studies indicate that phosphorous is only the algal growth determinant for low-level concentrations, and at higher concentrations of phosphorous, growth is not most affected by this nutrient.

Nitrate and nitrite concentrations, in contrast, exhibited a significant increase over the same time period, increasing at the rate of approximately 13 ug/L per annum[145]. Reasons for this are speculative; however, the increases appear to be a consistent observation for all the Great Lakes (except Lake Michigan). The Great Lakes Water Quality Board (GLWQB) highlighted its concern about this trend in its 1985 report[145].

In the Niagara Peninsula, only the Welland River experienced levels that exceeded objectives for phosphorus and nitrates. The surface waters of Lake Ontario contained about one-third more of phosphorus and nitrates than the waters of Eastern Lake Erie[144].

Some data and trend information on algal populations exist in Lakes Erie and Ontario that might indicate trends in the Niagara River.

Chrysophycean algae are common to some Great Lakes locations and frequently dominate the algal populations in the late spring and early fall. Increases in this group as a percentage of the total biomass have been shown to reflect decreases in phosphorous concentrations[146]. With high biomass levels of diatoms in the spring, silica concentrations can become a limiting factor, thus leaving room for more eutrophic green and blue-green forms to develop later in the season[146]. Diatom populations can be lost from the water quite rapidly by sedimentation but some of the blue-greens are transported great distances[146]. For this reason, populations of green and blue-green algae are more noticeable in late summer and early fall when silica levels are at a minimum.

The community structure in Lake Erie on an annual basis appears to be changing to one with lower relative importance of diatoms and Chryptophyceae (because of their absolute declines) to one with greens and blue-greens as more obvious components. Trends in Lake Ontario appear to follow this shift also[147].

One criterion that is agreed upon by various scientists to determine the trophic status of a body of water utilizes open water concentrations of chlorophyll a to assess the degree of algal growth in a body of water[148]. This method may be useful if extensive sampling for chlorophyll a is ever conducted on the Niagara River. Once again, the numerical values are not universally agreed upon, and in that sense are arbitrary.

eutrophic waters : chlorophyll a > 8.8 ug/L

mesotrophic waters : chlorophyll a 4.4-8.8 ug/L

oligotrophic waters : chlorophyll a < 4.4 ug/L

Some information is available regarding chlorophyll a levels in Lakes Erie and Ontario. Although trends from the data sources are not altogether clear, the offshore waters (depth > 50 m) of both Lake Ontario and the eastern basin of Lake Erie were considered mesotrophic in 1981, according to the above criteria[147]. A linear regression on the chlorophyll a concentrations in nearshore Lake Ontario from Ajax to Niagara-on-the-Lake indicates that there is virtually no change in levels for 1967-1979, and the concentration is roughly 4-4.5 ug/L; indicating no eutrophic problems[148]. One source[149] argues that the large range of values for chlorophyll a profiles and large spatial variability imply that year-to-year changes and long-term trends of the phytoplankton abundance in Lake Ontario are difficult to discern.

In Lake Erie, chlorophyll a levels in the eastern basin have shown only a slight decline from 1971 to 1978[150]. The eastern basin of Lake Erie indicates a bimodal seasonal change in chlorophyll concentration, with the highest concentrations occurring during the spring and in the early fall; the lowest concentrations are in the summer[42]. Levels seem to be contained in the 3 to 6 ug/L range. Seasonally normalized yearly average data from 1968, 1970, 1972 and 1980 (5.37, 5.23, 3.67 and 2.85 ug/L respectively) were regressed to yield a highly significant ($p<0.01$) decrease in chlorophyll a in the eastern basin[42].

The following equation (normalized for seasonal and spatial effects) is thought to relate the concentration of chlorophyll a to that of phosphorous:

$$[\text{chl } a]\ (\text{ug/L}) = 1.6 + 0.206\ [\text{total phosphorous}]\ (\text{ug/L})$$

If this is the case, then the past and present phosphorous levels imply a mesotrophic status in the Niagara River.

4.6.2.2 The Niagara River System

There is a lack of research for the Niagara River proper on lower trophic levels such as phytoplankton, particularly nannoplankton, which are quite abundant in the Great Lakes system[151].

A map apparently derived from a 1978 International Joint Commission publication indicates that the upper Niagara River is considered eutrophic, and the lower Niagara is meso/eutrophic[141]. However, this representation must be considered qualitative at best. No source reference is available for the map, and the river itself may just have been extrapolated inwards from the nearshore conditions of Lakes Erie and Ontario.

On the other hand, in 1980, the Water Quality Board of the IJC, in its analysis of areas of concern, identified the Niagara River as a Class A Area of Concern, but only with respect to contamination of the water, sediments and/or biota by organic and/or inorganic substances (excluding phosphorous). It was not seen as having eutrophication/phosphorous enrichment problems[152].

A 1985 IJC assessment supports this claim. In addressing areas of concern, problems and sources for the Great Lakes Basin, the IJC indicated that the Niagara River suffered from problems with conventional pollution, heavy metals and toxic organics, contaminated sediments, biological impacts and required fish advisories, but not from eutrophication[141]. All of these assessments were based only upon qualitative results so their value is limited.

One study on phytoplankton[151] compared biomass and taxonomic composition by algae group for test assemblages taken from the mouth of the Niagara River and mid-Lake Ontario in 1983. The phytoplankton biomass at the mouth of the Niagara River was 0.73 g/m^3 as opposed to 0.83 g/m^3 in Lake Ontario.

Diatoms (32%), green algae (29%), and Chrysomonads (19%) were the dominant groups at the mouth of the Niagara. As far as size is concerned, the 5-20 um fraction (19 species) was the dominant size and was a mixed assemblage of green algae, diatoms, cryptomonads and dinoflagellates. Cyclotella glomerata (Bachm.) (24%), Chrysochromulina parva (Lackey) (16%) and Gymnodinium varians (Maskell) (4%) were the dominant species in this size[151].

The u-algae (<5 um) consisted of only six species belonging to blue-green algae, green algae, chrysomonads, and diatoms, although the green alga Chlorella vulgaris (Beyer) was virtually the exclusive contributor.

The remaining size fraction (>20 um) consisted of 14 species belonging to blue-green algae, green algae, diatoms, cryptomonads and dinoflagellates. Oscillatoria limnetica (Lemm.) (4%), Gymnodinium sp (3%) and Cryptomonas erosa (Ehr.) (3%) were most common[151].

When compared to the mid-Lake Ontario bioassays, the following was found. In the u-algae size, there were also 6 species, although one species differed. Again Chlorella vulgaris (Beyer) dominated the class on a percentage basis, but was 4.5% less abundant overall. The 5-20 um class contained 21 species, and was dominated by Gymnodinium varians (Maskell) with 10%, Chrysochromulina parva (Lackey) (9%), and Cyclotella glomerata (Bachm.) (6%). The differences between sites may be the most significant in this size class. In the largest size class, 18 species were found, with Melosira granulata (Ehr.) Ralfs the most abundant (9%), followed by Oscillatoria limnetica (Lemm.) (3%), and Cryptomonas erosa (Ehr.) (3%)[151].

Overall, the diversity of species is reasonably consistent between the two locations and the only differences lies in which species are most predominant. Table 4.34 summarizes the taxonomy and size distribution results from the two stations at which sampling occurred.

4.6.2.3 Niagara Tributaries

Scant information exists for the Welland River and Lyons Creek. The samples, from which some of the information is derived, were collected in 1964.

The upper Welland River was characterized by an abundance of emergent aquatic plants, and a limited development of submergent aquatic vegetation. The filamentous algae, Cladaphora, was common in an isolated area directly downstream of the Cyanamid plant[153]. Filamentous algae were observed growing throughout the pondweeds and beyond them to a depth of about six feet.

Thirty-one genera of planktonic algae were observed in samples collected in July of 1964. Green algae predominated with 18 genera, while blue-green and diatoms were represented by four and six genera respectively[153]. Populations of planktonic algae were low throughout the Welland River except below Cyanamid's Welland plant, where a large number of genera made up a very dense population. A reduction in the number of genera and standing crop of algae was evident between Welland and the Cyanamid plant. All of the common genera taken below Welland were known to be tolerant to pollution[153]. Several genera, possibly intolerant to pollution, that were noticeable above Welland were absent below the city. At Port Robinson, a greater variety of algae indicated some improvement. A total of 24 genera of algae was established for samples taken below the Cyanamid plant[154]. Several forms not noted for tolerance to pollution were abundant. Apparently, the levels of ammonia did not impede the development of a varied and abundant population, and in fact, together with the levels of phosphorous, appeared to have promoted algae growth[153].

In Lyons Creek, high phosphorous levels were noted throughout the survey. A moderate amount of submerged vegetation was present at one sampling station in association with the algae[153].

TABLE 4.34

Algal Taxonomy and Size Distribution in the Niagara River and Lake Ontario

		Site Units	Niagara River	Lake Ontario (mid-lake)
	Biomass	g/m*3	0.73	0.83
Species Composition				
Cyanophyta		%	5.2	5.3
Chlorophyta		%	28.8	31.4
Chrysophyceae		%	18.6	10.7
Diatomeae		%	31.8	29.0
Cryptophyceae		%	8.0	9.2
Dinophyceae		%	7.7	14.5
Size Distribution	<5um	%	22.7	20
	<20um	%	60.7	55
	>20um	%	16.6	25

In more recent studies of the Welland River done in 1978 and 1980[87], a more detailed account of the algal growths was documented.

Severe reductions of periphyton diversity were found immediately below the Cyanamid outfalls with distinct recovery zones in the downstream part. Normal periphyton density and diversity occurred at sites approximately 1.6 km below the outfall[87].

The nature of the attached algal communities at each of the eight stations differed. Species diversity dropped in the primary recovery zones and improved with distance downstream. However, the overall algal biomass was greatest in the primary recovery zones (closest to discharge source). This is a result of the abundance of the filamentous blue-greens[87], which commonly thrive in polluted waters.

Species composition and relative abundances of the various groups and species of algae also varied between stations. In primary recovery zones, the algal community was dominated (in terms of numbers of individuals) by the blue-greens, particularly Oscillatoria and Lyngbya. Phormidium, however, was less abundant in these zones than in others. Green algae, especially Oedogonium, became increasingly more abundant (in terms of both number of individuals and species) in the secondary and tertiary recovery zones[87]. This may be expected since filamentous blue-greens are least sensitive to pollution, while filamentous greens appear most sensitive. Blue-greens were, however, the most abundant class in all zones[87]. No trend in diatom abundance with respect to distance from discharge could be determined.

The periphyton community showed alteration in response to waste discharges. Species richness and diversity were lowest immediately downstream of the discharges and increased with distance downstream. Species composition also showed variation corresponding to waste discharges. Blue-green algae were the dominant forms at all stations, especially at those nearest waste discharges[87]. Filamentous green algae displayed the opposite trend, becoming more common with distance downstream below discharges. Diatoms displayed no common trend in response to waste discharges. Replacement of Nitzschia dissipata by Nitzschia palea occurred immediately downstream of Thompson's Creek, but not at the other discharge site[87].

Sampling at the Binbrook Reservoir by the Niagara Peninsula Conservation Authority (NPCA) during 1988 supports the contention that algal blooms are localized and seasonal in nature. Blue-green blooms are typically most prevalent in September/October. A variety of algae species exist in this reservoir, and there are definite spatial variations. Blue-greens appear to be the most dominant type of algae in this reservoir, and depending on location, Oscillatoria, Nitzschia, Coelosphaerium, or Spirogyra are the dominant species. Cyanophyceae, Dinophyceae, Chrysophyceae, Chlorophyceae, and Bacillariophyceae are all represented.

In summary, the phosphorous control efforts appear to have arrested the water quality degradation which had created eutrophication problems in the Great Lakes earlier this century, but have not yet achieved the desired water quality conditions described in the 1978 Agreement. Nuisance algal blooms and associated turbidity appear under control and only occur in isolated instances and areas.

Insofar as algal blooms are concerned in the Niagara River Area of Concern, their incidence seems to have decreased, as it has in other Great Lakes regions, and their occurrence is localized and follows seasonal trends. There is no evidence to suggest that algal blooms occur as a result of human intervention on any large scale or frequent basis.

4.6.3 Foam

The cascade of water over the Horseshoe Falls, an average of about 1,200 to 2,500 tonnes per second, hits the pool below at a speed of about 10 metres per second over a crest length of some 760 metres. The impact of this water results in the creation of foam in the Maid-of-the-Mist Pool. This foam is natural in origin and composed primarily of plant decay products such as lignins, tannins and lipids. It is created by intense and continuous gas (air) injection as the water plunges into the pool of water below the falls. The air injected into the water provides a bubble surface attracting dissolved and particulate materials which are adsorbed onto a bubble's surface and concentrate as the bubble rises. This aeration is often cited as a mechanism for concentration (bubble scavenging) of organic and inorganic substances in the water column. Normally acceptable levels of both organic and inorganic compounds may be concentrated by this process into material with significantly higher levels of contaminants.

Upon surfacing, materials are incorporated into surface films and foams on natural waters. These films and foams themselves are especially subject to concentration of materials transported by air bubbles to the surface and are regions in which organisms can experience accelerated rates of accumulation of surface-active toxic materials[48]. This increase in exposure of organisms to elevated levels of toxins at the interface is of particular concern because the surface microlayer on natural waters is an especially rich biological microcosm[115] (Table 4.35).

These rising bubbles, as a dispersed gas phase, also provide an enhanced rate of gas transfer for those substances affected by differences in partial pressures in the atmosphere and near-surface waters. This transfer of substances via the gas phase is important in increasing the oxygen concentration in the water and in stripping volatile compounds from the water phase.

TABLE 4.35

Percent of filter area occluded by particles and concentrations of particle-associated bacteria bulk water samples taken above and below Niagara Falls.

Location	Filter	Area of Filter Occluded by Particles	Concentration of Bacteria
Above Falls (bulk water)	2 um (Nuclepore)	16 %	3.7x14E4/mL
Below Canadian Falls (bulk water)	2 um (Nuclepore)	74 %	7.4x14E4/mL

Most of the foam is short-lived in the Maid-of-the-Mist Pool, dispersing in the pool or being dissolved by the river's action in the Whirlpool Rapids. This dissolution, as well as the breaking of bubbles when they originally surface, can aggregate the adsorbed materials (surface coagulation). This process can convert dissolved and colloidal material into particulate form. This material can contain highly concentrated materials such as surface active toxins. This activity can increase the sedimentation rate of these particular materials and make them more readily available for ingestion by organisms[69].

The process of fractionation of chemicals by bubble injection caused by the falls at Niagara was studied in 1985 by a group of researchers from Dalhousie University[155]. On July 23 and 24 of 1985, samples of water were collected from locations above and below the falls along with foam samples from the Maid-of-the-Mist Pool. This study was undertaken to determine the types of substances that might be involved in these surface-active adsorption processes. The most significant result of bubble injection below Niagara Falls was determined to be the very high enrichment of particulate materials in the foam[155]. This is believed to be caused by the physical "scouring" of larger colloidal and particulate materials as the bubbles rise through the water column. This collection of particulates, particularly fine suspended clay particles, produces a light tan colouration to the foam.

In addition to particulate matter, concentrations of copper, cadmium, zinc and classes of lipids were measured in the water and the foam. No assessment was made of priority pollutant chemicals with the exception of the three trace metals.

The concentrations of the substances measured in bulk water changed typically by less than a factor of 2. In fact, for the three trace metals, copper concentrations showed little change and zinc concentrations could not be measured, while cadmium concentrations increased by about 1.5 (Table 4.36). However, as can be expected from this natural phenomenon, the foam showed much higher concentration of surface-active substances. Trace metal concentrations in the foam were concentrated by a factor of 289 for copper, 19 for cadmium and 78 for zinc.

Lipid class concentrations showed significant change after passage over the falls (Table 4.37). The concentration in water of some classes (hydrocarbons and ketone) decreased while others (triglycerides and phospholipids) showed an increase. All lipids are or may be natural in origin, related to zooplankton, chlorophyll and cell membrane components. Concentrations of lipids in the foam were highly enriched from 15 to 370 times those concentrations in the bulk water; however, the ratios of lipid classes were much different than those in water. Major foam contributors were

TABLE 4.36

Trace metal concentrations for bulk water (30 cm) from above and below the falls and for foam below the falls. Results for below refer to the Canadian (Horseshoe) Falls unless otherwise stipulated.

Location	Sample Type	Sample Fraction	Concentration (ng/ml)		
			Cu	Cd	Zn
above falls	b	d(0.4 um)	0.95	0	-
	b	p(12 um)	0.05	0	0.59
below falls	b	d(0.4 um)	0.85	0	5.1
	b	p(12 um)	0.102	0	0.91
	b	p(2 um)	0.119	0	1.4
	f	d(0.4 um)	130	6	242
	f	t	280	9	510
below American Falls	f	t	123	5	189

b=bulk water, f=foam, t=total, d=dissolved, p=particulate.
Filter pore size is in parenthesis.

monoglycerides, pigments and glycolipids, all derived from natural materials such as chlorophyll and algal blooms.

Foam samples from below the American Falls showed slightly less trace metals and similar concentrations of lipids to the foam from the Horseshoe Falls. Differences in concentrations below the two falls is attributable to the differences in physical processes at the two falls. The water over the Horseshoe falls is much greater in volume and plunges directly into the Maid-of-the-Mist Pool. The water over the American Falls (and satellite Bridal Veil Falls) is much smaller in volume and impacts on extensive rock talus beneath the falls before running off into the Maid-of-the-Mist Pool. The potential for bubble scavenging is far less from the American Falls as the depth of gas injection is less. No assessment was made of concentration of organic contaminants of man-made origin.

While the presence of foam below the falls is the most apparent result of bubble injection, this foam collapses downstream and near-surface enrichments are erased in turbulent mixing[156]. Thus, any contaminants collected by the foam are either re-released to the water column or volatilize to the atmosphere. Little of the foam remains after passing through the Whirlpool and Devil's Hole Rapids, although the action of these rapids may, in themselves, promote some surface active scavenging.

TABLE 4.37 (a)

Lipid classes in bulk water above and below the falls and from foam samples below the falls. Results from below refer to Canadian falls unless otherwise stipulated.
b=bulk water, f=foam, t=total, d=dissolved, p=particulate.
All filtrations refer to GFC filters.

Location	Sample Type	Sample Fraction	Class (ug/L)										
			HC	WE	ME	KET	TG	FFA	ALC	ST	DG	AMPL	PL
above falls	b	p	20	1.3	1.4	4	9.6	1.9	3.2	1.2	1.9	9.2	10
	b	d	50	6.3	-	5.3	43	40	-	15	14	21	1.8
below falls	b	p	21	0.9	0.7	0.5	4.4	3.8	-	1.1	0.9	9.1	7.2
	b	d	39	4.3	-	<2	83	66	-	4.5	-	34	8.7
	f	t	1400	97	130	66	1500	1100	220	2100	-	4200	960
below America Falls	f	t	1570	100	-	320	1150	1500	450	2580	-	4800	500

HC - Hydrocarbons	TG - Triglycerides	DG - Diglycerides
WE - Wax esters	FFA - Free fatty acids	AMPL - Acetone mobile polar lipids
ME - Methyl esters	ALC - Alcohols	
KET - Ketones	ST - Sterols	PL - Phospholipids

4.6.4 Climate

The southerly location of the Niagara region within the Province of Ontario causes the climate to be more temperate than that in other areas. This area has a mean annual growing season of 215 days and a frost-free period of 165 days. Normal daily temperatures range from -3°C to 20°C; annual average temperature is 8°C. Total annual precipitation in the Niagara Peninsula frequently exceeds 900 mm. The amount of snowfall varies across the peninsula, with lower snowfall in the northern portion and higher snowfall in the southern portion (caused by the presence of Lake Erie). The proximity of both Lake Ontario and Lake Erie tends to create sudden snowsquall activity throughout the peninsula and atmospheric condensation on the colder landmass is a frequent occurrence. Due to the southern location of the Niagara Peninsula, there is not a great deal of snowfall accumulation; snowmelt occurs throughout the winter period and provides a dampening of the traditional spring breakup and runoff in area creeks and streams.

Prevailing wind direction measured at Niagara Falls Ont., is from the southwest (more than of the time). Dominant wind direction is either from the southwest or from the west for each month of the year. Wind speed at Niagara Falls averages 15.4 km/hr annually and is about 4 km/hr weaker than corresponding winds measured at Buffalo.

TABLE 4.37 (b)

Lipid classes in bulk water above and below the falls and from foam samples below the falls. b=bulk water.. f=foam.. t=total.. d=dissolved.. p=particulate.
All filtrations refer to GFC filters.

	Sampling Location					
	above Niagara Falls		**below Horseshoe Falls**		**below American Falls**	
Sample Type	b	b	b	b	f	f
Sample Fraction	p	d	p	d	t	t
Class	**Concentration (ug/l)**					
Hydrocarbons	20	50	21	39	1400	1570
Wax esters	1.3	6.3	0.9	4.3	97	100
Methyl esters	1.4	-	0.7	-	130	-
Ketones	4	5.3	0.5	<2	66	320
Triglycerides	9.6	43	4.4	83	1500	1150
Free fatty acids	1.9	40	3.8	66	1100	1500
Alcohols	3.2	-	-	-	220	450
Sterols	1.2	15	1.1	4.5	2100	2580
Diglycerides	1.9	14	0.9	-	-	-
Acetone mobile polar lipids	9.2	21	9.1	34	4200	4800
Phospholipids	10	1.8	7.2	8.7	960	500

The prevailing wind directions would indicate that the area is not generally affected by airborne contaminants from urban centres to the northwest (Hamilton or St. Catharines), to the north (Toronto) or to the southeast (Buffalo). Airborne pollution originating in the industrial corridor of Niagara Falls (New York), North Tonawanda and Tonawanda is unlikely to be deposited on the Niagara River (Ont.) Area of Concern, although deposition in drainage basins on the New York side of the river may introduce these contaminants into the Niagara River waters.

4.6.4.1 Microclimates

The climate of a region is the general long-term weather condition that exists in that region and is based on the number of months the mean temperature is above a certain threshold value and the amount and distribution of the precipitation in that region. Within each climate category there are local conditions that vary from the regional climate by a variance in the temperature regime or a difference in the amount of precipitation. These variations from the regional climate are termed microclimates.

There are eight general climatic parameters that may vary depending on the local conditions in a region. It is the measurement of these parameters that defines the conditions of the microclimate.

The eight parameters that are used are:

radiation	sunshine
light	temperature
humidity	evaporation
air flow	precipitation

Each parameter's effect on the microclimate is determined by the physical conditions of the region.

Radiation energy is affected by the angle at which it strikes a surface and the relative facing of the surface to the radiation source. In the northern hemisphere, a south facing slope will receive more radiation energy then a north facing slope. Also a steeper slope will receive less radiation then a shallower slope. In addition the amount of shading caused by surrounding objects will affect radiative pattern of an area.

Sunshine, and light are dependent on the same basic factors as radiation. Thus the factors encompassing the degree of slope, aspect and the amount of shading of surrounding objects affect them the same way they affect radiation.

Temperature is closely related to radiative energy. It differs from sunshine and light in that with the movement of a different air mass into a region a change in temperature can occur with little change in radiative load.

The humidity of the region is influenced by the amount of water available. Vegetation, water surfaces and the ground (if water is within the top few centimetres of the soil) are all sources of water vapour. Therefore, it is to be expected that the humidity will be higher in regions with heavy vegetation and large bodies of open water.

Evaporation of water has the effect of cooling the air. Areas with dense vegetation or around water surfaces are cooler but with a higher relative humidity. The creation of a higher humidity will only occur if the local air flow is low.

The physical landforms of a region have a great effect on the air flow and precipitation. A hill can cause precipitation to occur on the windward side rather than the leeward side. Hills can also act as barriers with the ability to direct air flow. Some regions will have an increased air flow, while other areas will have a reduced air flow.

In addition to individual effects, all of these parameters interact with one another. It is the interactive effects that also determine the conditions of the microclimate.

4.6.4.1.1 Niagara Microclimates

There are a number of localities within the Niagara area which exhibit microclimates. Each is governed by a varied set of climatic parameters as identified above. Many of these have to do with local effects of the adjacent water bodies, enhanced by topographical features.

Two of the most significant microclimates within the Area of Concern border the area to the north and to the south. Only small portions of each microclimate are found within the Niagara river (Ont) Area of Concern.

The first locality is the far eastern end of Lake Erie. This area experiences severe winter conditions throughout the winter months. This is referred to locally as the "Buffalo Effect" and extends across the head of the Niagara River to the Fort Erie - Port Colborne area of Ontario. Strong westerly winds covering the length of Lake Erie and temperature and humidity effects of the lake combine to produce colder conditions and heavier snowfalls in this area than in the rest of the Niagara Peninsula.

The second locality is the area to the north of the Niagara Escarpment, a small band of which exists in the Area of Concern immediately to the west of the Niagara River. This area experiences much milder winters and springs than the majority of the area due to the blocking effect of the Niagara Escarpment and the influence of the waters of adjacent Lake Ontario. In the summertime, climate is strongly influenced by Lake Ontario and the prevailing wind direction.

Another zone that exhibits a microclimate is the Niagara Gorge. Parameters causing variations from the regional climate are the topography of the depression and the waters of the Niagara River. The turbulent action of the falls and the rapids significantly increases the humidity, particularly in the vicinity of the Horseshoe Falls. In addition, the vertical walls of the gorge combined with its narrowness limit the penetration of light and heat to the bottom of the gorge, while at the same time blocking the influence of most winds.

4.6.5 Air Quality

The Ontario Ministry of the Environment has established air quality guidelines on a one hour, 24-hour and annual basis as part of its Air Management Program to control man-made emissions so that they comply with ambient air quality standards. Sources of pollution are identified, their emissions evaluated, and appropriate control measures are instituted so that these objectives may be met.

It has been demonstrated that the combination of sulphur dioxide and particulate matter at high concentrations results in adverse health effects. Starting in 1970, the Air Pollution Index or API became one of the prime measures of air quality in the Province of Ontario. This index was derived from twenty-four hour running average concentrations of both sulphur dioxide and particulate matter. These were measured at single monitoring stations and the API was used as a warning system to alert the public to elevated air pollution levels. When the API value exceeded 50, industries were required to reduce their air emissions.

The formula for the calculation of API is site specific. For each monitoring locale, the coefficients vary depending on the nature and opacity of the airborne contamination.

API values and their associated significances are tabulated below:

Value	Significance
< 32	acceptable level
32	known as the advisory level if continued unfavourable conditions are forecast, significant industrial sources may be asked to voluntarily curtail operations
50	major emitters would be ordered by law to curtail some operations
75	further cutbacks would be required
100	all sources not essential to the public health and safety could be ordered to cease operations

The general air monitoring program throughout the Province measures the following contaminants:

A) Gases measured with continuous analyzers which include:

i) Sulphur Dioxide (SO_2)

It is mostly monitored near industrial sources but SO_2 is also a product of domestic space heating. Sulphur Dioxide combines with water to form acidic compounds that can cause eye and lung irritation, corrode metal and damage vegetation.

ii) Total Reduced Sulphur (TRS)

TRS is monitored only near industrial sources. Measurement of TRS includes hydrogen sulphide (H_2S), as well as other sulphur-containing compounds. They originate from industrial sources such as pulp and paper mills, coke ovens and refineries. They do not have a health impact at levels normally measured in the ambient air.

B) Particulates (dust) which are measured by three methods, each relating to a different size range of particles:

i) Dustfall

Dustfall incorporates the heavy material generally greater than 10 microns in size that settles out of the atmosphere by gravity.

ii) Total Suspended Particulates (TSP)

TSP is measured using high volume (hi-vol) samplers set up at permanent locations (near industrial sources). The particles collected by Hi-vol samplers range in size from submicron to approximately 50 microns.

iii) Soiling Index (Coefficient of Haze)

The coefficient of haze (COH) is monitored by tape samplers which measure fine particles (less than 10 microns) on an hourly basis.

The Ministry of the Environment has been conducting routine monitoring in the Niagara Falls area since the early 1970's.

At Niagara Falls the following stations are employed:

27056 - Allendale Avenue near Niagara Falls tourist area

27055 - Stanley Avenue 500 m northeast of General Abrasives

Ltd.

27053 - First and Bridge (500 m southeast of Cyanamid Inc., N.F.)

#27050 - Victoria Avenue (500 m east of Cyanamid Inc., N.F.)

Station #27053 was operated only in 1984 and 1985. Station #27050 replaced it in 1986 and is still operational. Stations #27055 and #27056 have been in continuous operation since 1984.

In Niagara Falls, during the 1976-1979 period, the 24-hour and annual criteria for sulphur dioxide (SO_2) were never exceeded. The one hour criterion was exceeded only once in 1976. The 24-hour criterion for suspended particulates was exceeded on six occasions during that same period; the annual criterion was not exceeded.

At station #27056, for the period from 1984 to 1987, the API was generally low and well below the advisory level. Sulphur dioxide and soiling index concentrations were also generally low and met all objectives. The data suggest that sulphur dioxide is mostly due to the influence of the Niagara Falls (N.Y.) industrial area. TSP were low and met the objectives - the trend from 1980 shows a decline to well below the yearly objective.

At station # 27055, all the objectives for sulphur dioxide were met and the data for SO_2 and TRS show mostly low levels for the period from 1984 to 1987. General Abrasives Ltd. is indicated as the primary source of both pollutants. The hi-vol sampler continuously showed a very high yearly mean for suspended particulates although levels did decrease between 1984 and 1987. There is a local fallout problem in the immediate vicinity of the plant. The major sources of dust emissions are both the silicon carbide and aluminum oxide furnaces. The former is also the major source of odours at the plant.

Data were collected at station # 27053 in 1984 and 1985. The annual geometric mean for suspended particulates was reduced by 12% in 1985 from 1984. The major influence was determined to be Cyanamid.

In 1986, monitoring was switched over from # 27053 to # 27050. The yearly mean for suspended particulates was well above the objective. It should be noted that this station is more downwind of Cyanamid with respect to predominant winds, which likely accounts for this increase. The major sources of dust from Cyanamid are the calcium carbide furnace and its product handling system.

The decade from 1980 to 1989 brought significant advances in air quality monitoring technology. In June of 1988, the reporting of air quality was revamped to a new Air Quality Index or AQI (which includes the Air Pollution Index) to more accurately reflect ambient air quality in response to growing concern with the quality of air in Ontario as well as scientific advancement.

The AQI incorporates the two contaminants, SO_2 and suspended particulate matter, which determined the API. In addition, the new AQI measures four additional air pollutants:

- carbon monoxide (CO)

  Carbon monoxide is a colourless, odourless and tasteless gas mainly resulting from automobile emissions. CO causes impaired perception and reflexes, and, at high levels, can aggravate chronic heart and respiratory diseases.

- nitrogen dioxide (NO_2)

  Nitrogen dioxide is an irritating gas produced by combustion processes. It can combine with water in the atmosphere to form acid rain and can also contribute to the formation of ozone or photochemical smog. Nitrogen dioxide can affect health, reduce visibility, corrode metals and damage vegetation.

- ozone (O_3)

  Ozone is a pungent, colourless gas produced by the sun's photochemical action on hydrocarbons and oxides of nitrogen. Ozone also occurs naturally. High levels of ozone can cause eye irritation, respiratory distress, decreased visibility and damage to vegetation.

- total reduced sulphur (TRS)

  As previously identified for site specific instances.

The AQI is based on the 24-hour running average concentrations of pollutants and does not emphasize short-term extreme readings. The air quality is reported as very poor, poor, moderate, good or very good based on an AQI number from 0 to 100 (Table 4.38). Various levels of pollutants as identified by the AQI can be associated with various human health effects (Table 4.39). Reported AQI levels are based on the most recent one hour concentrations and the previous 23 hourly readings. The AQI is reported four times a day and more frequently when the air quality is moderate or worse. When the AQI reveals high levels of pollutants, action is taken to reduce emissions. Elevated levels of any one parameter can cause the AQI to increase.

If the AQI reports poor, very poor or moderate conditions, the specific pollutants causing those conditions are identified along with actions being taken to reduce these pollutants to acceptable levels. An estimate is also given of how long these conditions are expected to persist. The API is still measured along with the AQI as it is used to control industrial air pollution in the area of the monitoring station.

For the last three years, all areas in the Province had AQI readings of either good or very good, 90% of the time. Poor conditions occurred less than 1% of the time. Very poor conditions did not occur.

Air quality standards on the U.S. side of the Niagara River are established by both U.S. EPA and N.Y. DEC. Between 1973 and 1979, annual criteria for sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and lead were not exceeded in the area of the escarpment (to the north and northeast of Niagara Falls). In Niagara Falls (N.Y.), the levels of particulate matter, both settleable and suspended, have consistently exceeded the State standard. This is probably a result of the location of the Buffalo Avenue industrial corridor in Niagara Falls and the prevailing wind direction, which would carry airborne particulates into the Niagara Falls (N.Y.) area. This combination is probably responsible for sporadic particulate exceedances in Lewiston and excessive ozone levels on two occasions in Niagara Falls (N.Y.).

There are little published data on the concentration of toxic species in the air along the river. The lack of such data does not allow an assessment of whether the river acts as a source of such chemicals to the air (or vice versa). It is reasonable to assume that any source segment along the river in the industrialized corridor may present a possible source of airborne contaminants including: direct emission from industry, urban emissions, volatilization from industrial or municipal wastewater systems and volitilization from the river itself.

Sampling has been conducted for gas-phase and particulate-phase polycyclic aromatic hydrocarbons in the Niagara river area[155]. This study confirmed the results of previous studies, that PAH concentrations in the air are greatest when the air mass is under the influence of urban and industrial sources. Along the Niagara River this indicates a south to north gradient in the concentration due to larger population in the Buffalo area.

TABLE 4.38

Ontario Air Quality Index
Table Units are Concentrations
Brackets Indicate Rationale

Pollutant	Units	Category / A.Q. Index				
		Very Good	Good	Moderate	Poor	Very Poor
		0-15	16-31	32-49	50-99	100+
Sulphur Dioxide 1 hr. avg.	ppm	0-0.16 (MD)	0.17-0.25 (OC)	0.26-0.34 (MA)	0.35-1.99 (PL)	>2.00
Coef. of Haze 1 hr. avg.	COH	0-1.0 (AR)	1.1-1.9 (AR)	2.0-3.9 (AR)	4.0-5.9 (AR)	>6.0
Carbon Monoxide 1 hr. avg.	ppm	0-12 (MD)	13-22 (EX)	23-30 (OC. MA)	31-49 (EQ8)	>50
Carbon Monoxide 1 hr. avg.	ppm	0-5 (MD)	6-9 (EX)	10-13 (OC. MA)	14-17 (MT)	>18
Nitrogen Dioxide 1 hr. avg.	ppm	0-0.10 (NE)	0.11-0.20 (OC. MA)	0.21-0.25 (EX)	0.26-0.52 (MT)	>0.53
Ozone 1 hr. avg.	ppb	0-50 (MD)	51-80 (OC)	81-120 (EPA)	121-199 (MT)	>200
Total Reduced Sulphur 1 hr. avg.	ppb	0-5 (OCM)	6-10 (OCP)	11-27 (SO)	28-999 (PL)	>1000
RATIONALE:	(MD) - Federal Maximum Desirable Level (MA) - Federal Maximum Acceptable Level (MT) - Federal Maximum Tolerable Level (OC) - Ontario Criteria (PL) - Prudent Level for Safety (EQ8) - Equivalent Effect as Federal Maximum Tolerable Level for 8 Hours (AR) - Arbitrarily Selected (EX) - Extrapolated (NE) - No Effects (EPA) - U.S.E.P.A. Standard (SO) - Strong Odor (OCP) - Ontario Criterion for TRS emitted from Pulp Mills(OCM) - Ontario Criterion for Methyl Mercaptan					

TABLE 4.39

Ontario Air Quality Index Health Effects by AQI Category					
Pollutant	Category				
	Very Good	Good	Moderate	Poor	Very Poor
Carbon Monoxide	No Effects	No Effects	Blood Chemistry Changes. NoDetectable Impairment.	Increased Cardiovascular Symptoms in Smokers With Heart Disease.	Increasing Cardiovascular Symptoms in Non-smokers With Heart Disease. Some Visual Impairment.
Nitrogen Dioxide	No Effects	Slight Odor	Odorous	Odor and Discoloration. Some Increase In Bronchial Reactivity in Asthmatics.	Increasing Sensitivity in Patients with Asthma and Bronchitis.
Ozone	No Effects	Injures Vegetation When Combined With Sulphur Dioxide.	Injures Many Vegetation Species.	Decreasing Performance by Athletes Exercising Regularly.	Light Exercise Produces Respiratory Effects in Patients with Chronic Pulmonary Disease.
Sulphur Dioxide	No Effects	Injures Vegetation When Combined With Ozone	Injures Some Vegetation Species.	Odorous. Increasing Vegetation Damage.	Increasing Sensitivity in Patients with Asthma @and Bronchitis.
Suspended Particulate	No Effects	No Effects	Some Decrease In Visibility	Visibility Decreased Soiling Evident.	Increasing Sensitivity in Patients with Asthma and Bronchitis.
SO2+ SP	No Effects	No Effects	Injurious to Vegetation	Increased Symptoms in Patients with Chronic Respiratory Disease.	Significant Respiratory Effects in Patients with Asthma and Bronchitis.
Total Reduced Sulphur	No Effects	Slight Odor	Odorous	Extremely Odorous.	Sensitive Individuals May Suffer Nausea and Headaches Due to Severe Odor.

During a one-week sampling period in September 1982, a screening of compounds was carried out at stations in Niagara-on-the-Lake (Fort George), Niagara Falls (Diversion Structure) and Fort Erie (Old Fort Erie). The majority of the organics detected consisted of compounds which are typical of urban and rural environments. Results showed a large amount of fatty acids associated with vegetative burning, for which there is no local source. The presence of high concentrations of these in the foam below Niagara Falls points to the river as a possible source. These compounds have also been noted in urban samples from Detroit and New York State. Chlorinated species were not seen during this full-range screening of compounds.

The sampling was repeated during the last week of January, 1983. At this time volatilization from the river was indicated as not likely to occur since the water temperature during the period was 0.4°C to 1.1°C. The study showed that concentrations of particulate PAHs were higher during winter months especially for phenanthrene and pyrene. This indicated that source input from a strong local influence was the controlling factor for the difference between September and January. In general, airborne PAH levels were highest in Fort Erie, lower in Niagara Falls and lowest in Niagara-on-the-Lake.

4.6.6 Odour

There have been occurrences recorded in the last decade of complaints of unacceptable air quality in the area of the Maid-of-the-Mist Pool. These complaints have been made by both visitors and residents. Most occurrences have been noted by those individuals who work in the vicinity of the Falls, the customs and immigrations staff at the Rainbow Bridge and the Maid-of-the-Mist fleet staff.

Although most complaints have not been verified because the emission has ceased before investigators arrive, some occurrences have been of sufficient duration to give an indication of responsible sources.

Most of the complaints which have been traced have been associated with discharges from Niagara Falls (N.Y.), either from industrial spills above the American Falls or discharges from the Falls Street Sewer or from the Adams Tailrace Tunnel. Particularly strong odours filled the Niagara Gorge in the Falls area on September 8, 12, 17, and September 21, 1987. The incident on September 12 was reported to Ontario's Spills Action Centre; eight Canada Customs Officials were overcome and three had to be taken to hospital for observation. During the same occurrence, staff and passengers of the Maid-of-the-Mist reported irritation of the eyes and throat.

The majority of odour complaints and poor air quality occurrences are linked to discharges to the Maid-of-the-Mist Pool. Three Hydro-electric plants discharge to the pool on the Canadian side. Investigations of these discharge systems do not show any possible route of introduction of contaminants to these waters. Their sole purpose remains the transfer of water from the upper river to the lower river for electrical power generation purposes.

The only recorded pollution sources to this portion of the river are the two main sewers for the City of Niagara Falls, New York. The Falls Street Tunnel is a combined sewer which contributes contaminated ground water to the Maid-of-the-Mist Pool during periods of high precipitation. The City, along with EPA and DEC are attempting to redirect as much of this water stream as possible to the Niagara Falls (N.Y.) Waste Water Treatment Plant (NFWWTP). The larger of the two outfalls is the Adams Tailrace Tunnel; it receives the discharge from the NFWWTP along with non-contact cooling waters from the chemical industries along Buffalo Avenue.

The NFWWTP has the ability to bypass influent directly to the Adams Tunnel in the event of a spill, from any of its significant industrial users, that threatens the operation of its treatment system, particularly the activated carbon beds. Bypassing has occurred in the past as excessive stormwater contributions threatened to hydraulically overload the plant. The municipal, state and federal authorities, once again, have been working on better control of flows through the plant.

The bypassing of a spill from the NFWWTP or a spill directly from the industries to the NFWWTP still poses a threat to the well-being of people and animals in the Maid-of-the-Mist area. These poorly treated, full-strength waste streams have the ability of creating serious air quality problems in the confined space at the bottom of the Niagara Gorge. This may be particularly true during periods of reduced flow over the falls and through the Maid-of-the-Mist Pool. These lower flow periods provide less dilution for the concentrated stream and create a longer residence time in the Maid-of-the-Mist Pool. Extending these periods of low flow or increasing their frequency would increase the risk of a combination of low flow with a spill condition. The severity of the exposure will depend on the nature of the contaminants involved.

4.6.7 Mist

Mist is formed in three ways at Niagara Falls and the amount formed by each method is dependent on the ambient temperature and humidity as well as the temperature differential between the air and the river water. One way involves the bubbles which are created by the plunge into the Maid-of-the-Mist Pool; the bubbles break upon surfacing, producing aerosol droplets that can carry surface-active materials into the atmosphere[157]. A second, and more important, method is by the spray of fine water droplets created by the impact of the cascade as it hits rocks or the surface of the water below; this fine spray is carried to the top of the gorge by the unpredictable updrafts of air from the Maid-of-the-Mist Pool. The third method involves the evaporation of water from the river's surface layer as it goes over the Falls. This evaporation cools and condenses in the air above the Falls.

It has been hypothesized that, although the process of volatilization by the falls at Niagara may provide a pathway for the removal via stripping of any volatile contaminants, it may in turn cause widespread dispersal of contaminants in aerosol form that may increase risk of human exposure to toxins and pathogens for individuals who work in the vicinity of Niagara Falls or to visitors to the falls area.

In 1987, a graduate thesis project from the University of Toronto involving mathematical modelling of toxic contaminants in the Niagara River theorized that significant amounts of toxic chemicals were being volatilized in the mist at Niagara Falls[158]. This project attempted to account for the introduction, movement and ultimate fate of eleven chemical species along the Niagara River. The model predicted that significant amounts of PCBs, tetrachlorobenzenes and chloroform were volatilized by the intense mixing of air and water going over the falls. An air to water entrainment ratio of 20:1 was estimated as the air breaks up in the "nappe", or falling curtain of water. A calculation was then made of an air flux of 59,000 m^3/s evolving out of the gorge due to the rising spray plume. The model could not be validated due to the lack of environmental data.

Comparing maximum in-plume concentration estimates with Air Concentration Guidelines from the Ministry of the Environment, it is possible for the predicted concentrations to exceed the daily and annual limit for PCBs. The total mass emission of PCB predicted by the model would make the falls the largest "point source" of PCBs to the atmosphere in North America.

Data used in the model were drawn from a wide range of sources and, consequently, were heavily qualified by the researchers. Some areas of study had no readily available information, so extrapolations were made from scientific research or permitted values. In a follow-up article written by Dr. D. Mackay[159], one of the researchers involved, the authors expressed concern over the reaction to the study. Dr. Mackay stated that, in reality, the concentrations, even in the plume (of mist) are low, and thus "non-toxic" and well below any levels applicable to occupational atmospheres. Unfortunately, the publicity surrounding the "bad news" that toxic chemicals were evaporating at the Falls was more widely distributed than the "good news" that no harm would be suffered by the visitors and residents.

In November, 1986, the Ontario Ministry of the Environment conducted an air survey[160] from the Niagara Falls area in the vicinity from Table Rock to the Diversion Structure. This survey indicated no PCBs above a detection limit of 40 ng/m^3.[583,585]

In response to recommendations in the previously mentioned thesis project, Environment Canada[155,156] and the Ontario Ministry of the Environment[584,160] conducted studies adjacent to the Horseshoe Falls on the Ontario side of the river.

During the week of June 15, 1987, the Air Resources Branch of the Ontario Ministry of the Environment deployed two sophisticated mobile air monitoring units (MAMUs) adjacent to Table Rock[160].

MAMU #1 contains a variety of analyzers that enabled screening of the ambient air in the mist arising from Niagara Falls for 141 different volatile organic compounds and up to ten common contaminants (NO_x, NO_2, TRS, NO, CH_4, SO_2, CO, O_3, total hydrocarbons and non-methane hydrocarbons). MAMU #1 also contains a complete meteorological station. MAMU #3 is a Trace Atmospheric Gas Analyzer (TAGA) unit (model 3000). It couples a mass spectrometer/APCI source with an Automated Short Term Adsorber (ASTA) to monitor specifically for PCBs in 2-minute intervals with a running half-hour average. Atmospheric conditions for monitoring during the entire survey were ideal: light to moderate winds and ambient temperatures in excess of 20°C. The mist was always present and the monitoring units were either in or directly downwind of the mist.

MAMU #1 analysed 15 one-hour volatile organics samples collected in the mist. In addition, 83 hours were spent at the Diversion Structure downwind of the mist (including all 64 hours of the overnight periods). These 83 readings of common contaminant data collected during the study showed compliance with the Ontario Guidelines, Air Quality Criteria or Provisional Guidelines. A total of 23 chlorinated alkanes (including chloroform), 9 chlorinated alkenes and 7 chlorinated aromatics (including chlorobenzene) were detected in the mist samples by the GC. None of these contaminant concentrations exceeded Guidelines or TLVs. A total of 405 air samples were screened for PCBs. Occasional detection-level interference occurred in the TAGA; however, these interferences were not indicative of the presence of PCBs since the data did not meet the criteria for the identification of PCBs[160].

In August, 1987, Environment Canada's Atmospheric Environment Service conducted a study to test the predictions of elevated air concentrations at the Falls[156]. Following a series of samplings and analyses, AES concluded that, although concentrations of pollutants were measured in the air at several locations around Niagara Falls, the concentrations of the chemicals measured were consistent with previous measurements of urban and rural concentrations in North America and in disagreement with the thesis model project predictions. Using the same Ontario Guidelines, AES concluded that the concentrations measured during the study are acceptable on a half-hourly, daily and yearly basis[156].

It is certain that contaminants are being released into the mist, the foam and the air as the Niagara River plunges over Niagara Falls and into the Maid-of-the-Mist Pool below. The tendency for some contaminants such as metals to concentrate on surface-active materials and for others such as low molecular weight organics to volatilize is a scientific fact. The question that must be answered is the degree to which this occurs and the threat posed by this degree of occurrence.

Simulation studies have been conducted by Ontario Hydro to determine the flow patterns in the upper Niagara River. In addition, mathematical modelling has been conducted by the University of Windsor for the Ministry of the Environment. These studies show that the upper Niagara River remains relatively unmixed due to the predominance of downstream flow over lateral flow. The waters passing over the Horseshoe Falls, representing primarily the waters of the Chippawa Channel, are of the same quality as Lake Erie water. Contributions from the lightly populated shores of the Chippawa Channel, including the urban area of Fort Erie, do not substantially change the quality of the water passing down the Chippawa Channel.

The heaviest degree of contamination of the Niagara River comes from the highly populated and industrialized corridor on the U.S. side of the river and the Buffalo area. These contaminants are carried predominantly by the Tonawanda Channel. These more contaminated waters are significantly diverted above the American Rapids by the New York Power Authority through their underground aqueducts to the Robert Moses Generating Station in Lewiston, New York. Some of the waters of the Tonawanda Channel are introduced into the Maid-of-the-Mist Pool over the American and Bridal Veil Falls.

It is suspected that concentrations of contaminants, particularly man-made organics, in the air and mist on the U.S. side are higher than on the Canadian side, given the higher water concentrations and the prevailing wind directions. This aspect has not been investigated by authorities on the U.S. side of the Niagara Falls. It may be difficult to assess an impact in this area given the much more highly industrialized nature of Niagara Falls, New York.

Some mixing of the waters of the Tonawanda and Chippawa Channels may occur in the Grass Island Pool due to the operation of the Diversion Structure by the two power authorities. Although this mixing is believed not to be a significant occurrence at this time, plans for increased use of the Niagara for power generation purposes may further exacerbate this mixing.

TABLE 4.2

List of Chemicals Detected in the Niagara River**

PARAMETER	CAS Number	NRTC Group#	PARAMETER	CAS Number	NRTC Group#
Acenaphthene	83-32-9	IIIS	Butylphenol, 4-t-	98-54-4	IIC
Acenaphthylene	208-96-8	IIDS	Carbon disulphide	75-15-0	III
Acetone	67-64-1	III	Carbon tetrachloride	56-23-5	I
Aldrin [HHDN]	309-00-2	IS	Chlordane, Alpha-	12789-3-6	I
Aminonaphthalene, 1-[1-Naphthylamine]		IIDS	Chlordane, Gamma-	57-74-9	I
Aniline	62-53-3	IIAS	Chloroanthracene		IID
Anthracene	120-12-7	IIG	Chlorobenzene [mono-]	108-90-7	IIC
Benzaldehyde	100-52-7	IIC	Chlorodibromoethane		IID
Benz(a)anthracene	56-55-3	I	Chlorodibromomethane1	24-48-1	IIA
Benzene	71-43-2	I	Chloroform	67-66-3	I
Benzene sulfonamide	98-10-2	IIC	Chlorohydroxybenzophenone		IID
Benzofluorene	30777-19-6	IIFS	Chlorohydroxyphenothiazine		IID
Benzoic acid [Benzyl benzoate]	65-85-0	IIDS	Chloromethoxybenzophenone		IID
Benzothiazole	95-16-9	III	Chloromethyl-bis(phenylmethyl)benzene		IID
Benzo(a)pyrene	50-32-8	I	Chloronaphthalene, 1-	90-13-1	IIA
Benzo(b)fluoranthene	205-99-2	I	Chloronaphthalene, 2-	91-58-7	IIA
Benzo(e)pyrene	192-97-2	IIDS	Chloro-o-nitrobenzene	88-73-3	IIDS
Benzo(g,h,i)perylene 1	91-24-2	IID	(Chlorophenyl)cyclohexene		IIDS
Benzo(k)fluoranthene	207-08-9	I	Chlorotoluene		IIC
Benzyl alcohol	100-51-6	IIIS	Chloro(trifluoromethyl)benzene, 2-		IIDB
Benzyl benzoate (see Benzoic acid)			Chloro(trifluoromethyl)benzene, 3-		IID
Benzylbutylphthalate	85-68-7	IIIS	Chloro(trifluoromethyl)benzene, 4-		IIDB
Benzylidene-4,4'-bis(dimethylaniline)		IIDS	Chrysene	218-01-9	I
Benzyl-n-ethylaniline, n-		IIDS	Coronene	191-07-1	IIFS
BHC Alpha- [A-Hexachlorocyclohexane]	319-84-6	I	Cumene	98-82-8	III
BHC Beta- [B-Hexachlorocyclohexane]		IIC,IIAS	DCPA [2,2-Dichloropropionic Acid]	75-99-0	IICSB
BHC Gamma- [G-Hexachlorocyclohexane]	58-89-9	I	DDD p,p'-		I
Biphenyl	92-52-4	III	DDE p,p'- [DDX]		I
Bis-(2-ethylhexyl)phthalate	117-81-7	I	DDT o,p-		IIAB,IICS
Bromoform [Tribromomethane]	75-25-2	IIA	DDT p,p'-	50-29-3	I
Butanal	123-72-8	IIC	Decadienal, 2,4-		IIDB
Butanol, n- [n-butyl alcohol]	71-36-3	IIC	Dibenzofuran		IIDS
Butanol, t- [t-butyl alcohol]	75-65-0	III	Dibenz(a,h)anthracene	53-70-3	IIB
Butanone, 2-	78-93-3	III	Dibromomethane [Methylene bromide]	74-95-3	IID

TABLE 4.2 (Cont'd.)

List of Chemicals Detected in the Niagara River**

PARAMETER	CAS Number	NRTC Group#	PARAMETER	CAS Number	NRTC Group#
Di-n-butylphthalate	84-74-2	IIE	Diethyl ether [Diethyl formamide]	60-29-7	III
Di-t-butylquinone		IIDS	Diethylphthalate 86-66-2 IICS		
Dichloroanthracene		IID	Dimethyladipate		IIGS
Dichlorobenzene, 1,2-	95-50-1	IIA	(Dimethylamino)benzophenone, 4-		IIDS
Dichlorobenzene, 1,3-	541-73-1	IIA	Dimethylaniline [,n,n-?]	121-69-7	III
Dichlorobenzene, 1,4- [PDB;paradichlorobenzene]	106-46-7	IIA	Dimethyl disulphide	624-92-0	IID
Dichlorobromoethane		IID	Dimethyl-2,5-heptadien-4-one, 2,4- [Phorone]		IICS
Dichlorobromomethane	75-27-4	IIB	Dimethylphenanthrene		IIDS
Dichloroethane, 1,1-	75-34-3	IICS	Dimethylphthalate [NTM;DMP]	131-11-3	IICS
Dichloroethane, 1,2- [Ethylene dichloride]	107-06-2	I	Dimethyl-2-propenoamide, n,n-		IID
Dichloroethylene, 1,2- (cis)	156-59-2	IIAS	Dinitroanisole, 2,4-	119-27-7	IICS
Dichloroethylene, 1,2- (trans)	156-60-5	IIAS	Di-n-octylphthalate	117-81-7	I
Dichloromethane [Methylene chloride]	75-09-2	I	Diphenylamine	122-39-4	IIAS
Dichloromethyl-bis(phenylmethyl)benzene		IID	Diphenylcyclohexane		IIDS
Dichloromethyldiphenylmethane		IID	Diphenyldifluoromethane		IID
Dichloronaphthalene		IIB	Diphenylhydrazine, 1,2-	122-66-7	IICS
Dichlorophenanthrene		IIDS	Endosulfan I [Thiodan I]	115-29-7	I
Dichlorophenol, 2,4-	120-83-2	IIC	Endosulfan II [Thiodan II]	?	I
Dichlorophenol, 2,5-		IIC	Endrin	44	I
Dichlorophenol, 2,6-	87-65-0	IIC	Ethylbenzene	100-41-4	IIA
Dichlorophenoxyacetic acid, 2,4- [2,4-D]	94-75-7	IIA	Ethyltoluene		IID
Dichloro-2-phenoxyethanol, 2,4-		IID	Ethyl-4-methylmaleic anhydride,3-		IIDS
Dichloropropane, 1,2-	78-87-5	IIC	Fluoranthene	206-44-0	I
Dichloropropylene, 1,2-	542-75-6	IIC	Fluorene	86-73-7	IIG
Dichloropropylene, 1,3- (cis)	10061-01-5	IIC	Fluoroethyl-pentachlorobenzene, 2-		IIDS
Dichloropropylene, 1,3- (trans)	10061-02-6	IIC	Fluorotrichloromethane ** see trichlorofluoromethane		**
Dichloroquinone		IIDS	Furan	110-00-9	IID
Dichlorotoluene, 2,6-		IIC	Heptachlor	76-44-8	IS,IIAB
Dichloro(trifluoromethyl)benzene		IID	Heptachlor epoxide	1042-57-3	I
Dicyclohexylphthalate		IIDS	Heptachlorodibenzofuran		IIDS
Dieldrin [HEOD]	60-57-1	I	Heptachlorotoluene		IIDS
Diethylbenzene	25340-17-4	IIE	Hexachlorobenzene [HCB]	118-74-1	IIA,ISB
Diethylcyclohexanone		IIDS	Hexachlorobutadiene [HCBD] 87-68-3		I
Diethyl disulphide	110-81-6	IIC	Hexachlorodibenzofuran		IIDS

TABLE 4.2 (Cont'd.)

List of Chemicals Detected in the Niagara River**

PARAMETER	CAS Number	NRTC Group#	PARAMETER	CAS Number	NRTC Group#
Hexachlorotoluene		IID	Pentachloroanisole		IIC
Hexanal		IIC	Pentachlorobenzene	608-93-5	IIC
Hexane	110-54-3	IIG	Pentachlorobiphenyl		IS
Hexenone		IIC	Pentachlorobiphenylene		IIDS
Hydroxybenzaldehyde, 4-		IIDB	Pentachlorocarbazole		IIDS
Indeno(1,2,3-c,d)pyrene	193-39-5	IIDS	Pentachlorodibenzofuran		IIDS
Isophorone	78-59-1	IICB	Pentachlorodifluoronaphthalene		IIDS
Lindane ** see BHC-G **			Pentachlorofluorene		IIDS
Methoxychlor [Methoxy-DDT, DMDT]	72-43-5	ISB	Pentachloromethylbis(phenylmethyl)benzene		IID
Methylanthracene		IIFS	Pentachlorophenol [PCP]	87-86-5	I
Methylbutanoic acid, 2-		IIDB	Pentachlorophenylfluoromethylether		IIDS
Methylcoumarin		IICS	Pentachlorotoluene		IID
Methyldibenzofuran		IIDS	Pentane		III
Methylene-4,4'-bis(n,n-dimethyl)aniline		IIDS	Perylene	198-55-0	IIFS
Methylene chloride **see Dichloromethane**			Phenanthrene	85-01-8	IIF
Methylfluorene		IIDS	Phenol	108-95-2	I
Methylfuran		IIC	Phenothiazine		IIC
Methyl-3-hexen-2-one, 5-		IIDB	Phenylacetaldehyde		IIDB
Methylnaphthalene, 1- 90-12-0		IIC	Phenylacetic acid		IIDB
Methyloxime-3-pentanone, o-		IIDS	Phenylnaphthalene		IIDS
Methylpalmitate		IIFS	Piperidinone		IIDB
Methylpentene		IIC	Propanol		III
Methylphenanthrene		IIES	Pyrene	129-00-0	I
Methylpivalate		IICS	Silvex **see Trichlorophenoxypropionic acid**		
Methylpyrene		IIDS	Styrene	100-42-5	IIA
Mirex [Dechlorane, Dechlorane plus]	2385-5	I	2,4,5-T **see Trichlorophenoxyacetic Acid**		
Naphthalene	91-20-3	III	TCDD **see Tetrachlorodibenzo-p-dioxin**		
Nitrosodiphenylamine, n-	86-30-6	IICS	Tetrachlorobenzene, 1,2,3,4-	634-66-2	IIC
Nonen-2-one, 3-		IIDB	Tetrachlorobenzene, 1,2,3,5-	634-90-2	IICB
Octachlorodibenzofuran		IIDS	Tetrachlorobenzene, 1,2,4,5-	95-94-3	IIC
Octachlorostyrene	29082-74-4	IICSB	Tetrachlorobiphenyl		IS
PCB - Arochlor 1242	53469-21-9	ISB	Tetrachlorocarbazole		IIDS
PCB - Arochlor 1254	11097-69-1	IS	Tetrachlorodibenzofuran		IIDS
PCB - Arochlor 1260	11096-82-5	I	Tetrachlorodibenzo-p-dioxin, 2,3,7,8-	1746-01-6	I

TABLE 4.2 (Cont'd.)

List of Chemicals Detected in the Niagara River**

PARAMETER	CAS Number	NRTC Group#	PARAMETER	CAS Number	NRTC Group#
Tetrachloroethane, 1,1,2,2-	79-34-5	IIC	Trichlorophenoxyacetic Acid, 2,4,5- [245T]	93-76-5	IIA
Tetrachloroethylene [Perchloroethylene]	127-18-4	I	Trichlorophenoxypropionic Acid, 2,4,5- [Silvex;Fenopro	245TP]93-72-	IIA
Tetrachloromethylbis(phenylmethyl)benzene		IID	Trichlorotoluene,2,4,5-	6639-30-1	IIC
Tetrachlorophenanthrene		IIDS	Trichlorotrifluoroethane		III
Tetrachlorophenol, 2,3,4,6-	58-90-2	IICB	(Trifluoromethyl)benzene		IID
Tetrachlorotoluene		IID	Trimethylbenzene	25551-13-7	IIC
Tetrahydrofuran 109-99-9		IIC	Trimethylbiphenyl		IIDB
Tetramethylbenzidene, n,n,n',n',-		IIDS	Trimethylphenanthrene		IIDS
(Tetramethylbutyl)phenol		IIC	Trimethyl-3a,4,5,6-tetrahydro-2-coumaranone, 3a,6,6-		IIDS
Thiodan ** see Endosulfan **			Xylene, m-	108-38-3	IIS
Toluene	108-88-3	III	Xylene, o-	95-47-6	III
Tribromomethane ** see bromoform **			Xylenol, 2,4-		IICS
Trichloroanthracene		IID	Zytron		IIDSB
Trichlorobenzene, 1,2,3-	87-61-6	IIC	Aluminum	7429-90-5	
Trichlorobenzene, 1,2,4-	120-82-1	IIC	Antimony	7440-36-0	I
Trichlorobenzene, 1,2,5-		IICB	Arsenic	7440-38-2	IS,IIA
Trichlorobenzene, 1,3,5-		IIC	Barium		IID
Trichlorobiphenyl		IS	Beryllium	7440-41-7	I
Trichlorodiphenylmethane		IID	Cadmium	7440-43-9	I
Trichloroethane, 1,1,1-		IIE	Chromium	7440-47-3	I
Trichloroethylene	79-01-6	IIA	Copper	7440-50-8	I
Trichlorofluoromethane	75-69-4	IIGS	Cyanide	57-12-5	I
Trichloromethyl-bis(phenylmethyl)benzene		IID	Lead	7439-92-1	I
Trichloronaphthalene		IIBS	Manganese	7439-96-5	IICS
Trichlorophenanthrene		IIDS	Mercury	7439-97-6	I
Trichlorophenol, 2,3,4-	15950-66-0	IIA	Nickel	7440-02-0	I
Trichlorophenol, 2,3,5-	933-78-8	IIA	Selenium	7782-49-2	I
Trichlorophenol, 2,3,6-		IIA	Silver	7440-22-4	I
Trichlorophenol, 2,4,5-	95-95-4	IIA,IB	Thallium	7440-28-0	IIDS
Trichlorophenol, 2,4,6-	88-06-2	IIA,ISB	Zinc	7440-	I
Trichlorophenol, 3,4,5-		IIA			

** Source: Niagara River Toxics Committee

TABLE 4.3

Group I, Chemicals of Concern**

Chemical	Phase			Monitoring	Characteristics					Assessment			See also
	Biota	Sediment	Water	Source	Trend	Medium	LC50	LD50	log(Kow)	BCF	Crit	HEC	Group
Aldrin		*		Y	S	W,B,S					S		
Antimony			*	Y	W	W,B,S		*	*	*	S	*	IID
Arsenic		*		Y	W,B,S	W,B,S				*		*	IIA
Benzene			*	Y	W	W,B,S					S		III
Benzo(b)fluoranthene			*	Y	W	W,B,S	*	*		*	S		IIB
Benzo(k)fluoranthene			*	Y	W	W,B,S	*	*		*	S		IIF
Benz(a)anthracene			*	Y	W	W,B,S	*	*			S		IIF
Benzo(a)pyrene		*	*	Y	W,S	W,B,S	*						
Berylium			*	Y	W	W,B,S		*	*	*	S	*	IID
BHC-alpha		*	*	Y	W,B,S	W,B,S				*	B,S		IIA
Bis(2-ethylhexyl)phthalate		*		Y	W,S	W,B,S		*			S		
Cadmium	*	*	*	Y	W,B,S	W,B,S					B		
Carbon tetrachloride			*	Y	W	W,B,S							
Chlordane		*	*	Y	W,B,S	W,B,S					S		IIA
Chloroform			*	Y	W,S	W,B,S				*	S		IIA
Chromium		*	*	Y	W,B,S	W,B,S			*		B		IIA
Chrysene			*	Y	W	W,B,S					S		IIB
Copper		*	*	Y	W,S	W,B,S		*	*	*			IIF
Cyanide		*	*	Y	W,S	W,B,S		*	*	*		*	
DDD		*	*	Y	W,B,S	W,B,S					S		IIA
DDE		*	*	Y	W,B,S	W,B,S	*				S		IIA
DDT		*	*	Y	W,B,S	W,B,S					S		IIA
1,2-Dichloroethane			*	Y	W	W,B,S				*			
Dieldrin		*	*	Y	W,B,S	W,B,S					S		IIA
Dioctyl phthalate			*	Y	W	W,B,S	*				S	*	IIC
Endosulphan		*	*	Y	W,B,S	W,B,S					S		IIA
Endrin		*	*	Y	W,B,S	W,B,S					S		IIA
Fluoranthene			*	Y	W	W,B,S				*	S		IIE

TABLE 4.3 (Cont'd.)

Group I, Chemicals of Concern**

Chemical	Phase			Monitoring	Characteristics					Assessment			See also
	Biota	Sediment	Water	Source	Trend	Medium	LC50	LD50	log(Kow)	BCF	Crit	HEC	Group
Heptachlor		*		Y	B,S	W,B,S					S		IIA
Heptachlor epoxide		*	*	Y	W,B,S	W,B,S	*				S		IIA
Hexachlorobenzene	*	*		Y	W,B,S	W,B,S	*				B,S		IIA
Hexachlorobutadiene	*	*	*	Y	W,B,S	W,B,S					B,S		
Lead		*	*	Y	W,B,S	W,B,S		*	*				IIA
Lindane		*	*	Y	W,B,S	W,B,S					S		IIA
Mercury		*	*	Y	W,S	W,B,S		*	*				
Methoxychlor	*	*		Y	B,S	W,B,S		*			B,S		
Methylene Chloride			*	Y	W	W,B,S				*	S		IIE
Mirex			*	Y	W,B,S	W,B,S					S		IIA
Nickel		*	*	Y	W,B,S	W,B,S		*	*		B		IIA
Pentachlorobiphenyl		*		Y	S	W,B,S		*					
Pentachlorophenol	*		*	Y	W,B	W,B,S					B		
Phenol			*	Y	W,B	W,B,S				*	S		IIA
PCB - Arochlor 1242	*	*		Y	B,S	W,B,S							
PCB - Arochlor 1254		*		Y	S	W,B,S							
PCB - Arochlor 1260			*	Y	W	W,B,S							
Pyrene			*	Y	W	W,B,S	*			*	S		IIE
Selenium			*	Y	W,S	W,B,S		*	*		S		IIA
Silver		*	*	Y	W,S	W,B,S		*	*				
TCDD (Dioxin)	*		*	Y	W,B	W,B,S		*					
Tetrachlorobiphenyl		*		Y	S	W,B,S		*					
Tetrachloroethylene			*	Y	W,S	W,B,S					S		IIA
Trichlorobiphenyl		*		Y	S	W,B,S		*					
2,4,5-Trichlorophenol	*			Y	W,B	W,B,S					B		IIA
2,4,6-Trichlorophenol	*	*		Y	B,S	W,B,S		*		*	B,S		
Zinc		*	*	Y	W,S	W,B,S		*	*		B		IIE

TABLE 4.3 (a)

Group IIA, Chemicals of Concern**

Chemical	Phase			Monitoring	Characteristics					Assessment			See also
	Biota	Sediment	Water	Source	Trend	Medium	LC50	LD50	log(Kow)	BCF	Crit	HEC	Group
Aniline		*			S	W,B,S		*		*	S		
Arsenic	*		*	Y	W,B,S	W,B,S				*			I
BHC		*			S	W,B,S				*	S		
BHC-alpha	*			Y	W,B,S	W,B,S				*	B.S		I
Bromoform			*		W	W,B,S							
Chlordane	*			Y	W,B,S	W,B,S					S		I
Chlorodibromomethane		*	*		W,S	W,B,S	*			*	S		
Chloroform		*		Y	W,S	W,B,S				*	S		I
Chloronaphthalene		*	*	W	W,S	W,B,S	*			*	S		
Chromium	*			Y	W,B,S	W,B,S			*		B		I
2,4-D			*	W	W,B,S								
DDD -(p,p)	*			Y	W,B,S	W,B,S					S		I
DDE	*			Y	W,B,S	W,B,S	*				S		I
DDT	*			Y	W,B,S	W,B,S					S		I
1,2-Dichlorobenzene		*	*		W,S	W,B,S		*			S		
1,3-Dichlorobenzene		*	*		W,S	W,B,S		*			S		
1,4-Dichlorobenzene	*	*	*		W,B,S	W,B,S		*			B,S		
1,2-Dichloroethylene		*			S	W,B,S		*		*	S		
Dieldrin	*			Y	W,B,S	W,B,S					S		I
Diphenylamine		*			S	W,B,S	*				S		
Endosulphan	*			Y	W,B,S	W,B,S					S		I
Endrin	*			Y	W,B,S	W,B,S					S		I
Ethylbenzene			*		W,S	W,B,S				*	S		
Heptachlor	*			Y	B,S	W,B,S					S		I
Heptachlor epoxide	*			Y	W,B,S	W,B,S	*				S		I
Hexachlorobenzene			*	Y	W,B,S	W,B,S	*				B,S		I
Lead	*			Y	W,B,S	W,B,S		*	*				I
Lindane	*			Y	W,B,S	W,B,S					S		I

TABLE 4.3 (a) (Cont'd.)

Group IIA, Chemicals of Concern**

Chemical	Phase			Monitoring	Characteristics					Assessment			See also
	Biota	Sediment	Water	Source	Trend	Medium	LC50	LD50	log(Kow)	BCF	Crit	HEC	Group
Mirex	*			Y	W,B,S	W,B,S					S		I
Nickel	*	*		Y	W,B,S	W,B,S		*	*		B		I
Phenol				Y	W,S	W,B,S				*	S		I
Selenium		*		Y	W,S	W,B,S					S		I
Silvex			*		W	W,B,S				*			
Styrene			*		W	W,B,S				*	W		
2,4,5-T			*		W	W,B,S				*	W		
Tetrachloroethylene		*		Y	W,S	W,B,S					S		I
Tribromomethane		*			S	W,B,S		*		*	S		
Trichloroethylene			*		W	W,B,S		*		*			
Trichlorophenol			*	Y	W,B	W,B,S					B		I

TABLE 4.3 (b)

Group IIB, Chemicals of Concern**

Chemical	Phase			Monitoring	Characteristics					Assessment			See also
	Biota	Sediment	Water	Source	Trend	Medium	LC50	LD50	log(Kow)	BCF	Crit	HEC	Group
Benzo(b)fluoranthene		*		Y	W	W,B,S	*	*		*	S		I
Chrysene		*		Y	W	W,B,S	*	*		*	S		I
Dibenz(a,h)anthracene		*	*			B	*	*		*	W,S		
Dichlorobromomethane		*	*			B,S	*	*		*			
Dichloronaphthalene		*	*		W	W,B	*	*			S		
Trichloronaphthalene		*					*	*			S		

Source: ** - Niagara River Toxics Committee

TABLE 4.5

Upstream/Downstream Monitoring Parameters

Persistent Toxic Chemicals of Concern

Chemical	1984-86	1986-87	1987-88	1988-89
Benzene	Monitored	Monitored	Monitored	Monitored
Carbon tetrachloride	Monitored	Monitored	Monitored	Monitored
Chloroform	Monitored	Monitored	Monitored	Monitored
Dichloroethane, 1,2-	Monitored	Monitored	Monitored	Monitored
Methylene chloride	Monitored	Monitored	Monitored	Monitored
Tetrachloroethylene	Monitored	Monitored	Monitored	Monitored
Acrolein	Not Monitored	Monitored	Not Monitored	Monitored
Acrylonitrile	Not Monitored	Monitored	Not Monitored	Monitored
bis(Chloromethyl)ether	Not Monitored	Monitored	Not Monitored	Monitored
Bromoform	Not Monitored	Monitored	Not Monitored	Monitored
Chlorobenzene	Not Monitored	Monitored	Not Monitored	Monitored
Chlorodibromomethane	Not Monitored	Monitored	Not Monitored	Monitored
Chloroethane	Not Monitored	Monitored	Not Monitored	Monitored
Chloroethylene	Not Monitored	Monitored	Not Monitored	Monitored
Chloroethylvinyl ether, 2-	Not Monitored	Monitored	Not Monitored	Monitored
Dichlorobromomethane	Not Monitored	Monitored	Not Monitored	Monitored
Dichlorodifluoromethane	Not Monitored	Monitored	Not Monitored	Monitored
Dichloroethane, 1,1-	Not Monitored	Monitored	Not Monitored	Monitored
Dichloroethylene, 1,1-	Not Monitored	Monitored	Not Monitored	Monitored
Dichloroethylene, 1,2-trans-	Not Monitored	Monitored	Not Monitored	Monitored
Dichloropropane, 1,2-	Not Monitored	Monitored	Not Monitored	Monitored
Dichloropropylene, 1,3- (cis)	Not Monitored	Monitored	Not Monitored	Monitored
Dichloropropylene, 1,3- (trans)	Not Monitored	Monitored	Not Monitored	Monitored
Ethylbenzene	Not Monitored	Monitored	Not Monitored	Monitored
Methyl bromide	Not Monitored	Monitored	Not Monitored	Monitored
Methyl chloride	Not Monitored	Monitored	Not Monitored	Monitored
Tetrachloroethane, 1,1,2,2-	Not Monitored	Monitored	Not Monitored	Monitored
Toluene	Not Monitored	Monitored	Not Monitored	Monitored
Trichloroethane, 1,1,1-	Not Monitored	Monitored	Not Monitored	Monitored
Trichloroethane, 1,1,2-	Not Monitored	Monitored	Not Monitored	Monitored
Trichloroethylene	Not Monitored	Monitored	Not Monitored	Monitored
Trichlorofluoromethane	Not Monitored	Monitored	Not Monitored	Monitored
Vinyl chloride	Not Monitored	Monitored	Not Monitored	Monitored

TABLE 4.5 (Cont'd.)

Upstream/Downstream Monitoring Parameters

Persistent Toxic Chemicals of Concern

Chemical	1984-86	1986-87	1987-88	1988-89
Dichlorophenol, 2,4-	NEW '89	NEW '89	NEW '89	Monitored
Dichlorophenol, 2,3-	NEW '89	NEW '89	NEW '89	Monitored
Dichlorophenol, 2,6-	NEW '89	NEW '89	NEW '89	Monitored
Chloro-m-cresol, p-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 2,3,5-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 2,4,6-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 2,4,5-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 2,3,4-	NEW '89	NEW '89	NEW '89	Monitored
Dichlorophenol, 3,5-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 3,4,6-	NEW '89	NEW '89	NEW '89	Monitored
Dichlorophenol, 3,4-	NEW '89	NEW '89	NEW '89	Monitored
Trichlorophenol, 3,4,5-	NEW '89	NEW '89	NEW '89	Monitored
Pentachlorophenol	NEW '89	NEW '89	NEW '89	Monitored
Phenol	NEW '89	NEW '89	NEW '89	Monitored
Chlorophenol, 2-	Not Monitored	Monitored	Not Monitored	Monitored
Dimethylphenol, 2,4-	Not Monitored	Monitored	Not Monitored	Monitored
Dinitrophenol, 2,4-	Not Monitored	Monitored	Not Monitored	Monitored
Dinitro-o-cresol, 4,6-	Not Monitored	Monitored	Not Monitored	Monitored
Nitrophenol, 2-	Not Monitored	Monitored	Not Monitored	Monitored
Nitrophenol, 4-	Not Monitored	Monitored	Not Monitored	Monitored
Tetrachlorophenol, 2,3,4,5-	Not Monitored	Monitored	Not Monitored	Monitored
BHC (alpha-)	Monitored	Monitored	Monitored	Monitored
BHC (gamma-)	Monitored	Monitored	Monitored	Monitored
Heptachlor	Monitored	Monitored	Monitored	Monitored
Aldrin	Monitored	Monitored	Monitored	Monitored
Heptachlor epoxide	Monitored	Monitored	Monitored	Monitored
Chlordane, GAMMA	Monitored	Monitored	Monitored	Monitored
Chlordane, ALPHA	Monitored	Monitored	Monitored	Monitored
DDE (p,p)	Monitored	Monitored	Monitored	Monitored
Dieldrin	Monitored	Monitored	Monitored	Monitored
Endrin	Monitored	Monitored	Monitored	Monitored
DDT (o,p)	Monitored	Monitored	Monitored	Monitored
DDD (p,p)	Monitored	Monitored	Monitored	Monitored
DDT (p,p)	Monitored	Monitored	Monitored	Monitored
Endosulphan (alpha-)	Monitored	Monitored	Monitored	Monitored
Endosulphan (beta-)	Monitored	Monitored	Monitored	Monitored
Mirex	Monitored	Monitored	Monitored	Monitored
Methoxychlor	Monitored	Monitored	Monitored	Monitored

TABLE 4.5 (Cont'd.)

Upstream/Downstream Monitoring Parameters

Persistent Toxic Chemicals of Concern

Chemical	1984-86	1986-87	1987-88	1988-89
PCB, Total all congeners	Monitored	Monitored	Monitored	Monitored
Hexachlorobutadiene	Monitored	Monitored	Monitored	Monitored
PCB Arochlor 1221	Congeners not speciated - total only			
PCB Arochlor 1232	Congeners not speciated - total only			
PCB Arochlor 1242	Congeners not speciated - total only			
PCB Arochlor 1016	Congeners not speciated - total only			
PCB Arochlor 1254	Congeners not speciated - total only			
PCB Arochlor 1260	Congeners not speciated - total only			
PCB Arochlor 1248	Congeners not speciated - total only			
BHC (beta-)	Not Monitored	Monitored	Not Monitored	Monitored
BHC (delta-)	Not Monitored	Monitored	Not Monitored	Monitored
Chlordane	Isomers identified separately			
D, 2,4-	Not Monitored	Monitored	Not Monitored	Monitored
Endosulphan sulphate	Not Monitored	Monitored	Not Monitored	Monitored
Endrin aldehyde	Not Monitored	Monitored	Not Monitored	Monitored
Octachlorostyrene	Not Monitored	Monitored	Not Monitored	Monitored
Toxaphene	Not Monitored	Monitored	Not Monitored	Monitored
Naphthalene	Monitored	NEW '89	NEW '89	Monitored
Methylnaphthalene, 2-	NEW '89	NEW '89	NEW '89	Monitored
Methylnaphthalene, 1-	NEW '89	NEW '89	NEW '89	Monitored
Chloronaphthalene, 2-	NEW '89	NEW '89	NEW '89	Monitored
Acenaphthylene	NEW '89	NEW '89	NEW '89	Monitored
Fluorene	Monitored	NEW '89	NEW '89	Monitored
Anthracene	Monitored	NEW '89	NEW '89	Monitored
Phenanthrene	Monitored	NEW '89	NEW '89	Monitored
Fluoranthene	Monitored	Monitored	Monitored	Monitored
Pyrene	Monitored	Monitored	Monitored	Monitored
Benz(a)anthracene	Monitored	Monitored	Monitored	Monitored
Chrysene	Monitored	Monitored	Monitored	Monitored
Benzo(b)fluoranthene	Monitored	Monitored	Monitored	Monitored
Benzo(k)fluoranthene	Monitored	Monitored	Monitored	Monitored
Benzo(a)pyrene	Monitored	Monitored	Monitored	Monitored
Indeno(1,2,3-cd)pyrene	NEW '89	NEW '89	NEW '89	Monitored
Dibenzo(a,h)anthracene	NEW '89	NEW '89	NEW '89	Monitored
Benzo(g,h,i)perylene	NEW '89	NEW '89	NEW '89	Monitored
Acenaphthene	Monitored	Monitored	Monitored	Monitored

TABLE 4.5 (Cont'd.)

Upstream/Downstream Monitoring Parameters

Persistent Toxic Chemicals of Concern

Chemical	1984-86	1986-87	1987-88	1988-89
Tetrachlorodibenzo-p-dioxin, 2,3,7,8-	NEW '89	NEW '89	NEW '89	Monitored
Heptachlorodibenzofuran	Monitored	Monitored	Not Monitored	Monitored
Heptachlorodibenzo-p-dioxin	Not Monitored	Monitored	Not Monitored	Monitored
Hexachlorodibenzofuran	Not Monitored	Monitored	Not Monitored	Monitored
Hexachlorodibenzo-p-dioxin	Monitored	Monitored	Not Monitored	Monitored
Octachlorodibenzofuran	Monitored	Monitored	Not Monitored	Monitored
Octachlorodibenzo-p-dioxin	Monitored	Monitored	Not Monitored	Monitored
Pentachlorodibenzofuran	Not Monitored	Monitored	Not Monitored	Monitored
Pentachlorodibenzo-p-dioxin	Not Monitored	Monitored	Not Monitored	Monitored
Tetrachlorodibenzofuran	Not Monitored	Monitored	Not Monitored	Monitored
Dimethylphthalate	NEW '89	NEW '89	NEW '89	Monitored
Diethylphthalate	NEW '89	NEW '89	NEW '89	Monitored
Di-n-butylphthalate	NEW '89	NEW '89	NEW '89	Monitored
Butylbenzylphthalate	NEW '89	NEW '89	NEW '89	Monitored
bis(2-Ethylhexyl)phthalate	Monitored	NEW '89	NEW '89	Monitored
Di-n-octylphthalate	NEW '88	NEW '88	Monitored	Monitored
Benzidene	Not Monitored	Monitored	Not Monitored	Monitored
bis(2-chloroethoxy) methane	Not Monitored	Monitored	Not Monitored	Monitored
bis(2-Chloroethyl)ether	Not Monitored	Monitored	Not Monitored	Monitored
bis(2-chloroisopropyl) ether	Not Monitored	Monitored	Not Monitored	Monitored
Bromophenyl phenyl ether, 4-	Not Monitored	Monitored	Not Monitored	Monitored
Chlorophenyl phenyl ether, 4-	Not Monitored	Monitored	Not Monitored	Monitored
Dichlorobenzidine, 3,3'-	Not Monitored	Monitored	Not Monitored	Monitored
Dinitrotoluene, 2,4-	Not Monitored	Monitored	Not Monitored	Monitored
Dinitrotoluene, 2,6-	Not Monitored	Monitored	Not Monitored	Monitored
Diphenylamine	Not Monitored	Monitored	Not Monitored	Monitored
Diphenylhydrazine, 1,2-	Not Monitored	Monitored	Not Monitored	Monitored
Hexachlorocyclopentadiene	Not Monitored	Monitored	Not Monitored	Monitored
Hexachloroethane	Not Monitored	Monitored	Not Monitored	Monitored
Isophorone	Not Monitored	Monitored	Not Monitored	Monitored
Nitrobenzene	Not Monitored	Monitored	Not Monitored	Monitored
n-Nitrosodimethylamine	Not Monitored	Monitored	Not Monitored	Monitored
n-Nitrosodiphenylamine	Not Monitored	Monitored	Not Monitored	Monitored
n-Nitrosodi-n-propylamine	Not Monitored	Monitored	Not Monitored	Monitored
Trichlorotoluene, 2,4,5-	Not Monitored	Monitored	Not Monitored	Monitored

TABLE 4.5 (Cont'd.)

Upstream/Downstream Monitoring Parameters

Persistent Toxic Chemicals of Concern

Chemical	1984-86	1986-87	1987-88	1988-89
Dichlorobenzene, 1,2-	Monitored	Monitored	Monitored	Monitored
Dichlorobenzene, 1,3-	Monitored	Monitored	Monitored	Monitored
Dichlorobenzene, 1,4-	Monitored	Monitored	Monitored	Monitored
Trichlorobenzene, 1,3,5-	Monitored	Monitored	Monitored	Monitored
Trichlorobenzene, 1,2,4-	Monitored	Monitored	Monitored	Monitored
Trichlorobenzene, 1,2,3-	Monitored	Monitored	Monitored	Monitored
Tetrachlorobenzene, 1,2,3,4-	Monitored	Monitored	Monitored	Monitored
Pentachlorobenzene	Monitored	Monitored	Monitored	Monitored
Hexachlorobenzene	Monitored	Monitored	Monitored	Monitored
Tetrachlorobenzene, 1,2,3,5-	Not Monitored	Monitored	Not Monitored	Monitored
Tetrachlorobenzene, 1,2,4,5-	Not Monitored	Monitored	Not Monitored	Monitored
Atrazine	NEW '89	NEW '89	NEW '89	Monitored
Metolachlor	NEW '89	NEW '89	NEW '89	Monitored
Asbestos	Not Monitored	Monitored	Not Monitored	Monitored
Cyanide	Not Monitored	Monitored	Not Monitored	Monitored
Lithium	Monitored	Monitored	Monitored	Monitored
Aluminum	Monitored	Monitored	Monitored	Monitored
Vanadium	Monitored	Monitored	Monitored	Monitored
Chromium	Monitored	Monitored	Monitored	Monitored
Manganese	Monitored	Monitored	Monitored	Monitored
Iron	Monitored	Monitored	Monitored	Monitored
Cobalt	Monitored	Monitored	Monitored	Monitored
Nickel	Monitored	Monitored	Monitored	Monitored
Copper	Monitored	Monitored	Monitored	Monitored
Zinc	Monitored	Monitored	Monitored	Monitored
Arsenic	Monitored	Monitored	Monitored	Monitored
Selenium	Monitored	Monitored	Monitored	Monitored
Strontium	Monitored	Monitored	Monitored	Monitored
Molybdenum	Monitored	Monitored	Monitored	Monitored
Silver	Monitored	Monitored	Monitored	Monitored
Cadmium	Monitored	Monitored	Monitored	Monitored
Antimony	Monitored	Monitored	Monitored	Monitored
Barium	Monitored	Monitored	Monitored	Monitored
Lead	Monitored	Monitored	Monitored	Monitored
Mercury	Monitored	Monitored	Monitored	Monitored
Beryllium	Monitored	Monitored	Monitored	Monitored
Thallium	Not Monitored	Monitored	Not Monitored	Monitored
Tetraethyl lead	Not Monitored	Monitored	Not Monitored	Monitored

TABLE 4.6

Priority Pollutant List

United States Environmental Protection Agency

Class	Chemical	Class	Chemical	Class	Chemical
PAH	Acenaphthene	VOL	Methylene chloride	VOL	Vinyl chloride
VOL	Acrolein	VOL	Methyl chloride	PES	Aldrin
VOL	Acrylonitrile	VOL	Methyl bromide	PES	Dieldrin
VOL	Benzene	VOL	Bromoform	PES	Chlordane
BN	Benzidene	VOL	Dichlorobromomethane	PES	DDT (p,p)
VOL	Carbon tetrachloride	VOL	Trichlorofluoromethane	PES	DDE (p,p)
VOL	Chlorobenzene	VOL	Dichlorodifluoromethane	PES	DDD (p,p)
BN	1,2,4-Trichlorobenzene	VOL	Chlorodibromomethane	PES	Endosulphan (alpha-)
BN	Hexachlorobenzene	BN	Hexachlorobutadiene	PES	Endosulphan (beta-)
VOL	1.2-Dichloroethane	BN	Hexachlorocyclopentadiene	PES	Endosulphan sulphate
VOL	1,1,1-Trichloroethane	BN	Isophorone	PES	Endrin
BN	Hexachloroethane	PAH	Naphthalene	PES	Endrin aldehyde
VOL	1,1-Dichloroethane	BN	Nitrobenzene	PES	Heptachlor
VOL	1,1,2-Trichloroethane	AE	2-Nitrophenol	PES	Heptachlor epoxide
VOL	1,1,2,2-Tetrachloroethane	AE	4-Nitrophenol	PES	BHC (alpha-)
VOL	Chloroethane	AE	2,4-Dinitrophenol	PES	BHC (beta-)
	bis(Chloromethyl)ether	AE	4,6-Dinitro-o-cresol	PES	BHC (gamma-)
BN	bis(2-Chloroethyl)ether	BN	n-Nitrosodimethylamine	PES	BHC (delta-)
VOL	2-Chloroethylvinyl ether	BN	n-Nitrosodiphenylamine	PCB	PCB Arochlor 1242
PAH	2-Chloronaphthalene	BN	n-Nitrosodi-n-propylamine	PCB	PCB Arochlor 1254
AE	2,4,6-Trichlorophenol	AE	Pentachlorophenol	PCB	PCB Arochlor 1221
AE	p-Chloro-m-cresol	AE	Phenol	PCB	PCB Arochlor 1232
VOL	Chloroform	BN	bis(2-Ethylhexyl)phthalate	PCB	PCB Arochlor 1248
AE	2-Chlorophenol	BN	Butylbenzylphthalate	PCB	PCB Arochlor 1260
BN	1,2-Dichlorobenzene	BN	Di-n-butylphthalate	PCB	PCB Arochlor 1016
BN	1,3-Dichlorobenzene	BN	Di-n-octylphthalate	PES	Toxaphene
BN	1,4-Dichlorobenzene	BN	Diethylphthalate	MET	Silver
BN	3,3'-Dichlorobenzidine	BN	Dimethylphthalate	MET	Arsenic
VOL	1,1-Dichloroethylene	PAH	Benz(a)anthracene	MET	Beryllium
VOL	1,2-trans-Dichloroethylene	PAH	Benzo(a)pyrene	MET	Cadmium
AE	2,4-Dichlorophenol	PAH	Benzo(b)fluoranthene	MET	Chromium
VOL	1,2-Dichloropropane	PAH	Benzo(k)fluoranthene	MET	Copper
VOL	1,3-Dichloropropylene (cis-)	PAH	Chrysene	MET	Mercury
VOL	1,3-Dichloropropylene (trans-)	PAH	Acenaphthylene	MET	Lead
AE	2,4-Dimethylphenol	PAH	Anthracene	MET	Nickel
BN	2,4-Dinitrotoluene	PAH	Benzo(g,h,i)perylene	MET	Antimony
BN	2,6-Dinitrotoluene	PAH	Fluorene	MET	Selenium
BN	1,2-Diphenylhydrazine	PAH	Phenanthrene	MET	Thallium
VOL	Ethylbenzene	PAH	Dibenzo(a,h)anthracene	MET	Zinc
PAH	Fluoranthene	PAH	Indene(1,2,3-cd)pyrene	IN	Cyanide
BN	4-Chlorophenyl phenyl ether	PAH	Pyrene	MET	Asbestos
BN	4-Bromophenyl phenyl ether	VOL	Tetrachloroethylene	BN	2,3,7,8-TCDD
BN	bis(2-chloroisopropyl) ether	VOL	Toluene		
BN	bis(2-chloroethoxy) methane	VOL	Trichloroethylene		

Class Definition:

AE - Acid Extractable Organics
BN - Base-Neutral Extractable Organics
PAH - Base Neutral Extractable PAH's
PCB - Polychlorinated Biphenyl Isomers
VOL - Volatile (Purgable) Organics
PES - Pesticides
MET - Metals and Asbestos
INO - Other Inorganic Compounds

TABLE 4.7(a)

Persistence Determination

Chemical	KOW	MW	log BCF	Carcinogenicity
CHLOROBENZENES				
hexachlorobenzene	5.23	284.78	3.89	2
pentachlorobenzene	5.19	250.34	3.70	-1
1,2,3,4-tetrachlorobenzene	4.99	215.90		-1
1,2,4,5-tetrachlorobenzene	4.97	215.90		-1
1,2,3,5-tetrachlorobenzene	4.46	215.90		-1
1,2,3-trichlorobenzene	4.26	181.50		-1
1,3,5-trichlorobenzene	4.26	181.50	2.36	-1
1,2,4-trichlorobenzene	4.23	181.50	3.32	-1
1,2-dichlorobenzene	3.38	147.01	3.00	-1
1,3-dichlorobenzene	3.38	147.01	3.00	-1
1,4-dichlorobenzene	3.38	147.01	2.33	-1
CHLOROPHENOLS				
pentachlorophenol	5.01	266.40	2.89	1
2,3,4,5-tetrachlorophenol	4.10	231.89		-1
2,4,5-trichlorophenol	3.84	197.50	3.28	-1
2,3,5-trichlorophenol	3.70	197.50		-1
2,4,6-trichlorophenol	3.62	197.50		2
2,3,4-trichlorophenol	3.61	197.50		-1
3,4-dichlorophenol	3.13	163.00		-1
2,3-dichlorophenol	3.10	163.00		-1
2,4-dichlorophenol	3.08	163.00	1.53	2
2,6-dichlorophenol	2.88	163.00		-1
HALOGENATED ALICYCLICS				
gamma BHC	3.89	290.85	12.15	2
alpha BHC	3.36	290.85	12.26	2
HALOGENATED ALIPHATICS				
hexachlorobutadiene	3.74	260.74	3.00	2
carbon tetrachloride	2.64	153.82	1.24	2
tetrachloroethylene	2.53	165.83	1.69	2
trichloroethylene	2.47	131.50		2
tribromoethylene	2.30	252.77	2.64	1
1,2-dichlorethylene	2.00	96.95		-1
chlorodibromoethane	2.00	208.29		-1
chloroform	1.95	119.39	0.78	2
1,2-dichloroethane	1.79	98.96		2
methylene chloride	1.51	89.94		-1
OTHER CHLORINATED COMPOUNDS				
octachlorostyrene	6.29	376.00	4.52	-1
Total PCB's	5.00	4.70		2
methoxychlor	4.30	345.65	3.92	0
toxaphene	3.30	413.80	4.88	2
MIREX AND DERIVATIVES				
mirex	6.89	545.49	4.26	2
photomirex	6.00	511.06		-1

TABLE 4.7(b)

Persistence Determination

Chemical	KOW	MW	log BCF	Carcinogenicity
DIOXINS AND FURANS				
08CDF	6.70	443.72		-1
H7CDF	6.50	409.28		-1
08CDD	6.50	459.72		1
H6CDF	6.30	374.84		-1
H7CDD	6.30	425.28		-1
H6CDD	6.10	390.84		-1
P5CDF	6.00	340.40		-1
P5CDD	5.80	356.40		-1
2,3,7,8-TCDF	5.70	305.96		-1
T4CDF	5.70	305.96		-1
T4CDD	5.50	321.96	3.67	2
DDT AND METABOLITES				
DDE	5.69	318.03	4.71	2
TDE	5.75	320.05	3.43	1
o,p' DDT	5.75	354.50	4.57	-1
p,p' DDT	5.75	354.50	4.47	2
CHLORINATED PHENOXY COMPOUNDS				
silvex	3.93	269.50		-1
2,4,5-T	3.72	255.49		1
2,4-D	2.81	221.04	1.74	1
CYCLODIENES				
aldrin	5.67	364.93	3.10	1
dieldrin	5.48	380.93	4.11	2
heptachlor	5.44	373.35	4.30	2
heptachlor expoxide	5.40	389.30	4.16	2
chlordane	5.16	409.80	2.51	2
endrin	4.56	380.93	3.17	0
endosulphan	3.60	406.95		0
PHTHALATES				
dioctyl phthalate	4.00	390.62	3.97	2
bis-2-ethyl-hexyl phthalate	5.11	390.62	2.93	2
AROMATICS				
ethylbenzene	3.15	106.17		-1
benzene	2.11	78.12	1.10	2
aniline	0.90	93.13		1

TABLE 4.7(c)

Persistence Determination

Chemical	KOW	MW	log BCF	Carcinogenicity
POLYCYCLIC AROMATIC HYDROCARBONS				
benzo(k)fluoranthene	6.06	252.32		-1
benzo(a)pyrene	6.06	252.30	1.85	2
benzo(g,h,i)perylene	6.05	276.00		-1
indenopyrene	6.00	276.34		-1
chrysene	5.61	228.20		2
fluoranthene	5.33	202.00		-1
benzo(b)fluoranthene	5.22	254.04		2
pyrene	4.88	202.26	3.43	0
acenapthalene	4.50	152.20		-1
phenanthrene	4.46	178.22	3.42	0
anthracene	4.34	178.23	2.96	0
dibenz(a,h)anthracene	4.32	278.35		2
fluorene	4.18	166.22		0
monochloronapthalene	4.12	163.00		-1
acenapthene	3.92	154.21	2.59	-1
naphthalene	3.45	128.17	2.63	1
ORGANOMETALS				
tetraethyllead	6.12		4.00	-1
INORGANIC CHEMICALS				
Ag		107.87	>2.15	2
Al		26.98		-1
As		74.92		1
Cd		112.40	2.32	2
Cu		63.55	2.17	-1
Fe		55.85		-1
Hg		200.59	3.70	1
Mn		54.94		-1
Ni		58.71	1.78	2
Pb		207.20	3.00	1
Sb		121.75	0.00	-1
Se		78.96	0.80	1
Zn		65.37		-1

LEGEND:

KOW -octanol/water coefficient determines miscibility of chemical
MW -molecular weight of the chemical
log BCF - chemical uptake has a logrithmic relationship
BCF -Bio-Concentration Factor
Carcinogenicity is rated on a scale of -2(low) to +2(extreme)

TABLE 4.7(d)

Acute Toxicity Values

Chemical	KOW	LC50 (m moles/L) Rainbow Trout	Bluegills	Fathead Minnows
CHLOROBENZENES				
hexachlorobenzene	5.23		0.000430	
pentachlorobenzene	5.19	0.009800	0.001000	0.001000
1,2,3,4-tetrachlorobenzene	4.99	0.002300		0.005100
1,2,4,5-tetrachlorobenzene	4.97		0.007410	0.007200
1,2,3,5-tetrachlorobenzene	4.46	0.007100	0.029600	
1,2,3-trichlorobenzene	4.26			0.275000
1,3,5-trichlorobenzene	4.26			0.275000
1,2,4-trichlorobenzene	4.23		0.018700	0.016000
1,2-dichlorobenzene	3.38	0.017000	0.038100	0.388000
1,3-dichlorobenzene	3.38	0.006000	0.034000	0.053000
1,4-dichlorobenzene	3.38	0.009900	0.029000	0.027000
CHLOROPHENOLS				
pentachlorophenol	5.01	0.000600	0.000720	0.000852
2,3,4,5-tetrachlorophenol	4.10			
2,4,5-trichlorophenol	3.84			0.002300
2,3,5-trichlorophenol	3.70			
2,4,6-trichlorophenol	3.62	0.002900	0.001600	0.003000
2,3,4-trichlorophenol	3.61			
3,4-dichlorophenol	3.13			
2,3-dichlorophenol	3.10			
2,4-dichlorophenol	3.08	0.016000	0.012400	0.050000
2,6-dichlorophenol	2.88	0.016000	0.012000	
HALOGENATED ALICYCLICS				
gamma BHC	3.89	0.000090	0.000230	0.000090
alpha BHC	3.36			0.000258
HALOGENATED ALIPHATICS				
hexachlorobutadiene	3.74		0.001250	0.000390
carbon tetrachloride	2.64	0.810000	0.346000	0.170000
tetrachloroethylene	2.53		0.078000	0.081200
trichloroethylene	2.47			0.309500
tribromoethane	2.30		0.114800	0.115000
1,2-dichloroethylene	2.00			
chlorodibromoethane	2.00			
chloroform	1.95	0.510000		
1,2-dichloroethane	1.79		4.350000	1.192000
methylene chloride	1.51	2.490000		2.146000
OTHER CHLORINATED COMPOUNDS				
octachlorostyrene	6.29		0.001760	
Total PCB's	5.00			
methoxychlor	4.30	0.000064	0.000179	0.000110
toxaphene	3.30	0.000013	0.000045	0.000034
MIREX AND DERIVATIVES				
mirex	6.89	>0.183	>0.183	>0.183
photomirex	6.00			

TABLE 4.7(e)

Acute Toxicity Values

Chemical	KOW	LC50 (m moles/L) Rainbow Trout	Bluegills	Fathead Minnows
DIOXINS AND FURANS				
08CDF	6.70			
H7CDF	6.50			
08CDD	6.50			
H6CDF	6.30			
H7CDD	6.30			
H6CDD	6.10			
P5CDF	6.00			
P5CDD	5.80			
2,3,7,8 TCDF	5.70			
T4CDF	5.70			
T4CDD	5.50			1.74e-10
DDT AND METABOLITES				
DDE	5.69	0.000100	0.001260	
TDE	5.75	0.000220	0.000130	0.013700
o,p' DDT	5.75			
p,p'DDT	5.75	0.000027	0.000023	0.000054
CHLORINATED PHENOXY COMPOUN				
silvex	3.93	0.054900	0.035600	0.001300
2,4,5-T	3.72	0.003800	0.001760	>0.0391
2,4-D	2.81	0.004980	0.004100	0.000600
CYCLODIENES				
aldrin	5.67	0.000020	0.000040	0.000036
dieldrin	5.48	0.000026	0.000021	0.000042
heptachlor	5.44	0.000051	0.000509	0.000019
heptachlor epoxide	5.40	0.000051	0.000014	
chlordane	5.16	0.000050	0.000140	0.000090
endrin	4.56	0.000018	0.000016	0.000016
endosulphan	3.60	0.000740	0.000010	0.000002
PHTHALATES				
dioctyl phthalate	4.00			
bis-2-ethyl-hexyl phthalate	5.11	>0.256	>0.256	>0.256
AROMATICS				
ethylbenzene	3.15	0.033800	0.330200	0.398400
benzene	2.11	0.103000	0.280000	0.410000
aniline	0.90	0.389000		

TABLE 4.7(f)

Acute Toxicity Values

Chemical	KOW	LC50 (m moles/L) Rainbow Trout	Bluegills	Fathead Minnows
POLYCYCLIC AROMATIC HYDROCARBONS				
benzo(d)fluoranthene	6.06			
benzo(a)pyrene	6.06			
benzo(g,h,i)perylene	6.05			
indenopyrene	6.00			
chrysene	5.61			
fluoranthene	5.33		0.019800	
benzo(b)fluoranthene	5.22			
pyrene	4.88	0.000150		
acenaphthalene	4.50			
phenanthrene	4.46			
anthracene	4.34			
dibenz(a,h)anthracene	4.32			
fluorene	4.18		0.004600	
monochloronaphthalene	4.12		0.013900	
acenapthene	3.92		0.006000	
naphthalene	3.45	0.005500		0.053800
ORGANOMETALS				
tetraethyllead	6.12	0.000034		
INORGANIC CHEMICALS				
Ag		0.000121		0.000370
Al				7.400000
As		0.356400		0.198000
Cd		0.000089		0.007400
Cu		0.002400	0.055000	0.003900
Fe		>0.18		
Hg			0.000800	0.000790
Mn				
Ni		0.545100		0.048000
Pb		0.005790	0.114900	0.031200
Sb				0.074000
Se		0.072200		0.028400
Zn		0.030000	0.229000	0.121000

LEGEND:
KOW -octanol/water coefficient determines miscibility of chemical
LC50 -concentration which is lethal to 50% of the test organisms

TABLE 4.7(g)

Chemical Properties

Chemical	CAS NO	MW	log KOW	log BCF
CHLOROBENZENES				
2,4,5-trichlorotoluene	6639-30-1	195.47	4.94	
chlorobenzene	108-90-7	112.60	2.84	2.650
CHLOROPHENOLS				
p-chloro-m-cresol	59-50-7	142.89	3.10	
2-chlorophenol	95-57-8	128.56	2.19	2.330
NITROPHENOLS				
4 nitrophenol	100-02-7	139.11	1.91	2.100
2 nitrophenol	88-75-5	139.11	1.77	
2,4 dinitrophenol	51-28-5	184.11	1.51	
4,6 dinitro-o-cresol	524-52-1	198.13	1.07	
ALKYLPHENOLS				
2,4 dimethylphenol	105-67-9	122.16	2.42	2.180
Phenol	108-95-2	94.10	1.49	
AROMATICS				
Diphenylamine	122-39-4	169.23	3.59	1.480
1,2 diphenyldrazine	122-66-7	184.26	3.03	
Styrene	100-42-5	104.14	2.95	
Toluene	108-88-3	92.14	2.69	1.850
Benzidine	92-87-5	184.26	1.81	
NITRO AROMATICS				
2,4 dinitrotoluene	121-14-2	182.15	2.10	
2,6 dinitroatoluene	606-20-2	182.15	2.00	
nitrobenzene	98-95-3	123.12	1.88	1.180
SMALL HALOGENATED ALIPHATICS				
Hexachloroethane	67-72-1	236.76	3.93	2.140
1,1,2-trichloroethane	79-00-5	133.41	2.42	
1,1,2,2-tetrachloroethane	79-34-5	167.85	2.39	0.900
1,1,1-trichloroethane	71-55-6	133.41	2.17	0.950
1,2 dichloropropane	78-87-5	112.99	2.16	
1,1 dichloropropane	75-34-3	98.96	1.79	
cis 1,3 dichloropropane	10061-01-5	110.97	1.74	
Chloroethane	75-00-3	64.52	1.54	
1,1-dichloroethylene	75-35-4	96.95	1.48	
Chloroethylene	75-01-4	62.50	1.40	
bromomethane(methylbromide)	74-83-9	94.95	1.19	
chloromethane(methylchloride)	74-87-3	50.49	0.91	
HALOETHERS				
4 bromophenyl phenyl ether			5.07	
4 chlorophenyl phenyl ether			4.92	
Bis(2-chloroethoxy)methane	111-91-1	173.05	1.50	
Bis(s-chloroisopropyl)ether	108-60-1	171.08	1.12	1.040
2 chloroethyl vinyl ether	110-75-8	106.55	1.00	
bis(2-chloroethyl)ether	111-44-4	143.01	0.95	

TABLE 4.7(h)

Chemical Properties

Chemical	CAS NO	MW	log KOW	log BCF
CYCLODIENES				
Hexachlorocyclopentadiene	77-47-4	272.75	3.99	1.040
Endosulfan	115-29-7	406.91	3.60	
Endrin Aldehyde				
PHTHALATES				
Di-n-butylphthalate	84-74-2	278.34	5.20	3.820
Butylbenzylphthalate	85-68-7	312.40	4.73	2.820
Dimethylphthalate	131-11-3	194.18	1.61	1.760
Diethylphthalate	84-66-2	222.24	1.40	2.070
POLYCYCLIC AROMATIC HYDROCARBONS				
benzo(b)fluoranthene	205-99-2	252.32	6.20	
Benzo(a)anthracene	56-55-3	228.30	5.61	4.000
1-methylnaphthalene	90-12-0	142.20	3.96	2.480
2-methylnaphthalene	91-57-6	142.20	3.95	2.480
NITROSOAMINES				
N-nitrosodiphenylamine	156-10-5	198.23	3.13	
N-nitrosodipropylamine	621-64-7	130.22	1.50	
n-nitrosodimethylamine	62-75-9	74.08	-0.57	
OTHER ORGANIC CHEMICALS				
3,3' dichlorobenzidine	91-94-1	253.14	2.76	2.700
Isophorone	78-59-1	138.21	1.67	0.850
Acrylontrile	107-13-1	53.06	1.20	
Acrolein	107-02-8	56.10	0.90	2.540
INORGANIC CHEMICALS				
Asbestos	1332-21-4			
Thallium	7440-28-0	204.37		
Chromium	7440-47-3	52.00		2.301

LEGEND:

KOW	-octanol/water coefficient determines miscibility of chemical
MW	-molecular weight of the chemical
log BCF	-chemical uptake has a logrithmic relationship
BCF	-Bio-Concentration Factor
CAS NO	-Chemical Abstracts Service registration number

TABLE 4.9

List of Aquatic Criteria, Objectives and Standards

(Values are ug/l)

Chemical	EPA Aquatic	EPA Health	DEC Aquatic	DEC Health	IJC	MOE	EC
Aldrin			0.001(c)	0.002	0.001(c)	0.001(c)	0.004(c)
Benzo(a)pyrene			0.0012	0.002			
Benzo(b)fluoranthene				0.002			
Benzo(k)fluoranthene				0.002			
Benz(a,h)anthracene				0.002			
BHC, alpha-			0.01	0.02			
BHC, gamma-			0.01	0.02			
Bis(2-ethylhexyl)phthalate			0.6	4		0.6	
Cadmium	1.1(b)	10	1.5	10	0.2	0.2	0.8(b)
Carbon tetrachloride				0.4			
Chlordane	0.0043		0.002	0.02	0.06	0.06	0.006
Chloroform	1240(a)			0.2			
Chromium	note 1	note 2	279	50		100	2
Chrysene				0.002			
DDT and metabolites	0.001		0.001	0.01	0.003	0.003	0.001
Dichloroethane, 1,2-	20000(a)			0.8			
Dieldrin	0.0019		0.001(c)	0.0009	0.001(c)	0.001(c)	0.004(c)
Di-n-octyl phthalate				50			
Endosulphan, alpha-	0.056		0.009			0.003	0.02
Endrin	0.0023	0.2	0.002	0.2	0.002	0.002	0.0023
Fluoranthene				50			
Heptachlor	0.0038		0.001(d)	0.009(d)	0.001(d)	0.001(d)	0.01(d)
Heptachlor epoxide			0.001(d)	0.009(d)	0.001(d)	0.001(d)	0.01(d)
Hexachlorobenzene				0.02		0.0065	0.0065
Hexachlorobutadiene	9.3(a)		1	0.5			0.1
Hexachloroethane	540(a)						
Lead	3.2(b)	50	5.1	50	25	7	2(b)
Mercury	0.012	2	0.2	2	0.2	0.2	0.1
Methoxychlor	0.03	100	0.03	35	0.04	0.04	
Mirex	0.001		0.001	0.04		0.001	
Naphthalene	620(a)				10		
PCBs, total	0.014		0.001	0.01		0.001	0.001
Pentachlorophenol	13(e)		0.4	1		0.5	0.5
Pyrene				50			
Tetrachlorobenzene				10		0.1	0.1
Tetrachlorodibenzofuran							
Tetrachlorodibenzo-p-dioxin	0.00001		0.00001				
Tetrachloroethylene	840(a)		1	0.7			260
Trichlorobenzene, 1,2,3-			5	10		0.9	0.9
Trichlorobenzene, 1,2,4-			5	10		0.5	0.5
Trichlorobenzene, 1,3,5-			5	10		0.65	0.65
Trichlorophenol, 2,4,6-	970(a)		1	1			

a =insufficient data to develop criterion, value presented is lowest observed effect level
b =hardness dependent criterion (100mg/l used)
c =sum of aldrin and dieldrin
d =sum of heptachlor and heptachlor epoxide
e =pH dependent criterion (pH = 7.8 used)
note 1 - 11ug/l for hexavalent chromium; 210 ug/l for trivalent chromium @ 100mg/l hardness)
note 2 - 50ug/l for both hexavalent and trivalent chromium (@ 100mg/l hardness)

TABLE 4.13

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
GENERAL PARAMETERS			
Total Alkalinity (as CaCO3)	1984-83,1981,1978	93(20)	82.6(10)
Chloride,Unfiltered Reactive (as Cl~)	1984-83,1981	5.8(14)	17.3(4)
Colour (i) HZU	1984-83,1978	<4.3(19)	
	1983,1978		<1.0(7)
(ii) TCU	1984	5.8(1)	
	1984-78		1.3(3)
Fluoride,Unfiltered Reactive (as F~)	1984-83,1981	0.12(3)	0.12(4)
Total Hardness	1984-83,1981,1978	118(20)	111(10)
Nitrate Nitrogen (as N)	1983,1981	0.2(2)	
	1984-1983,1981		0.2(4)
Nitrite Nitrogen (as N)	1981		<0.01(1)
	1984-83,1981		0.0(4)
pH	1984-83,1981,1978	7.7(10)	8.2(20)
Sodium, Unfilt.React.(as Na)	1983	9.0(1)	
	1984-83		8.8(3)
Turbidity	1984-83,1981,	2.9(20)	0.29(10) 1978
MICROBIOLOGICAL			
Bacti Fecal Coliforms	1984	28(48)	
Bacti Fecal Streptococci	1984	12(50)	
Bacti Total Coliforms	1984	182(50)	
Background	1984	22,950(50)	
RADIOLOGICAL			
Alpha, Gross	1980	<1(1)	
Beta, Gross	1980	2(1)	
Cesium Cs 134	1980-1979	<23(2)	
Cs 137	1980-1979	<23(2)	
Cobalt Co 60	1980-1979	<23(2)	
Radium Ra(226)	1980	0.1(1)	
Strontium Sr 89	1980-1979	<0.3(2)	
Sr 90	1980-1979	0.7(2)	

LEGEND:

Concentrations are mg/L (ppm) for parameters on this page (if applicable)
Concentrations are ug/L (ppb) for metals and organic parameters
Numbers in brackets indicate number of samples used to calculate mean

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
INORGANIC			
Aluminum, Unfilt.Tot.(as Al)	1984	143(2)	
	1983	20(1)	77(1)
	1981	66(1)	310(1)
Antimony, Unfilt.Tot.(as Sb)	1984		0(2)
Arsenic, Unfilt.Tot.(as As)	1984		0(2)
	1983	<1(1)	<1(1)
	1981	<1(1)	<1(1)
Barium, Unfilt.Tot.(as Ba)	1984		11
	1983	18(1)	17(1)
	1981	18(1)	17(1)
Beryllium, Unfilt.Tot.(as Be)	1984		0(2)
	1983	<10(1)	<10(1)
Boron, Unfilt.Tot.(as B)	1981	<0.02(1)	<0.03(1)
Cadmium, Unfilt.Tot.(as Cd)	1984		0(2)
	1983	<2(1)	<2(1)
	1981	0.3(1)	0.3(1)
Calcium, Unfilt.Tot.(as Ca)	1984		33.9(2)
	1983	37.5(1)	38.7(1)
Chromium, Unfilt.Tot.(as Cr)	1984		2(2)
	1983	<10(1)	<10(1)
	1981	2	1
Cobalt, Unfilt.Tot.(as Co)	1983	<0.010(1)	<0.010(1)
Copper, Unfilt.Tot.(as Cu)	1984		4(2)
	1983	80(1)	50(1)
	1981	26(1)	5(1)
Cyanide, Avail.Unf.React.(asCN)	1984		4(1)
	1983	0(1)	0(1)
	1981	<10(1)	<10(1)
Iron, Unfilt.Tot.(as Fe)	1984		0.22
	1983	0.07(1)	
	1981	0.025(1)	0.005(1)
Lead, Unfilt.Tot.(as Pb)	1984		0(2)
	1983	<30(1)	<30(1)
	1981	4(1)	<3(1)
Magnesium, Unfilt.Tot.(as Mg)	1984		8.0(2)
	1983	8.90(1)	8.45(1)
Manganese, Unfilt.Tot.(as Mn)	1983	0.000(1)	0.012(1)
	1981	0.002(1)	0.002(1)
Mercury, Unfilt.Tot.(as Hg)	1984		0(2)
	1983	0.01(1)	0.01(1)
Nickel, Unfilt.Tot.(as Ni)	1984		0(2)
	1983	<10(1)	<10(1)
	1981	2(1)	2(1)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
Selenium, Unfilt.Tot.(as Se)	1984		0(2)
	1983	<1	<1
	1981	<1	<1
Silver, Unfilt.Tot.(as Ag)	1984		0(2)
	1983	<5(1)	<5(1)
	1981	<5(1)	<5(1)
Strontium, Unfilt.Tot.(as Sr)	1983	0.160(1)	0.140(1)
Zinc, Unfilt.Tot.(as Zn)	1984		2(2)
	1983	<10(1)	<10(1)
	1981	4(1)	2(1)
ADDITIONAL DATA			
Calcium	1983	27(5)	28(5)
Magnesium	1983	6.9(5)	5.2(5)
Molybdenum	1983	<0.010(1)	<0.010(1)
Sodium	1983	9.0(1)	9.5(1)
	1981	10(1)	10(1)
Titanium	1983	<0.010	<0.010
Vanadium	1983	<0.010	<0.010
VOLATILE ORGANICS			
Benzene	1984		0(2)
	1983	0.1(1)	0.1(1)
	1982	0.0(4)	0.3(14)
	1981	0.3(6)	0.2(5)
	1980	0.3(11)	0.6(9)
	1979	0.030(6)	0.175(3)
	1978	0.18(2)	
Bromoform	1983		0.4(11)
	1982		0.4(21)
	1981		0.3(10)
	1980	0(4)	0.5(11)
	1979		0.4(4)
Carbon tetrachloride	1984		0(2)
	1983	0(1)	0.1(2)
	1982	0(2)	0.3(4)
	1979	0(2)	0.05(1)
Chlorobenzene	1984		0(2)
	1983	0(1)	
	1979		0(2)
Chlorodibromomethane	1984		5(2)
	1983	0(4)	3.9(11)
	1982	0(6)	4.4(21)
	1981	0(4)	4.0(10)
	1980	0(5)	4.0(11)
	1979	0(2)	TR(5)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration Raw Water	Treated Water
Chloroform	1984		12(2)
	1983	0.2(13)	9.8(12)
	1982	0.3(19)	12.7(22)
	1981	0.2(8)	9.1(11)
	1980	<0.2(11)	5.5(11)
	1979	0.1(6)	14.4(5)
	1978		0(1)
Dibromomethane (Methylene bromide)	1984		0(2)
	1982	0.1(2)	0.1(2)
Dichlorobenzene 1,2-	1984		0(1)
	1983	0(2)	
Dichlorobenzene 1,3-	1984		0(2)
Dichlorobenzene 1,4	1984		0(2)
	1982	<0.1(1)	<0.1(1)
Dichlorobromomethane	1982	0.0(1)	4.5(2)
Dichloroethane 1,2-	1984		0(2)
	1982	0.1(1)	
Dichloromethane (Methylene chloride)	1984		0(2)
	1983	0.0(2)	
	1982	8.3(9)	10.6(8)
	1981	0.5(7)	0.67
	1980	1.8(10)	1.4(5)
Dichloropropane 1,2-	1984		0(2)
	1980		0(1)
Hexachlorobutadiene	1984		0(2)
Pentachlorobenzene	1984		0(2)
Styrene	1984		0(2)
	1983	0.1(1)	
	1982	<0.1(1)	
	1980	0(3)	0(1)
Tetrachlorobenzene 1,2,3,4-	1984		0(2)
Tetrachloroethane 1,1,2,2-	1984		0(2)
	1982	0(1)	
Tetrachloroethylene	1983	0(2)	0(1)
	1982	0.1(4)	0.0(4)
	1981	0.0(2)	
	1980	0.0(3)	0.0(1)
	1979	0.0(5)	0.0(4)
Toluene	1983	0.1(10)	0.3(10)
	1982	<0.1(15)	0.4(18)
	1981	0.0(6)	0.1(6)
	1980	0.0(3)	0.1(12)
	1979	0.1(6)	0.05(3)
	1978	0.06(3)	

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration Raw Water	Treated Water
Trichlorobenzene 1,2,3-	1984		0(2)
Trichlorobenzene 1,2,4-	1984		0(2)
Trichlorobenzene 1,3,5-	1984		0(2)
Trichloroethane 1,1,1-	1984		0(2)
	1983	0(1)	
	1982	0(5)	0(2)
	1981	0.1(3)	0.1(3)
	1980	0(3)	0.4(1)
	1979	0.2(1)	
Trichloroethylene	1983	0.0(3)	0.0(1)
	1982	0.1(6)	0.0(6)
	1981	0.1(2)	0.0(4)
	1980	0.0(6)	0.0(4)
	1979	0.007(6)	0.008(4)
	1978	0.0(1)	
Xylene 1,3- (meta-)	1983	0.1(1)	0.1(6)
	1982	0.1(1)	0.1(16)
	1981	0.1(1)	0.1(6)
	1980	0.1(1)	0.2(1)
Xylene 1,4- (para-)	1982	TR(1)	TR(1)
Additional Data			
Acetone	1983	0.3(12)	0.3(10)
	1982	1.0(11)	1.3(14)
	1981	0(1)	0.4(1)
Carbon Disulphide	1983	0(3)	0.1(1)
	1980	0(1)	0(3)
	1979	0(1)	TR(1)
Chlorodibromoethane	1984		0(2)
Chloro(difluorochloromethylbenzene	1984		0(2)
Chlorotoluene	1984		0.0(2)
	1978	0.0(2)	
3-Chloro(trifluoromethylbenzene	1984		0(2)
m-Chlorotrifluorotoluene	1984	0(2)	
Dichlorobenzene	1980	0(2)	
	1978		0(1)
Dichlorobromomethane	1984		5(2)
	1983	0(4)	6.3(11)
	1982	0(2)	8.4(20)
	1981	0(6)	8.6(10)
	1980	0.0(9)	7.0(10)
Methylpentenes	1984		0.0(2)
	1979		TR(1)
Parachlorotrifluorotoluene	1981		0(1)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water
Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
1,2,4,5-Tetrachlorobenzene	1984		0.005(2)
Tetrachloroethane	1984		0(2)
Tetrachlorotoluenes	1984		0(2)
1,1,4-Trichlorobutadiene	1983		0.3(11)
	1982		0.2(18)
	1981		0.2(1)
Trichloroethane	1984		0(2)
	1979	0(1)	0(1)
2,4,5-Trichlorotoluene	1984		0.007(2)
Trichloro-trifluoroethane	1981	0.0(1)	
	1979	0.0(1)	
alpha,alpha,alpha- Tribluoromethylbenzene	1984		0.0(2)
Trimethylbenzenes	1984		0.0(2)
	1978	0.0(1)	
Xylene	1980	0.0(5)	0.0(3)
	1979	0.0(2)	0.0(3)
	1978	0.0(3)	
BASE-NEUTRAL ORGANICS			
Anthracene	1984		0(2)
Benz(a)anthracene	1984		0(2)
Benzo(b)fluoranthene	1984		0(2)
Benzo(k)fluoranthene	1984		0(2)
Benzo(g,h,i)perylene	1984		0(2)
Benzo(a)pyrene	1984		0(2)
bis(2-Ethylhexyl)phthalate	1984		0(2)
Chrysene	1984		0(2)
Fluoranthene	1984		0(2)
Fluorene	1984		0(2)
Phenanthrene	1984		0(2)
Pyrene	1984		0(2)
Additional Data			
Benaldehyde	1984		0(2)
	1981		0(1)
	1980		0(3)
	1980		0(1)
Benzenesufonamide	1984		0(2)
Butanal	1984		0(2)
	1981	0(1)	
	1980	0(3)	0(1)
Butan-2-al	1980	<0.1(3)	0(1)
n-Butanol	1983	0(2)	0.1(2)
t-Butanol	1983	0(1)	0.4(1)
	1980	0(3)	

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
Chloroanthracenes	1984		0(2)
Chlorohydroxyphenothanzenes	1984		0(2)
Chloromethydiphenylmethane	1984		0(2)
Chloromethoxybenzophenone	1984		0(2)
Chloronaphthalenes	1984		0(2)
Cumene	1979		0(2)
Dibenzo(a,h)-anthracene	1984		0(2)
Di-n-butylphthalate	1984		0(1)
Dichloroanthracenes	1984		0(2)
Dichloromethylbis- (phenylmethyl)-benzene	1984		0(2)
Dichloromethyldiphenylmethane	1984		0(2)
Dichloronaphthalenes	1984		0(2)
2,4-Dichloro-2-phenoxyethanol	1984		0(2)
Dichloro(trifluoromethyl)- benzophenone	1984		0(2)
Dimethylaniline	1984		0(2)
N,N Dimethyl-2-propenamide	1984		0(2)
Dioctylphthalate	1984		0(1)
Dioxin	1982	0.002(7)	0.0(7)
	1981	0.0(10)	0.0(10)
	1980	0.0(12)	0.0(12)
Diphenylfluoromethane	1984		0(2)
Ethanal	1983	0(3)	0.1(2)
	1982	0-1(1)	0(1)
Furan	1982		0(2)
Heptanal	1982	0(1)	
HCB	1984	<1(3)	<1(5)
	1983	<1(20)	<1(19)
	1982	<1(19)	<1(20)
	1981	<1(12)	<1(10)
	1980	<1(11)	<1(7)
	1979	<1(7)	<1(5)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
Hexachlorotoluene	1984		0(2)
Hexanal	1984		0(2)
	1983	0(1)	0.5(1)
	1982		0.5(1)
	1981	0.1(3)	
	1980	<0.1(5)	0.2(2)
Hexanone	1980	0(1)	
Hexanones	1984		0(2)
Isobutanal	1984		0(2)
	1979	TR(1)	
Isobutanol	1984		0(2)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
Isopropanol	1982	0.0(2)	0.3(4)
Methylethyl Ketone	1983	0.1(5)	0.2(19)
	1982	0.0(5)	0.3(1)
	1981	0.1(1)	
Methylfuran	1984		0.0(2)
	1983		0.2(1)
	1982	0.1(1)	
	1980	TR(1)	
Methylnaphthalenes	1984		0(2)
2 Methylpyrrole	1983	0(1)	
Pentachloranisole	1984		0(2)
Pentachloromethlybis (phenylmethyl)-benzene	1984		0(2)
Pentachlorotoluene	1984		0(2)
Phenothiazine	1984		0(2)
	1982	0.6(1)	
Propanol	1982	0.6(1)	
Propylene sulfide	1981		0.1(1)
TCDD	1984		0.0(2)
Tetrachlorodioxins	1984	<1(2)	<1(2)
	1983	<1(3)	<1(3)
	1982	<1(7)	<1(7)
	1981	<1(10)	<1(10)
	1980	<1(11)	<1(7)
	1979	<1(7)	<1(5)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
Tetrachloromethylbis-(phenylmethyl)-benzene	1984		0.0(2)
Tetrahydrofuran	1984		0(2)
	1983	0(8)	0.3(2)
	1982	0.0(2)	0.0(2)
	1981	0.0(6)	0.0(7)
Trichloroanthracenes	1984		0.0(2)
Trichlorodiphenylmethane	1984		0.0(2)
Trichloromethylbis-(phenylmethyl)-benzene	1984		0.0(2)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
PESTICIDES & PCBs			
Aldrin	1984	<1(3)	<1(3)
	1983	<1(20)	<1(19)
	1982	<1(19)	<1(20)
	1981	<1(10)	<1(10)
	1980	<1(11)	<1(7)
	1979	<1(7)	<1(5)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
BHC (alpha-)	1984	4(5)	4(3)
	1983	<2(22)	<3(21)
	1982	<5(37)	<5(38)
	1981	<4(19)	<4(19)
	1980	<3(17)	<3(11)
	1979	<2(8)	<1(6)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
Beta-BHC	1984	<1(3)	<1(5)
	1983	<1(19)	<1(18)
	1982	<1(22)	<1(22)
	1981	<1(11)	<1(11)
	1980	<1(13)	<1(7)
	1979	<1(8)	<1(6)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
BHC (gamma-) Lindane	1984	<1(3)	<1(5)
	1983	<1(20)	<1(19)
	1982	2(29)	<1(33)
	1981	<1(14)	<1(14)
	1980	<1(16)	<1(8)
	1979	<1(7)	<1(7)
	1978	<1(1)	
	1975	<1(1)	
	1974	<16(2)	
Chlordane	1984		0(2)
Dieldrin	1984	<2(3)	<1(5)
	1983	<2(20)	<2(19)
	1982	<2(19)	<2(20)
	1981	<2(10)	<2(10)
	1980	<2(13)	<2(9)
	1979	<2(10)	<2(7)
	1978	<2(1)	
	1975	<2(1)	
	1974	<2(1)	

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
D 2,4-	1984		0(2)
DDD (p,p)	1984	<5(3)	<5(5)
	1983	<5(20)	<5(19)
	1982	<5(19)	<5(20)
	1981	<5(10)	<5(10)
	1980	<5(11)	<5(7)
	1979	<5(7)	<5(5)
	1978	<5(1)	
	1975	<5(1)	
	1974	<5(1)	
DDE (p,p)	1984	<1(3)	<1(5)
	1983	<1(20)	<1(20)
	1982	<1(19)	<1(20)
	1981	<1(10)	<1(10)
	1980	<1(11)	<1(7)
	1979	<1(7)	<1(7)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
DDT (o,p)	1984	<5(3)	<5(8)
	1983	<5(20)	<5(19)
	1982	<5(19)	<5(19)
	1981	<5(10)	<5(10)
	1980	<5(11)	<5(7)
	1979	<5(7)	<5(5)
	1978	<5(1)	
	1975	<5(1)	
	1974	<5(1)	
Endrin	1984	<4(3)	2(5)
	1983	<4(20)	<4(19)
	1982	<4(19)	<4(20)
	1981	<4(10)	<4(10)
	1980	<4(13)	<6(8)
	1979	<4(8)	<4(6)
	1978	<4(1)	
	1975	<4(1)	
	1974	<4(1)	
Endosulphan (alpha-)	1984	<2(3)	<2(4)
	1983	<2(20)	<2(19)
	1982	<2(19)	<2(20)
	1981	<2(10)	<2(10)
	1980	<2(11)	<2(7)
	1979	<2(9)	<1(7)
	1978	<2(1)	
	1975	<2(1)	
	1974	<2(1)	

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
Endosulphan (beta-)	1984	<4(3)	<2(5)
	1983	<4(20)	<4(19)
	1982	<4(19)	<4(20)
	1981	<4(10)	<4(10)
	1980	<4(11)	<4(7)
	1979	<4(7)	<4(5)
	1978	<4(1)	
	1975	<4(1)	
	1974	<4(1)	
Heptachlor	1984	<1(3)	<1(3)
	1983	<1(20)	<1(19)
	1982	<1(19)	<1(20)
	1981	<1(10)	<1(10)
	1980	<1(13)	<1(9)
	1979	<1(8)	<1(6)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
Heptachlor epoxide	1984	<1(3)	<1(5)
	1983	<1(20)	<1(19)
	1982	<1(19)	<1(20)
	1981	<1(10)	<1(10)
	1980	<1(11)	<1(7)
	1979	<1(7)	<1(5)
	1978	<1(1)	
	1975	<1(1)	
	1974	<1(1)	
Mirex	1984	<5(3)	<3(5)
	1983	<4(26)	<4(25)
	1982	<3(35)	<3(36)
	1981	<3(20)	<3(20)
	1980	<3(21)	<3(13)
	1979	<3(14)	<3(9)
	1978	<2(3)	
	1976	0(2)	
	1975	<5(1)	
	1974	<5(1)	
Oxychlordane	1984	<2(3)	<2(3)
	1983	<2(20)	<2(19)
	1982	<1(19)	<2(20)
	1981	<2(9)	<2(9)
	1980	<2(11)	<2(7)
	1979	<2(7)	<2(5)
	1978	<2(1)	
	1975	<2(1)	
	1974	<2(1)	
TP 2,4,5-	1984		0(4)

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
<u>Additional Data</u>			
Alpha Chlordane	1984	<2(3)	<2(3)
	1983	<2(20)	<2(19)
	1982	<2(10)	<2(10)
	1981	<2(11)	<2(7)
	1980	<2(7)	<2(5)
	1979	<2(1)	
	1978	<2(1)	
	1974	<2(1)	
Gamma Chlordane	1984	<2(3)	<2(3)
	1983	<2(19)	<2(19)
	1982	<2(19)	<2(20)
	1981	<2(10)	<2(10)
	1980	<2(12)	<2(8)
	1979	<2(8)	<2(6)
	1978	<2(1)	
	1975	<2(1)	
	1974	<2(1)	
Endosulfan Sulphate	1984	<4(3)	<4(3)
	1983	<4(20)	<4(19)
	1982	<4(19)	<4(20)
	1981	<4(9)	<4(9)
	1980	<4(11)	<4(7)
	1979	<4(7)	<4(5)
	1978	<4(1)	
	1975	<4(1)	
	1974	<4(1)	
B-BHC Hexachlorocyclohex	1983	3(2)	3(2)
G-BHC Hexachlorocyclohex	1983	0(1)	0(1)
DMDT-Methoxychlor	1984	<5(3)	<5(3)
	1983	<5(19)	<5(18)
	1982	<5(19)	<5(20)
	1981	<5(9)	<5(9)
	1980	<5(11)	<5(7)
	1979	<5(7)	<5(5)
	1978	<5(1)	
	1975	<5(1)	
	1974	<5(1)	

TABLE 4.13 (Cont'd.)

Chemical Monitoring Results for Raw and Treated Drinking Water

Niagara Falls Water Treatment Plant

	Period	Mean Concentration	
		Raw Water	Treated Water
PCB	1984	<20(3)	<12(5)
	1983	<15(26)	<14(25)
	1982	<12(33)	<11(36)
	1981	<10(20)	<10(20)
	1980	<12(23)	<9(15)
	1979	<10(14)	<11(9)
	1978	<10(2)	
	1976	0(1)	
	1975	<20(1)	
	1974	<20(1)	
Pentane	1983	TR(1)	
	1982	0.9(1)	
	1980	0(2)	0(1)
ACID EXTRACTABLE ORGANICS			
Pentachlorophenol	1984		0(2)
Phenol	1984		0(2)
Trichlorophenol 2,4,6-	1982	<0.04(8)	<0.04(8)
	1981	<0.03(10)	<0.02(10)
	1980	0(2)	<0.04(4)
Additional Data			
t-Butylphenols	1984		0(2)
Chlorohydroxybenzophenone	1984		0(2)
Dichlorophenols	1984		0(2)
Phenols, reactive	1984		0(2)
Tetramethylbutylphenols	1984		0(2)
Trichlorophenols	1984		0(2)
2,3,5-Trichlorophenol	1982		<0.04(8)
<0.06(8)			
	1981	<0.03(10)	<0.03(10)
	1980	0(2)	<0.04(4)
2,3,4;2,4,5-Trichlorophenol	1982	<0.04(8)	<0.04(8)
	1981	<0.03(10)	<0.04(10)
	1980	0(2)	<0.04(4)
2,3,6-Trichlorophenol	1982	<0.04(8)	<0.06(8)
	1981	<0.04(10)	<0.04(10)
	1980	0(2)	<0.04(4)
3,4,5-Trichlorophenol	1981	<0.03(8)	<0.03(8)
	1980	0(2)	<0.03(4)

<u>LEGEND:</u>

All concentrations ug/L unless otherwise indicated
Numbers indicated < are below detection limit
Numbers in brackets refer to number of analyses
0 indicates too few samples (all below detection) to calculate mean
ADDITIONAL DATA refers to compounds not on priority pollutant list

TABLE 4.17

Organochlorine Residues in Young-of-the-Year

Spottail Shiners From the Niagara River

(Concentrations in ng/g)

Sampling Site	Year	n #	PCB	Total DDT	Mirex	Chlordane	Total BHC	HCB	Octachloro -styrene
Niagara River Fort Erie Ont.	1982	6	181+/-69	31+/-12	ND	6+/-4	4+/-1	TR	ND
	1983	7	66+/-20	7+/- 6	ND	ND	TR	ND	ND
	1984	7	118+/-12	25+/- 8	ND	TR	TR	ND	ND
	1985	7	63+/-10	10+/- 6	ND	ND	ND	TR	ND
	1987	7	34+/-27	19+/- 2	ND	ND	ND	ND	ND
	1989	7	ND	TR	ND	ND	ND	ND	ND
Frenchman's Creek Ont.	1980	5	66+/-31	13+/- 9	ND	9+/-3	3+/-1	ND	NA
	1981	5	164+/-56	37+/-19	ND	TR	1+/-1	ND	NA
	1982	7	216+/-34	57+/-10	ND	8+/-6	6+/-1	1+/-1	ND
	1983	7	64+/-21	24+/- 6	ND	TR	ND	ND	ND
	1985	7	81+/-16	73+/-49	ND	2+/-1	ND	2+/-1	ND
	1990	6	78+/-21	18+/- 5	ND	ND	ND	ND	3+/-1
Pettit Flume N.Y.	1984	7	896+/-234	14+/- 3	ND	4+/-1	ND	780+/-84	28+/-13
	1985	5	251+/- 71	15+/- 2	ND	8+/-8	ND	5+/- 4	2+/- 1
Cayuga Creek N.Y.	1981	4	573+/- 84	23+/- 4	18+/- 4	18+/-4	34+/- 9	11+/- 2	NA
	1982	6	880+/-136	50+/- 4	6+/- 2	19+/-7	29+/-10	12+/- 2	ND
	1983	5	406+/-194	29+/-15	9+/-15	5+/-4	14+/-19	5+/- 5	ND
	1985	5	750+/-180	23+/- 9	ND	3+/-1	38+/-17	24+/- 7	ND
	1990	3	217+/- 23	9+/- 2	5+/- 2	ND	5+/- 1	6+/- 5	ND
Gill Creek N.Y.	1985	5	1960+/-711	185+/-37	ND	3+/-2	267+/-71	273+/-85	ND
Usher's Creek Ont.	1982	7	124+/- 14	30+/- 5	ND	10+/-2	ND	1+/- 1	ND
	1983	7	67+/- 17	24+/- 4	ND	TR	ND	ND	ND
	1984	7	99+/- 28	23+/- 5	ND	ND	ND	ND	ND
	1985	7	49+/- 19	15+/- 9	ND	ND	ND	TR	ND
	1986	7	29+/- 25	12+/- 9	ND	ND	ND	3+/- 2	ND
	1987	7	ND	16+/-13	ND	ND	ND	ND	ND
	1989	7	ND	11+/- 5	ND	ND	ND	ND	ND
Niagara River Queenston Ont.	1979	7	108+/- 28	34+/- 9	ND	21+/-6	4+/-4	6+/- 3	NA
	1980	7	134+/- 20	11+/- 6	TR	21+/-19	7+/-2	1+/- 1	NA
	1981	6	329+/-120	107+/-57	15+/-8	47+/-20	4+/-3	3+/- 2	NA
	1982	5	245+/- 21	61+/-19	7+/-6	8+/-2	3+/-1	3+/- 0	2+/-1
	1989	6	30+/- 30	34+/- 8	ND	ND	ND	2+/- 1	2+/-0
	1990	6	198+/- 23	37+/- 8	11+/-3	ND	ND	TR	3+/-0
Niagara River Niagara-on-the-Lake Ont.	1975	5	690+/-195	244+/-52	ND	ND	ND	ND	NA
	1977	9	626+/-154	157+/-38	13+/-4	55+/-2	626+/-26	27+/-11	NA
	1978	8	320+/- 49	99+/-49	29+/-8	8+/-10	7+/- 2	2+/- 1	NA
	1979	8	153+/- 23	26+/- 9	TR	22+/-18	ND	4+/- 1	NA
	1980	7	266+/- 51	41+/- 9	11+/-2	24+/-6	26+/- 7	4+/- 3	NA
	1981	7	327+/- 62	73+/-15	10+/-3	11+/-4	ND	2+/- 1	NA
	1982	5	255+/- 24	82+/-14	6+/-2	17+/-7	4+/- 1	4+/- 1	4+/-1
	1983	6	136+/- 55	9+/- 9	ND	3+/-1	ND	3+/- 3	2+/-1
	1984	7	273+/-107	71+/-23	10+/-6	3+/-1	ND	15+/- 3	4+/-1
	1985	7	127+/- 38	13+/-13	ND	TR	ND	1+/- 1	1+/-1
	1987	7	116+/- 18	34+/- 9	8+/-3	TR	ND	3+/- 1	ND
	1988	7	145+/- 59	47+/-30	ND	ND	ND	TR	TR
	1989	6	82+/- 21	53+/-10	ND	ND	ND	2+/- 1	4+/-1
	1990	7	226+/- 32	72+/-11	10+/-1	ND	ND	ND	4+/-1

LEGEND:
NA = Not Analysed
ND = Below Detectable Limits
TR = Trace

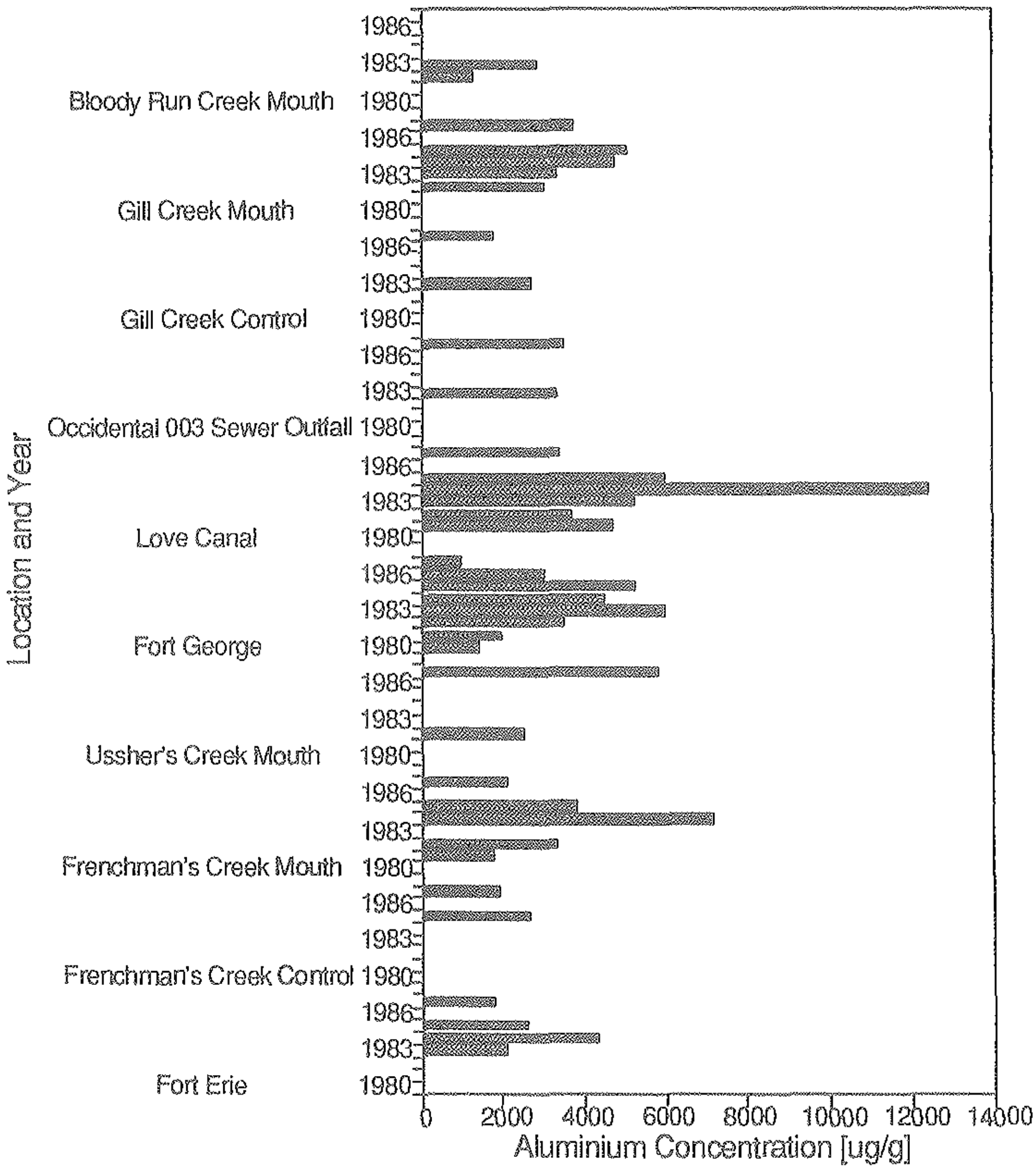


Figure 4.4 (a)

NIAGARA RIVER BIOMONITORING

Accumulation of Aluminium in Cladophora

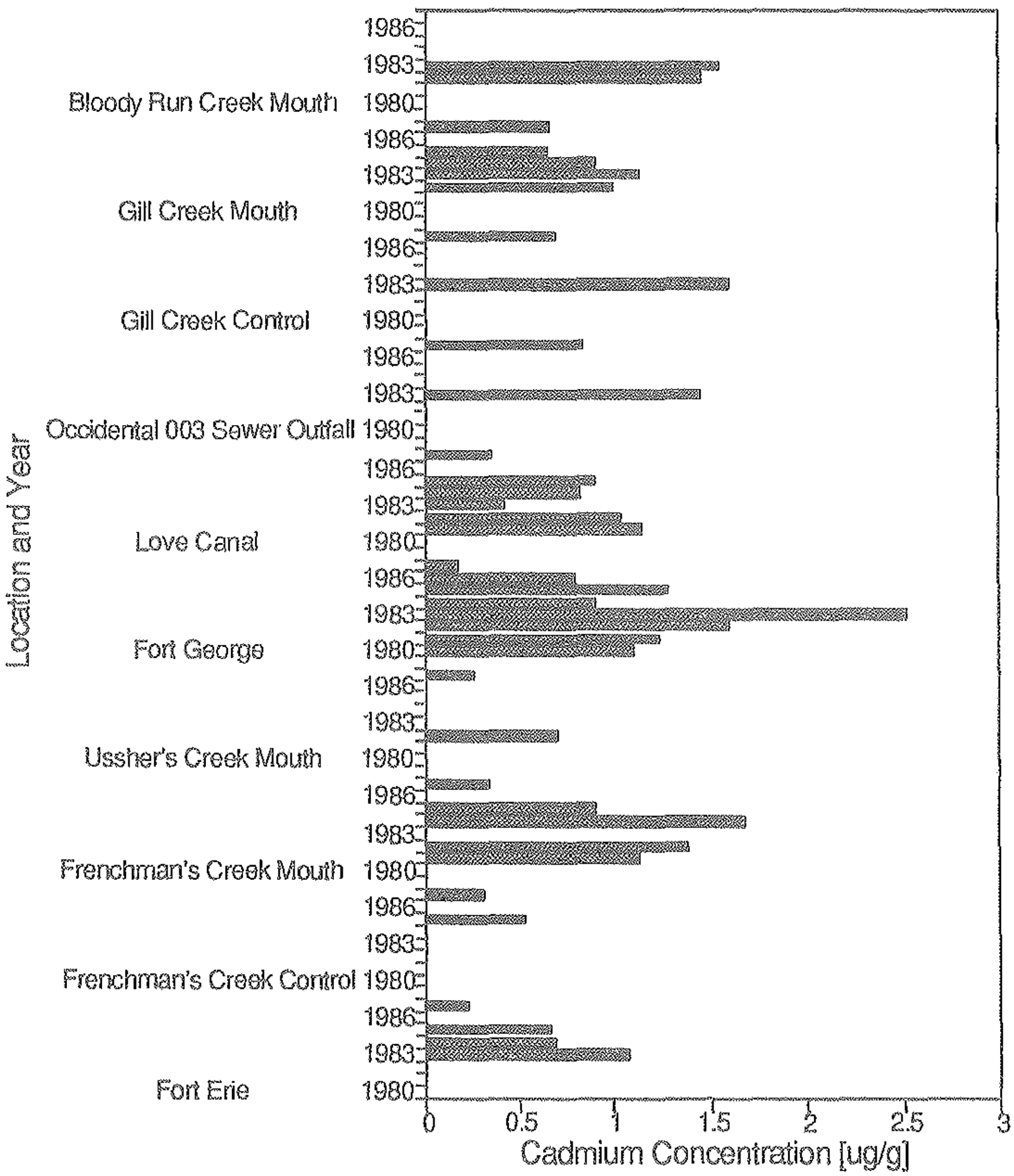


Figure 4.4 (b)

NIAGARA RIVER BIOMONITORING

Accumulation of Cadmium in Cladophora

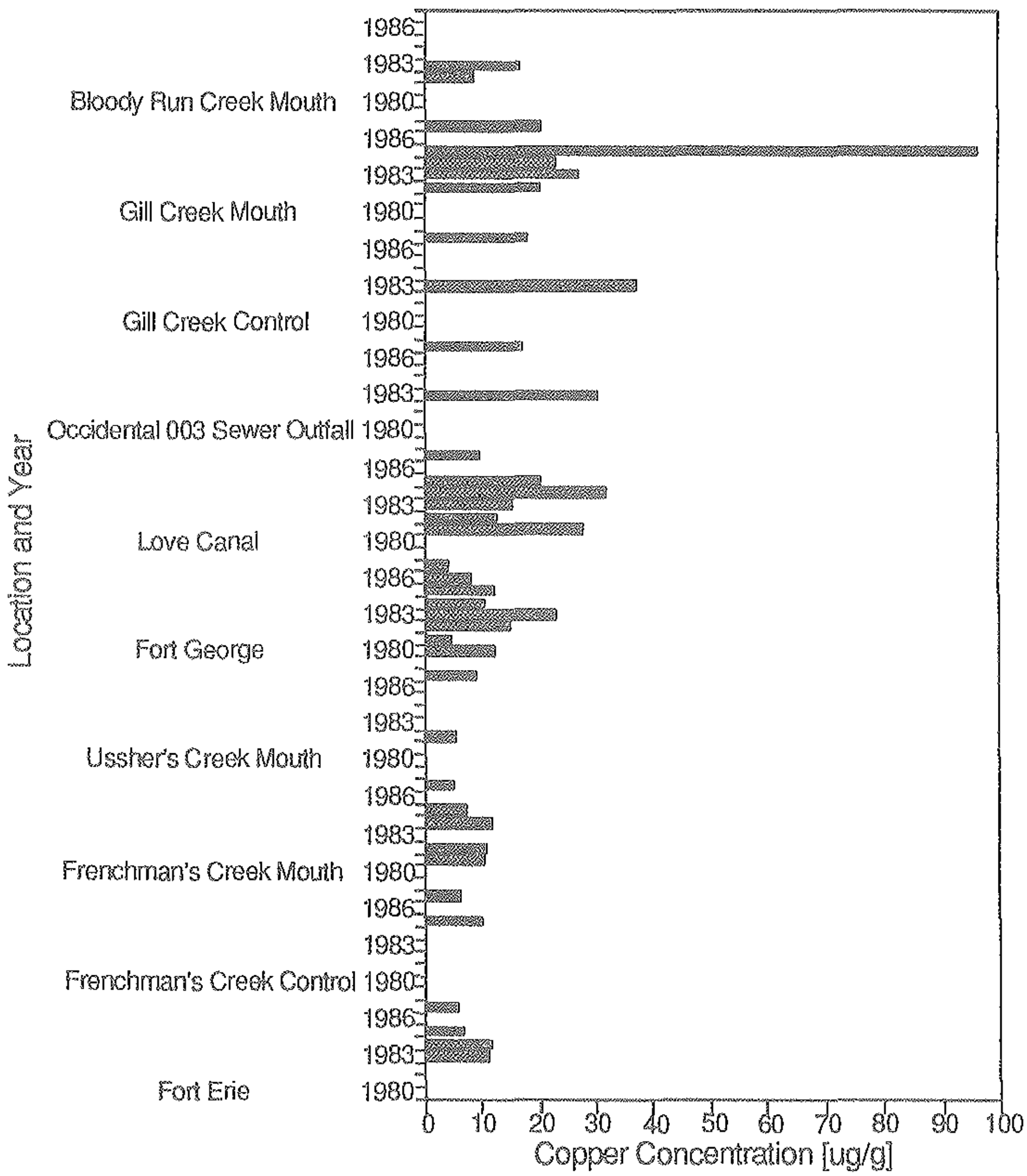


Figure 4.4 (c)

NIAGARA RIVER BIOMONITORING

Accumulation of Copper in Cladophora

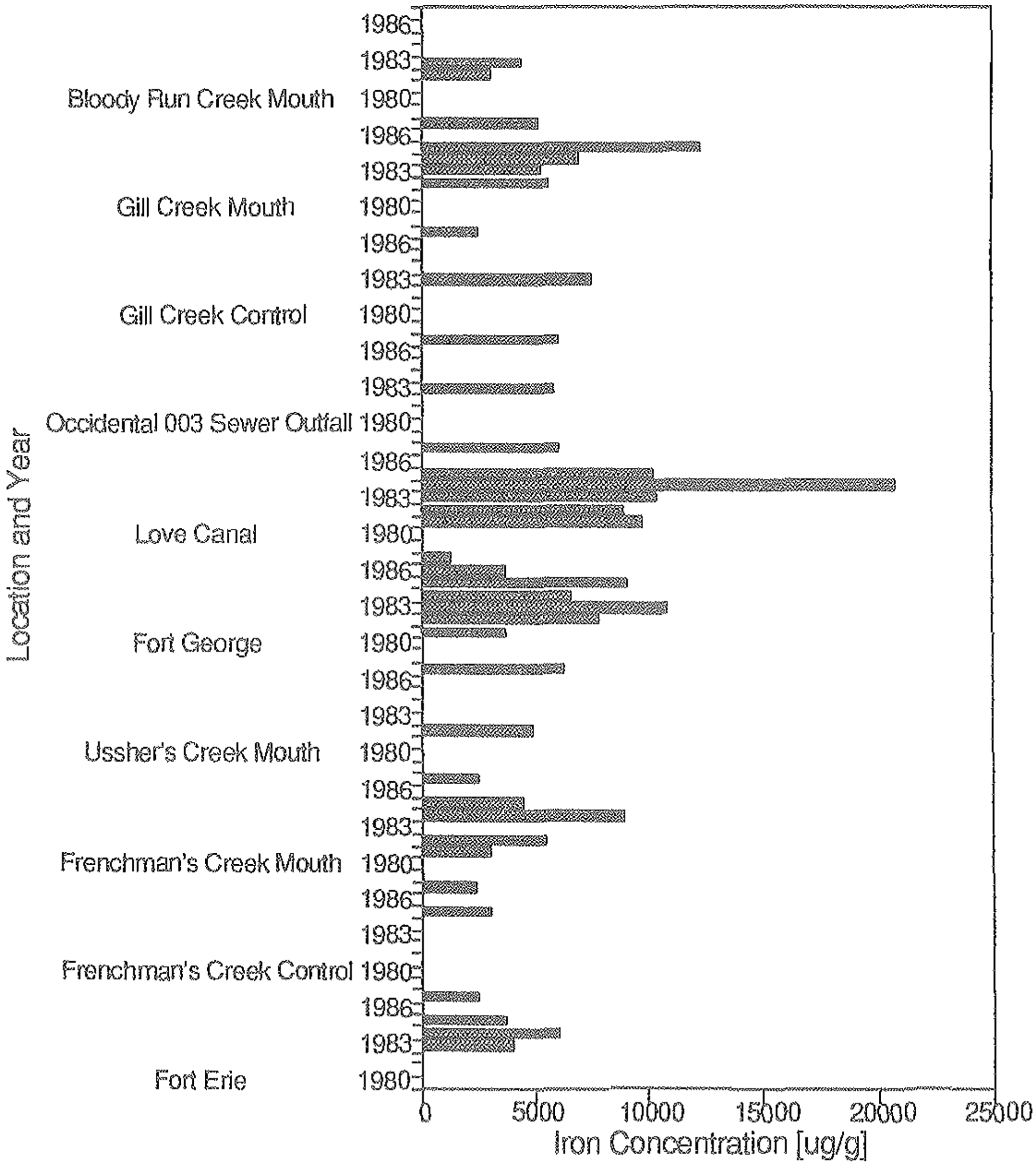


Figure 4.4 (d)

NIAGARA RIVER BIOMONITORING

Accumulation of Iron in Cladophora

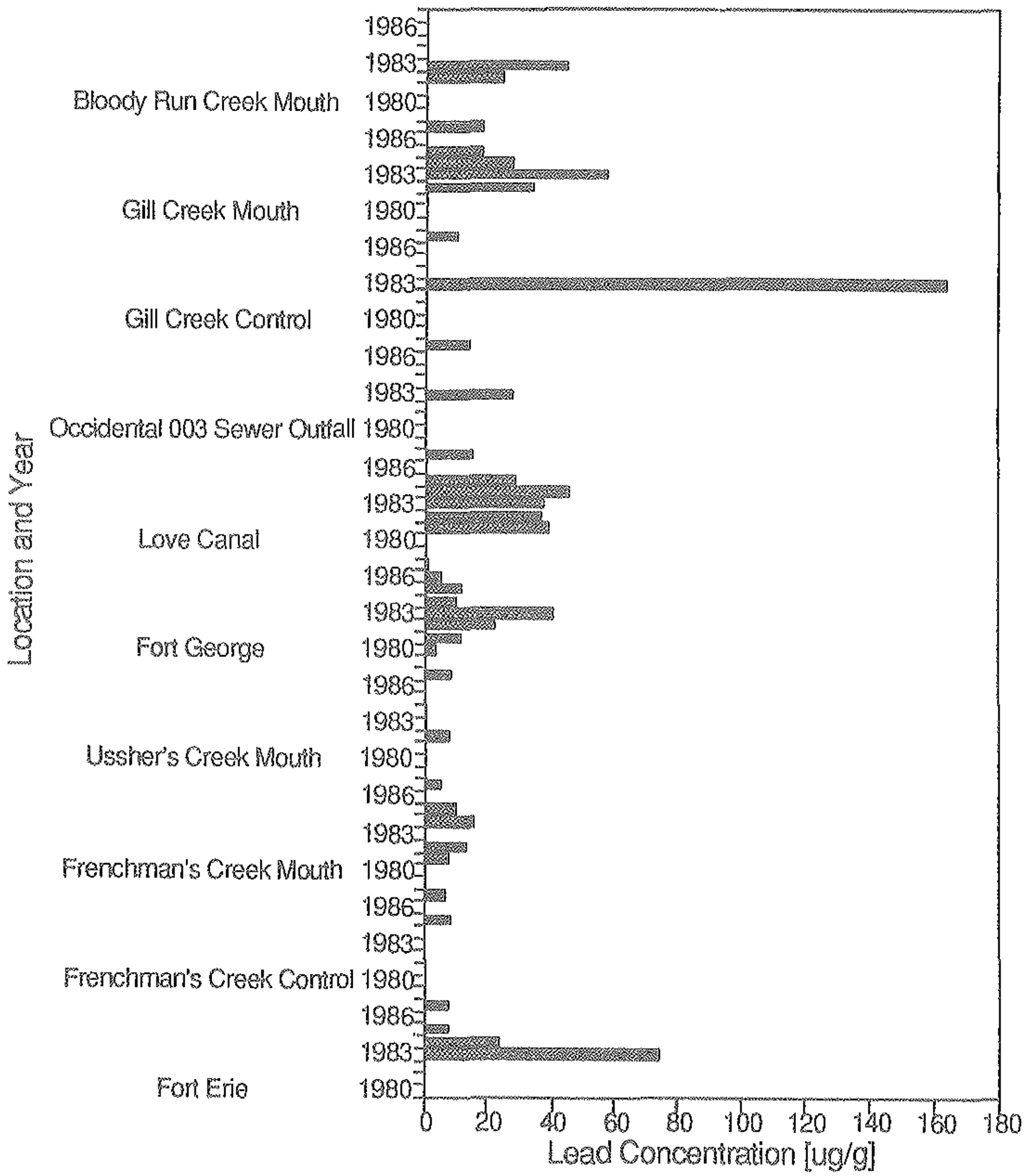


Figure 4.4 (e)

NIAGARA RIVER BIOMONITORING

Accumulation of Lead in Cladophora

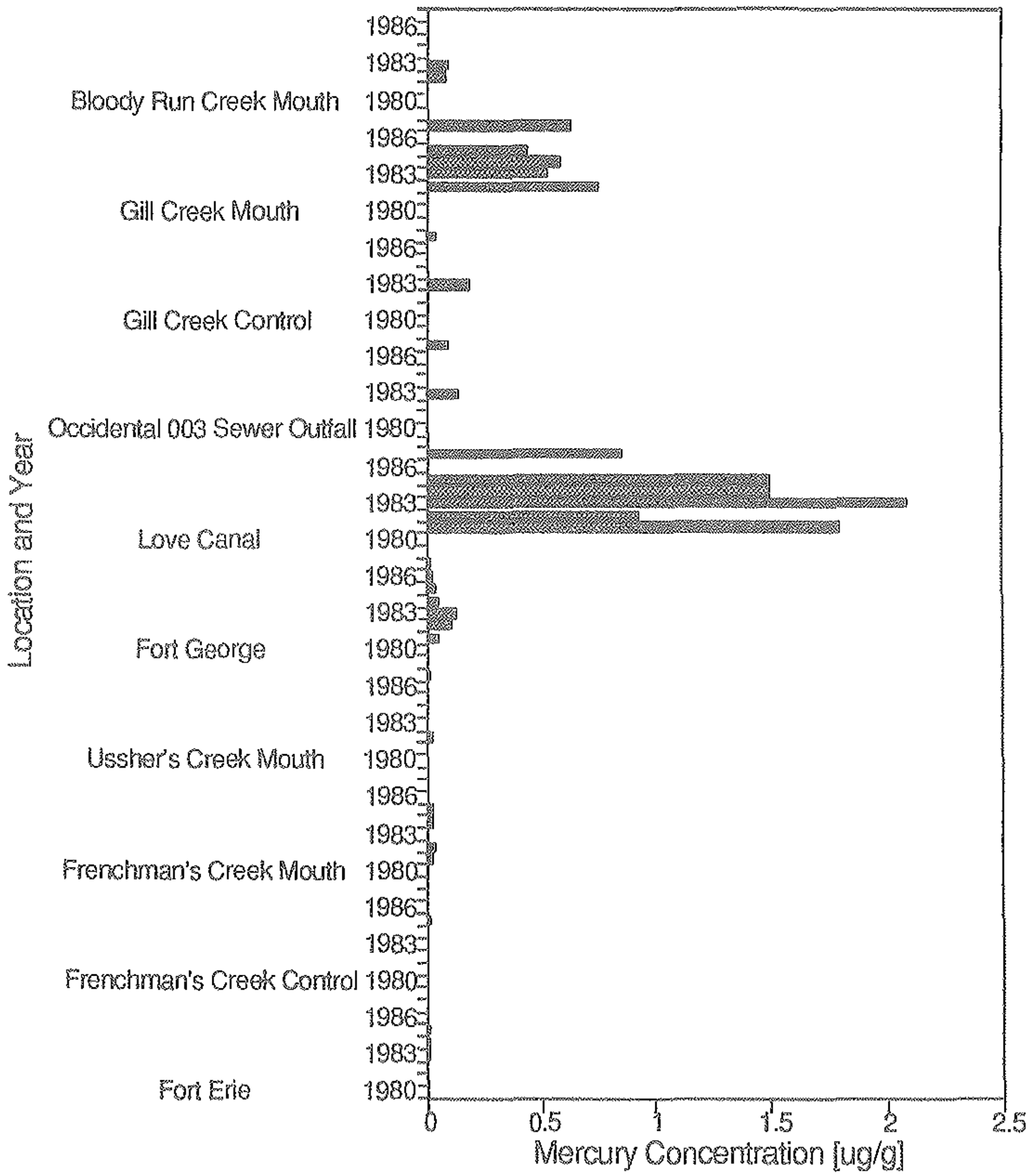


Figure 4.4 (f)

NIAGARA RIVER BIOMONITORING

Accumulation of Mercury in Cladophora

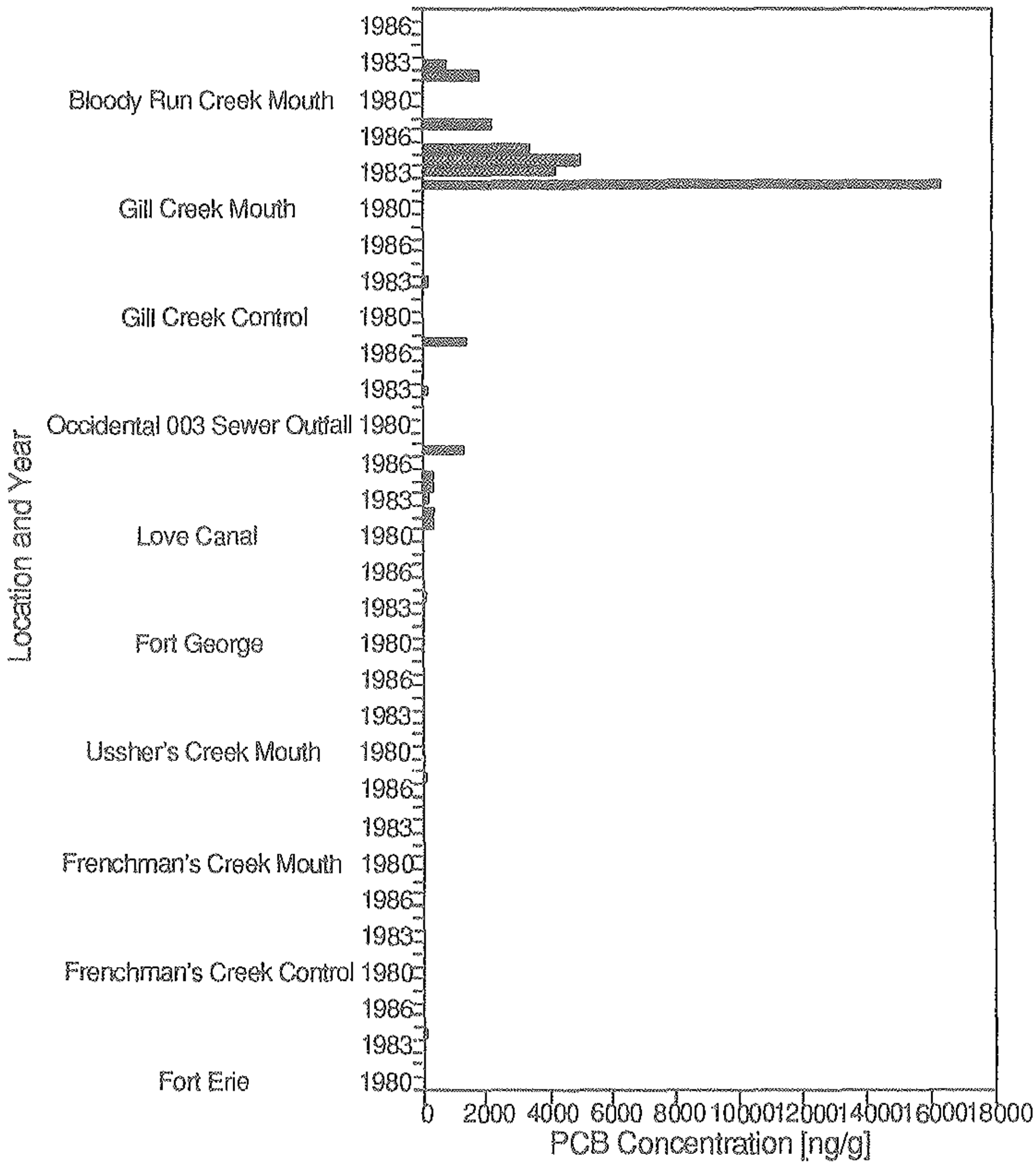


Figure 4.4 (g)

NIAGARA RIVER BIOMONITORING

Accumulation of PCB in Cladophora

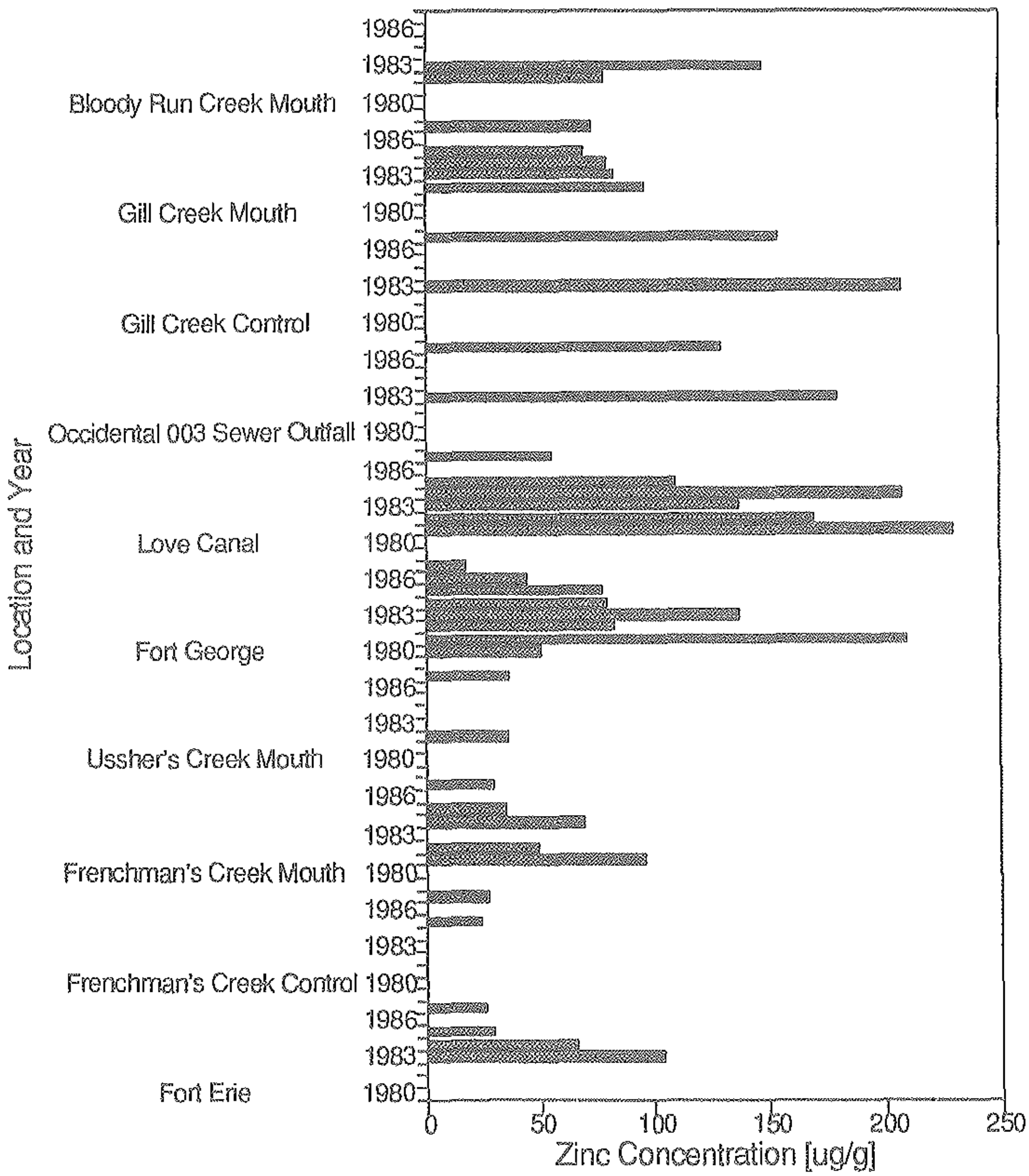


Figure 4.4 (h)

NIAGARA RIVER BIOMONITORING

Accumulation of Zinc in Cladophora

5.0 DESCRIPTION OF CONTAMINANT SOURCES

5.0 DESCRIPTION OF CONTAMINANT SOURCES

Pollution to the Niagara River from Ontario originates from both point and non-point sources. Point sources are readily identifiable municipal and industrial discharges to the Niagara or Welland Rivers or to their tributaries. Non-point sources are either not readily identifiable or irregular discharges of complex origin such as: urban runoff, combined sewer overflows, atmospheric deposition and recharge of contaminated ground water from waste disposal sites and facility operations.

All of the Ontario point sources in the Niagara River drainage basin have been surveyed annually since 1981 to obtain estimates for toxic loadings to the river. These loading estimates are updated annually with data collected from the discharge sampling programs. In 1981/1982 when the first toxics samples were collected from the Ontario point sources for the NRTC studies, approximately 154 kg/day of Priority Pollutants were being released to the river. Of this amount, the majority of contaminants were heavy metals[30]. The gross Ontario loading of Priority Pollutants represented about 11% of the total point source load of Priority Pollutants to the Niagara River[30]. The remaining 89% was calculated to originate from point sources in New York State. The 23 Ontario point sources shown in Figure 5.1 include:

Municipal Sources	Map ID
Fort Erie (Anger Ave.) WPCP	3
Stevensville-Douglastown Lagoons	4
Welland WPCP	13
Port Robinson Lagoons	9
Niagara Falls WPCP	21
Queenston WPCP	22
McMaster Avenue Combined Sewer - Welland	11
Stanley Avenue Combined Sewer - Niagara Falls	16
Industrial Sources - Upper Niagara Area	
Canadian-Oxy Chemicals Ltd.	2
GNB (Canada) Ltd. - formerly Gould Batteries	23
Fleet Manufacturing Ltd.	1
Diner's Delite - formerly Holiday Farms	24
Industrial Sources - Welland Area	
Atlas Specialty Steels Division	12
Gencorp-Diversitech General	14
Stelco-Stelpipe Welland Tube Works	10
Ford (Canada) - Niagara Falls Glass Plant	5
B.F. Goodrich Inc.	8
Cyanamid of Canada Ltd. - Welland Plant	7
Laidlaw Environmental Services - formerly Tricil	15
Industrial Sources - Niagara Falls Area	
Washington Mills - Electro Minerals	18
Norton Company Canada Ltd.	19
Washington Mills Ltd.	17
Cyanamid of Canada Ltd. - Niagara Falls Plant	20

Abatement actions have occurred at virtually all Ontario point sources since the first estimates of Priority Pollutant loadings were made in the 1984 NRTC Report. Control Orders, Certificates of Approval, voluntary programs by industries and sewage treatment plant upgrading and expansions have resulted in dramatic declines in the point source loadings since the 1981/1982 loading estimates. The Ministry of the Environment has estimated[799] that from 1981/1982 until the 1988/1989 monitoring year, a reduction in toxic Priority Pollutant loadings from Ontario point sources to the Niagara River of approximately 86%

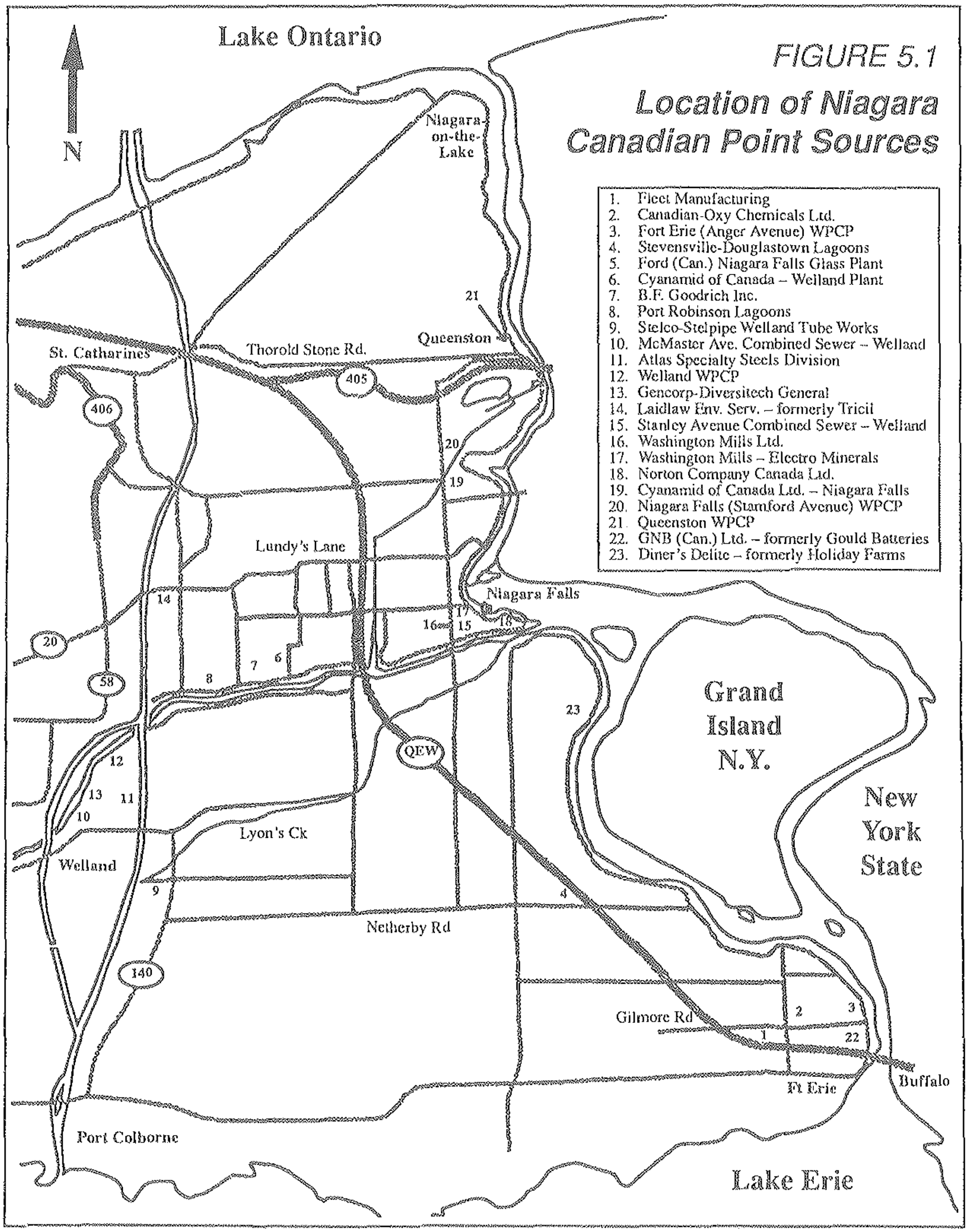


FIGURE 5.1
Location of Niagara Canadian Point Sources

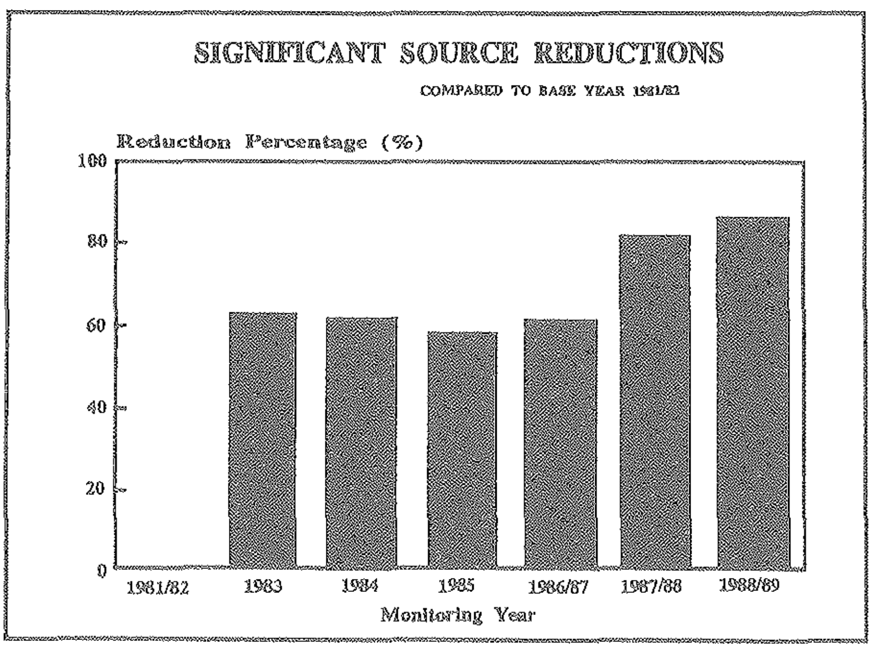
has occurred (Table 5.1). Figure 5.2 illustrates how the Ontario point source loadings have declined during recent years.

TABLE 5.1

Ontario Point Source Loadings of Toxic Priority Pollutants to the Niagara River

Year	Loading (kg/d)	Reduction (kg/d)	Reduction (%)
1981/82	154.4	0	0.0%
1983/84	54.1	100.3	65.0%
1984/85	58.9	95.5	61.9%
1985/86	66.7	87.7	56.8%
1986/87	60.8	93.6	60.6%
1987/88	30.2	124.2	80.4%
1988/89	21.8	132.6	85.9%

FIGURE 5.2



Detailed descriptions of remedial programs that have been put in place at the different point sources over the last decade are included in each description.

Pollutant loadings from non-point sources are not as well defined due to the complexity of determining the exact movement of contaminants from these sources[30]. Additional studies are required to generate or refine loading estimates for these sources.

Point Sources

Currently, within the Ontario Niagara River drainage basin, six municipal point source discharges (water pollution control plants) exist.

The Town of Fort Erie (Anger Ave.) Water Pollution Control Plant (WPCP) is operated by the Regional Municipality of Niagara. Until December 1989, the plant provided enhanced primary treatment. At that time, this sewage treatment plant was upgraded to an extended aeration activated sludge facility and now provides secondary wastewater treatment to the sewage generated in Fort Erie. The plant also provides physical-chemical treatment for storm flows. The new secondary treatment plant which was commissioned in December 1989 was the final municipal wastewater treatment plant in Ontario, discharging to the Niagara River to be upgraded to a minimum of, or equivalent to, secondary wastewater treatment.

Along the Chippawa Channel, facultative stabilization ponds owned and operated by the Regional Municipality of Niagara, serve the small rural communities of Stevensville and Douglastown (part of the Town of Fort Erie). Both the Fort Erie (Anger Ave.) WPCP and the Stevensville-Douglastown Lagoons are direct point source discharges to the Niagara River.

The City of Welland is served by an activated sludge plant that has recently (1990) been expanded to a tertiary treatment facility providing effluent filtration and partial nitrification. The expansion of the plant to tertiary treatment follows expansion of the secondary treatment system in 1983. The facility is owned and operated by the Regional Municipality of Niagara. This plant discharges its treated effluent to the Welland River.

At Port Robinson in the City of Thorold, a new sewage treatment facility was constructed and commissioned to resolve health concerns over failed septic tanks and tile fields. The facility, which is owned and operated by the Regional Municipality of Niagara, consists of aerated and facultative lagoons. The treatment works are located on the bank of the Welland River downstream from the Port Robinson syphon. This facility discharges treated municipal effluent to the Welland River.

In the City of Niagara Falls, Ontario, the sewage treatment plant (known as the Niagara Falls (Stamford) WPCP) was expanded to the equivalent of secondary treatment in 1985. The secondary treatment phase of the Niagara Falls plant consists of 35 rotating biological contactors. The Niagara Falls (Stamford) WPCP is also owned and operated by the Regional Municipality of Niagara and discharges treated effluent to the Queenston-Chippawa Power Canal at a point upstream of the forebay of Ontario Hydro's Sir Adam Beck power generating stations.

At Queenston, in the Town of Niagara-on-the-Lake, a new sewage treatment facility has been constructed to resolve health concerns over failed septic tanks, tile fields and grey water discharges. The facility, which is owned and operated by the Regional Municipality of Niagara, consists of a package activated sludge plant. The treatment works are located at the base of the escarpment at Queenston on the west bank of the Niagara River and discharge treated effluent directly to the Niagara River.

The Town of Niagara-on-the-Lake and the Village of Crystal Beach are serviced by municipal water pollution control plants that discharge respectively to Lake Ontario and Lake Erie directly outside the Niagara River Area of Concern.

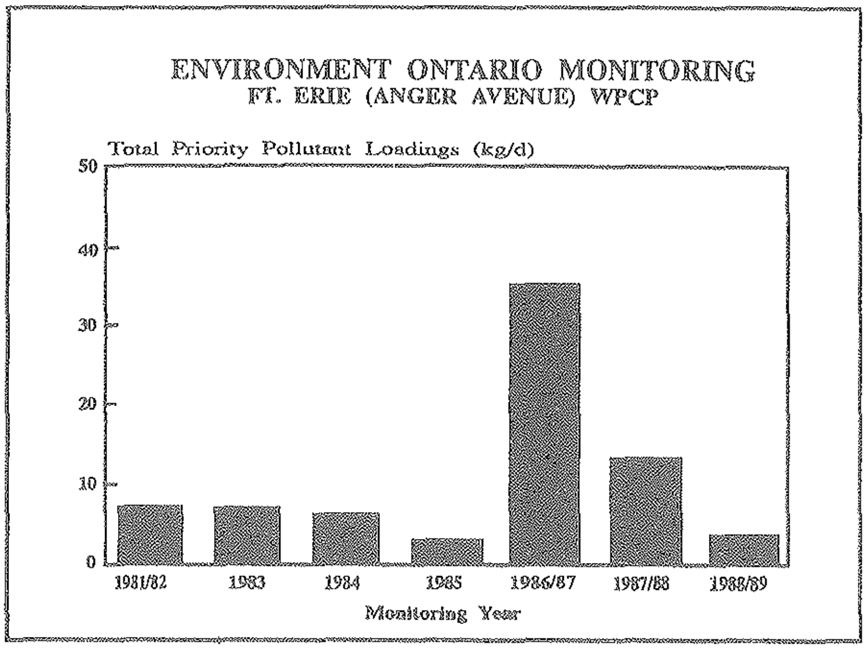
5.1.1 Fort Erie (Anger Ave.) WPCP

The Fort Erie (Anger Ave.) Water Pollution Control Plant historically provided enhanced primary treatment with phosphorous removal by ferric chloride addition. The plant, owned and operated by the Regional Municipality of Niagara, was designed to serve a population of approximately 13,800. Flow specifications for the plant indicated a hydraulic rated capacity of 16,300 m^3/d and a peak hydraulic capacity of 32,600 m^3/d. Average daily flows to the plant over the eight year period ending in 1988 are listed in the table below.

YEAR	AVG. DAILY FLOW (m3/d)
1981	17,100
1982	15,100
1983	14,100
1984	12,900
1985	13,000
1986	10,740
1987	10,765
1988	9,530

Due to the condition and type of sewer infrastructure which existed in the area served by the plant, flows often exceeded the design capacity of the treatment plant during wet weather periods. Frequent sewage pumping station and combined sewer overflows have been documented. Resolution of these problems has been occurring over the past three years and will continue with sewer separation and infiltration reduction measures, plus other solutions to reduce the overflow problem including storage, increased pumping station capacity and increased trunk sewer capacities.

FIGURE 5.3



Influent to the treatment plant is comprised largely of domestic sewage (approximately 90% of the average daily inflow) and a small contribution (the remaining 10%) being industrial wastewater. The types of industries which discharge to the plant include metal and steel fabricators and paint, plastics and pharmaceutical manufacturers.

A new wastewater treatment facility was designed and has been constructed at the Fort Erie (Anger Ave.) WPCP to provide extended aeration activated sludge treatment for the sewage generated in the Town of Fort Erie. Special considerations were required for the design of the treatment works due to the weak organic nature of the influent sewage. The weak sewage is a result of the aforementioned infrastructure problems. The treatment plant was commissioned in December 1989.

At the upgraded treatment plant, wastewater enters the facility by forcemain from the Parkway Pumping Station and passes through a meter chamber and mechanically cleaned bar screens. Following grit removal, the wastewater enters the extended aeration activated sludge portion of the treatment works. Aeration is accomplished using fine bubble diffusers. Following activated sludge treatment, gravity separation occurs in the final clarifiers. Clarified effluent enters a two stage chlorine contact chamber prior to discharge through a 100 meter submerged diffuser outlet in the Niagara River.

Based on the results of the 1984 NRTC study, this facility had been designated a significant point source to the Niagara River. Monitoring results of total priority pollutants for the period 1981-1989 are shown in Figure 5.3.

5.1.2 Stevensville-Douglastown Lagoons

Stevensville and Douglastown are the two small communities within the predominantly rural portion of the Town of Fort Erie. The Stevensville-Douglastown

Lagoons were constructed because of concerns raised by Niagara Regional Health Unit officials following observed deterioration of many private sewage treatment systems (septic tanks and tile fields) and evidence of raw or partially treated sewage entering Black Creek. Septic tank and tile field failures were due in part to the heavy clay soil which predominates throughout both communities.

The facultative stabilization lagoon treatment system was chosen because of the remote location of the treatment facility, its relatively low capital and maintenance costs and low staff operating requirements. The simple waste stabilization pond, which services the two residential communities, provides an effluent of quality that is equal to or greater than that of a much more expensive and labour intensive secondary sewage treatment plant.

The treatment lagoons are located on a site bounded by the Queen Elizabeth Way to the east, Baker Road to the north and the Niagara Falls city limits to the south.

The lagoons were designed for a projected population of 1,565 plus a future industrial component bringing the total design equivalent to 2,750 persons. The lagoon consists of two large cells (at present), with room for expansion to three cells.

The lagoons were designed for an organic (BOD) loading of 22 kilograms/hectare/day (20 pounds/acre/day). The ponds cover a surface area of 9.7 hectares (24 acres) and are 1.3 meters deep. The lagoon hydraulic retention time is 103 days at the design average flow rate of 1,470 m^3/day. The peak hydraulic flow to the lagoons is 2,940 m^3/day.

The average daily flows to the lagoons for the six year period (beginning with the year the lagoons were placed into use and ending in 1988) are as follows:

YEAR	AVG. DAILY FLOW (m3/d)
1983	208
1984	363
1985	459
1986	647
1987	573
1988	580

The effluent from the lagoons is discharged continuously to the Chippawa Channel of the Niagara River. The discharge pipe and diffuser extend 137 metres into the river from the shore. The diffuser is 13 metres long and is located in a depth of 5 metres of water.

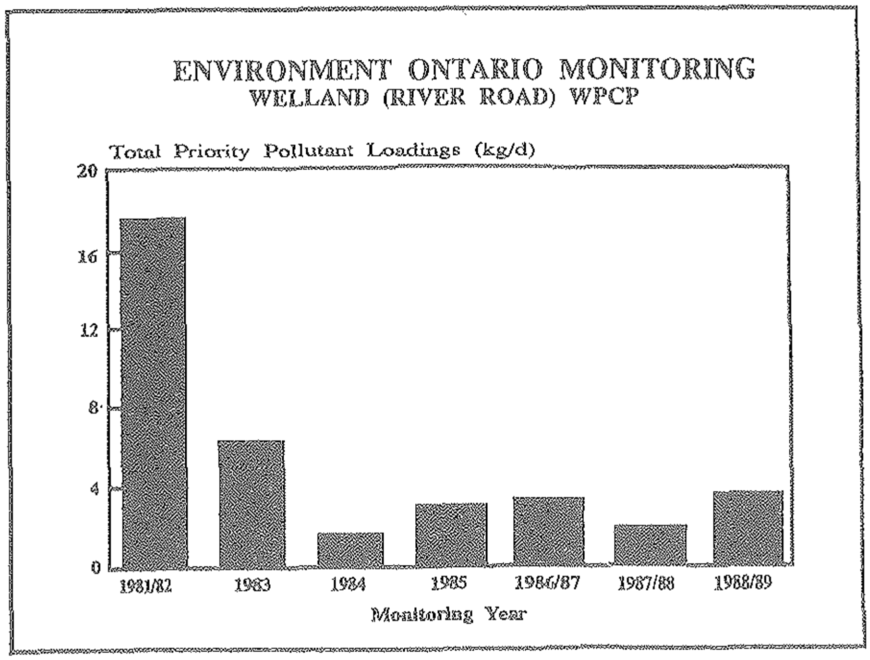
The Stevensville-Douglastown lagoon facility is not considered a significant point source to the Niagara River if NRTC criteria are applied.

5.1.3 Welland WPCP

The City of Welland Water Pollution Control Plant has, until recently, been operated as a conventional activated sludge treatment plant providing secondary treatment and phosphorous removal to a mixed domestic and industrial wastewater stream. The industrial portion of the wastewater accounts for approximately 35% of the influent. The plant is owned and operated by the Region of Niagara and serves a population of approximately 47,200.

The plant has undergone two expansions in recent years. In 1983, the facility was expanded with the installation of two additional secondary clarifiers and a new chlorine contact chamber. Hydraulically, the plant was upgraded to a rated capacity of 45,460 m^3/d. In 1990, a second expansion of the facility was completed and includes improvements to the main sewage pumping station, new mechanical screening facilities, new aerated grit removal chambers, upgraded flash mixing and flocculation tanks, additional primary clarification capacity, additional aeration cells, effluent filtration facilities, improved chlorine contact facilities and additional anaerobic digestion facilities. The activated sludge portion of the treatment works has the capability of providing full nitrification.

FIGURE 5.4



Nitrification and filtration capabilities at this treatment works result in a tertiary treatment rating for this facility.

Average daily flows to the plant for the six year period to 1988 are as follows:

YEAR	AVG. DAILY FLOW (m3/d)
1983	48,778
1984	40,240
1985	35,840
1986	37,959
1987	35,013
1988	33,180

The wastewater enters the treatment plant grit removal tanks following collection in the River Road Interceptor Sewer and pumping at the main sewage pumping station. The influent passes through screening and grit removal facilities and passes into the flash mixing and flocculation section where chemical coagulants are added. The wastewater then enters primary clarifiers, biological activated sludge aeration, final clarifiers, effluent filters and chlorine contact chambers prior to release to the Welland River. Wastewater treatment sludge (primary and waste activated) is treated using a two stage anaerobic sludge digestion process.

Based on the results of the 1984 NRTC study, this facility had been designated a significant point source. Monitoring results for total priority pollutants for the period 1981-1989 are shown in Figure 5.4.

5.1.4 Port Robinson Lagoons

In 1989, the community of Port Robinson in the City of Thorold had a new wastewater treatment facility constructed and commissioned to treat up to 441 m^3/day of sewage. The plant is owned and operated by the Regional Municipality of Niagara and is located immediately adjacent to the Welland River, downstream of the Port Robinson syphon (the point where the Welland River crosses underneath the Welland Ship Canal).

Influent sewers discharge to an aerated lagoon with a volume of 2,384 m^3 with a side water depth of 3 m. The total hydraulic retention time of the aerated cell is 5 days. Following aeration, the partially treated sewage then enters two facultative cells having a combined surface area of 2.5 hectares (6.2 acres). The side water depth of the facultative cells is 1.5 m and provides a hydraulic retention time of 76 days. Effluent from the treatment facilities is discharged continuously via an outfall extending into the Welland River.

Because this facility was recently commissioned, no toxics data exist as yet to determine the impact of this source to the Niagara River. It is expected that these lagoons will not be a significant source of toxics to the Niagara River if the NRTC criteria were applied.

5.1.5 Niagara Falls (Stamford Ave.) WPCP

The Niagara Falls (Stamford) Water Pollution Control Plant was expanded in 1985 to provide secondary treatment to a combined domestic and industrial wastewater stream. The plant is owned and operated by the Region of Niagara and is designed for a population of 107,050. Hydraulically, the plant has a rated capacity of 68,200 m^3/d with peak factors of 2 and 1.47 for the primary and secondary section of the plant respectively. Average daily flows to the treatment plant for the eight years prior to 1989 are:

YEAR	AVG. DAILY FLOW (m3/d)
1981	44,500
1982	51,800
1983	61,270
1984	56,150
1985	57,060
1986	56,706
1987	56,755
1988	58,500

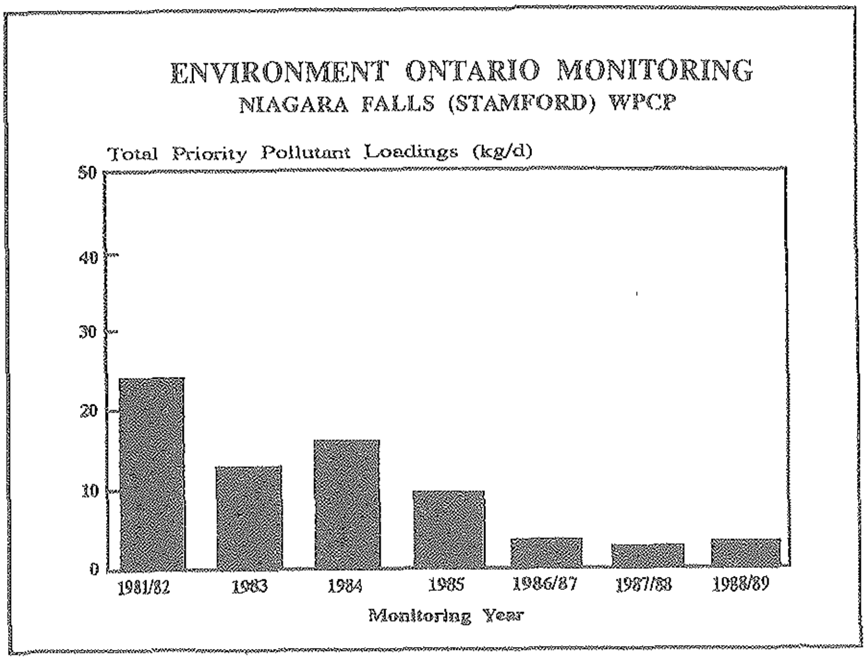
Wastewater enters the treatment plant by gravity and passes through a series of manually cleaned coarse bar screens. The sewage is then pumped to grit removal and pre-aeration prior to entering the primary settling tanks.

Following primary treatment, clarified sewage enters the secondary treatment stage. Secondary treatment consists of 35 covered rotating biological contactors (RBCs) in a series of 5 trains. The secondary plant was constructed to accommodate shock loading arising during the canning/grape crushing season. The RBCs were not designed to provide complete secondary treatment for the entire waste stream for the whole year. Under the existing Certificate of Approval, all influent wastewater receives 100% primary treatment. However, three different operating schemes exist for secondary treatment. During the period of August, September, October and November, the RBCs receive 51% of the primary effluent for treatment. The remaining 49% of primary effluent is blended with the RBC effluent prior to chlorination. During December, January and February, the RBCs receive 80% of the primary effluent while 20% is blended prior to chlorination. During March, April, May, June and July, the RBCs receive 100% of the primary effluent.

Ferric chloride is added at numerous locations throughout the plant for phosphorous removal. Sludge stabilization is accomplished using two-stage anaerobic digestion for primary and biological sludge. Following secondary treatment and blending of primary effluent, the treated sewage is chlorinated prior to release to the Queenston-Chippawa Power Canal.

In 1984, the NRTC designated this facility as a significant point source to the Niagara River. Loadings of total priority pollutants discharged from this source over the past 7 years are shown in Figure 5.5.

FIGURE 5.5



5.1.6 Queenston WPCP

The Regional Municipality of Niagara has recently completed the construction and commissioning of an extended aeration water pollution control plant at Queenston in the Town of Niagara-on- the-Lake. The plant is rated for an average daily flow of 500 m^3/d with a peak capacity of 1700 m^3/d.

The influent sewage enters the treatment facilities at a raw sewage lift station and is pumped to the velocity controlled grit removal channels. Following the grit removal stage, the sewage flows through a comminutor prior to entering the extended aeration compartment. Aeration of the sewage, using coarse bubble diffusers in spiral-roll type compartments, occurs for a minimum of 18 hours. The volume of the aeration section is 375 m^3. Following aeration, treated effluent is gravity-separated in a single settling tank, disinfected in a chlorine contact chamber and discharged directly to the Niagara River from a shore-based headwall outlet.

Because this facility was recently commissioned, no toxics data exists yet to determine the impact of this source on the Niagara River. It is expected to be a non-significant source of toxics to the Niagara River if the NRTC criteria were applied.

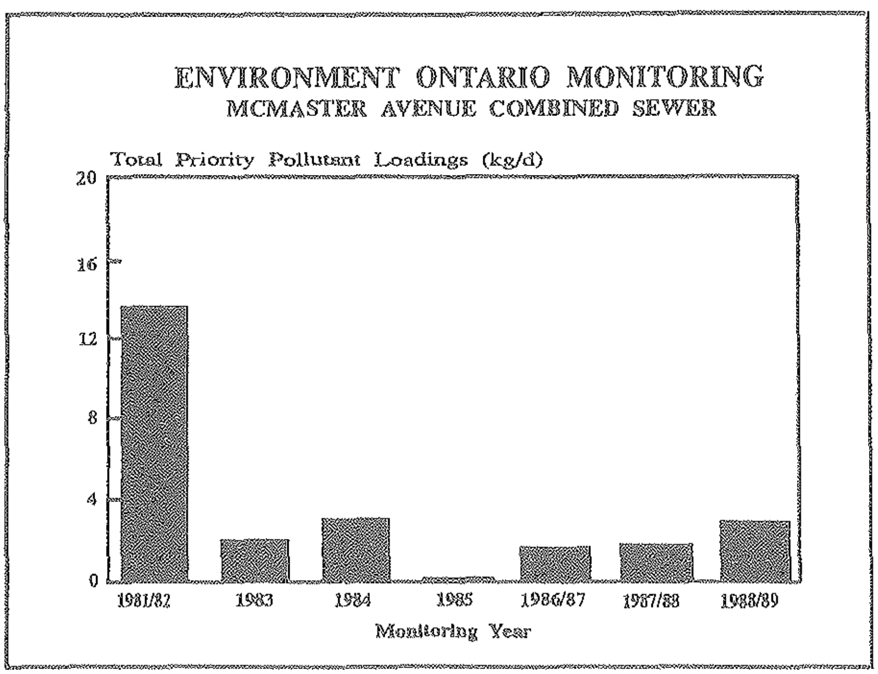
5.1.7 McMaster Avenue Combined Sewer - Welland

Prior to 1989, the McMaster Avenue Combined Sewer discharged to the Welland River downstream of the point where the Welland River flows under the Old Welland Canal and upstream of Atlas Steel's 42" sewer outfall.

In 1984, the McMaster Avenue combined sewer was a 48" combined sewer which discharged industrial process wastewater, cooling water, domestic sewage and storm water directly to the Welland River. Since that time, considerable effort has been made by the industries connected to the McMaster Avenue sewer to segregate contaminated domestic and industrial waste water from the once- through cooling water and storm water. The City of Welland has built a parallel storm sewer to the McMaster Avenue Combined Sewer for storm water and cooling water discharges.

In October 1989, the necessary diversions of cooling water and storm water were completed. At the time, the City of Welland connected the McMaster Avenue sewer to the River Road Interceptor which conveys the flow to the Welland WPCP. Therefore this source no longer discharges to the Welland River on a continuous basis.

FIGURE 5.6



The McMaster Avenue sewer was determined to be a significant point source based on the NRTC's cut-off values during the 1981/1982 studies. Total priority pollutant loadings from the McMaster Avenue combined sewer for the period 1981-1989 are given in Figure 5.6.

5.1.8 Stanley Avenue Combined Sewer - Niagara Falls

The Stanley Avenue Combined Sewer, at the time of the NRTC study, discharged industrial waste and untreated domestic sewage directly to Chippawa Creek (Welland River).

Shortly after the 1981/1982 studies by the NRTC, the Stanley Avenue sewer was segregated. Industrial wastewaters and sewage were redirected to the Chippawa Parkway low lift pumping station, thus leaving a storm sewer which received both urban storm run-off and industrial non-contact cooling water discharge (from Washington Mills - Electro Minerals). The Stanley Avenue storm sewer discharges to Chippawa Creek.

At the time of the NRTC surveys, the Stanley Avenue sewer was determined to be a non-significant source of toxics to the Niagara River.

5.2 Industrial Point Sources

Fourteen industrial point sources in Ontario discharge to the Niagara River drainage basin. Four industries discharge to the Upper Niagara River and Frenchman Creek. Six industries discharge to the Welland River or Lyons Creek and the remaining four discharge to the Chippawa Creek/power canal system. One of these also discharges to the lower Niagara River at the Whirlpool.

5.2.1 Upper Niagara River Area

In 1984, three industries in Fort Erie discharged directly to receiving water bodies: Canadian-Oxy Chemicals Ltd., Gould Manufacturing and Fleet Manufacturing. They discharged a combined total of 1,290 m^3/d of wastewater directly to the Niagara River or indirectly via Frenchman Creek to the Niagara River. In 1988, Fleet Manufacturing directed its process waters to the Fort Erie WPCP leaving the non-contact cooling water being discharged to Frenchman's Creek. Since 1988, Gould Manufacturing has been connected to the Fort Erie municipal system and no longer discharges to the Niagara River. In the Chippawa Channel area, the Ontario side of the Niagara River is relatively undeveloped.

5.2.1.1 Canadian-Oxy Chemicals Ltd.

Canadian-Oxy Chemicals Ltd., Durez Division, is a division of Canadian Occidental Petroleum which has its head office in Calgary, Alberta. The plant, located on Dunlop Street in Fort Erie, was built in 1970. Approximately 50 people are employed at the plant which operates 5 days per week.

The company manufactures Phenol-Formaldehyde (P/F) resins and moulding compounds, furfuryl alcohol-formaldehyde resins and ethylene bis-stearamide wax. All production is in semi-continuous batches. Raw materials used in P/F resins include nonyl phenol, phenol, cresol, formaldehyde and catalysts. Furfuryl alcohol, formaldehyde and furfuraldehyde are used to produce the furan resins. The resins are used in the manufacture of coatings and insulation.

Approximately 330 m^3/day of water is purchased from the Town of Fort Erie and used in the process. Approximately 140 m^3/day of non-contact cooling water is discharged by sewer to Frenchman Creek. The remaining contact cooling water is discharged to town and regional sewers for treatment at the Anger Avenue WPCP.

Reaction water from the P/F resin kettles is distilled off and this highly contaminated phenol-bearing distillate water is stored on-site prior to being shipped for product recovery or disposal. Cooling water is the major discharge from the plant. A single sewer conveys the cooling water and storm water to Frenchman Creek and subsequently to the Niagara River.

The major cooling water discharge comes from the "flaker" operation. Molten product is poured from kettles to the flaker where cooling water is used to solidify the product. Although the water is used to cool flaker equipment, product can contaminate the cooling water stream. Phenol in the cooling water is the major contaminant.

The NRTC determined that this plant was a minor point source of contaminants to the Niagara River.

5.2.1.2 Gould Manufacturing of Canada Ltd.

Gould Manufacturing of Canada Ltd. (Gould National Batteries or GNB) is located on Lewis Street in Fort Erie. Gould manufactures lead acid storage batteries, primarily for industrial applications such as lift trucks, aircraft, railroad and mining equipment. Battery plates are formed by casting molten lead/ antimony or lead/calcium alloys into a mould. After casting, plates are trimmed and stamped into final shape with the scraps being recharged into the melting operation furnace. Plates are pasted with lead oxide and cured in humidity and temperature controlled ovens.

A number of charging operations (both wet and dry) occur prior to final assembly and finishing of the batteries.

Process wastewater is generated primarily from washwater and cooling water in the battery disassembly, casting and charge cycle areas. Wastewater is treated by pH adjustment and solids separation prior to release from the plant.

The major contaminant from this facility has been lead. Until recently, the plant discharged approximately 120 m^3/d of process wastewater. Gould's discharge entered a ditch which drained to the Niagara River approximately 1 km away.

Due to increasingly tighter restrictions placed on the company for effluent compliance, primarily for lead contamination, the company rerouted its wastewaters and now discharges entirely to the Town of Fort Erie sanitary sewer system. Effluent has been therefore treated at the Anger Avenue WPCP since 1988.

The ditch at Gould became heavily contaminated with lead due to an extensive period when high lead concentrations occurred in the company's effluent. The company has complied with requirements of the Ministries of the Environment and Natural Resources in remediating the drainage ditch. Approximately 1 km of ditch, sediment, bedding and banks was excavated and the contaminated materials were removed and disposed of at an approved waste disposal site. The ditch was subsequently restored and no longer provides either a source or a pathway for heavy metals to the Niagara River.

Gould was designated a minor point source by the NRTC in 1984.

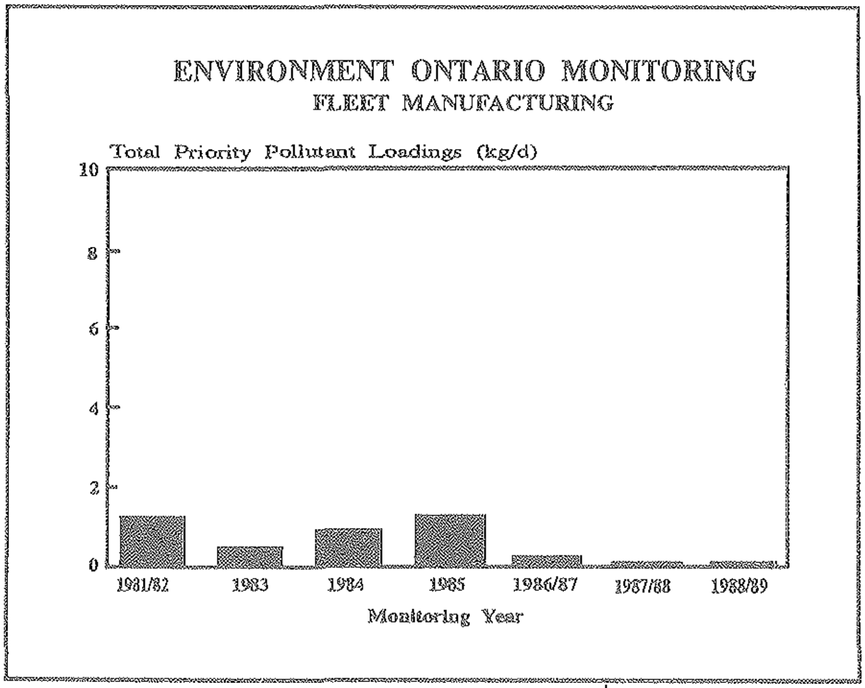
5.2.1.3 Fleet Manufacturing Ltd.

Fleet Manufacturing Division of Ronyx is located on Gilmore Road in Fort Erie. The company manufactures airplane components, sonar and radar assemblies and satellite components. Process operations include machining, degreasing, drying, bonding, plating, autoclaving and primer finishing.

Numerous organic solvents (trichloroethylene, xylene, etc.), inorganic acids, plating solutions (chromium and metal cyanide) and salt baths (sodium and potassium nitrate) are used throughout the plant operations.

Process wastewater discharges consist of noncontact cooling water, boiler blowdown, treated spent anodizing and plating solutions, plating rinse waters, treated spent spray booth recirculation water and contaminated spray water. Contaminants in the process wastewater discharge primarily consist of heavy metals (cadmium and chromium), cyanide from plating operations and organic solvents (trichloroethylene) from degreasing operations. Treated sanitary wastewater along with the process wastewater has

FIGURE 5.7



been diverted to the municipal sewer to receive treatment at the Anger Road WPCP. Non-contact cooling water is discharged to Frenchman's Creek.

Fleet was designated as a significant point source in 1984 by the NRTC due to loading of chromium in the combined effluent entering Frenchman Creek. This source should be reduced to the municipal sewer as the only flows to Frenchman's Creek are non-contact cooling water. Figure 5.7 illustrates the trend in loading of toxics in the effluent from 1981 to the present.

5.2.1.4 Diner's Delite

Diner's Delite, formerly Holiday Farms Ltd. is located on Marshall Road at the intersection with Niagara River Boulevard. The plant historically discharged combined process and sanitary wastewater, that had undergone settling in a metal tank, directly to the Chippawa Channel, 4 km upstream of Navy Island. Originally, the NRTC concluded that Holiday Farms was a minor point source discharge to the Niagara River.

Since that time, Diner's Delite has purchased the facility which prepares frozen dinners only. No slaughtering operations are performed at this plant. Major processing operations include food preparation, cooking and packaging. The present operation has been downsized from Holiday Farms Ltd. original volume.

Process wastewater originates from operations such as cooking water, poultry defrosting, product cooling water and clean-up water. Wastewater is frequently mixed with detergent and bleach. Other process related water uses include boiler water and steam condensate.

All process wastewaters flow via floor drains to a common sump. From the sump, wastewater passes through flotation separators for oil and grease removal. Following grease removal, process wastewater enters a recently constructed stabilization pond and is spray irrigated back on plant property thus removing this as a Niagara River point source.

Historically, the total plant discharge at maximum production was 90 m^3/day. The parameters of concern in the discharge from Holiday Farms were primarily conventional pollutants, including BOD, suspended solids and oil and grease.

5.2.2 Welland Area

The Welland area has six industries which discharge to the Welland River either directly or indirectly via Lyons Creek.

In the City of Welland, Atlas Specialty Steels Division and Gencorp-Diversitech General discharge treated industrial wastewater to the Welland River. Stelco-Stelpipe Welland Tube Works Division discharges industrial wastewater to Lyons Creek which ultimately flows into Chippawa Creek (Welland River).

In the area between Welland and Niagara Falls, Ford Motor Company Ltd., B.F.Goodrich and Cyanamid of Canada-Welland Plant discharge industrial wastewater to the Welland River. In addition, Laidlaw Environmental Services, a hazardous waste transfer station located in Thorold, discharges storm water from site runoff to the Welland River near Port Robinson.

5.2.2.1 Atlas Specialty Steels Division

Atlas Specialty Steels Division, until recently a part of Rio Algom Ltd. and now owned by Sammi Steel, is located in Welland, east of the Welland River between Brown Road and East Main Street. The plant employs 1200 people and produces specialty grades of steel. The steel grades include carbon, stainless, low and high alloy, tool, machinery and mining steels in billet and ingot form. During 1987, Atlas Specialty Steels produced 200,000 tonnes of steel.

Atlas Steels was identified as the single largest contributor of priority pollutant metals to the Niagara River from Canadian point sources during the studies carried out by the NRTC.

Electric arc furnaces are used to melt scrap metal. Argon ladle refining, vacuum oxygen refining and vacuum arc degassing are used to refine the steel melt. The steel is then continuously cast or subject to top and/ or bottom pour ingot teeming. Surface imperfections are removed from billets and ingots in conditioning operations prior to further processing. No coke making operations (coke oven batteries) or blast furnaces exist at this facility.

The steel undergoes either forging or hot rolling. Hot rolling consists of primary rolling to produce blooms, billets and large bars and secondary rolling to produce specialty steel shapes. Following the forging and hot rolling processes, the steel may undergo heat treating, machining or cold finishing.

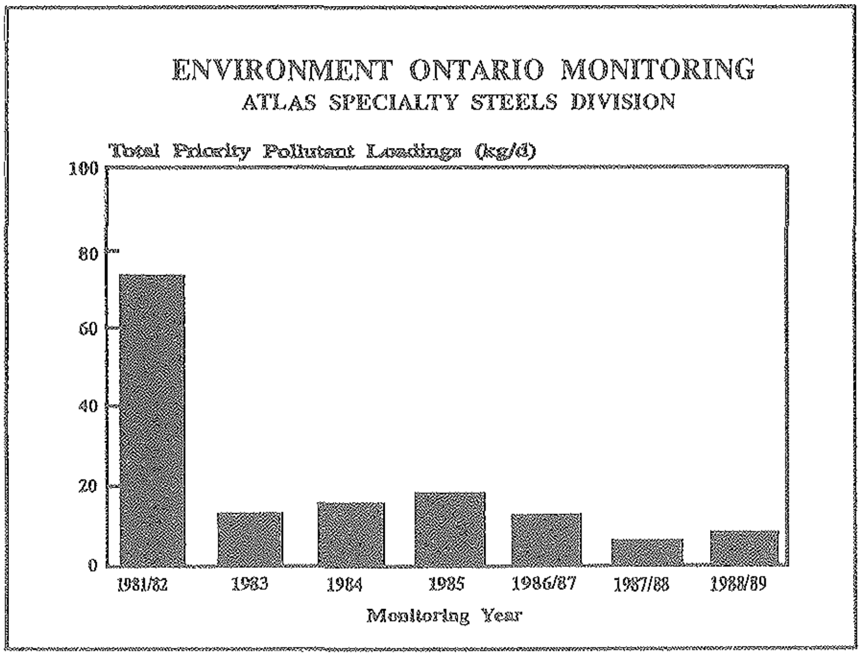
Atlas Steels discharges approximately 85% of its process wastewaters (cooling and treated process) through a single sewer known as the Atlas 42" Sewer. The Atlas final effluent is composed of mainly contact and non-contact cooling water with a minor contribution of treated pickling rinse water and treated effluent from the Waste Acid Solidification Plant. Discharge from Atlas Steels through this sewer averages 24,700 m^3/day.

Atlas raw cooling water is pumped from the Old Welland Canal for use in the plant and then treated in two water filtration plants prior to being discharged to the Welland River. An ongoing sewer separation project performed at the plant has resulted in all contaminated streams being treated in the treatment plants prior to release to the 42" sewer.

Figure 5.8 shows the trend in effluent loading of toxics from Atlas Steels to the Welland River and ultimately the Niagara River for the period commencing 1981.

Historic deposition of materials, mostly metals, have accumulated in the river at the 42" sewer discharge forming the Atlas "reef". This zone of con-

FIGURE 5.8



taminated sediment has been discussed in detail in section 4.5.1.2. Preliminary clean-up efforts have been conducted and the results are being assessed. Biological assessment and further work is continuing with excavation of contaminated material contemplated in the near future.

5.2.2.2 Gencorp-Diversitech General

The Engineered Elastomers Division of Gencorp-Diversitech General is located at John and Bernard Streets in the City of Welland. Gencorp is the single largest user of treated City water in Welland. The company manufactures automotive rubber trim (window, door, trunk seals) and, prior to 1992, sporting equipment (bowling balls and hockey pucks). Effluent from this operation is discharged via a number of outfalls to either the McMaster Avenue Combined Sewer or to Atlas Steels' 42" sewer.

The Diversitech operation involves the mixing of raw rubber, carbon black and formulating chemicals to obtain a processed rubber with desirable characteristics for extrusion into automotive products or sporting equipment. Following extrusion, the processed rubber is generally cured using either high temperature and pressure or a hot liquid salt bath (normally sodium nitrite). Following curing, excess rubber is removed from the product and gluing to appropriate frames is performed using an isocyanate-based glue. After final curing, the finished product is shipped from the plant to appropriate markets.

The company has implemented a water reduction program, increased cooling water reuse, and is in the process of replacing the hot liquid salt baths with air curing equipment to reduce discharges.

Limited data exists at this time to determine the impact of the Diversitech operation and whether or not this is a significant source of toxics to the Niagara River.

5.2.2.3 Stelco-Stelpipe Welland Tube Works

The Stelpipe Welland Tube Works is located on Ridge Road in Welland just east of the Welland Ship Canal. Process wastewater passes through an oil/ water separator and a settling lagoon before being discharged to the headwaters of Lyons Creek, a tributary to the Chippawa Creek portion of the Welland River. Results indicate this facility was identified as a non-significant source of toxics to the Niagara River.

Two plants for manufacturing of steel tube are located at the Stelpipe Works. The two plants are capable of manufacturing tube from 20 to 60 inches in diameter. The older of the two plants, known as the "U and O" Mill produces pipe from 20 to 36 inches in diameter using a submerged arc welding process. The newer plant, known as the Stelform Mill, produces 36 to 60 inch diameter tubes using the spirally formed submerged arc welding processes.

Steel skelp (plate) is brought into the facility from other sources and formed and welded on site. Materials used during the processing of the steel skelp into finished pipe include: welding fluxes, trichloroethane for degreasing, toluene solvent and paints for finishing of the tubes. In addition to process and cooling water discharges from operations involving these contaminants, silver bromide is also discharged from photographic processing of X-ray films used to quality assure welds on the tubes. Water is also used for pressure sizing (expansion), hydrostatic testing of finished pipe and rinsing in preparation for surface finishing. Site stormwater is discharged to a lagoon for settling prior to overflow to Lyons Creek. Wastewater is now treated through a reverse osmosis process, prior to discharge to the sanitary sewer.

5.2.2.4 Ford Motor Company of Canada - Niagara Falls Glass Plant

Ford's Niagara Glass Plant is located in Niagara Falls, on Montrose Road, on the south bank of the Welland River. There are two discharges from this facility, both to the Welland River. The discharge points are approximately 1 kilometre upstream of the confluence of Chippawa Creek and the Welland River, where they form the headwaters of the Queenston-Chippawa Power Canal. The Ford Glass Plant was determined by the studies of the NRTC to be a non-significant source of toxics to the Niagara River.

The plant manufactures automobile and truck windshields, rear windows and body glass (side windows) from raw materials including float glass and polyvinylbutyral resin (laminate for safety glass). Major process operations include cutting, seaming, edge grinding and laminating. In addition, there are several detergent wash and water rinse steps between stages of the process operations. Other materials used in the manufacturing operations include cutting oil, grinding coolant, detergent, calcium carbonate powder and autoclave oil. Xylene and silver paste are used in the rear window defogger application process.

Water supply for domestic purposes is provided by the City of Niagara Falls' municipal water supply system. Process water used in the plant is drawn from the Welland River. Raw water from the Welland River is treated on-site at Ford's water treatment plant prior to distribution to the various process operations. The treatment consists of coagulation/flocculation, clarification, filtration and chlorination. Sludge from the treatment process is directed to the process effluent treatment lagoon.

The majority of plant process wastewater is generated on a continuous basis and originates from cooling water locations at autoclave wash baths and rinse tank overflows. Intermittent flows include weekly batch discharges of coolant tanks, wash baths and rinse tanks and from periodic clean-up operations. The majority of the cooling water is non-contact and therefore is of the same quality as the treated water provided to the facility by the process water treatment plant. Some cooling streams may contain minor quantities of particulate.

Potential contaminants to the effluent include suspended solids, BOD_5, oil and grease, dissolved salts and minor quantities of xylene, silver and phosphorus.

The company is reviewing its present sanitary wastewater treatment facility and is embarked on a wastewater reduction plan.

5.2.2.5 B.F.Goodrich Inc.

B.F. Goodrich is located on Thorld Townline Road in Thorold. The plant manufactures polyvinyl chloride (PVC) and PVC/polyvinyl acetate resins from monomers. These resins are used in the manufacture of clothing, automobile trim, piping, wire insulation, window frames, swimming pool liners and siding for houses.

Intake water for the plant is pumped from the Welland River. The site makes use of cooling towers to reduce fresh cooling water inputs. Blowdown is routed through the biological treatment plant prior to recirculation. Total effluent discharged is approximately 2 329 m3 per day.

Until the summer of 1988, two distinct processes were employed in production, emulsion/polymerization and suspension. The emulsion process is the older of the two processes used at this facility. It results in greater contamination of water due to the inherent nature process and the age of the plant. Wastewater from the emulsion process was steam stripped in three tanks prior to biological treatment. The treated effluent was then routed to an aeration pond, followed by a polishing lagoon prior to discharge into the Welland River.

In June 1990, a facility for compounding PVC with plasticizers and stabilizers was opened. Both PVC resin and cubes of compound began production under this method. The newer suspension unit process uses a distillation column to recover vinyl chloride monomer before the wastewater is discharged to the common aeration pond and polishing lagoon.

Waste PVC and thickened biological sludge were dewatered in a reclaim pond equiped with underdrains. The resulting leachate was directed to a valved off leachate pond which was batch discharged to the Welland River every 1 to 2 months.

The old emulsion process was phased out with the full commissioning of the new suspension process plant. The emulsion process ceased by June 1991 and the plant was decommissioned in November 1991.

Coinciding with the process change was an upgrading of the on-site wastewater treatment system. The stabilization ponds were removed and replaced with two equalization basins. Biological treatment was increased to two activated sludge units followed by a secondary clarifier. Tertiary treatment was added in the form of a gravity sand filter system. A vacuum filter was also installed for the sludges generated by the primary and secondary clarifiers. The resulting supernatant is now routed back to the treatment system while the filter cake is disposed of off-site.

The NRTC determined that this plant was a minor source of contaminants to the Niagara River.

5.2.2.6 Cyanamid of Canada Limited - Welland Plant

Cyanamid of Canada's Welland plant is located at the western boundary of Niagara Falls at Garner Road and Chippawa Creek Drive. The Welland facility manufactures ammonia, dicyandiamide, 50% cyanamide solutions, phosphine and phosphine derivatives and electronic grade chemicals. It currently has one effluent disharge into Thompson's (Miller) Creek which drains into the Welland River.

The ammonia production facility was closed in April 1990. Previously, ammonia was manufactured by the reaction of hydrogen gas with nitrogen over a catalyst at elevated temperatures and pressures. Natural gas is reformed at high temperatures to supply hydrogen, while nitrogen is obtained from the air. Carbon dioxide is formed as a by-product.

Dicyandiamide is formed when hydrogen cyanamide solution is reacted at elevated pH. The resulting dicyandiamide solution is then crystallized, centrifuged and dried. Hydrogen cyanamide solution is also concentrated and sold as product.

Water for process operations is pumped from the Welland River to the facility and treated for use as process water. Approximately 28,800 m^3/day of Welland River water is used. Approximately the same volume is discharged to Thompson's Creek. Until recently, backwash from the filtration plant had been discharged directly back to the Welland River. The filtration plant is no longer in operation at this facility.

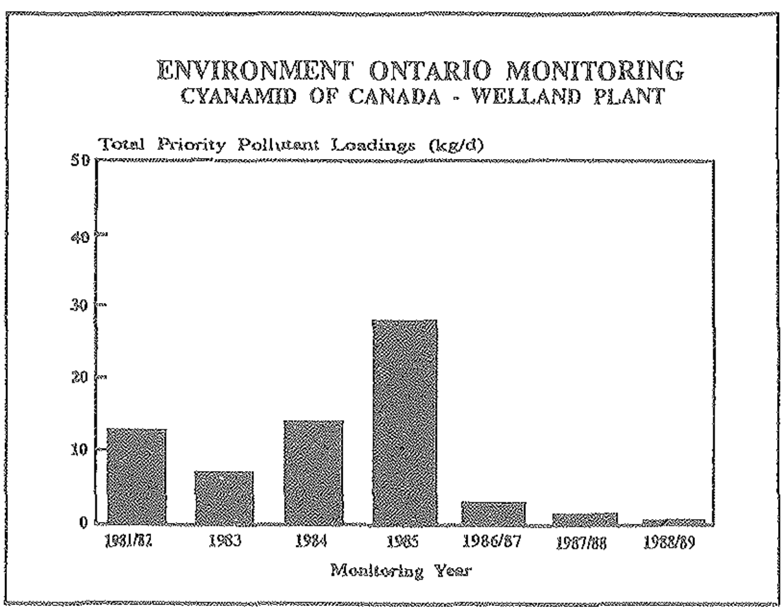
Wastewater is generated from boiler, compressor, cooling tower and steam plant blowdowns. Wastewater also originates from once- through cooling water streams, barometric condensers, and decant water from a sludge settling pond. All process units discharge to Thompson's Creek, which runs through Cyanamid property. The active sludge pond on site receives waste sludge from the phosphine and dicyandiamide plants; the solids settle out in the pond and the water overflows into Thompson's Creek.

In the past, discharge from this facility has been subject to sudden pH changes as well as sudden changes in electrolytes (as measured by changes in specific conductance). Cyanamid has installed an equalization pond upstream of its final outfall point in order to reduce the severity and frequency of occurrence of these surges in the makeup of the effluent.

Phosphine gas is produced when yellow phosphorus is heated with steam in a reactor.

In May 1987, a major portion of the Cyanamid - Welland facility was shut down. Unit processes which are no longer operative at this facility produced nitric acid, ammonium nitrate, calcium phosphate and urea. In the spring of 1990, all manufacturing operations except phosphine and cyanamide were shut down.

FIGURE 5.9



In 1984, the NRTC designated the Cyanamid of Canada - Welland Plant as a significant point source due to the loading of cyanide and heavy metals entering the Welland River from Thompson's Creek and an old outfall (since abandoned) to the Welland River. Figure 5.9 illustrates the trend in effluent loading of toxics to the Niagara River for the period beginning in 1981. The major source of heavy metal has been eliminated with the discontinuation of the use of chrome in the cooling tower.

5.2.2.7 Laidlaw Environmental Services Facility

Until recently, the Laidlaw Environmental Services Facility was known as the Tricil-Syntath hazardous waste transfer station. This site is located in the Port Robinson portion of the city of Thorold. Laidlaw's Thorold operation can best be described as two separate operations, previously known as Syntath and Alero.

The Syntath portion of the site processes waste laboratory materials or LAB-PACKS. Waste laboratory solvents, acids, bases, etc., are transported to the site where the materials are bulked, blended and neutralized in a batch reactor. The blended material is then stored in two storage tanks prior to shipment to the Laidlaw-Tricil Sarnia operation for incineration. Syntath can process most waste types provided they are small quantities and limited to laboratory wastes.

The Alero portion of the Laidlaw site processes primarily industrial waste liquids such as solvents. The waste is transported to the site and bulked into dedicated storage tanks or 45 gallon drums. The bulk material is then re-shipped either to recyclers or for final disposal. The site's activity is restricted to bulking chemicals.

No process wastewater is generated at this facility. However, a storm water management system onsite results in storm water being collected in a holding area, monitored for a number of parameters and discharged at controlled rates to the Welland River. This storm water management system has been in place for only a short period of time and its impact as a significant or non-significant source to the Niagara River has not yet been assessed.

5.2.3 Niagara Falls Area

In the Niagara Falls area, four industries discharge wastewater to Chippawa Creek, the Queenston-Chippawa Power Canal or the lower Niagara River. In Chippawa, Washington Mills - Electro Minerals and the Norton Company discharge cooling waters to Chippawa Creek and Pell Creek (tributary to Chippawa Creek). In the same area, a second Washington Mills Ltd. plant also discharges wastewaters to a small unnamed tributary of Chippawa Creek. In the north end of Niagara Falls, Cyanamid of Canada's Fourth Avenue plant discharges wastewaters to the power canal and to Whitty's Creek, a small tributary of the Niagara River near the Whirlpool.

5.2.3.1 Washington Mills - Electro Minerals

Washington Mills - Electro Minerals Corporation has undergone a number of corporate name changes over the past decade. This facility has previously been known as Electro Minerals, Sohio and Canadian Carborundum. The plant is located on the east side of Stanley Avenue near McLeod Road in Niagara Falls. There are two combined effluent discharges: one to the headwaters of Pell Creek and the other to the Stanley Avenue storm sewer, which discharges to Chippawa Creek.

Washington Mills - Electro Minerals manufactures a variety of metallic abrasive rods. These rods are brown alumina, pink alumina, alumina bubbles, ferrosilicon, fused mag-chrome and ferro-carbo briquettes. Electro Minerals employs approximately 100 people.

All of the products are manufactured by similar processes and vary only in the starting raw materials. All raw materials are weighed and fed into a furnace in defined proportions where they are fused together and poured into moulds for cooling. The cooled material is then crushed, sorted and screened to yield the final product. Raw materials include bauxite, coke, iron, white alumina, chromic oxide, ferro-silicon, magnetite and chromium ore.

Intake water is pumped from Chippawa Creek at a rate of approximately 30,000 m^3/day. Wastewater is generated from power transformer cooling, contact cooling of product during solidification and head cooling of furnaces. The cooling water is sent to two settling lagoons for solids removal and oil and grease removal prior to discharge to Pell Creek and the Stanley Avenue sewer.

The NRTC determined that this plant was a minor point source of contaminants to the Niagara River.

5.2.3.2 Norton Company Canada Ltd.

The Norton facility is located in Chippawa on the north bank of Chippawa Creek (Welland River) and employs approximately 225 people. The facility has four discharges, two to Pell Creek (a tributary to Chippawa Creek) and two to Chippawa Creek directly. Norton manufactures various types of abrasive grains including light and dark aluminum oxide, alumina-zirconia and chromic oxide.

The dark aluminum oxide is produced by fusing bauxite, coke and iron together in cupolas. The material is then cooled, crushed and ground before shipping as a granular product.

The light aluminum oxide is produced in a similar manner; however, sulphur is added during the reduction process while in the electric arc furnaces. Light aluminum oxide is formed into ingots and crushed. The grains are first slaked in acid before being washed with water to remove iron impurities. Finally, the grains are dried and undergo magnetic separation. Alumina-zirconia is manufactured by fusing calcined alumina, baddelyite (zirconia) and coke together. The melt is solidified and crushed to produce a very tough abrasive grain.

Intake water for the facility is pumped from Chippawa Creek at a volumetric rate of approximately 14,200 m^3/day. Wastewater is generated from cooling water for furnace shells, power transformers and cooling moulds. Wash water from the light aluminum oxide process is neutralized and discharged to a settling lagoon prior to being pumped to the Pell Creek discharge location.

In 1984, the NRTC determined that this plant was a minor point source of contaminants to the Niagara River.

5.2.3.3 Washington Mills Ltd.

Washington Mills other facility is located on the west side of Stanley Avenue at the end of Progress Street in the south end of Niagara Falls. The plant, which employs approximately 35 people, has one discharge point on a small tributary to Chippawa Creek. The facility manufactures aluminum oxide abrasive grains, ferro-silicon and crude aluminum oxide.

Aluminum products are manufactured in electric arc furnaces where bauxite, coke and iron are fused together to produce an aluminum oxide melt. The melt is poured into cooling pots for solidification. Solid material is then extracted from the cooling pots and broken down to final product grains.

Intake water is supplied from an on-site well at a rate of 1,630 m^3/day. Wastewater is generated from cooling of furnace shells and melt pots. Spent cooling water is collected in open channels and flows to a cooling pond for solids settling. A portion of this water is recycled while excess overflows to Chippawa Creek.

Limited toxics data exist for this facility and its impact as a source to the Niagara River is still being assessed. However, preliminary indications are that this source will be a non-significant source of toxics to the Niagara River if the NRTC criteria were applied.

5.2.3.4 Cyanamid of Canada Limited - Niagara Falls Plant

Cyanamid of Canada's Niagara Falls plant is located on 4th Avenue in the City of Niagara Falls. The company employs approximately 300 people at this facility. It manufactures calcium carbide, calcium cyanide, calcium cyanamide and desulphurization reagents.

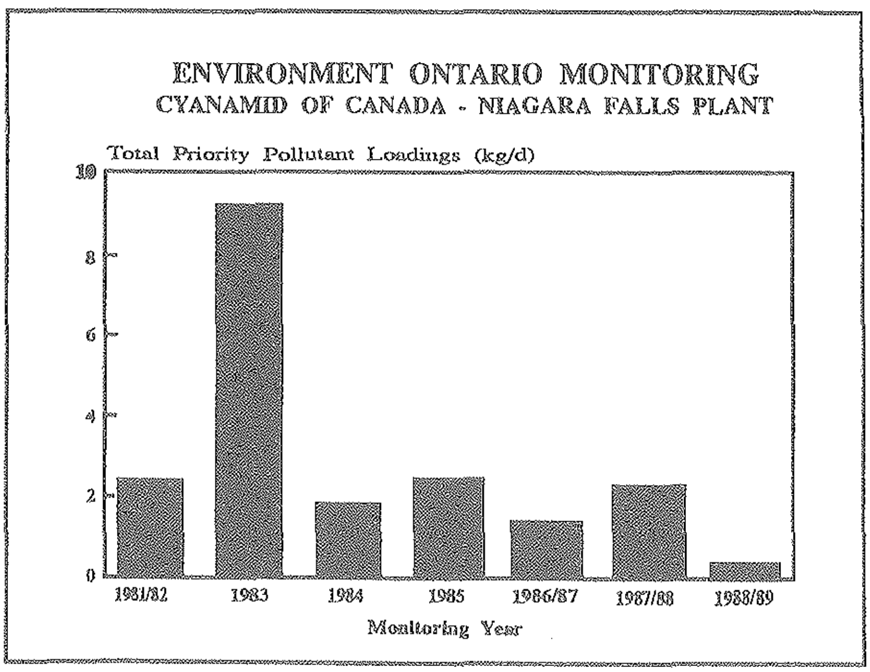
Calcium carbide is manufactured by reacting coke with lime in an electric arc furnace at high temperature. Calcium cyanamide is formed from the reaction of calcium carbide, nitrogen and fluorspar. By-products formed from these processes include carbon monoxide, oxygen and calcium carbonate sludges. Desulphurization reagents are formed from the blending of diamide lime with calcium carbide.

Calcium carbide is used in the manufacture of acetylene gas, as an intermediate for calcium cyanide and in the steel industry for desulphurization of steel. Calcium cyanide is used in the gold refining industry.

Water for the plant processing is pumped from the Queenston-Chippawa Power Canal at a rate of approximately 32,400 m^3/day.

The process water is used mostly for cooling jackets of the electric furnaces and transformer cables. Approximately one-third of the cooling water is discharged directly back to the Power Canal while the remainder is discharged to the cooling water pond where it can be recycled. Overflow from the cooling water pond, approximately two-thirds of the total daily plant flow, discharges to the Niagara River at the Whirlpool via Whitty's Creek from a 54" sewer outfall. Contamination of cooling water within the plant occurs from spillage of raw materials and product into storm drains that discharge directly into cooling water discharges.

FIGURE 5.10



All production facilities at the Niagara Plant were permanently shutdown in March 1992, thereby eliminating this facility as a point source to the Niagara River.

Cyanamid of Canada's Niagara Falls plant was designated as a significant point source by the NRTC due to loading of cyanide and heavy metals entering both the Power Canal and the Niagara River. The trend in effluent loading of toxics for the period commencing 1981 from this facility is shown in Figure 5.10.

5.3 Combined Sewer Overflows

Over the past 10 to 15 years, a lot of money has been spent to build or upgrade municipal wastewater treatment facilities within the Regional Municipality of Niagara. However, relatively little has been spent on building or upgrading the sewers that carry wastewater to the treatment plants and which are commonly referred to as the "infrastructure".

Historically, sewers were designed as combined sewers throughout Ontario, including Niagara Falls, Welland, Niagara-on-the-Lake and Fort Erie. These sewers conveyed both sanitary wastewater and storm water either directly to watercourses or to the nearest wastewater treatment facility. Over the decades (between 1950 and 1990) direct discharge of combined sewers to surface waters has been reduced by either redirection of flows to a treatment plant or sewer separation. Combined sewer flows to municipal treatment plants work well during dry weather when only sanitary wastewater is involved; however, during wet weather events, the quantities of storm water generated as a result of the intensity and duration of storms requires that overflows be built into the sewage collection system or infrastructure. During these wet weather events, overflows of dilute untreated wastewater occur to the surface waters from adjacent communities. This type of pollution is very difficult to quantify for total loading to and impact of contaminants on the environment.

During recent years, sewage infrastructure has increasingly been designed with separate systems for sanitary wastewater and storm water. Generally, these separated systems do not incorporate overflows. Pumping stations are used to deliver sanitary sewage to the wastewater treatment plant in areas where flow via gravity alone cannot occur. However, the pumping stations are generally designed with emergency overflows incorporated into them.

During wet weather periods, overflows at pumping stations may occur due to inflow or infiltration where the influx causes the combined flow to exceed either the pumping capacity of the station or the capacity of sewers further up in the system. Inflow and infiltration are terms used to define the entry of storm water or ground water, respectively, into the sanitary sewer system. Inflow can occur due to storm water entering the sanitary sewer from connections such as roof drains and foundation weeping tile drains in residential areas. Infiltration can occur when ground water enters the sewer through cracks or poor joints in the sewer pipe.

In the Niagara River drainage area, the four major municipalities have both combined sewer overflows and overflows at sewage pumping stations. The municipalities of Fort Erie, Niagara Falls, Welland and Niagara-on-the-Lake all have relatively old centre cores and infrastructure, which result in combined sewer overflows and pumping station overflows to the Niagara and Welland Rivers.

These municipalities are currently in various stages of conducting Infrastructure Needs Studies (INS). These detailed studies of the infrastructure system are designed to determine the general condition of the sewer system and the extent and cause of the combined sewer overflows and the pumping station overflows and to recommend remedial measures for dealing with these problems.

In Niagara-on-the-Lake, the INS has been completed. The study recommends the expenditure of approximately 11.7 million dollars for repair to and upgrading of the local infrastructure. Several storm sewer separation projects have been completed in addition to increasing the Pumping Station capacities to transfer sewage flows to treatment facilities.

In Niagara Falls, the municipality is continuing INS for the community of Chippawa. A city-wide study commenced in 1991. The city has committed to a doubling of the budget to 4.0 million dollars annually for sewer remediation projects. Half of the remediation will occur in the tourist/commercial core of the city, which is currently served by combined sewers and which is undergoing considerable redevelopment. Niagara Falls is pursuing the installation of water conservation devices in new development to reduce the base flow in sewers and thereby reduce the quantity of overflows or eliminate them completely. Existing large diameter trunk sewers have been retrofitted with flow control weirs to increase storage capacity during storm flow events.

The Infrastructure Needs Study for the Town of Fort Erie is complete. Recommendations for appropriate upgrading of the system and the use of storage facilities for overflows is currently being finalized by the municipality for future implementation. The Town has implemented a water conservation program and increased storm sewer separation projects.

In Welland, combined sewer overflows also exist and the municipality has also embarked on an Infrastructure Needs Study. The municipality is also involved in extensive storm sewer separation projects.

5.4 Urban Non-Point Runoff

Urban runoff in the Canadian basin of the Niagara River was studied in 1982 to establish frequencies and annual loading of selected persistent toxic substances[161]. The cities of Welland and Niagara Falls and the Town of Fort Erie were surveyed to obtain representative samples of runoff and sediments. A total of 110 wet and dry events were sampled at 16 sites. The samples were analyzed for PCBs, organochlorine pesticides, PAHs, chlorinated benzenes and heavy metals. The annual runoff and solids loading were estimated to be 21 million cubic metres/year and 6 thousand tonnes/year, respectively, for this study area (1,360 km^2 area).

In the sediment samples, the most frequently detected substances were metals (arsenic, copper, lead, selenium and zinc), PCBs, some pesticides and several chlorinated benzenes. PAHs were rarely detected. In general, concentrations of toxic substances in the runoff samples were several orders of magnitude lower than those in the sediments. Two metals (mercury and zinc), one organic (1,2-dichlorobenzene) and two pesticides (alpha-BHC and lindane) were the most frequently detected compounds in the runoff samples. None of the metal or pesticide concentrations detected in the runoff samples exceeded the Great Lakes Water Quality Objectives on average; however, this does not preclude exceedance for individual events.

The issue of stormwater runoff may not be as significant for the Niagara River (Ontario) Area of Concern as it is for other, more urbanized AOCs. The urban areas of this AOC are relatively residential with minor amounts of historical or current heavy industry. Stormwater runoff from the New York side is likely to have a much greater impact on the river itself. Urban runoff from the Ontario AOC likely affects the water quality of the Welland River and other tributaries, and possibly impacts some beaches.

5.5 Rural Non-Point Runoff

Non-point sources represent a complex hydrological and biogeochemical problem. In 1984, the U.S. Environmental Protection Agency determined that, in many cases, water quality goals could not be attained unless non-point sources of pollution were cleaned up or mitigated[162]. Almost any type of land use is a potential contributor of non-point source pollution. Non-point sources have been simplistically defined as those which are diffuse and do not discharge through a pipe. This definition does not consider urban stormwater runoff or irrigation return flow which are treated as non-point sources but discharge via drains, ditches, culverts and storm sewers which are by strict definition point sources. A better definition of non-point sources are those sources where contaminants are available on the land surface and contaminant transport depends on surface runoff or leaching based on precipitation (rain, snowmelt or irrigation). As the state of environmental knowledge progresses, other non-point sources such as contaminated sediments, urban runoff and atmospheric deposition broaden the nature of non-point pollution beyond the traditional.

Natural areas such as forests, marshes and grasslands generally contribute little to the pollution or alteration of rivers and indeed likely improve and protect water quality. Water passing through these ecosystems acquires a characteristic concentration of many substances, considered normal for that geologic area. This natural concentration of substances generally fosters a wide range of aquatic organisms. Although naturally added materials can cause occasional upsets, these are usually cleaned up by natural methods or are small enough to be solved by natural dilution.

Non-point pollution has traditionally centred on the issue of rural runoff. For many years, studies have been centred around farming activities and usually involved pesticides, herbicides, bacteria, nutrients and other conventional contaminants or the erosion and deposition of the soil particles themselves. The overall objective of these studies has been to reduce the hazard associated with sediment and agricultural chemical losses (and possibly to simultaneously protect the soil resource and improve efficiency of chemical use)[163].

Water quality monitoring and assessment have historically revolved around either loading determinations or basin mouth assessments in dealing with rural non-point pollution. These types of studies do not readily lend themselves to identification of specific problem sites. Locations within the drainage network are not always specified, and distances between sources and monitoring points are not generally known.

Extensive agricultural activities throughout the Welland River Basin and areas on the west side of the Upper Niagara River may have already caused some contamination of ground water, surface waters and river sediments, although the impact and extent are not known[164].

Agricultural practices that generated concern during the 1950's are still problems that exist today, although some attempts have been made to control this off-site migration through the use of better farming practices. New methods of control of pests and vegetation are contributing toward a reduction in the impact of contaminants coming off fields, orchards and feedlots. Some residual contamination from past practices, particularly the application of long-life herbicides and pesticides, is still being felt by the ecosystem. This may continue for some time at low levels, until these substances have been leached out, bound permanently in place by the native clay and till soils of the upper Niagara Peninsula or been otherwise degraded to other, safer substances.

The traditional rural method of disposing of domestic wastes through septic tank systems can lead to contamination of ground and surface waters, particularly when these systems fail. This tendency to failure is significant in older septic beds. In the Niagara Peninsula, the tight clay soils compound the problem, since their capacity to assimilate the sewage is poor.

This problem has already surfaced in the Stevensville-Douglastown area where extensive septic system failure has led to contamination of Black Creek.

Similar massive system failure in the Queenston area also affected a reach of the lower Niagara River immediately below the escarpment. The problems in these two communities have since been rectified with the construction and operation of communal sewage treatment facilities.

Rises in contaminant levels in the waters of the Niagara River and its tributaries which may be attributable to rural non-point runoff are typically associated with precipitation events. Rainfall or snowmelt causes considerable erosion of the fine clay soils in the Niagara area. These soil particles remain suspended in the water column and can be carried considerable distances before settling to the bottom of the creeks, rivers, the Sir Adam Beck Reservoir or Lake Ontario. These soils carry with them, the tightly bound chemicals (pesticides, herbicides and fertilizers) and organic matter (manure).

Soil conservation methods, such as the buffering by green strips along river banks, contour plowing and agricultural planning can all contribute to the prevention of soil loss as well as organic and chemical contamination of surface waters. However, the need for economic productivity from the farming community often makes such measures uneconomical to the average farmer.

Delivery of pollutants from agricultural areas to the mouth of a watershed, such as the Welland River basin, involves a number of chemical, biological and physical steps. These processes and pathways can be grouped into two distinct phases. Once flow starts, the overland or subsurface flow is significantly different from the in-channel flow. Both subsurface (ground water) flow and surface runoff are slow moving physical processes compared to in-stream flows due to the differences in hydraulics involved. This is particularly true for ground water flow through the active surface soils, where the soil matrix has an opportunity to participate in physical-chemical processes. Pollutants exist in either dry or damp conditions on the ground surface depending on the moisture content of the soils. Pollutants under dry conditions are susceptible to wind-driven movement through the air in random directions, while those in moist conditions can start percolating downward to more mobile ground water routes. Once these chemicals enter the surface water channels, the chemical and biological conditions are markedly different. Biogeochemical processes vary dramatically between the aquatic and terrestrial environments[165]. These processes (infiltration, runoff, erosion, adsorption-desorption and chemical transformation) control chemical partitioning, decomposition, decay and recombination.

The loss of pesticides in subsurface drainage is usually small due to pesticide adsorption to soil, in particular to tight clay or organic soils. The exceptions are weakly adsorbed anionic herbicides such as dicamba, picloram, 2,4-D propionic acid or amiben[166,167]. Pesticides are generally not found in ground or tile water[168,169,170]; when they are found in these waters, they are at dilute concentrations[171,172,173] or are the result of polluted irrigation water[174] or direct contamination[175]. In studies on herbicide runoff loss[176], it was found that where herbicides were surface applied with discing carried out with or following application, runoff losses were markedly reduced; however, those herbicide losses which did occur were mostly (75%) associated with dissolution in water and therefore erosion control measures would be ineffective. The average herbicide concentrations in runoff from treated fields is low (ppb level) in the long term; however, intense rainfall or rainfall shortly after application can result in high (ppm level) concentrations in runoff water[163].

The impact of snowmelt on nutrient concentrations has been studied. Snowmelt has been determined to account for 56 to 100 percent of soluble nitrogen loss from mixed cover watersheds[177].

The concentrations of pesticides in runoff water from agricultural areas only exceeds drinking water objectives some of the time[163]. In-stream (rivers, lakes and ground water) concentrations rarely exceed the criteria. As far as nutrients are concerned, the drinking water objective for nitrate is sometimes exceeded in surface and ground waters receiving agricultural run-off: however, instances have been noted where the concentrations in rainwater themselves exceed these criteria. It is possible that ammonia levels in runoff can exceed 2 ppm which may be acutely toxic to fish. In addition, concentrations of nitrogen and phosphorus in runoff from intensively farmed cropland are usually sufficient for the growth of algae in nearby receiving waters[163].

The problem of contamination of the Welland and Niagara Rivers from agricultural areas on the Canadian side of the Niagara River has traditionally been viewed as a minor contribution to a much larger and complex problem. Suspended solid information for the Welland River, measured at Empire Corners, suggest that this might not be a minor problem but may be a significant cause of depressed fish populations in the Welland River.

Recent efforts have centred on identifying and solving contamination from point source discharges and landfills. In considering the need for pollution controls, the relationships (timing, flows and loads) between point and non-point sources of pollution are very important. Statements are sometimes made that control of point sources is not necessary because they only contribute a small percentage of the load a water body receives. However, it must be remembered that the point source is often a nearly constant load regardless of streamflow, whereas the non-point load, if from surface runoff, usually comes only during short-duration, high flows. Therefore, if concentration-duration criteria for a problem are used, the point source may represent a much greater problem, if uncontrolled, than its percentage of the total load would indicate[163].

In order to properly define the amount of contamination from these sources, more extensive investigation may be required. This basin-intensive type of data collection may involve wash-off monitoring over specifically defined areas, determination of contributing areas to various monitoring points and evaluation of the effect of distance on the area's hydraulic and biogeochemical processes. The question of distance also brings into consideration additive effects and multi-media interactions.

5.6 Waste Disposal Sites

Solid waste disposal associated with industrial and municipal activities has been deposited in a number of landfills throughout the Province of Ontario. Within the Niagara and Welland River watersheds, 16 landfill sites were identified in 1983 by the Ontario Ministry of the Environment[111] as part of the studies undertaken for the Niagara River Toxics Committee. In addition to existing closed and operating landfills, the Ontario Waste Management Corporation has also selected its prime candidate site within the drainage boundaries of the Welland River. Of the 16 landfill sites identified by the NRTC, in its 1984 report, five of these were identified as having a significant potential to impact on the water system[30]. This significant site classification does not necessarily imply that off-site contaminant migration is actually occurring[30]. The five sites classified by the NRTC as significant are indicated in the following table.

Site	Location	Reasons for Classification
Atlas Landfill	Welland	2,5
Cyanamid Landfill	Welland	1,4
Cyanamid Landfill	Niagara Falls	1,2
Bridge St.Landfill	Fort Erie	3
CNR Landfill	Niagara Falls	2,5
Legend: 1983 assessment	1 chemical contents (Cyanide) 2 proximity to surface waters 3 known ground water contamination 4 size of site 5 local topography	

The first four sites come under provincial jurisdiction while the fifth is under federal jurisdiction. Investigations have been undertaken at all five of these landfills.

Atlas Landfill

Atlas Steels has operated a 17.7 ha. landfill on the east bank of the Welland River since the 1930's[836]. This site is located at the north end of Welland immediately north of the new Woodlawn Ave.- Cambridge Rd. extension (Figure 5.11). Wastes disposed of at this site is primarily electric furnace slag but in the past has also included baghouse dust, concrete and refractory rubble, lining bricks, metal scale, grinding swarf, excavated soils and waste acid sludges and rinses[836]. This waste was never measured nor weighed. Since 1984, waste acids ceased to be transported to the landfill.

The slag disposed at the site is predominantly calcium oxide and silicon dioxide with minor amounts of alumina, magnesium oxide, manganese oxide, chromate and iron oxides. It may also contain zinc, nickel and cadmium oxides. For the most part, heavy metals in slag tend to remain in place due to the chemical properties of metals in this highly alkaline medium. Provided the metals are kept at high pH, they do not dissolve in water (with the exception of lead).

The major problem with Atlas' landfill arose in 1982 with the mixture of the heavy-metal bearing slag with waste acids. The site has been used over the years for the disposal of these spent acid wastes and acid rinses in a natural depression in the centre of the landfill since a clay bottom already existed there. The walls of the depression were extended upwards by landfilling the slag material. As acidic waters overflowed the natural depression, they ran through the permeable slag cover and became neutralized by the alkaline lime in the slag before emerging at the toe of the landfill. Problems arose when the "buffering capacity" of the slag between the depression and the toe had been used up. In the early 1980's the water leaking from the toe of the landfill started to emerge at low pH. This acidic water also started to dissolve the heavy metals in the spent slag and carry them away to the Welland River.

Atlas Investigations

The Ontario Ministry of the Environment conducted a preliminary hydrogeological investigation of this landfill[657]. It was concluded that the tight clay soils of the area would prevent any significant downward migration of contaminants[657,835] (heavy metals). Lateral migration of contaminants was restricted by the construction of a clay berm around the toe of the landfill and treatment of solids in a settling pond prior to discharge to the Welland River. The major cause of contaminant movement, the waste acid, was removed from the depression in 1985 and treated at Atlas' waste acid solidification plant (WASP) constructed under a Ministry Control Order. Waste acids generated in Atlas' processes are now all neutralized at the WASP. The solidified heavy metal WASP sludges are now disposed of at the landfill in an engineered facility in alternating layers with alkaline slag to keep the heavy metals immobilized as part of Atlas' operations management plan[836]. The landfilling of heavy metals in a strong alkaline environment is designed to retain these contaminants in their solid phase and prevent migration to surface waters. Capping of the closed portions of the landfill with native clays is continuing to restrict infiltration. A long term monitoring program for the landfill was prepared in 1987[835] following recommendations in the Ministry's study and requirements of the Ministry's staff in the Welland District Office in 1986. The monitoring program recognizes that the prime pathway for contaminant migration is through and/or under the berm separating the landfill from the Welland River and its flood plain. There is a collection ditch between the landfill and the berm. The ditch water and local runoff is collected in a settling pond which overflows to the Welland River. Elevated levels of Al, Mo, Cr and Cu were present in this discharge in

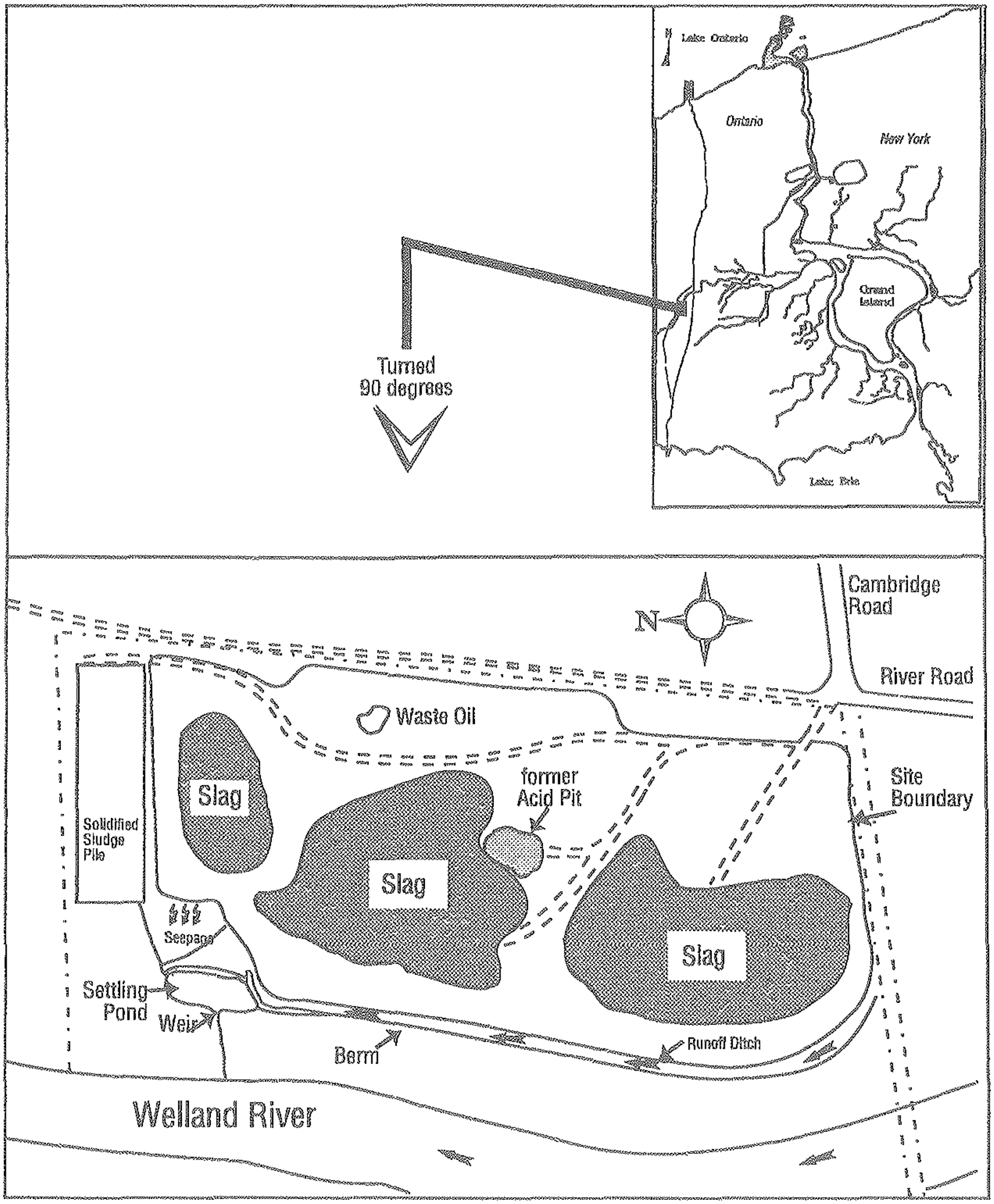


Figure 5.11 ***Atlas Steel Landfill***

1987 although the pH remained above 9. A surface water and ground water monitoring program was recommended for the site to evaluate changes over time.

Cyanamid Welland Landfill

Cyanamid's Welland Plant occupies a large tract of land on the north bank of the Welland River at the northwest corner of Garner and Chippawa Creek Roads on the border between Niagara Falls and Thorold (Figure 5.12). The plantsite is located on a flat to gently rolling clay plain. A large part of the property is taken up by a series of solid waste "slurry" cells used to dispose of process slurries from the Welland Plant operations since 1942. Cyanamid's property is bisected by Thompson's Creek in an east-west direction. Process wastewaters are discharged to the creek from the plant which sits on the south side of the creek; most of the slurry cells are on the north side. These cells, cover some 97 hectares of the plant site and, for the most part, predate the approvals process. Cyanamid also operates three approved (C of A A820065) waste disposal sites which are still in operation.

A three hectare site, the West Dump, is approved to receive 0.9 tonnes per day of non-hazardous wastes generated at the Welland Plant including: floor sweepings, fly ash, scrap fibre and steel drums, wood and filter material[837]. This dumpsite was the focus of litigation in 1983, when workers, excavating part of the waste site for Cyanamid's wastewater treatment facilities, were affected by fumes from the waste material. The problem has since been attributed to small amounts of chemicals having been accumulated with the wastes and released during the excavation procedures. Empty 45 gallon drums were removed in 1982, reusable ones to a scrap metal dealer and unusable ones (about 200) to the Brown Road Dump[837]. Operations at the West Dump are now more rigorously controlled including control of burning practices and the establishment of a new drum holding area.

A second area, the Brown Road Dump, located on top of cells 4 and 6 on the north edge of the plantsite, is approved to accept 45,000 tonnes per year of 100% non-hazardous waste, primarily lime, limestone, carbon, ash, calcium carbonate, calcium oxide, rubble and coke dust from Cyanamid's other plant on Fourth Avenue in Niagara Falls. This site has been in operation since 1974 when cyanide-bearing wastes from areas at the Niagara Falls plant associated with a calcium cyanide process were moved to this site. Also disposed at the Brown Road Dump are rubble, scrap steel, construction wastes and, at one time, empty non-reusable metal drums (in poor condition) from the West Dump.

The third approved site is the currently operating waste sludge cell number 11. Cell 11 is currently receiving waste sludge from the plant; however, much of the sludge is now reused in the plant processes and the cell life has been substantially extended.

The slurry cells, dating back to World War 2, are various shapes and sizes, contained by clay berms. Until 1974, the waste material consisted of a calcium oxide/ calcium carbonate slurry from the dicyandiamide plant mixed with waste acid from the picrite (nitroguanidine) plant[837]. Cell #6 also received 32,000 tonnes of cyanide-bearing (0.16%) waste from the Fourth Avenue plant. In 1974, graphite and lime wastes from the Fourth Avenue plant were added to the slurry for neutralization.[837]

The picrite plant was closed in the early 1980's and the slurry now originates in the dicyandiamide and phosphine plants. The slurry (20% solids) consists of 50% $CaCO_3$, 40% $CaSO_4$, and 10% graphite. The slurry has always been pumped to a raised cell (currently a 5-6m. high clay-bermed lagoon) where the solids settled out and the water fraction decanted to Thompson's Creek. As each cell filled, it was covered with approximately 20cm. of local clay soils and seeded. Some cells are filled to a depth of 12 m. with the wastes. Although berm failure has occurred in the past, none have taken place since 1974. Most of

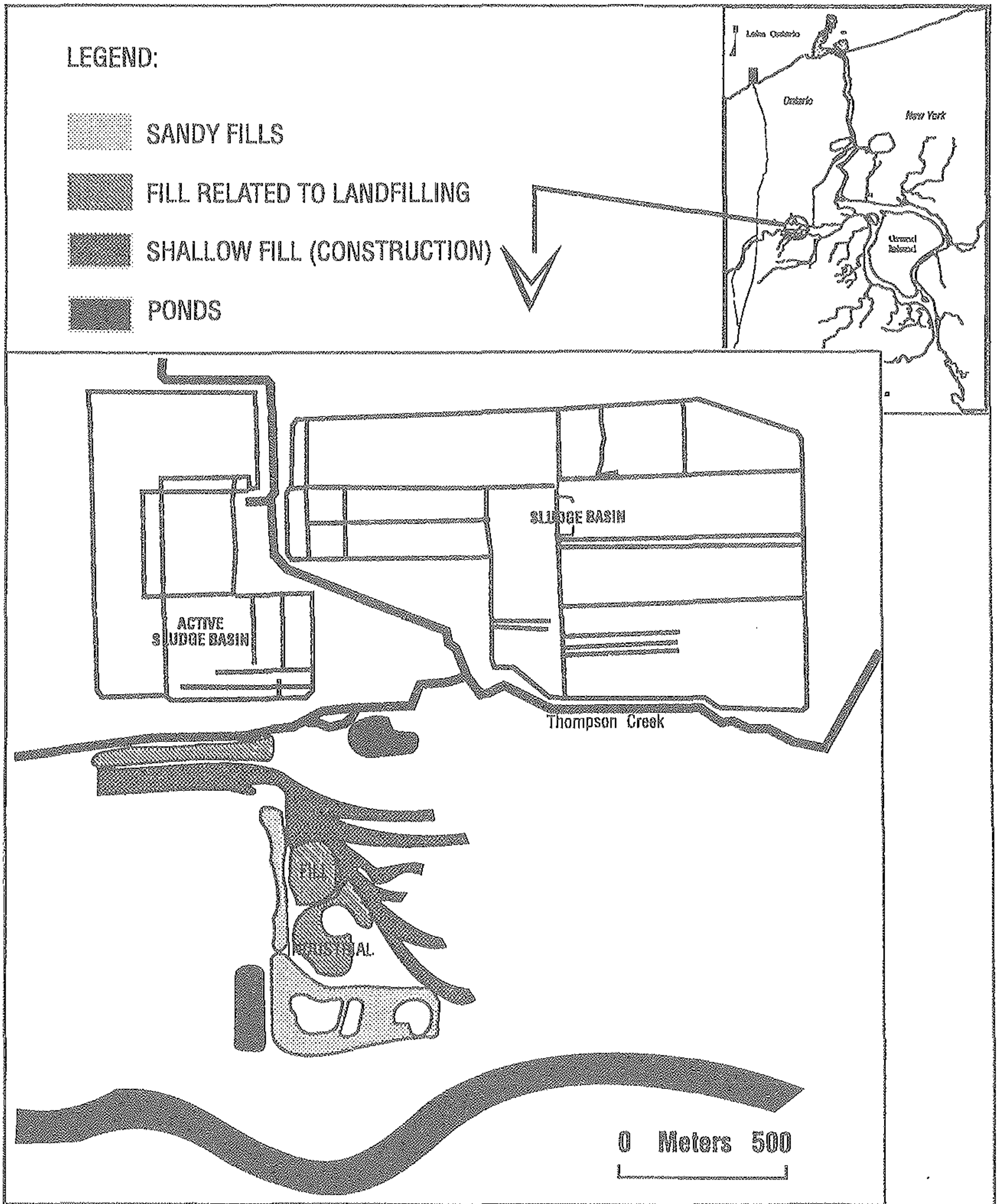


Figure 5.12 ***CYANAMID WELLAND LANDFILL***

the older cells are well vegetated with a wide variety of plants and occupied by a large mixture of wildlife including deer and coyote.

Cyanamid Welland Investigations

In 1983, Cyanamid was involved in litigation with the Ontario Ministries of Environment and Labour. This litigation resulted in an agreement between the parties and approved by the court which provided for a thorough hydrogeological evaluation of the entire plant site which was reclassified in total as a waste disposal site. The investigation, started in March, 1984 by Gartner Lee Ltd. was designed to define the hydrogeology of the site along with the surface flow regime, the location of waste deposits, the interaction of waste and water and the potential for contaminant movement and provision for recommendations for a monitoring program.

The investigations revealed the presence of an abandoned mine tailings site on the southwest corner of the property. Part of this area also involves a 100,000 m^3 area of 1 m deep sandy fill (tailings) which abutted the West Dump Site on the southwest corner and water movement through this sandy fill is subject to a monitoring program. This site, operated by Noranda Inc. on leased land has been rehabilitated by Cyanamid as part of its Control Order program.

The investigations also identified a network of utility excavations in the shallow weathered clay beneath the operational area of the plant site between Thompson's Creek and the Welland River. Shallow ground water movement in this area is dominated by the bedding of these excavations. Some of the utilities and their bedding are causing drawdowns of the water table and are acting as ground water drains and discharges[837,838]. The study concluded that the depth (9-15m.) and the type (stratified lacustrine clayey silts) of overburden at this site would make ground water transport a problem only in the weathered upper 3-5m., with downward movement of contaminants inhibited by the lower unweathered clays which operate as an aquitard to this migration[837]. Contamination, where present, is in the weathered clay surface soils. Migration of contaminants off-site is highly unlikely. Problems where present were identified to be of a surface water nature[838]. The majority of contaminant movement occurs on the surface and through the utility systems to surface waters[837]. There is great difficulty in separating the identification of contaminated ground water infiltration from process wastewater in discharge from these sewers.

Contaminants identified with subsurface waters as elevated above background levels include: nitrates, nitrites, ammonia, TKN, cyanide (at Brown Road Dump), fluoride, sulphate (at the West Dump and the bermed cells), and chromium (associated with wastes from the Fourth Avenue plant).

The study was completed in 1986 and submitted to the Ministry of the Environment for review. The Ministry has responded to Cyanamid, generally agreeing with the consultant's findings and has asked Cyanamid to proceed with implementing the report's recommendations. The Ministry is presently requesting Cyanamid to undertake a surface water control and management program on the site.

Cyanamid Niagara Falls Landfill

The landfills that comprise this area are located to the north of the Fourth Avenue plant in the City of Niagara Falls. The sites are bounded by the Whirlpool, Victoria Avenue, Bridge Street, the Power Canal and the St. David's buried gorge. The lands involved are owned by Cyanamid, CN Rail, Ontario Hydro, Theeb Ltd. and the City of Niagara Falls. The Wastes were generated by Cyanamid at the Fourth Avenue plant. In various cases, this waste is mixed with waste from other owners: shot rock from canal construction (Hydro), construction rubble and debris (Theeb), rail-car sweepings (CNR) and incinerator ash (Niagara Falls). The Cyanamid waste was generated between

1917 and 1973 from the production of calcium cyanide and calcium cyanamide and disposed primarily on lands leased from Ontario Hydro. In 1979, about 32,000 tonnes of above-grade waste was removed from Ontario Hydro property (area B-1) to the Brown Road Dump at Cyanamid's Welland Plant.

The area involved at the Niagara Falls plant includes three ancestral ravines (subsequently identified as A, B and C) into which waste, Cyanamid raw materials and fill material were placed to ground level. The creek beds of these ancestral ravines are potential contaminant pathways for surface and ground water migration. The Queenston-Chippawa Power Canal, the St. David's Buried Gorge and the Whirlpool Gorge form hydrogeologic boundaries to contaminant migration because they act as receivers. Discontinuous layers of clay, till and sand provide potential for lateral and vertical ground water contaminant migration in certain areas, along with natural weathering of surface soils and relief fracturing of bedrock formations near the gorge edges and around the power canal.

Cyanamid Niagara Falls Investigations

The Ontario Ministry of the Environment undertook a preliminary investigation[658] of a portion of this site, later identified as area B-1 following the recommendations of the NRTC. This investigation led to the identification of substantial amounts of Cyanamid-generated waste at site B-1 despite the removal of considerable waste material in 1979. The contaminant identified was cyanide. Following the Ministry's report and consideration of the recommendations by the site owners (Ontario Hydro, Cyanamid, Theeb Ltd.) and the waste generator (Cyanamid), detailed investigations were undertaken[401,402,403,404] to define the extent of the problem. In the reports on these investigations, reviewed by the Ministry, consultants to the owner/generator identified a series of disposal sites in the vicinity of the Ministry-identified landfill. Although the site originally identified by the Ministry for the NRTC appears to contain the highest amount of cyanide contamination, the other sites were identified as having some portion of Cyanamid-generated materials present. Offsite migration was not found to impact the Niagara River at that time[401]. A chain-link fence was placed to restrict access to the originally identified site and to other identified sites. Consultants for the owner/generator have investigated all of the areas originally identified. Phased studies have been conducted for the wastes, overburden and bedrock.

It has been concluded[403] that ground water is mounded in the waste. This causes leachate to seep around the periphery of the waste deposits. Most contaminated ground water flows vertically downward through the overburden soils to the top of the bedrock where it moves laterally through the weathered top zone. All nitrogenous species, including free cyanide are present in the ground water. Natural processes (photolysis, volatilization and microbial oxidation)[833] appreciably degrade free cyanide once it reaches the surface waters and some processes also reduce levels in the ground water by conversion to total cyanide (unavailable) and to ammonia as it migrates. Total cyanide is a form generally not taken up by aquatic organisms. Estimates of loadings from ground water[403] are listed in the Contaminant Loading Table below.

Contaminant Loading from Cyanamid N.F. Landfills: g/day

Receiver	Free CN-	Total CN-	Ammonia
Power Canal	136	5128	30,000
Whirlpool	67	370	4,726
Buried Gorge	0.4	406	550
Total Load (kg/day)	0.2	5.9	35

Reference: 403

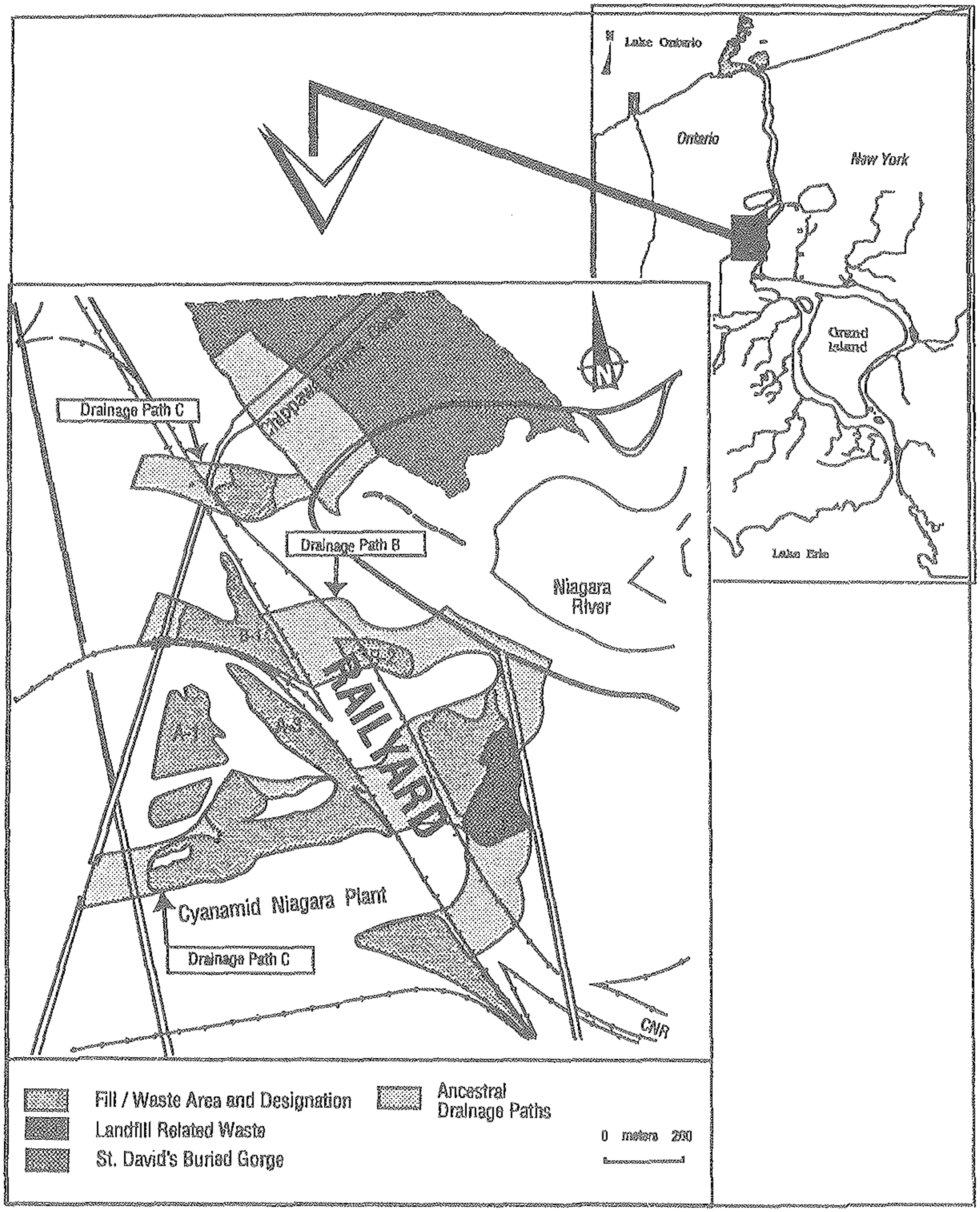


Figure 5.13 ***CYANAMID NIAGARA LANDFILL***

These studies have shown both free and total cyanide contamination of all the strata that were investigated. Although this chemical is reaching the power canal, it is rapidly converted to nitrate nitrogen. No evidence of this contaminant reaching the Niagara River exists. The sole chemical contaminant associated with these sites remains cyanide. A detailed review on other wastes and disposal areas led to the discovery of a small deposit of Thimet (organic phosphate pesticide) in the waste material of the Ontario Hydro right-of-way section of area A-2[403]. Subsequent ground water monitoring showed no levels of Thimet detected in 5 adjacent ground water monitors.

Cyanamid and Ontario Hydro have prepared a remedial plan for each of these sites. This plan was submitted to the Ministry of the Environment in November 1991 and is currently under review. Details of this plan will be presented to the public in the spring of 1992. If the proposed plan is acceptable, remediation is anticipated to start in 1993.

Bridge Street Landfill

The Bridge Street landfill is the current municipal landfill site for the Town of Fort Erie and is located in the northeast corner of Bridge Street and Pettit Road on the western edge of Fort Erie (Figure 5.14). The site (under Ministry of the Environment Certificate of Approval No. A120501 to receive solid non-hazardous waste and sewage sludges) has been operational since 1972. Prior to that year, the site was privately operated. The site lies on a poorly drained, gently-sloping clay plain dissected by several creeks draining to the north and ultimately to the Niagara River. This Haldimand clay plain exhibits varying thickness. At the site, the overburden ranges from less than 1.0m to 4m in thickness. The site straddles a rock scarp, likely the Onondaga Escarpment, which runs beneath the site in an east-west direction. A small scarp also exists north of the site. The south portion of the site used to be occupied by shallow sewage sludge lagoons and may also have been involved with early landfill operations involving trenching. The sludge lagoons were closed in 1988 and that area is now part of the landfill. General ground water movement beneath the site is from south to north. Movement within the waste and nearby surface water is to the northeast and northwest. There is a potential for surface waters to move offsite in the same directions. This effect was noted in early investigations[325] and the Town of Fort Erie has taken steps to contain surface water runoff on site or on an adjacent buffer property.

Records show that the landfill was used by a number of local industries in the early days. Although most waste materials were inert, the potential for some toxic wastes being disposed here exists. The site was operated with open access and without security for the first 12 years of operation. The site is currently approved for 156,000 cubic metres of waste and the C of A expires in 1992.

Bridge Street Investigations

In 1984, the Fort Erie Municipal Landfill on Bridge Street was identified by the NRTC as having significant potential to contaminate the Niagara River. This finding was based on the identification of contamination in ground water beneath the site. In further investigations by consultants to the Town, it was found that contamination was by conventional anion (carbonates, sulphates and chlorides) and cation (sodium, iron and manganese) contaminants and that contamination was assimilated close to the landfill site. Subsequently, the Town of Fort Erie expropriated undeveloped property downgradient of the landfill to serve as a buffer zone for assimilation of contaminants in the shallow ground water system. The Ministry of the Environment conducted a hydrogeological reevaluation[325] of data collected at the site and several concerns were identified. These concerns involved the placement and sampling of wells, monitoring programs and concern over surface water contamination. Consultants for the town of Fort Erie rapidly responded to these concerns with a detailed assessment of the hydrogeology of the site.[841] Surface water control was instituted with construction of a drainage

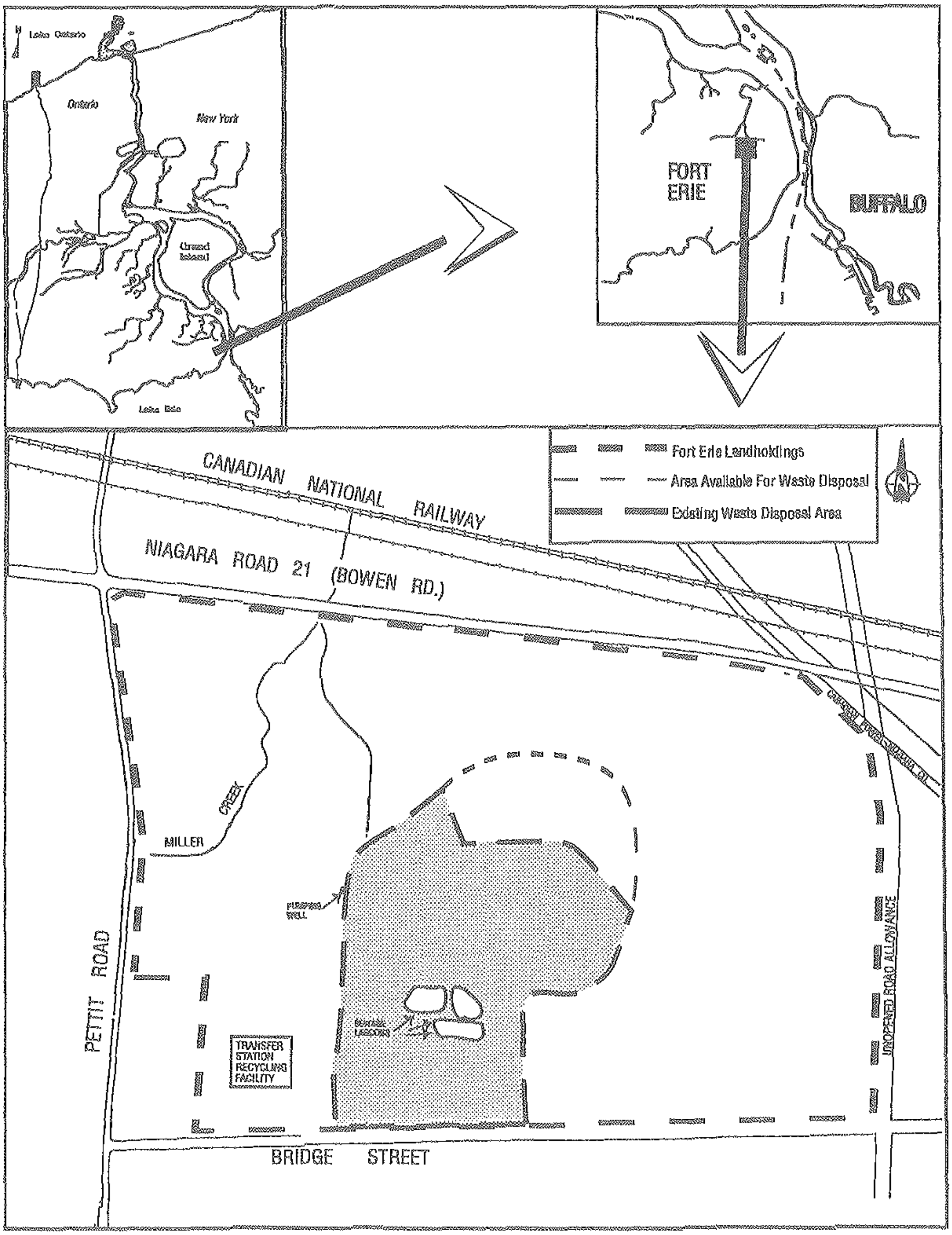


Figure 5.14 **FORT ERIE - BRIDGE ST. LANDFILL**

collection ditch and surface water ponds. Investigations and assessment included more well installations and increased and expanded ground water monitoring. In the hydrogeologic assessment of the site, the Town's consultants generally concluded that the Bridge Street landfill had not caused a significant impact to water resources in the area, was not a threat to any known private ground water supply in the area and that there was no evidence of a significant impact on Miller Creek[841]. In specific conclusions on landfill impact, the following was determined[841]:

1) Leachate generation caused two impacts - seasonal seepage into watercourses on-site and slow migration downward in the overburden.
2) Long-term temporal variation existed in bedrock water quality monitoring making identification of leachate impacts based on inorganic parameters difficult.
3) Leachate in ground water is generally assimilated within site boundaries.
4) Methane gas does not present a hazard at this site.

Recommendations were made[841] in a number of areas to ensure continued minimization of environmental impact. These include the following:

1) Recommendations on slope, cover and other design criteria to minimize leachate production, control leachate seepage and protect ground water.
2) Preparation of contingency systems (containment well(s) and leachate collection (french drain)) in the event that containment is required in either surface or subsurface contaminant migration.
3) Ground water, leachate and surface water sampling and analytical programs, well sealing plans, methane gas and private well monitoring programs to provide a database for environmental impact assessment.
4) Plans for implementation of contingency systems in 2) above in the event that offsite migration of contaminated ground water or excessive leachate seepage to surface water occurs.

In 1989, the C of A for the site was amended to include requirements for annual reporting, waste tracking, increased ground water monitoring and well installation, leachate collection system planning, surface water management planning, operational, closure and design limitations.

Recent monitoring of the site shows that ground water travels to the north perpendicular to the Onondaga Escarpment and then swings to the east and downward to the bedrock in the area north of the site.[840] These 1990 studies confirm earlier indications of leachate in bedrock wells near to the landfill site (DOC, TKN, Fe). In addition, volatile organic parameters (primarily benzene and chloroform) have been detected in bedrock monitoring wells[840]; however, the source of these contaminants is uncertain since they appear in both upgradient and landfill wells. This contaminant will be focused on in the 1991 monitoring program. Leachate seepage still occurs; this is contained in the perimeter ditches and is not believed to impact Miller Creek[840]. Iron levels in Miller Creek already exceed the PWQO of 0.3 mg/L. In order to address concerns over surface water runoff, consultants for the town have submitted a stormwater management plan design proposal for review by the Ministry of the Environment[842] to deal with site drainage and stormwater detention based on a 1 in 100 year storm event.

The 1989 approval for interim expansion of the site expires in May 1992. The Town of Fort Erie and the City of Port Colborne are currently working on a waste master plan to solve the garbage disposal crisis in the area for the foreseeable future. There will be a gap between the end of the current landfilling period and start of the master plan solution. The Town of Fort Erie is currently working on measures to bridge the gap. This may involve continued operation of the Bridge Street site as one interim solution.

CNR Landfill

The CN Rail site occupies the southwest corner of Victoria Avenue and Niagara Parkway in Niagara Falls (designated as area B-2 on Figure 5.13). It is immediately adjacent to the operations building of a helicopter business. The site is located on the side and end of a steep ravine about 250m from the Niagara River and adjacent to Niagara Parks Commission lands. The site is approximately 60m by 200m in area and was used primarily for disposal of domestic waste, construction materials, scrap metal, clean-out wastes (slag, ore, rock) from rail cars and minor amounts of oil and machine shop wastes[839]. The site operated as an open dump with burning and occasional cover from 1962 to 1978. It was closed in 1981 due to problems with fire and graded level with waste rock. In 1986, CN Rail capped the site with native soils and revegetated the face of the ravine. A gabioned floodway was included on the ravine face.

CNR Investigations

The contamination at this landfill was evaluated by Environment Canada. The hazard from the site was assessed and the site classified as a Priority II site[839]. Environment Canada's hazard assessment "This site drains by way of an intermittent creek at its base to the Niagara River." Water in the creek is iron-stained and has elevated conductivity measurements. Only a small fraction of the waste is considered medium concern - metal filings with oil film from machine shops. The potential for impact scores high mostly because of surrounding recreational and residential land uses. Also, the Whirlpool on the river below is known to be where pacific salmon and rainbow trout congregate during fall migration."[839]

Subsequently the site was investigated by consultants to CNR and a report[834] prepared for CN Rail was accepted by Environment Canada. A piezometer was installed in the floor of the ravine near the toe of the landfill. Water levels in the bedrock here are above ground level resulting in an upward hydraulic gradient. Ground water, when it flows, ultimately discharges to the intermittent creek that flows through this ravine. The water from the piezometer was sampled and analyzed. The ground water showed similar inorganic levels to the ravine creek. Four categories of organic substances were analyzed and none were found in detectable concentrations. The consultant concluded that, although various wastes were disposed of at this landfill, there is no evidence of ground water contamination by chlorinated hydrocarbons and phenoxys in the vicinity of the landfill[834]. CNR has closed and capped this site in accordance with Environment Canada protocols.

5.7 Spills

The inadvertent release of pollutants commonly referred to as a "spill" represents a potentially significant source of contaminants to the Niagara River. It is within the mandate of the Ontario Ministry of the Environment to attempt to minimize any potential environmental impact of pollutants associated with spills. Despite proper precautions, stringent policies and procedures for chemical handling, spills still occur. The most common causes of spills to the environment are: equipment failure, accidents on highways, railways and waterways, forces of nature, human error and third party error.

There are several mechanisms, based in legislation, through which the Ministry attempts to reduce spills and their environmental impacts.

In 1991, the Ministry adopted a Spills Reduction Strategy (SRS) under section 17 of the Environmental Protection Act[204]. This is a proactive program which asks industries with a high potential for a spill that could negatively impact on the environment to evaluate their operations with respect to spills reduction. This evaluation includes the following:

- hazards analysis (determining the vulnerability of a geographic area, or a particular process or facility to a hazardous materials release);
- assessment of the adequacy of spills containment, diversion and treatment;
- determination of the need, presence and adequacy of spills detection and warning devices, including maintenance schedules and
- provision of all necessary spill containment and clean-up equipment including a detailed spills response plan which includes internal and external notification procedures, training and refresher courses for all staff in emergency response, emergency communications (This includes provisions for informing the public as what hazards to expect and what precautions to take, including the potential for evacuation)

Federal proactive legislation also plays a significant role in the control of and response to spills, primarily under the Canadian Transportation of Dangerous Goods (TDG) Act[275] which controls all aspects of materials shipping from forwarding yards including transport and warehousing. The TDG Act obligates the carrier of hazardous materials to remove any potential danger associated with the release of such materials. The co-ordination of the clean-up and safe disposal of the spilled material remains the responsibility of the Provincial Environment Ministry. Ontario has enacted the Dangerous Goods Transportation Act (DGTA) which provides for the province to adopts the federal legislation (including identification and transport standards) and also provides a mechanism to improve and review truck safety. The DGTA is administered by the Ministry of Transportation (MOT).

The actual response to spill incidents is governed by several pieces of legislation. Under the Canada/U.S. Water Quality Agreement[66], Ontario is involved in a joint contingency plan which organizes the national, provincial/state and local resources to deal with spills. Also covered in this agreement is the Canada/U.S. Joint Marine Pollution Contingency Plan (Annex 9). This plan is specific to the boundary waters of the Great Lakes and holds the Canadian and United States Coast Guard responsible for coordinating and maintaining the Plan. Federal, provincial, state and local agencies are responsible for the organization of a spills response.

In addition to the Joint Contingency Plan, a separate Canadian Marine Continency Plan organizes the same Canadian resources as above, but applies only to those navigable waters which do not cross international boundaries.

The Province of Ontario Contingency Plan specifically addresses how Ontario agencies will respond to the national contingency plan and also deals with the specifics of the containment, clean-up and disposal phases of spills of significant magnitude to cause environmental damage, but which are not a threat to human health and safety. This plan designates the Provincial Environment Ministry to be in charge of the response effort but also allows that Ministry to draw on the resources of the Ministry of Labour, Ministry of the Solicitor General, Ministry of Natural Resources, Ministry of Health, Ministry of Consumer and Corporate Relations, Ministry of Transportation, Environment Canada and Canadian Coast Guard. Similarly, under the Ministry of the Solicitor General's Ontario Nuclear Plan, the Ministry of Health's Health Protection and Promotion Act, and the municipal Emergency Plans Acts, the Ministry of the Environment is at the disposal of these groups in an advisory capacity.

In 1985, in response to the increasing occurrence of and concern over spills in Ontario, a 24 hour-a-day environmental Emergency Response Program (ERP) was established under Part IX of the Environmental Protection Act and administered by the Ministry of the

Environment. This ERP legally defined the roles and responsibilities of those involved in a spill and created a Spills Action Centre (SAC) to provide a focus for spill reporting and response in Ontario. This Centre is operated by Ministry personnel on a 24-hour basis in order to:

- contact local Ministry of the Environment personnel in order to initiate the field response;
- contact other agencies or potentially affected parties as necessary eg. local police, fire and ambulance, Coast Guard, US authorities, etc.;
- notify senior Ministry of the Environment personnel to co-ordinate briefing of the public;
- maintain a liaison with other agencies and
- provide chemical handling and clean-up precautions, either directly or through the Canadian Transport Emergency Centre (CANUTEC).

Under the provincial Emergency Response Program, one staff member in each MOE District Office is on emergency 24-hour a day call to respond. In the Niagara Area of Concern, ERP personnel are on duty for the Welland and Hamilton District Offices. These personnel operate completely equipped environmental response vehicles and receive regular training in spills handling. In addition to these initial response units, the Ministry of the Environment has second and third level response units. These units predominantly deal with high risk materials, atmospheric (gas and vapour) spills and human risk situations.

In the co-ordination of a spills response, the discharger is held responsible for the adverse effects of a spill. The discharger is seen as having taken a foreseeable risk for which they should be prepared. Most companies have spill clean-up procedures, stockpiled containment and clean-up equipment and either trained staff which respond to spills or contractors which are retained to clean-up spills. In the event of a spill during transportation, when the spill exceeds the carrier's ability to respond, several outside parties are available to assist. These include:

- The Transportation Emergency Assistance Plan (TEAP), organized by the Canadian Chemical Producers Association. This response group involves the pooling of member's resources such as shared information banks, expertise and specialized equipment;
- The Ontario Petroleum Association (OPA) which, along with 5 independent industrial co-operatives is capable of responding to major oil spills;
- Local municipal agencies which are required to undertake surveillance in determining the occurrence and source of spills and are required to take physical countermeasures to a spill. A number of smaller municipalities in Ontario pool their resources for a collective spills response network;
- Environment Canada which provides current information on countermeasure techniques, recovery equipment and chemical treatment agents; meteorological data to assist in determining required containment and 24 hour access to the Environmental Emergency Management Information System;
- Transport Canada/Canadian Coast Guard which are both accessible by a 24 hour emergency phone line and are able to provide booms, skimmers, sorbents, boats, special vehicles, protective clothing, tools and equipment as well as emergency communications and

- The Canadian Transport Emergency Centre (CANUTEC) which provides a product information bank which outlines the physical and chemical properties of products, health hazards, fire and explosion hazards and appropriate clean-up procedures.

The Canadian Coast Guard is the primary response agency to the canadian waters of the Great Lakes including the Canadian side of the Niagara River. Between January 1987 and December 1990, 19 incidents of pollution or potential pollution were recorded in the Niagara peninsula. This area includes the Niagara River proper, the Welland Ship Canal and the Fort Erie area of Lake Erie.

One potential spill occurred on the Buffalo River. A ship carrying toluene and xylene ran aground; however, no leakage was detected.

Four reported spills of oil slicks on the water were investigated and determined to be wave action creating the appearance of an oil sheen. All were false alarms.

Five reports of spills other than oil were investigated. The pollutants all originated on shore and were identified as shore based spills of sewage, coal dust or fertilizer. One small shore-based oil spill was reported.

Eight ship-generated diesel oil spills were reported during fuelling. The average amount spilled was 26 gallons.

6.0 OUTSIDE INFLUENCES

6.0 OUTSIDE INFLUENCES

There are significant influences outside of the Niagara River (Ontario) Area of Concern which also affect the water quality within.

It has been recognized that the majority of the contamination in the Niagara River comes from sources on the U.S. side of the river.[30] It has also been shown that contamination from the Buffalo River Area of Concern contributes to degradation of water quality in the Niagara River.[186]

Contamination from sources in the four up-stream Great Lakes contribute to background levels in the Niagara River.[588]

The large surface area of the upper Great Lakes and the geographical location of Lake Erie makes these bodies receptors of significant loads of airborne pollutants which contribute to the background levels in Lake Erie.[746]

These elevated background contaminant levels, of both water and sediment, reduce the capacity of the Niagara River to handle wastes discharged or leached to it from sources within its own basin.

6.1 Inputs from the Niagara River (U.S.)

The Niagara River Area of Concern is the focus of two Remedial Action Plans, one for the Ontario side and one for the U.S. side. The discharge of contaminants, particularly toxic chemicals, from outfalls and hazardous waste landfills in New York State has been identified as the major influence on the environmental quality of the Niagara River.[30,649,733,682,732,712,725,209,610]

The New York side of the Niagara River is home to over 100 municipal and industrial point source dischargers, including 22 which were described as significant by the NRTC. These include 7 municipal wastewater treatment plants and 10 major industrial complexes. One of the 22 significant industrial dischargers is presently closed. Smaller industries also contribute contaminants to the Niagara River either directly or indirectly (connected to municipal sewer systems). The major U.S. based point source dischargers to the Niagara River are shown on Figure 6.1. These facilities are identified in Table 6.1 along with associated EPA priority pollutant groupings.

U.S. point sources along the Niagara River were calculated to contribute 1,160 kg/d of toxic chemicals to the river in 1984[30]. This figure represents approximately 95% of the estimated total discharged from all point sources. A considerable loading of conventional contaminants is also added to the aquatic system. Subsequent studies reported by DEC[180] have reported a reduction in the total loading of the most important organic and inorganic priority pollutants to 245 kg/day in 1985-86 and to 150 kg/day in 1986-87. In 1987-88[181], these loadings increased by 18% to 184 kg/day.

The largest impacts of toxic chemicals on the Niagara River occur in the lower portion of the river below Niagara Falls. In this portion, the river recognizes no national boundary. The waters from both countries mix routinely as the water moves towards Lake Ontario. Environmental impacts also recognize no borders; impairments in the New York Area of Concern mirror impacts identified for the Ontario Area of Concern. Fish consumption advisories exist and are mutually recognized by the public in both areas. Water and sediment quality is impacted by elevated levels of PCBs, mirex and heavy metals.

Contaminants leaking from hazardous waste sites along the U.S. side of the Niagara River are known to enter the waters of the Niagara River and Lake Ontario. These contaminants include some of the most hazardous chemicals known, including: mirex, PCBs, chlorobenzenes, chlorotoluenes, chlorophenols, polycyclic aromatic hydrocarbons

TABLE 6.1

Significant Dischargers of EPA Priority and Special Pollutants on the New York Side of the Niagara River

Discharger		Pollutant Classes (1981-82 NRTC Data*)	Fig 6.1 #
Industrial	General Motors Corp.	ACM	1
	Niagara Mohawk Power Corp.	ACM	2
	Dunlop Tire & Rubber Corp.	M	3
	FMC Corp.	M	4
	Spaulding Fibre Co.	MP	5
	Occidental Chemical Corp. Durez Div.	ADV	6
	Occidental Chemical Corp. Niagara Plant	ABDFGMV	7
	E.I. DuPont Tonawanda Plant	IV	8
	E.I. DuPont Niagara Plant	M	9
	Union Carbide Corp. Linde Div.	H	10
	L-TEC (formerly Union Carbide Weldflux)	M	11
	SOHIO Electro Mineral Co.	M	12
	Olin Corp.	CMV	13
	CWM Chemical Services	M	14
Municipal (Waste Water Treatment Plants)	Buffalo Sewer Authority WWTP	ABCDHIMOV	15
	Tonawanda WWTP	ACDMO	16
	Amherst WWTP	M	17
	North Tonawanda WWTP	ACMV	18
	Niagara County SD#1 WWTP	AMV	19
	Grand Island SD#2 WWTP	BM	20
	Niagara Falls WWTP	ADFMOV	21
	Gorge Stn. Overflow	BDHMV	22
	City Diversion Sewer	BCFMOV	23
	Lewiston MSIA WWTP	M	24
LEGEND:	* - groups of chemicals over NRTC cutoff limits B = Base/Neutral Extractables (other) D = Chlorobenzenes F = Chlorotoluenes H = Polycyclic Aromatic Hydrocarbons M = Metals (other) P = Polychlorinated Biphenyls	A = Acid Extractables (other) C = Cyanide E = Chlorophenols G = Mirex I = Mercury O = Organo_chlorine Pesticides V = Volatile Organics (other)	

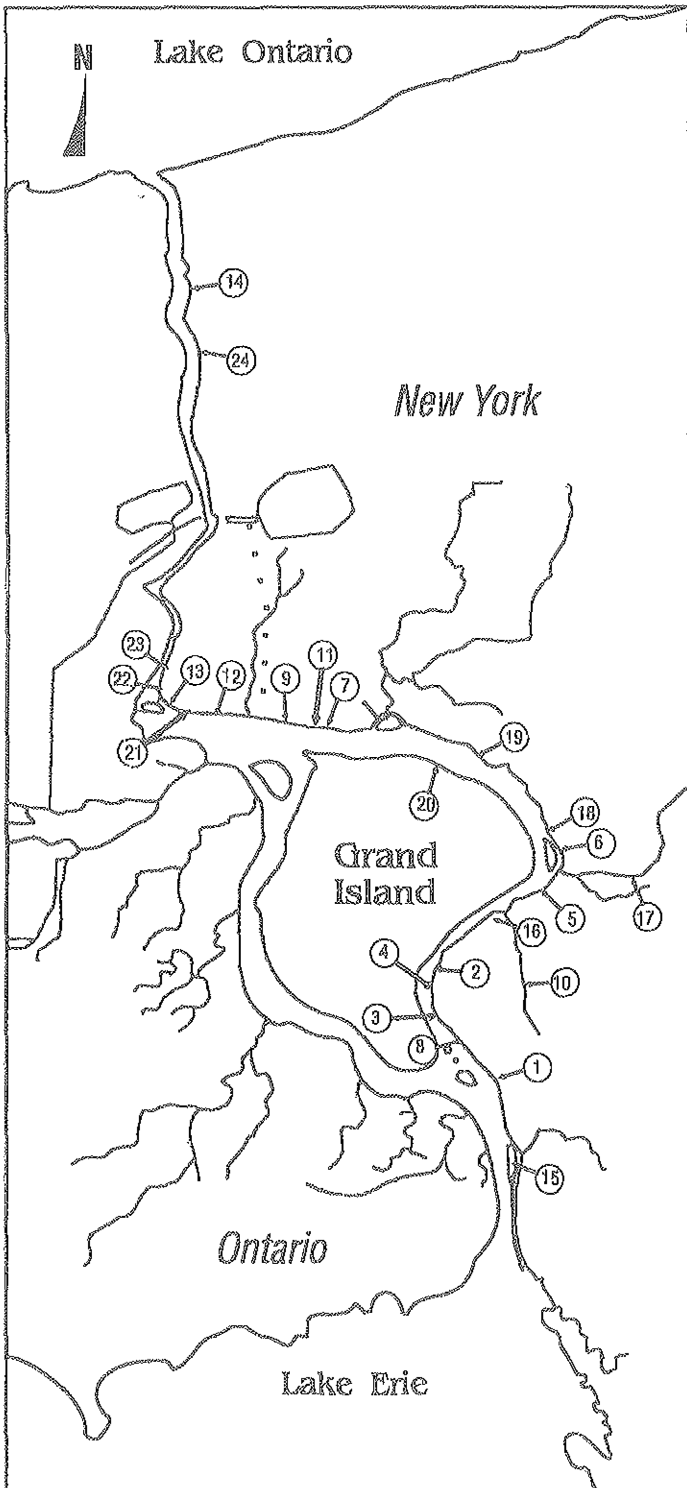


Figure 6.1

US Point Source Discharges To Niagara River

1. General Motors Corp.
2. Niagara Mohawk Power Corp
3. Dunlop Tire & Rubber Corp
4. FMC Corp
5. Spaulding Fibre Co.
6. Occidental Chemical - Durez Div.
7. Occidental Chemical - Niagara Plant
8. El duPont deNemours & Co. (Tonawanda Plant)
9. El duPont deNemours & Co. (Niagara Plant)
10. Union Carbide Corp. Linde Div.
11. Union Carbide Corp. Welding Flux
12. Carborundum Corp.
13. Olin Corp.
14. CWM Chemical Services
15. Buffalo Sewer Authority
16. Town of Tonawanda WWTP
17. Town of Amherst WWTP
18. North Tonawanda WWTP
19. Niagara County S.D. #1 WWTP
20. Grand Island S.D. #2 WWTP
21. Niagara Falls WWTP
22. Gorge St Overflow
23. City Diversion Sewer
24. Lewiston MSIA WWTP

0 5 10
kilometres

(PAHs), 2,3,7,8-tetrachlorodibenzo-p-dioxin, BHC and other chlorinated organic pesticides. It is assumed that a number of chemicals with unknown properties that are by-products of the manufacturing processes that produced the above chemical compounds and/or combination products of the above chemicals could also be escaping to the river. It has been estimated that, of 307 kg/d of total priority pollutants, 179 kg/d of organic priority pollutants enter the Niagara River via contaminated ground water discharge from the 33 most significant site areas.[179] However, this estimate may be out by several orders of magnitude[178].

In 1979, a total of 215 hazardous waste disposal sites were identified in Niagara and Erie Counties[182]. In 1984, that list was reviewed and updated by the NRTC. At that time, 164 sites within three miles of the Niagara River were identified as potential contaminant sources to the Niagara River[30]. The Department of Environmental Conservation has now identified over 300 waste sites in Niagara and Erie Counties[183].

The EPA's National Priority List (NPL) identifies sites, America-wide, that pose a significant risk to human health. Five of the waste disposal sites on the New York side of the Niagara River have been assigned to the NPL for Superfund consideration and two additional sites are on the New York State Superfund list. All seven sites are known to leach contaminants directly to the Niagara River.

In 1988, the United States Environmental Protection Agency released the results of a study[179] which attempted to estimate actual and potential loadings of toxic chemicals to the Niagara River from hazardous waste sites in the United States. This report focussed priority on 70 hazardous waste sites and grouped together a number of associated or adjacent waste sites into clusters. In all, 33 site areas or clusters were evaluated.

Of these 33 areas, 24 waste sites, some being clusters of individual waste areas, were associated with leaching 307 kg/day (677 lb/day) of priority pollutants to the Niagara River directly. The remaining 9 areas leached some 8 kg/day (17 lb/day) to the Buffalo River[179]. The authors indicated that this figure was an "order of magnitude" calculation. Based on a review of the assumptions and data used in generating this number, an evaluation prepared for the MOE[184] determined that the possible errors could be ± 2-3 orders of magnitude.

Eighteen of the 24 areas that contribute contaminants to the Niagara River directly have been linked with one or more of the 15 priority toxics of concern in the Niagara River (Table 6.2). In addition to the 24 sites investigated, 11 others were identified as contributors of toxic chemical loading to the river. The waste sites are identified and estimated loadings are presented in Table 6.3. The locations of these 24 sites are shown on Figure 6.2.

Late in 1989, DEC and EPA released a follow-up report[185] for these sites. In this document, remediation schedules and measures are identified for each of the 33 site areas or clusters. These measures will achieve an estimated 99.9% reduction in the known loadings from these sites by the year 1996. This reduction assumes that the remedies will be 100% efficient from the moment they are completed.

TABLE 6.2

Priority Toxic Chemicals of Concern under the River Toxics Management Plan

Chemical	Water Quality Exceedance	Fish Flesh Exceedance	Significant Niagara River Source
benz(a)anthracene	Yes	No	Yes
benzo(a)pyrene	Yes	No	Yes
benzo(b)fluoranthene	Yes	No	Yes
benzo(k)fluoranthene	Yes	No	Yes
chlordane	No	Yes	No
chrysene	Yes	No	No
dieldrin	No	Yes	No
hexachlorobenzene	No	Yes	Yes
mercury	No	Yes	Yes
mirex	No	Yes	Yes
octachlorostyrene	No	Yes	No
PCBs	Yes	Yes	Yes
DDT & metabolites	No	Yes	No
2-3-7-8-TCDD	No	Yes	Yes
tetrachloroethylene	Yes	No	Yes

TABLE 6.3

Loading of EPA Priority Pollutants from Hazardous Waste Sites on the New York Side of the Niagara River

Waste Site	Site #	Loading (lb/d)
Occidental Chemical Corp. Niagara Plant	41b	340
Niagara County Refuse Disposal	81	88
Dupont Necco Park/CECOS	14/78	65
Occidental Chemical Corp. Hyde Park	39	57
102nd Street	40	26
Bell Aerospace Textron	5	19
BTL Specialty Resins	66	15
Occidental Chemical Corp. S_Area	41a	14
Stauffer Chemical- Lewiston	255	12
Solvent Chemical	251	9.3
SKW Alloys	1	8.6
Olin Corp. Buffalo Ave.	58	7.1
DuPont Buffalo Ave.	15	6.6
Buffalo Harbour Containment*	254	6.1
Buffalo Color*	120	4.4
Bethlehem Steel*	118	3.0
INS River Road	136	2.7
Frontier Chemical- Pendleton	67	2.6
Occidental Chemical Corp. Durez	24	2.0
Small Boat Harbour*	253	1.8
Gratwick Riverside Park	68	1.3
Mobil Oil*	141	1.3
Alltift Realty*	162	0.17
Charles Gibson	242	0.16
Great Lakes Carbon	22	0.13
Huntley Power Station	182	0.11
Times Beach Containment*	241	0.091
Tonawanda Coke	108	0.056
Allied Chemical*	107	0.020
Tonawanda Landfill	207	0.0061
Dunlop Tire & Rubber	125	0.0017
Columbus McKinnon	123	0.0001
Love Canal	38	0.0000

* = sites in Buffalo area

= refers to location on Figure 6.2

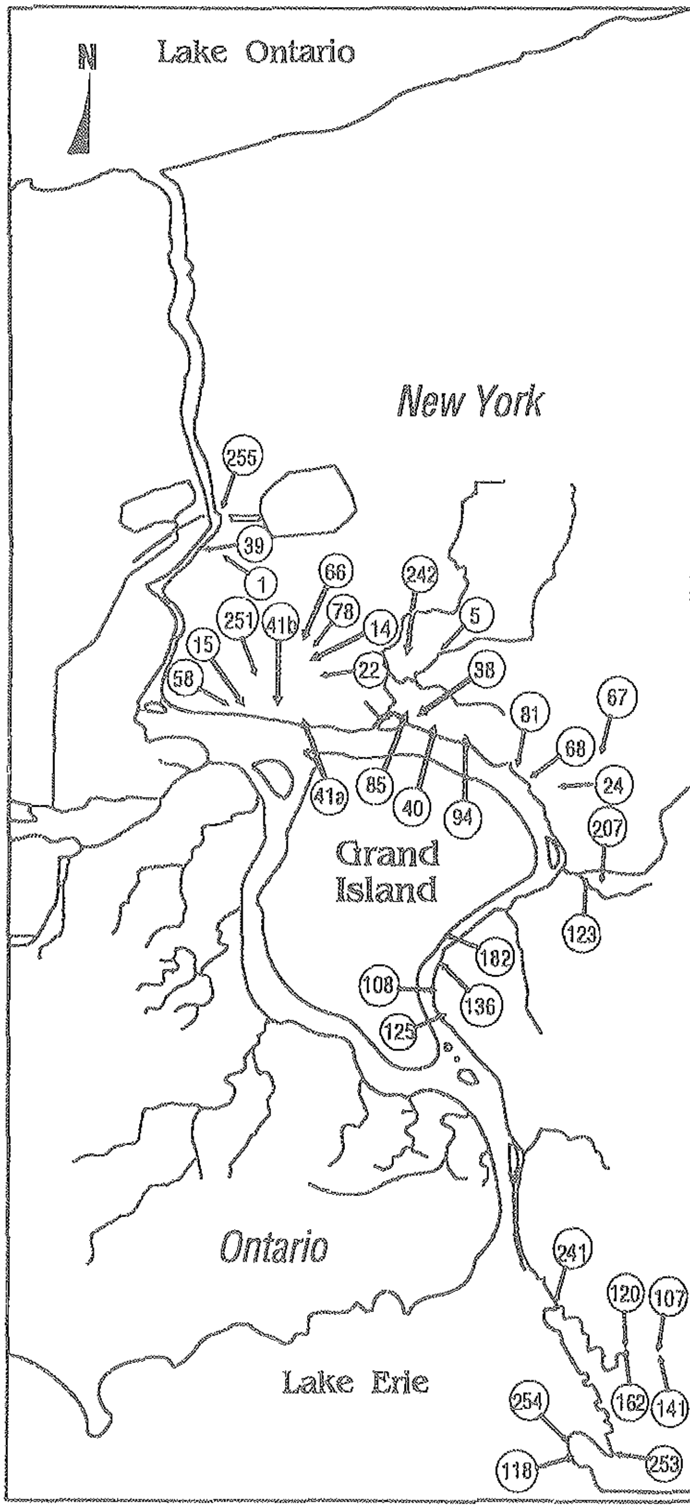


Figure 6.2

U.S. TOXIC WASTE SITES

1. SKW Alloys
5. Bell Aerospace Textron
14. duPont Necco Park
15. duPont - Buffalo Ave Plant
22. Great Lakes Carbon
24. Occidental Chemical - Durez
38. Love Canal
39. Occidental Chemical - Hyde Park
40. 102nd Street
41a. S-Area
41b. Occidental Chemical - Buffalo Av
58. Olin - Buffalo Av Plant
66. BTL Specialty Resins
67. Frontier Chemical - Pendleton
68. Gratwick Riverside Park
78. CECOS Inter'l/Niag Recycling
81. Niagara County Refuse Disposal
107. Allied Chemical
108. Tonawanda Coke
118. Bethleham Steel
120. Buffalo Color
123. Columbus-McKinnon
125. Dunlop Tire and Rubber
136. River Road (INS Equipment)
141. Mobil Oil
162. Alltift Realty
182. Huntley Power Station
207. Tonawanda landfill
241. Times Beach Containment
242. Charles Gibson
251. Solvent Chemical
253. Small Boat Harbor Containment
254. Buffalo Harbor Containment
255. Stauffer plant, PASNY Site

0 kilometres 5 10

6.2 Buffalo River

The Buffalo River has also been identified as one of the 43 Great Lakes Areas of Concern and, therefore, has been undergoing a process of environmental assessment and Remedial Action Planning. The discharge of the Buffalo River enters the Niagara River at Buffalo, thereby representing a significant input to the Niagara River Area of Concern.

Impairments in the Buffalo River watershed include:

- fish consumption advisories due to elevated levels of PCBs, Chlordane and DDT in fish flesh;
- evidence of tumours on fish and tainting of fish flesh likely caused by elevated PAH levels in the water and sediment;
- contamination of sediments by metals and cyanides; and
- low dissolved oxygen levels in the water.

Since the early 1970's, the Buffalo River watershed has been home to 5 major industrial complexes[186]. The major industries (3 of which are presently closed) consisted of 2 chemical plants, 1 coking operation, an oil refinery and an iron and steel complex. Smaller industries in the Buffalo River area, such as food processing and grain milling operations are connected to the Buffalo Sewer Authority system. In addition, the watershed includes 7 combined sewer overflows and 32 inactive hazardous waste sites[186].

Results of spottail shiner collections from the Buffalo River suggest that it is a significant source of PCBs to the Niagara River[64]. Studies conducted by Ontario Ministry of the Environment, at a transect located just downstream from the mouth of the Buffalo River, have shown bacteria, nutrients and levels of inorganic and organic contaminants in the Niagara River (1980-82) to be higher on the U.S. side of the river than on the Canadian side.

6.3 Inputs from Lake Erie

Chemical contamination from Lake Erie has been shown to enter the Niagara River. High concentrations of some contaminants have been detected at Fort Erie[30]. Given the flow regime at the head of the Niagara River, it is unlikely that the contamination measured at Fort Erie originates in the vicinity of Buffalo. It is more likely that this reflects contamination in the western basin of Lake Erie.

Most of the studies on Lake Erie water chemistry have centred on those chemicals which contributed to the severe eutrophication problems in the mid-1960's. The understanding of these nutrient cycles within the water and sediment and the extensive control and reduction programs of governments on both sides of the lake has resulted in a much more stable chemical structure in the lake's waters[42]. Phosphorus loadings were reduced from 28,000 tonnes in 1968 to 12,350 tonnes in 1983[42]. Routine open lake monitoring has shown a reduction in open lake phosphorus concentrations in all three basins[187]. Although these show a more conservative decline than loading figures, probably due to resuspension of phosphorus-laden sediments, they do indicate a positive environmental effect in Lake Erie. This is reflected by a decrease in chlorophyll a concentrations since 1970 in all three basins. These declines correspond generally with the reduction in phosphorus loading to the lake. Modelling of chlorophyll a concentrations in the eastern basin showed a highly significant ($p<0.01$) trend of decreasing concentration for the years 1968, 1970, 1972 and 1980[188].

The net west-to-east movement of water through the lake is considerably more complex than a simple unidirectional flow[42]. Water movement through the central and eastern basins varies considerably during stratified and non-stratified thermal conditions and is heavily influenced by prevailing winds and major storms[189].

The chemical makeup of Lake Erie is significantly affected by oxygen depletion in the bottom of the lake's central basin[190]. The eastern basin has oxygen-rich water and during storm events this water can be transferred into the depleted portion of the central basin and re-oxygenate the bottom layers[44,191,192]. The rate of oxygen depletion in the central basin was highest in the 1960's and 1970's[45]. Studies undertaken between 1980 and 1984 indicate that the oxygen depletion rates in the central basin appear to have stabilized or decreased.

The activity of sediment resuspension by strong winds is an important factor in the redistribution of nutrients and contaminants throughout the water column in the eastern and central basins of Lake Erie during periods where these basins are unstratified. In the western basin, which does not permanently stratify, resuspension occurs periodically throughout the summer.

The tributaries to the western basin of Lake Erie are a second major source of suspended sediment[193]. Although some attempts at remediation of erosion of soils from these predominantly agricultural basins have been made, resuspension of unconsolidated sediments is virtually uncontrollable. This is evidenced by the nearshore concentrations of nutrients and major ions remaining high along the predominantly agricultural south shore of the western and central basins.

Four of the five major tributaries to the western basin are themselves IJC Areas of Concern: the Maumee River, the River Raisin, The Rouge River and the Detroit River. Only the Huron River has not been designated by the IJC as an area of concern. Over the years, industrial and residential development of these waterways has led to the combination of conventional and toxic contaminants in wastewater discharges with the sediment runoff from these basins. Since many toxic substances prefer the sediment phase to the water phase, they have attached themselves to the soil particles which have subsequently been deposited in the basins of Lake Erie.

The eastern basin is the least affected by spring runoff or sediment resuspension and therefore does not exhibit the wide annual fluctuations of the other two basins. There is still some fluctuation, similar to the central basin. The highest phosphorus level occurs in the eastern basin in the spring and declines through the summer and fall periods. During turnover of the water column, some increase in contaminant levels does occur but below those for the spring period[42]. It can be expected that concentration patterns of other contaminants follow the same trend exhibited by the well-studied phosphorus levels.

Over time, these contaminated sediments have worked themselves eastward and likely cause the majority of the background contamination in the waters and sediments of the Niagara River. This residual background contamination from upstream sources inhibits the capacity of the Niagara to assimilate contaminants originating within the Niagara River Area of Concern.

Organic substances and metals are measured in biota. For these chemicals, the trend is to generally declining concentrations. Long term biomonitoring data for total PCBs and total DDT from young-of-the-year spottail shiners in Lake Erie suggest a real downward trend in all sites monitored. Most of the decline was observed during the late 1970's[42].

Although there are no trends in Lake Erie for metal contamination[194], recent studies have shown elevated levels of arsenic, cadmium, copper, iron and selenium in the water column (exceeding GLWQA objectives)[43]. Elevated levels of cadmium, chromium, copper, lead, nickel, mercury and zinc were also detected in the sediments[195,196]. This corresponds well with four of the six chemicals identified by the NRTC as having exceeded the most stringent guideline or standard at Fort Erie: chromium, cadmium, copper and lead[30]. Elevated concentrations of aluminum were also noted at Fort Erie. Aluminum is a major constituent of the natural sediment found in all three basins of Lake Erie. Aluminum is a primary constituent of the fine grain clay soils which is common to the area and this naturally occurring phenomenon may by mainly responsible for the high levels detected at Fort Erie. The highest concentrations of aluminum in Lake Erie were found in the major sediment depositional zones[195]. Silver, the sixth element found in elevated concentrations at Fort Erie is found in low concentrations throughout Lake Erie. Although no detectable concentrations of silver were found in the eastern basin, silver was detected in the western basin and the eastern portion of the central basin[196].

The assessment of Lake Erie water quality trends concluded that although the single most significant source is the Detroit River[197] (Table 6.4), loadings of heavy metals from atmospheric deposition and sewage discharges are certainly significant.

The effects of remedial efforts in upstream areas of concern will likely be felt very slowly in the waters and sediments of Lake Erie. It will take a considerable period of time for contaminant levels in the sediments to stabilize or decline to levels where their impact on the water column through resuspension is negligible.

6.4 Long-Range Atmospheric Deposition

Atmospheric deposition of toxic pollutants to surface waters has long been recognized as a "pathway" in the environmental cycling of some of these chemicals[198]. Organic and inorganic chemicals enter the water by wet deposition (snow, rain, aerosols), dry particulate deposition and vapour exchange at the air-water interface. The latter process may also result in the loss of volatile species to the atmosphere from the water.

TABLE 6.4

Inventory of Sources and Sinks of Heavy Metals in Lake Erie

	Flux Rate (tonnes)			
Source	**Cadmium**	**Copper**	**Lead**	**Zinc**
Detroit River	N/A	1640	630	5220
U.S. Tributaries	N/A	100	52	271
Can. Tributaries	N/A	31	19	140
Sewage Plant Discharges	5.5	448	283	759
Dredged Spoil Action	4.2	42	56	175
Atmospheric Deposition	39.0	206	645	903
Shoreline Erosion	7.9	190	221	308
Total Inputs	N/A	2657	1906	7776
	Flux Rate (tonnes)			
Sink	**Cadmium**	**Copper**	**Lead**	**Zinc**
Niagara River/Welland Canal	N/A	1320	660	4400
Retained in Sediment	N/A	1337	1246	3376

Atmospheric transport and deposition of individual chemical species depends on the distribution of the chemical between the particulate and vapour phase and the relevant removal efficiencies of each. At the present time there are insufficient data to reliably estimate the relative importance of the atmospheric deposition of many of these contaminants to the Great Lakes.

For more than two decades, researchers have investigated the relative importance of the atmosphere as a long range carrier of persistent toxic substances. Large quantities of these substances have been deposited from the atmosphere into the Great Lakes. In October 1986, the International Joint Commission (IJC) sponsored a workshop[199] to discuss the significance of selected persistent toxic chemicals deposited by atmospheric transport in the Great Lakes and to develop mass balance budgets for chemicals derived from atmospheric sources.

The upper Great Lakes receive a significantly greater fraction of their total inputs from the atmosphere than do the lower Great Lakes. This is attributed to the larger surface areas and lack of local sources.

There were fourteen chemicals of interest; however, information was available for only five chemicals: PCBs, DDT, benz(a)pyrene, mirex and lead. The most complete data were available for lead and PCBs. These data indicate that 90% of the total PCBs input to Lake Superior come from atmospheric deposition, whereas in Lake Ontario only 7% is attributed to atmospheric sources. Similarly, atmospheric deposition of lead ranges from 99.5% in Lake Michigan to 46% in Lake Erie.

Evidence suggests that precipitation scavenging of both fine particles (<2 um) and vapours dominates atmospheric inputs that are at some distance from the major point source or source region. Dry deposition of large particles may be more significant closer to the sources.

The 1987 amendments to the Great Lakes Water Quality Agreement added a distinct Annex for airborne toxic substances. Annex 15 advocates the establishment of an Integrated Atmospheric Deposition Network (IADN) for the identification of selected toxic substances with emphasis on persistent toxic substances.

The IJC, through its Atmospheric Deposition Monitoring Task Force and three working groups, is investigating atmospheric transport of contaminants in the Great Lakes basin. To date, a Canadian Master Station for depositional monitoring has been installed at Point Petre in Lake Ontario (October 1988), thus joining the U.S. Master Station at Green Bay Wisconsin. Two additional Master Stations (one in the U.S. and one in Canada) are scheduled to be installed. These master stations will be accompanied by five U.S. and five Canadian satellite stations placed around the Great Lakes.

Although long-range transport of toxic chemicals from the American mid-west and other upwind sources such as Nanticoke and Detroit/Sarnia reaches the Niagara River Area of Concern, the amount of deposition is hard to determine. Since the ratio of land mass to open water is large, the greatest amount of the deposition will likely occur on land. The buffering capacity of the soils in the area may reduce any detectable impact to insignificant levels.

With regard to localized deposition, the Niagara River is fortunate in that the major industrial sites within the watershed are to the east of the River and hence most of the airborne pollutants are dispersed away from the area by the predominately south-southwest winds.

7.0 IDENTIFICATION AND DELINEATION OF SPECIFIC CONCERNS

7.0 IDENTIFICATION AND DELINEATION OF SPECIFIC CONCERNS

The Niagara River, over the years, has achieved a considerable amount of notoriety. From a perception as one of the world's most scenic rivers, it has been perceived in the last two decades as an "open sewer" that conveys man's waste directly into Lake Ontario. In the environmental decade of the 1980's, attention has been focused directly on toxic chemicals in the waters of the Niagara River.

The activities in the Niagara area over the last 50 years, and in particular those associated with the heavily urbanized U.S. shoreline, have introduced many toxic chemicals, both persistent and non-persistent, to the Niagara River. The presence of many of the most famous toxic dumpsites, such as Hyde Park, Love Canal, S-Area, 102nd St., Necco Park and Durez, along the shore of the Niagara has contributed to the "open sewer" perception. Many of these sites, filled with the most toxic chemicals created by man, have been leaking into the Niagara River for some time. Remediation of these sites has been occurring but it is a long and expensive process which involves experts in many areas, areas where expertise is scarce. Although progress continues to be made, because of the complex nature of the remediation, it has to be measured in years rather than days.

The heavy industrial complexes on the shores of the river affect the ecosystem. Their discharges, combined with those from the municipalities in which they sit, have contributed to the contaminant burden on the river over the years. Although many of the discharge problems have been corrected over the last 30 years, some contaminants still enter the system through wastewater discharges.

The definition of specific problems associated with the water quality of the Niagara River (Ont.) Area of Concern has been discussed at length by both the RAP team and the Public Advisory Committee (PAC). These discussions have taken place independently to ensure that all applicable problems are identified.

7.1 Impaired Uses and the IJC Criteria

The IJC has required the preparation of Remedial Action Plans (RAPs). As part of the RAP control process, the IJC has identified a number of 'criteria' under which each RAP will be judged. These criteria cover fourteen diverse ecosystem impairments. Not all criteria may be applicable in each Area of Concern. In addition, some of the potential uses which may relate to the IJC criteria may not be desired.

In Annex 2 of the 1987 Great Lakes Water Quality Agreement, Section 1.(c) states:

"Impairment of beneficial use(s)" means a change in the chemical, physical or biological integrity of the Great Lakes System sufficient to cause any of the following:

i) Restrictions on fish and wildlife consumption;

ii) Tainting of fish and wildlife flavour;

iii) Degradation of fish and wildlife populations;

iv) Fish tumours and other deformities;

v) Bird or animal deformities or reproductive problems;

vi) Degradation of benthos;

vii) Restrictions on dredging activities;

viii) Eutrophication or undesirable algae;

ix) Restrictions on drinking water consumption, or taste and odour problems;

x) Beach closings;

xi) Degradation of aesthetics;

xii) Added costs to agriculture or industry;

xiii) Degradation of phytoplankton and zooplankton populations; and

xiv) Loss of fish and wildlife habitat.

Because the IJC criteria are broad it has been necessary to be more specific in identifying problems (impaired uses) for the Niagara River Area of Concern.

7.2 Problem Definition by the Public

One of the major tasks required of the public in the preparation of the Remedial Action Plan is the identification of beneficial uses that are impaired. Although the public has expressed dismay at the length of time taken to prepare a RAP for the Niagara River, it has become apparent that the problems and solutions in this Area of Concern are not clear cut.

Statements that "we all know what the problems are" have not been readily converted to a written definition. Considerable time has been spent in clarifying different concepts of the environmental issues in the Niagara River Area of Concern. A number of different points of view and several misconceptions have been discussed by the Public Advisory Committee on the road to developing problem statements that the members could agree on.

In July 1989, the PAC agreed upon a mission statement or overall philosophy for the Niagara River Remedial Action Plan. That statement was as follows:

"The mission of the Niagara River RAP is to re-establish, protect and maintain the integrity of the ecosystem for the Niagara River."

At the same meeting, the PAC also identified 23 environmental issues of concern in the Niagara area. These 23 issues are:

·Water Quality

·Use of Water For Human Consumption

·Fishing and Consumption of Fish

·Aquatic Life (Fish and Algae)

·Recreational Boating and Water Sports

·Industrial and Municipal Use

·Wetlands

·Birds and Mammals

·Aesthetics

·Economic Growth

·Power Generation

·Access

·Legislation

·Hiking and Rock Climbing

·Sediment Quality

·Irrigation - Agricultural Use

·Commercial Shipping

·Education of the Public (keeping it informed)

·Clean Air (Mist/ Acid Rain/ Toxic Rain)

·Additional Control Structures

·Ecosystem Health

·Sustainability

·International Cooperation.

In order to step up progress on defining the problem, the issues developed by the PAC were more specifically defined during a workshop in Niagara Falls on January 27, 1990. At that workshop, the PAC members reviewed the preceding issues and organized them into groups of similar issues. Six of these issues were identified as non-specific problems and were set aside for future development. These six were :

·Ecosystem health

·Sustainability

·Additional Control Structures

·International Cooperation

·Legislation and

·Education of the Public.

The PAC decided that these six did not represent environmental problems or goals but rather, principles or solutions and may relate more directly to the mission statement.

The remaining 17 issues were divided into 5 categories (also numbered in order of priority by the PAC members) as follows:

Priority/Group 1

Water Quality

Use of Water for Human Consumption

Clean Air (Mist/Toxic Rain/Acid Rain)

Priority/Group 2

Aquatic Life (Fish and Algae)

Wetlands

Birds And Mammals

Sediment Quality

Priority/Group 3

Power Generation

Irrigation - Agricultural Use

Industrial and Municipal Use

Commercial Shipping

Economic Growth/ Tourism

Priority/Group 4

Hiking and Rock Climbing

Aesthetics

Access

Recreational Boating and Water Sports

Priority/Group 5

Fishing and Consumption of Fish

Working groups were established for each group of issues and a statement of the problem associated with each issue was developed. The following sections contain the problem statements developed by the PAC.

7.2.1 Water Quality Related Uses

7.2.1.1 Water Quality

'The water in the lower Niagara River, although it generally meets the provincial water quality guidelines, is perceived to be unacceptable because of possible long-term effects related to the toxics it contains. Impacts on aquatic organisms have been observed and are of present concern. Lower levels of toxics have been observed in the upper Niagara River.

In the upper Niagara River, siltation and biological contamination are a concern to municipal water treatment systems, industry and Niagara shore wells.

The impact of zebra mussels on water quality is a concern that needs to be investigated. Water quality guidelines are frequently exceeded in several tributary streams.

7.2.1.2 Clean Air

'The water of the Niagara River has been adversely affected by pollution carried through the air and deposited on the Niagara River Area of Concern by acid or toxic rain; the river itself is also a source of volatile organic chemicals to the atmosphere.'

7.2.2 Aquatic and Wildlife Uses

7.2.2.1 Aquatic Life (Flora and Fauna)

'Aquatic flora and fauna in the lower Niagara River Area of Concern are unsuitable for human or animal consumption. The bioaccumulation of toxins has affected the production and species composition of Niagara River flora and fauna.'

7.2.2.2 Birds and Mammals

'The reduced quality and quantity of water has impaired the food source and habitat of birds and mammals in the lower Niagara River Area of Concern. Increased boating activity has increased the risk to resident and migratory waterfowl populations.'

7.2.2.3 Wetlands

'Waterborne pollutants and encroaching development have reduced the quality and quantity of wetland for use by native fish, wildlife and vegetation.'

7.2.2.4 Sediment Quality

'Contamination of sediment in the Welland River and lower Niagara River has impaired both aquatic and terrestrial food chains, resulting in a reduction in the species composition of biota and increased the body-burden of toxic substances. In addition, excessive erosion in uplands areas has produced excessive siltation in the lower Welland River and the mouths of tributaries; this siltation has also contributed to the reduction of species composition and the loss of habitat.'

7.2.3 Industrial, Municipal and Agricultural Uses

7.2.3.1 Power Generation

'The use of the Niagara River for hydro-electric power generation can be limited by lake water levels. Physical (suspended solids), chemical (acidity) and biological (zebra mussels) contamination reduces machine efficiency, and increases electricity generating costs which in turn affects the quality of life in Ontario.'

7.2.3.2 Agricultural Use

'Use of waters within the Niagara River Area of Concern for crop and fruitland irrigation as well as for livestock watering is perceived to lead to a buildup of toxins in food for consumption by humans and animals.'

7.2.3.3 Industrial and Municipal Use

'Physical (contaminated sediments/siltation), chemical (pathogenic or toxic substances) and biological (zebra mussels, algal blooms) contamination of the Niagara River increases water treatment costs and poses a threat to Niagara River wells without sophisticated treatment systems. These also reduce the capability of the river to assimilate municipal and industrial wastewaters.'

7.2.3.4 Commercial Shipping

'The siltation in portions of the upper and lower Niagara River as well as on the Niagara River bar, combines with chemical contamination to produce a risk to commercial shipping, dredging and mining of the Niagara bar. In addition, commercial shipping itself can result in release of chemical and biological agents (spills) which are themselves threats to the Area of Concern.'

7.2.3.5 Tourism and Economic Growth

'Contamination of the Niagara River and its long-time perception as an "open sewer", combined with extensive flow controls adversely affect the image of the Niagara River to tourists and naturalists.'

7.2.4 Recreational Uses

7.2.4.1 Aesthetics

'All recreational uses experience an impairment of aesthetics due to the visible presence of algae, foam, debris, organic odours and poor water clarity. Industrial and municipal discharges, landfill sites and poorly planned and administered development and power generation projects have marred the natural beauty of the Niagara area. The Niagara Parks Trail is reduced to urban sidewalks in the area of the Niagara Falls.'

7.2.4.2 Access

'Waterborne contamination and contaminated sediment, along with drastically fluctuating water levels restrict the areas of the Niagara River accessible for aquatic activities. The amount of access to the lower river for boating is insufficient.'

7.2.4.3 Boating and Water Sports

'Contamination of the waters of the Niagara and Welland Rivers by bacteria, toxic chemicals and sediment load restricts the extent of primary contact recreation. Boating is affected by operation of water level controls. Boating itself, through spillage of oil and gas, presents a risk to the river and its users.'

7.2.5 Fishing

7.2.5.1 Sports Fishing

'Toxic contaminants in the lower Niagara River has contributed to reduced populations of native species. Fish in the lower river are subject to unacceptable concentrations of these chemicals. The "image" of poor fish quality in the lower river affects the amount of angling in this area.'

7.2.5.2 Commercial or Consumable Fishing

'Niagara River fish are unsuitable for consumption. Consumption guidelines exist from MOE/MNR and DEC for specific sizes and species of fish in both the upper and lower Niagara River, based on a variety of toxins.'

7.3 Problem Definition by the RAP Team

The RAP team independently developed a set of problem definitions for the Niagara River Area of Concern. The purpose was to ensure that all environmental problems not identified by the PAC were identified by the RAP team and also because the views of each group may focus on different facets of a problem.

Some problems identified by either the PAC or the RAP team may not be remediated by this RAP or may not be related to water quality. It was felt that these problems, once identified, should not be discarded if they cannot be solved through the RAP process. In stage I all problems are identified; in stage II the problems which cannot be resolved by RAP options will be identified and avenues of resolution outside of the RAP process discussed.

This section covers the problems, both real and perceived, in the Niagara River (Ontario) Area of Concern, as determined by the members of the RAP Team. The concerns in the previous sections are described in detail and associated, where possible, with the potential or known causes described in the following sections.

The descriptions of the problems and impaired uses were structured to follow as closely as possible those identified separately by the Public Advisory Committee. Each problem issue is identified and described in five parts as follows:

Part 1) Environmental <u>Scope</u> of the Problem

Part 2) Description of Potential <u>Sources</u>

Part 3) <u>Impaired</u> Uses Experienced

Part 4) <u>Data Gaps</u>

Part 5) Current <u>Status</u> and Activities in the Problem Issue.

7.3.1 Water Quality Related Problems

7.3.1.1 Water Quality Violations

Scope:

A number of toxic contaminants have been identified in the Niagara River at levels which exceed water quality guidelines. These are: iron, PCBs, tetrachloroethylene, benz(a)anthracene, benzo(b)fluoranthene, chrysene, benzo(a)pyrene and benzo(k)fluoranthene at Niagara-on-the-Lake and aluminum, cadmium, chromium, copper, lead and silver at other locations in the Niagara River.

Source:

Chemicals from various sources such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water quality in the Area of Concern.

Impairment:

Water quality criteria for the protection of aquatic life are exceeded.

Data Gaps:

Some chemicals have no accepted method of analysis. The data base is too small to determine contaminant trends.

Status:

Environment Canada has been conducting weekly monitoring at Niagara-on-the-Lake and Fort Erie; this activity is scheduled to continue. The four-agency Niagara River Toxics Management Plan (NRTMP) includes a commitment for 50% reduction in the loading of chemicals of concern from point sources by 1996. The Ontario MOE has conducted ambient river monitoring in the upper and lower Niagara River. These data are currently being compiled. Further in-stream monitoring is planned.

7.3.1.2 Non-compliance of Industrial/ Municipal Dischargers

Scope:

1988 monitoring programs, Industrial Monitoring Information System (IMIS) and Utility Monitoring Information System (UMIS), pre-MISA point source monitoring and reporting programs cover the discharge of conventional and some toxic (on a case-by-case basis) chemical pollutants. Non-compliance occurrences were identified at the following sources:

- BOD (B.F. Goodrich, Fleet, Ford and Washington Mills).
- Suspended Solids (Atlas, B.F.Goodrich, Fleet, Washington Mills & Stelco Welland Tube Works).
- Cadmium (Atlas Steel, Fleet).
- pH (Atlas Steel).
- Phosphorus (Welland WPCP, Ft. Erie WPCP, Niagara Falls WPCP).
- Solvent Extractables [oil & grease] (Stelco).
- Phenolics (Can-Oxy Durez).

Source:

All sources of wastewater and cooling water discharge are potential sources of contamination. All sources have chemical level requirements for their discharges and are required to monitor and report measured levels on a regular basis. On occasion, required levels are exceeded and the discharger is considered to be out of compliance for that occasion. If these exceedances are excessive or frequent, action is taken to correct the problem. Discharge monitoring records show that the following industrial and municipal dischargers were out of compliance at least once during 1988: Atlas Steels, B.F. Goodrich, Fleet Manufacturing, Canadian Oxy Durez, Ford Glass, Washington Mills, Niagara Falls WPCP, Stelco Welland Tube Works, Ft. Erie WPCP and Welland WPCP.

Impairment:

Water quality criteria for protection of aquatic life are exceeded.

Data Gaps:

An extensive suite of monitored parameters are not measured at this time. Some industries and all sewage treatment plants are not currently under the MISA monitoring program. Compliance limitations have been established on small groups of chemicals, mostly conventional pollutants, until discharge regulations are established under MISA. MOE monitors all parameters for the Niagara River Toxics Management Plan (NRTMP); however, these results are not used to determine compliance.

Status:

The MISA monitoring program is currently underway or has been completed for 7 of 14 Ontario dischargers to the Niagara River or its tributaries. The remainder are small industries that are anticipated to be included in future MISA programs.

7.3.1.3 Unregulated Discharges

Scope:

In 1989, two sources of untreated wastewater existed on the Ontario side of the Niagara River. Prior to 1990, the McMaster Avenue Combined Sewer discharged storm, cooling and industrial process water and raw sewage to the Welland River. The Stanley Avenue Combined Sewer was separated in 1984; however, it still carried direct discharge of industrial (Washington Mills) wastewater to Chippawa Creek.

Source:

Water quality criteria for the protection of aquatic life are exceeded in outfall areas. The capability of the waterway to provide body contact recreation is restricted in nearby areas.

Impairment:

Current monitoring programs are sufficient.

Data Gaps:

Monitoring of the McMaster and Stanley Avenue sewers shows contaminant levels are reducing as proper sewer connections are made to sanitary sewers. The discharge of wastewater to the Stanley Avenue sewer is predominantly cooling water from the oil-water separator at Washington Mills although some sanitary sewage connections still exist to this sewer. Separation of the McMaster Avenue sewer connections continue. The City of Welland connected the remaining discharge to the Welland WPCP River Road interceptor in 1990 with provision for overflow in excessive storm events.

Status:

The McMaster and Stanley Avenue combined sewers have been separated although provision has been made at these locations for emergency overflow. The urban portion of the Area of Concern contains a number of unregulated discharges to the Niagara and Welland Rivers and the Power Canal. All municipalities involved are undertaking or planning Infrastructure Needs Studies to identify and resolve these issues.

7.3.1.4 Combined Sewer Overflows (CSOs)

Scope:

Continual raw sewage discharge and the potential for additional intermittent overflow exist due to age and design of combined sewer systems and the capacity of pumping stations and forcemains in the sewage systems.

Source:

Numerous municipalities in the Niagara River Area of Concern (both Ontario and New York) operate combined sewer systems. These Municipalities are the City of Niagara Falls (Ontario), City of Welland, Town of Fort Erie, Town of Niagara-on-the-Lake, City of Buffalo, City of Niagara Falls (New York), Town of Lewiston, Town of Grand Island, City of Tonawanda, Town of Niagara and City of North Tonawanda.

Impairment:

Water quality criteria for the protection of aquatic life are exceeded. The capability of the waterway to provide body contact recreational activities is restricted in urban areas.

Data Gaps:

Intermittent discharges of raw sewage from CSOs are not required to be monitored at this time. Consequently, not much information exists on the chemical composition and flows associated with CSOs.

Status:

Ontario CSOs currently are being addressed in Pollution Control Plans and Infrastructure Needs Studies under development by the Regional Municipality of Niagara.

7.3.1.5 Potential Contamination from Landfill Sites

Scope:

Potential and actual non-point sources (landfills) of contamination were identified in the NRTC report and subsequent reports issued by individual environmental agencies.

Source:

In 1984, the Niagara River Toxics Committee identified five landfills on the Ontario side of the Niagara River that had a significant potential to leach contaminants to the Niagara River. These five were the Fort Erie (Bridge St.) municipal landfill, Atlas Steels landfill, CNR Victoria Avenue landfill, Cyanamid Welland plant disposal areas and Cyanamid Niagara Falls plant waste disposal sites. In addition, a large number of hazardous waste disposal sites on the New York side of the Niagara River were determined to be leaking to the Niagara River.

Impairment:

Water quality criteria for the protection of aquatic life are exceeded.

Data Gaps:

There is great difficulty in establishing the loadings and impacts from landfill sites. Although both U.S. EPA and MOE have attempted to estimate the loadings from these landfill sites, these estimates are inaccurate due to the complexity of the calculations and the uncertainty of the databases available. Consequently, estimates may be out by several orders of magnitude. Statistical analysis cannot be conducted on the limited data that are currently available.

Status:

All sites have been investigated. MOE prepared an assessment of loadings from the five Ontario landfills based on the methodology developed by U.S. EPA in its prior assessment. U.S. EPA has set a timetable for reduction of contamination from U.S. hazardous waste sites (99% by 1996). Ontario has determined that one landfill discharges continuously (CNR) to the Niagara River system. A remediation plan is under development.

7.3.1.6 Potential Impact of Stormwater Releases

Scope:

There is a potential for impact of contaminants in stormwater on the Welland and Niagara Rivers. This involves all of the landmass in the drainage basin.

Source:

Stormwater from urban and rural areas has the potential for contamination of surface waters, particularly with respect to heavy metals (urban) and pesticides or herbicides (rural). Release of organic contaminants such as fuels and de-icing compounds from servicing facilities at Mount Hope Airport and Welland Airport may also impact receiving waters during storm events.

Impairment:

Water quality criteria for protection of aquatic life may be exceeded.

Data Gaps:

Loadings and impacts from these sources are uncertain.

Status:

A program for stormwater runoff from airport facilities is currently being developed by MOE West Central Region. Complete characterization of stormwater will be performed to determine if a problem exists.

7.3.1.7 Drinking Water Consumption

Scope:

The presence of chemical contaminants in the sources of potable water has created significant concern among the public that its tap water is also contaminated. The only municipal water filtration plant in the Niagara River AOC is in Niagara Falls (Ont.). Tests of treated water at this facility have shown it to be acceptable for drinking purposes, however, some members of the community still fear that the water is contaminated. There is greater concern for those users of shore wells along the banks of the upper and lower Niagara River, whose potable water supply is not routinely treated by filtration and disinfection.

Source:

Chemicals from various sources such as: municipal, industrial and agricultural point & non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water quality in the Area of Concern.

Impairment:

Consumption of Niagara River water may be affected by the public perception that the treated water may contain low levels of toxics. There is also belief that the Niagara-on-the-Lake filtration plant was taken out of service in 1984 solely because of chemical contamination of the Niagara River. There is also increased concern over the use of chlorination at filtration plants to destroy pathogenic bacteria, due to the creation of trihalomethanes which are introduced into the treated water by the disinfection process. This has resulted in the increased use of modified water supplies (bottled, home treatment).

Data Gaps:

Enough information, no data gaps.

Status:

The Niagara Falls drinking water supply is monitored regularly as part of the Drinking Water Surveillance Program. No Provincial Drinking Water Objective has been violated during the monitoring program.

7.3.1.8 Niagara Mist

Scope:

Researchers have theorized that chemicals in the water passing over the Horseshoe and American Falls volatilize into the atmosphere or become tied up in the mist generated at the falls.

Source:

Chemicals from various sources such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) introduced into the upper river can affect air quality at Niagara Falls through volatilization.

Impairment:

The belief that the air and mist at Niagara Falls is contaminated affects the aesthetics of the area. A second aspect of this is a health concern of workers at Niagara Falls.

Data Gaps:

The air in the Niagara Mist and the surrounding area has been monitored several times and no indication of contaminants at elevated levels has been given. The question of "fumes" from spills to the river can only be addressed on a case-by-case basis.

Status:

No evidence has been found of elevated levels of contaminants in the water, air or mist which would present a health risk associated with mist from the Falls. There may be some air pollution risk associated with volatilization of chemicals during industrial or municipal spills to the Maid of the Mist Pool from the Falls Street Tunnel or the Adams Tunnel, due to the confined space in the Niagara Gorge.

7.3.1.9 Water Quality Problems Associated With U.S. Sources

Scope:

The problems in the Niagara River, particularly in the lower river are created by sources on both sides; however, the largest amount of contamination comes from identified and suspected sources on the U.S. side of the river. If the Ontario Area of Concern alone was cleaned up, the problems in the Niagara River would remain.

Source:

Point source discharges in the New York portion of the Area of Concern and the Buffalo River contribute a wide range of chemicals to the water column. The most significant portion of the problem is believed to originate in leaking hazardous waste sites. Many extremely toxic chemicals leach directly or through groundwater routes to the Niagara River. In addition, vast urban areas and contaminated industrial sites have the potential to add considerable amounts of pollutants in stormwater runoff. In-situ sediments contaminated by past activities leach contaminants to the water column of the Niagara River and its feeder streams.

Impairment:

Fish consumption restrictions and exceedance of water quality criteria.

Data Gaps:

Data is continuously collected and analyzed. No major data gaps are believed to exist.

Status:

The State of New York is currently preparing a Remedial Action Plan for the Niagara River (New York) Area of Concern. The Ontario RAP Team and the PAC are relying on this RAP to address U.S. sources of contamination that are creating the problems in either Canadian or U.S. waters of the Niagara River.

7.3.2 Aquatic and Wildlife Problems

7.3.2.1 Tumour Incidence in Fish

Scope:

Researchers have undertaken pathological studies of several fish species in the lower Welland River between Welland and Montrose. These studies have indicated an elevated frequency of tumours and gonadal neoplasms in wild carp-goldfish hybrids. No conclusion has yet been made whether this is a characteristic of the hybridization or of the environment. Deformities have been noted in the labial plate of one group of benthic organisms (chironomids). The incidence of deformity is elevated over those larvae taken from natural areas but it has not yet been determined whether this is a result of urbanization or of specific contamination in the Welland River.

Source:

Chemicals from various sources in the Welland River watershed such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water and sediment quality in the Area of Concern. This contamination may cause cancer in certain aquatic species.

Impairment:

The occurrence of tumours in fish species affects the health of that species and may be an indicator of future effects on other organisms.

Data Gaps:

No evidence of tumours or other deformities has been noted in fish from the Canadian side of the Niagara River. New evidence exists connecting tumours with contaminants in isolated areas on the U.S. side. The link has not been established with either the environmental condition of the lower Welland River or the genetic history of the wild carp-goldfish hybrid. Investigations into deformities of chironomid labial plates has not yet reached the stage of determining the cause of elevated deformities in this species.

Status:

University researchers are continuing the study of biota in the Welland River to determine the extent and cause of deformities in aquatic species.

7.3.2.2 Impaired Benthic Community

Scope:

Studies have shown that some impairment of the benthic community exists downstream of Strawberry Island and in the Tonawanda Channel (compared to similar locations in the Chippawa Channel) and at several locations in the lower Niagara River. This impairment correlates well with contaminant levels (heavy metals, PCBs, endrin, dieldrin, mirex) in sediment.

Source:

The presence of elevated levels of toxic chemicals in bottom substrates, particularly the shallow sediments, causes a decline in benthic species diversity.

Impairment:

Sediment guidelines for protection of aquatic life (benthos) lowest effect level (LEL) have been exceeded in some locations. Provincial sediment guidelines are also exceeded in some cases of severe impairment severe effect level (SEL).

Data Gaps:

The effects of sediment quality on aquatic organisms have not yet been sufficiently studied to develop guidelines for many chemicals of concern. In addition, there are currently inadequate data on body-burden.

Status:

Draft Provincial Sediment Quality Guidelines, (PSQG), have been developed by MOE to assist in determining areas and extent of impact. Draft PSQG's are currently being applied in some RAP AOC's for existing parameters. Some chemicals do not yet have criteria established.

7.3.2.3 Fish Kills

Scope:

At times, chemical contaminants have been discharged at levels exceeding acute toxicity levels for some or all aquatic species (flora and fauna) in the Area of Concern (at some locations in Welland River and some tributaries). These are associated with spills, or in the past, with acutely toxic effluents or shock loadings.

Source:

Fish kills are associated with acutely toxic levels of contaminants, which occur as a result of releases during agricultural or industrial spills or effluent discharges.

Impairment:

During a spill, water quality criteria for protection of aquatic life are frequently exceeded. There is a localized temporary or long-term reduction in fish populations depending on frequency of these events. Severe occurrences may reduce the invertebrate and vegetative communities. Long-term occurrences may alter the species composition of all aquatic organisms.

Data Gaps:

Fish kills are relatively well understood as they relate to acute toxicity. The sub-lethal effects of many chemicals are not known. Some fish kills, such as the March 1992 kill of shad and alewife in Lake Erie that resulted in hundreds of dead fish in the Niagara River has been attributed to natural causes, although the specific cause is unknown. Pathological testing has ruled out chemical toxins as the cause.

Status:

Industries and government sites with the potential for or history of spills have been directed by the Ministry of the Environment to prepare spill plans to mitigate the damage of spills on or from their properties. These potential spill sources are also required to provide containment for liquid storage facilities on their properties. These measures attempt to contain or minimize the environmental impact (generally fish kills) of spills from known sites; however, fish kills can occur from many other natural and man-made occurrences and these may be difficult or impossible to control.

7.3.2.4 Degraded Fish Populations

Scope:

A reduction in fish populations has been noted for the upper Niagara River. Species include: sturgeon, emerald shiner, and northern pike. In the Welland River and other tributaries of the Niagara River, a decline in the population of most fish species has been noted.

Source:

A number of causes have been identified as contributing to the decline in fish populations, particularly among native fish species. Most causes are the result of human activities which have resulted in significant habitat degradation. Natural erosion and siltation have been compounded by human activities in the basin, which have increased the sediment loading considerably from non-conservative agricultural activities. The natural barrier of the Niagara Falls has blocked a major potential migration route for river spawning species. Salmonoid stocking in Lakes Erie and Ontario have increased the competition for food for native fish populations. Over the past three decades, considerable progress has been made in reducing excessive nutrient enrichment of Lake Erie and the Welland River; however, considerable nutrient enrichment still occurs from bottom sediments and from agricultural runoff. Another factor in declining fish populations is summer water stagnation in some tributaries causing severe oxygen depletion and stress to all resident fish species. The burden of acute and chronic toxicity from spills also contributes to a decrease in fish population or a migration of species to another area. It is also considered that the presence of the Lake Erie ice boom which holds the ice sheet back over Lake Erie, delays warming of water in the spring and this may affect fish populations in the Niagara River and Lakes Erie and Ontario.

Impairment:

Human activities and natural occurrences combine to degrade or stress native fish populations. This results in a limitation of sport fishing harvest from the Niagara River and its tributaries, as well as a depletion of baitfish stocks.

Data Gaps:

No data are currently available to determine the status of the emerald shiner and grass pickerel. Some endangered or rare species, such as the sturgeon, are too scarce to determine trends, although indications are that the species will soon become (or may already be) extirpated from this area.

Status:

For most areas, degradation appears to be the result of mechanical or natural alteration of the drainage basin. Secondary impacts result from contaminant loadings.

7.3.2.5 Loss of Fish/Wildlife Habitat

Scope:

Loss of habitat for both fish and wildlife is primarily associated with man's activities.

Source:

Land development in the Niagara region, as well as the rest of the Great Lakes Basin, has resulted in the destruction of and encroachment on vast areas of natural terrain. Erosion of cleared lands, removal of vegetation and chemical contamination has further reduced the usable habitat of fish, birds and wildlife. One of the significant problems has been the loss of shoreline habitat and wetlands through shoreline reconstruction and development.

The high river velocity between Fort Erie and Niagara-on-the-Lake has resulted in significant deposition in Lake Ontario. Excessive nutrient enrichment and the presence of other contaminants have reduced the acceptable areas for fish and wildlife.

Impairment:

Fish and Wildlife habitat has been lost from the Area of Concern for a number of reasons, most associated with the activities of humans.

Data Gaps:

Little information is available on many wildlife issues in the Niagara Peninsula including habitat. The rural-suburban nature of the Area of Concern has already effected changes from pristine conditions, modifying habitat. Few studies on wildlife habitat have been carried out in the vicinity of either the Niagara River or its tributaries.

There is no information on fish habitat in the middle section of the Niagara River due mainly to its inaccessibility. The habitat of the remainder of the Niagara, as well as the Welland River and the other tributaries has not been extensively studied.

Status:

The RAP Team is planning to investigate habitat in future studies, depending on the availability of funding for these activities.

7.3.2.6 Contaminants in Wildlife

Scope:

Elevated levels of PCBs, mirex, b-BHC and dieldrin have been detected in black-crowned night heron eggs taken from nests along the Niagara River. In addition, mirex has been found for a number of years in common tern and herring gull eggs taken from nesting colonies in the Niagara River. Analysis of waterfowl has shown measurable levels of PCBs and DDT. The most noticeable wildlife species affected by contamination are the aquatic birds; no assessment has yet been made regarding uptake of contaminants by mammals.

Source:

Chemicals from various sources such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water quality in the Area of Concern. Contaminants taken up by wildlife in the area, either directly or through the food chain, may be bioconcentrated.

Impairment:

No known consumption advisories are in effect for Niagara area wildlife (birds or mammals). Elevated levels of some contaminants in the past have caused genetic or reproductive abnormalities in some waterfowl. The GLWQA Objective for concentration of PCBs, for the protection of fish-eating birds, has been exceeded in fish species.

Data Gaps:

Analysis of contaminants in some wildlife continues on a reduced scale. Many wildlife species have not been investigated to determine whether or not adverse effects have been experienced.

Status:

The Canadian Wildlife Service's herring gull egg monitoring program is still operational. A collection of herring gull and night heron eggs was again conducted in 1989 and chemical analysis is still outstanding. Tests conducted in 1986 on herring gull eggs indicate that dioxin levels appear to have declined from previous years' samples.

7.3.2.7 Contaminated Sediments

Scope:

Elevated levels of heavy metals were found in the Sir Adam Beck PGS Reservoir and at tributary mouths. Mining of the Niagara Bar may contribute contaminants to the Lake Ontario water column.

Source:

Chemicals from various sources both inside and outside of the Area of Concern such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments from upstream locales) can affect water quality in the Area of Concern. Elevated chemical levels in the water column or suspended sediment create elevated levels of chemicals in bottom substrate, particularly the shallow sediments.

Impairment:

Sediment guidelines for protection of aquatic life (benthos) are being exceeded. Sediment guidelines for open water disposal have been exceeded for the following compounds: arsenic, cadmium, chromium, silver, copper, iron, lead, nickel and zinc in sediments in the Sir Adam Beck Reservoir and at tributary mouths.

Data Gaps:

Although studies have been made of contaminants within the Area of Concern, the fast-flowing nature of the Niagara River tends to maintain sediment in suspension until current velocity decreases at the mouth of the River where most of the sediment load is deposited at the Niagara River Bar in Lake Ontario. At this time, little is known about the composition and areal extent of contamination in the deposition zone, hence, more information is needed on the Niagara River Bar as a whole before conclusions can be made about the environmental health of this area.

Status:

Chemical contaminants in the sediment do not currently restrict dredging operations on the Ontario side of the Niagara Bar.

7.3.2.8 Atlas "Reef"

Scope:

Investigations by government agencies and university researchers have discovered the presence of a zone of extensive iron oxide deposition in the Welland River. This deposit manifests itself as a semi-submerged 'reef' of hard material, which also contains high levels of heavy metals in exceedance of provincial sediment guidelines.

Source:

The reef is attributed to historical discharge of heavy metal laden wastewater from Atlas Steels. These solids have combined with sediment load from agricultural erosion in the upstream Welland River to produce a rock-hard deposit in the Welland River.

Impairment:

Sediment guidelines for protection of aquatic life (benthos) have been exceeded. Sediment guidelines for open water disposal have also been exceeded for a number of heavy metals. The potential for resuspension and partition back into the water phase may lead to exceedance of aquatic criteria for protection of aquatic life.

Data Gaps:

Extensive studies of the reef, undertaken in 1989 and 1990 have defined the extent of these contaminated sediment areas. Upstream (ambient) sediment contamination and sources are a concern. These have been and will continue to be investigated through Ministry of the Environment abatement activities.

Similar contamination of the flood plain of the Welland River has been identified. Attempts are underway to delineate the extent of this contamination.

The success of dredging and treatment technologies used during the 1991 demonstration project are still being reviewed and the results are not currently available. This Stage II activity is expected in the spring of 1992.

Status:

The extent of contaminated sediment has been well defined. The contaminated floodplain areas have been investigated and the data is being interpreted. The company, in association with Environment Canada under Great Lakes Action Plan funded programs undertook a dredging and treatment demonstration project in the fall of 1991. The information is currently being evaluated and a report on the success of the demonstrated methods is expected in 1992. If that report indicates success of the methods tested, full-scale removal and treatment of the contaminated sediments will be undertaken.

7.3.3 Industrial, Municipal and Agricultural Problems

7.3.3.1Potential Impact of Municipal and Industrial Development

Scope:

Discharge of contaminants from public and private land development may impact the water quality of the Welland and Niagara Rivers if environmental considerations are not stressed in the planning, implementation and operational phases.

Source:

The discharge of stormwater containing toxic contaminants or causing excessive soil loss may impair aquatic habitat and degrade aquatic life.

Impairment:

Water quality criteria for protection of aquatic life may be exceeded.

Data Gaps:

Loadings and impacts from each source must be evaluated on a case-by-case basis and all feasible measures taken to minimize environmental impact.

Status:

Development in the Peninsula is slow during 1991-92 due to the impact of the recession; however, the area is prime for development throughout when the economy recovers. Major projects underway which may affect the aquatic environment are the proposed OWMC facility in West Lincoln and the expansion of the Sir Adam Beck Hydro electric facility in Queenston. Both of these projects are involved in the Ontario Environmental Assessment (EA) process. Minimal impacts should occur if all issues are addressed under the EA process.

7.3.4 Recreational Problems

7.3.4.1 Eutrophication or Undesirable Algae

Scope:

High nutrient levels in the slower moving portions of the watershed have created areas of abundant macrophyte and algal growth.

Source:

On the Ontario side, sewage treatment plants at Fort Erie and Niagara Falls are occasionally out of compliance for discharge of total phosphorus. Sewage treatment plants on the U.S. side, combined with storm water runoff, may cause non-compliance areas in the Tonawanda Channel. Misapplication of fertilizers in the heavily agricultural areas of the Welland River, combined with sheet erosion of soil-bound nutrients, may complicate the problems in the lower Welland River.

Wastewater discharges from Cyanamid's Welland Plant fertilizer facility may provide nutrient enrichment in downstream areas where levels are below toxic concentrations.

Impairment:

The levels of total phosphorus generally exceed Water Quality criteria at most Ontario tributary mouths and in the Tonawanda Channel. Excessive nitrogen levels are still present in the lower Welland River.

Data Gaps:

Environmental data on the lower Welland River are scarce both in terms of nutrient levels and aquatic communities.

Status:

Environmental studies were carried out in the Welland River in the summer of 1990.

7.3.4.2 Presence of Scum or Debris in Water or on Shore

Scope:

Public concern has been raised over the existence of foam and debris at the docking area and midstream in the Maid of the Mist Pool.

Source:

No upstream sources of foaming agents are known. At the Horseshoe Falls, no wastewater discharges are present upstream. Investigations of the foam show that the foaming agents are naturally occurring compounds, known as lipids.

Impairment:

No criteria exist for contaminant concentrations in foam. The foam, which is light brown in colour, contributes to a degradation of aesthetics.

Data Gaps:

Although some research has been done on the constituents and mechanisms of the foam, analytical methods and interpretative methods do not exist.

Status:

It is likely with the identification of the natural origin and composition of the foam, that nothing can be done to reduce the amounts of this natural phenomenon. Given the wildness of nature, the foam and debris will continue to occur. Debris of human origin occurs when human products go up against nature. This man versus the elements battle is likely to continue.

7.3.4.3 Bacterial Contamination

Scope:

Bacterial contamination has resulted in closings of each monitored beach in the Area of Concern. In addition, posting of other areas has also occurred.

Source:

Bacterial contamination may occur from Municipal WPCPs with inadequate disinfection, stormwater runoff, greywater discharges or bypassing, combined sewer overflows and failed septic systems on both sides of the river and on tributaries.

Impairment:

Swimming at monitored beaches and in tributaries is at times impaired. Water quality criteria are exceeded for total and fecal coliforms at locations in the Welland River drainage, Chippawa Channel and lower Niagara River.

Data Gaps:

Current beach monitoring programs are sufficient.

Status:

A report on 1988 water quality conditions is in progress.

7.3.5 Fishing Problems

7.3.5.1 Contaminants in Fish Flesh

Scope:

Unacceptable levels of toxic chemicals are found in fish taken from the Niagara River. Consumption advisories are in effect for large size classes of all sport fish. High levels are also found in non-sport species.

Source:

Chemicals from various sources such as: municipal, industrial and agricultural point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water quality and subsequently fish populations in the Area of Concern.

Impairment:

The 1989 Guide to Eating Ontario Sports Fish identifies contaminant groups in consumable species and provides consumption advisories. In the lower Niagara River (Queenston to Whirlpool) and nearshore areas of Lake Ontario (Niagara-on-the-Lake to Jordan Harbour), consumption advisories are in place for large sizes of the following species:

- chinook salmon,
- coho salmon,
- lake trout,
- rainbow trout,
- brown trout,
- carp,
- american eel,
- smallmouth bass,
- white bass,
- freshwater drum,
- channel catfish,
- yellow perch and
- white perch.

In addition to these consumption advisories, the commercial eel fishery on both sides of western Lake Ontario is currently closed.

In addition to consumption advisories in the lower Niagara River and Lake Ontario, consumption advisories are currently listed for larger size classes of two species in the upper Niagara River: freshwater drum and white suckers.

Elevated levels of contaminants identified in the edible portions of these species include: mercury in the upper river and mercury, PCBs and mirex in the lower river.

Elevated levels of PCBs and organochlorine pesticides have also been detected in scientific studies of fish species lower in the food chain, young-of-the-year spottail shiners, at some locations.

Besides exceeding levels for unlimited consumption by humans, the levels of PCBs in fish also exceed the GLWQA PCB Objective for the protection of fish-eating birds.

Data Gaps:

The analysis of contaminants in fish flesh is restricted to sport fish and some indicator species such as spottail shiners. Many fish species are not tested. In addition analysis of the fish that are tested is restricted to those numbers and size classes that are collected. Despite these shortcomings, the fish contaminants program has an excellent database to evaluate contaminants in those species caught for human consumption.

The sub-lethal or chronic effects of these contaminants on the fish themselves are not well known.

Status:

Fish flesh contamination programs will continue to be a major joint project of the Ministries of Natural Resources and Environment. More data makes trend analysis easier to undertake and this information is essential to the removal of consumption restrictions and the delisting of Areas of Concern.

7.3.5.2 Tainting of Fish

Scope:

There exists a potential for fish-tainting in certain portions of the Niagara River Area of Concern due to sources of phenolic input to the river and its tributaries. Evidence of elevated levels of total phenolics in the Niagara River exists, occasionally exceeding criteria. Non-compliance discharge of phenolics to Frenchman Creek has been reported.

Source:

Phenolic compounds from several sources in the Area of Concern such as: municipal and industrial point and non-point sources, urban runoff and in-place pollutants (contaminated sediments) can affect water quality and consequently, taint fish flesh in the Area of Concern. One local source of phenolics to Frenchman Creek is located in Fort Erie.

Impairment:

The suitability of fish for human consumption is potentially affected.

Data Gaps:

No direct link between sources of phenolic compounds and fish tainting has been made. There is currently no evidence that fish tainting is an actual problem in the Niagara River Area of Concern.

Status:

The Ontario Ministry of the Environment is continuing compliance monitoring activities for phenolic compounds. Abatement action over the past decade has significantly reduced the total loadings and concentration of phenolics.

7.3.5.3 Reduced Fisheries Production

Scope:

The numbers of emerald shiners in the upper Niagara River has declined over the past 10 years, resulting in a reduced harvest of this species by the bait fish industry.

Source:

The decline in the emerald shiner population has been attributed to overfishing by the commercial industry. However, other possible causes include: the recovery of walleye populations in Lake Erie, stocking of salmonoids in Lake Erie, lake water levels, behaviourial changes in emerald shiners, destruction of tributary stream habitat and Lake Erie phosphorous reductions. Other causes likely exist but have not been studied.

Impairment:

A decline in the population of emerald shiners may be indicative of potential future problems in the food chain supply. Further decline may result in an impaired fishery in the upper Niagara River both bait and sport fishery).

Data Gaps:

Inadequate data exist to determine the extent of this problem.

Status:

Studies on the trend of the population of this fish are not available nor are plans underway to collect this information at this time.

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7.2.1.2 Water for Human Consumption

'The water of certain sections of the Niagara River is unacceptable for human consumption in municipal systems, river wells and for sanitary use. The presence of varying amounts of toxic chemicals in potable water (including trihalomethanes from water treatment) lead to a perception or fear that drinking the water is damaging to health in the long term. There is some perception that the cancer rate in the Niagara Region is higher than the provincial average. In the upper Niagara River, siltation and biological contamination (zebra mussels and algal growth) pose a threat to municipal water treatment systems and Niagara River shore wells.'

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