2002-2003

Operation of the Lake Erie - Niagara River Ice Boom

A report to the
International Niagara Board of Control
by the
International Niagara Working Committee

September 2003

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The International Niagara Board of Control
On the 2002-2003 Operation of
The Lake Erie-Niagara River Ice Boom

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Cover:
Repair work underway following
4 February Storm event (NYPA Photo)

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International Joint Commission . . . . . www.ijc.org
New York Power Authority . . . . . www.iceboom.nypa.gov
International Niagara Board of Control . . . . . www.lre.usace.army.mil/storage/HH/IJC/Niagra/index.shtml
COE, Buffalo District . . . . . www.lrb.usace.army.mil
COE, Detroit District. . . . . www.lre.usace.army.mil
Great Lakes Information Network . . . . . www.great-lakes.net
Our Great Lakes . . . . . www.on.ec.gc.ca/water/greatlakes/intro-e.html

Data in this report are in metric units followed by approximate English units (in parentheses). The latter are provided for information purposes only. Water levels are based on the International Great Lakes Datum, 1985 (IGLD 1985).

1. Highlights

Installation of the Lake Erie - Niagara River ice boom's 22 spans began on 11 December and was completed on 12 December, 2002.

An ice cover began forming behind the boom during the second week of January 2003.

A major breach of the ice boom occurred during a storm event on 4 February when 12 of the boom's 22 spans were opened. Closure of the boom was completed on 26 February, 2003.

Ice boom removal was accomplished on 10-11 April with all spans at their summer storage area by 15 April.

Representatives of the International Niagara Working Committee conducted two helicopter flights to measure ice thickness and one fixed-wing flight to observe ice coverage and conditions during the 2002-2003 season.

Appendix "A" contains a description of the Lake Erie/Niagara River area. Appendix "B" gives background information on the ice boom.

2. Operation of the Ice Boom During the 2002-2003 Ice Season

2.1 Installation of the Boom

A new video system was installed prior to the 2002-2003 season to provide coverage to monitor the ice boom. The Internet address for information on the ice boom as well as current images can be visited at: ***http://www.iceboom.nypa.gov.***

The marine radar system for monitoring surface ice coverage in the Chippawa-Grass Island Pool (CGIP) was used by the Power Entities (Ontario Power Generation and the New York Power Authority) during the 2002-2003 ice season. The computer network links to the radar system enable staff at the New York Power Authority's (NYPA) Niagara Power Project, it's Energy Control Center in Marcy NY, and it's engineering staff in White Plains, NY, as well as staff at Ontario Power Generation's (OPG) Niagara Falls generating stations and it's headquarters office in Toronto, Ontario to view movement in the CGIP.

Lake Erie water temperature, as measured at the City of Buffalo water intake reached 4 degrees Celsius (°C) (39 degrees Fahrenheit (°F)) on 3 December. In accordance with Condition (d) of the International Joint Commission's 5 October 1999 supplementary Order of Approval, installation of the Lake Erie -Niagara River ice boom's spans commenced on 11 December 2002. Installation may begin when the Lake Erie water temperature reaches 4°C (39°F) or on 16 December, whichever occurs first.

Preparations for span placement began on 2 December when six flotation barrels were installed. A further eight barrels were installed on 3 December and the final nine were placed on 4 December. All strings of pontoons were removed from the summer storage area and placed inside the Buffalo Harbor breakwall by 9 December.

Installation of the ice boom's spans began on 11 December when 16 spans were placed, starting from the Canadian side. The last six spans, continuing on towards the U.S. shore, were installed on 12 December.

2.2 Ice and Hydrometeorological Conditions

The average monthly air temperature data for November 2002 through April 2003, as measured at the Buffalo Airport, are shown in Table 2-2.

The air temperatures for the period November 2002 through April 2003 averaged about 1.4°C (2.5°F.) below average.

A summary of Lake Erie water temperatures (as measured at the Buffalo water intake) is contained in Table 3-1.

The November 2002 monthly weather summary for Buffalo characterized it as a typical dark and chilly November. The monthly averages were very close to normal for temperature, precipitation and snowfall. The November average temperature of 4.1°C (39.4°F) was 0.5°C (0.8°F) below the monthly average. There were no significant weather events in the Buffalo area during November. The Lake Erie at Buffalo water temperature was 5.6°C (42.0°F) at month's end compared to 8.3°C (47.0°F) at the same time in 2001.

December started out cold and snowy with a major lake effect storm dropping around 38 centimetres (cm) (15 inches (in)) of snow over the first two days of the month. The first week was very cold, but conditions moderated during the second week. Below freezing temperatures dominated the last half of the month. The December average air temperature of -2.0°C (28.4°F) was 0.8°C (1.4°F) below the monthly average. The Lake Erie at Buffalo water temperature remained above freezing.

January 2003 was cold and snowy. There was a 21 day stretch of below freezing temperatures that did not end until the last day of the month. The average temperature of -7.2°C (19.0°F) was 3.0°C (5.5°F) below the monthly average. The water temperature at Buffalo reached 0^{o}C (32.0°F) on 15 January. Ice, which had formed in the river, was first observed at the International Niagara Control Works on 11 January. Beginning on 14 January, and for various periods into early March, ice procedures combined with activity by the Power Entities' ice breakers were used to maintain movement of ice through the CGIP. An ice bridge formed in the Maid-of-the-Mist Pool, below the Falls, on 17 January.

Ice began forming behind the Lake Erie-Niagara River ice boom during the second week of January. Strong southwest winds with gusts of up 82 kilometres per hour (kph) (51 miles per hour (mph)) were experienced on 13 January. Subsequently, as the result of clamp fatigue, span "E" of the ice boom was found to be open. This allowed small amounts of lake ice to enter the river but no problems were experienced as a result of the break. Repairs were completed on 20 January. Lake Erie was covered by ice by the last week of January.

During the six week period leading up to the failure of span "E", 25 days experienced peak winds over 40 kph (25 mph). Of those 25 days, six had peak winds of between 40 and 65 kph (30 and 40 mph), seven between 65 and 80 kph (40 and 50 mph) and one day over 80 kph (50 mph). Wind and wave action exerted sustainable forces on various components of the ice boom during this period.

February began with relatively mild temperatures. A storm passed to the north of the lake early on the 4th which allowed a brief but strong thaw accompanied by some rain. At the beginning of the day, the water level at the Buffalo gauge was 173.70 metres (569.88 feet). The barometric pressure dropped to 986.0 millibars (29.11 inches) around 6 a.m. Average wind speeds from the southwest of up to 60 kmh (37 mph), with gusts up to 92 kmh (57 mph), were experienced later that morning. The water level at Buffalo peaked at 174.54 m (572.64 ft) just before noon.

Air temperatures in the 5 days prior to the storm were above freezing and contributed to the ice field behind the boom becoming unstable. Boom components were bonded into the ice and unable

to submerge when exposed to pressure from the ice field. The rising lake level broke the ice arch upstream of the boom. Large ice floes detached from the central portion of the shore bound ice field and moved downstream. The force exerted by the moving ice field resulted in 12 of the ice boom's 22 spans being forced open. Some of the open spans also received extensive damage, including stretched or broken cables, detached pontoons and damaged hardware. One anchor cable was also broken and several floatation barrels were damaged.

Ice passed through the open spans and entered the upper Niagara River. The lake ice run lasted for a few hours but was handled through ice management procedures at the CGIP where the early warning system for ice stoppages/jamming was in place. NYPA's Flood Warning Notification Plan (in the event of ice affected flooding in the upper Niagara River) would have been implemented had conditions warranted. As the storm subsided, the remaining intact spans helped to restrain ice while a stable ice arch re-formed upstream of the boom. No significant amounts of lake ice entered the river.

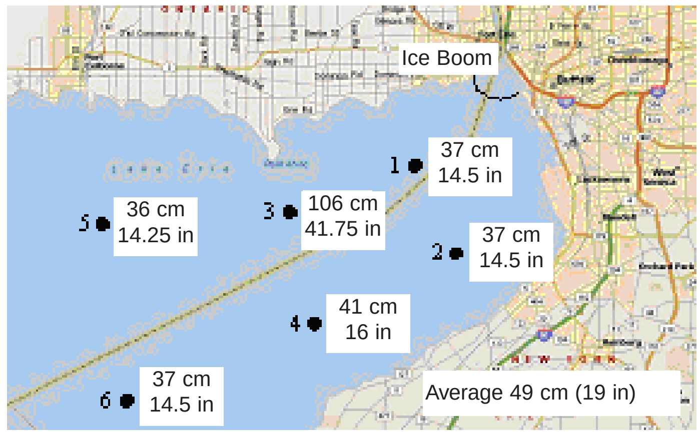
Weather conditions after the event delayed repairs. The NYPA crew had to retrieve 24 pontoons and several floatation barrels from various locations along the upper Niagara River as they had been detached during the event. Closing of spans started on 7 February. Repairs were made to damaged anchor cables, and broken or stressed clamps, while equipment such as chain links, etc. were replaced. Boom closure was completed on 26 February. There was no ice jamming and no instances of flooding or reports of shoreline property damage.

Following the early February storm, harsher mid-winter cold temperatures returned and held for most of the month. The average temperature of -6.2°C (20.8°F) was 2.8°C (5.1°F) below the February average. After the 4 February storm, winds were moderate for the remainder of the month.

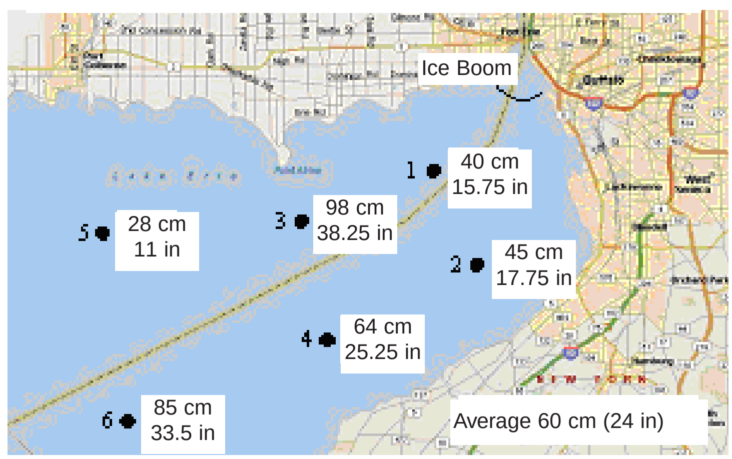
The Buffalo office of the National Weather Service (NWS) characterized March 2003 as a "normal" month for the Buffalo area. Although the persistent cold continued through the first two weeks, it was replaced by spring-like warm weather for the last two weeks. The contrast is illustrated by the fact that Buffalo experienced its coldest March daytime temperature in 118 years with a maximum of only -19°C (-3°F) recorded on the 3rd while for the 28th a June-like 23°C (73°F) was reported. The monthly temperature of 0.8°C (33.5°F) was only slightly below the March average of 1.3°C (34.3°F). The lake remained ice covered, with shore fast ice in the eastern portion extending westward along the south shore. By mid-month, some open water areas along the north shore began to appear.

Ice thickness measurements (see below) were taken at six sites in the eastern part of Lake Erie on 17 February, with the average thickness being 49 centimetres (19 inches). The site located south of Point Abino, Ontario, had a thickness of 106 centimetres (42 inches). The difference in thickness from the rest of the sites may be attributed to the concentration of ice off the end of the Point from wind action. By comparison, the last time similar measurements were taken was in February 2001 when the thickness averaged 26 centimetres (10 inches) for the six sites sampled.

A second set of measurements were taken on 18 March with the average thickness being 60



Ice Thickness Measurements - 17 February 2003



Ice Thickness Measurements - 18 March 2003

centimetres (24 inches). In March 2001, the thickness averaged 28 centimetres (11 inches).

The NWS reported April as the driest in 68 years in the Buffalo area. The dry, sunny days and a preponderance of northeast rather than southwest direction winds aided in the reduction of Lake Erie ice cover by dispersing the ice and moving it westward where it melted rapidly. April averaged 1.3°C (2.3°F) below the monthly average of 7.4°C (45.3°F).

2.3 Ice Boom Opening

Representatives of the Board conducted a fixed-wing flight on 24 March to observe ice conditions. Ice cover in the eastern basin was calculated to be 3200 square kilometres (1240 square miles) or 62 percent, with an extensive ice bridge remaining in the Maid-of-the-Mist Pool. The Board notified the Commission by letter, dated 25 March, 2003, that the ice boom opening would be delayed beyond 1 April due to the amount of ice remaining.

The ice bridge in the Maid-of-the-Mist Pool broke apart and began moving out on 30 March. By 2 April, the ice cover in the eastern basin had reduced somewhat to 2600 square kilometres (1000 square miles) or 51 percent. During the month of April, winds over the eastern part of Lake Erie were generally moderate and from the northeast. By 8 April ice cover was 700 square kilometres (270 square miles) or 14 percent and on 10 April was calculated as 490 square kilometres (190 square miles) or about 10 percent. Although some ice remained in the bays along the north shore, most of it was moving westward along the southern portion of the basin. No ice remained in the eastern part of the eastern basin beyond 8 April.

Considering that there was no longer an accumulation up of ice below the Falls and the eastern part of the lake was open water, ice boom opening and removal began on 10 April. It was completed the next day and all spans were placed at the summer storage area by 15 April.

Floatation barrels were removed, tag lines installed and the upper ends of all anchor cables inspected on 16 - 17 April, completing the 2002-2003 ice boom operation.

Based on RADARSAT information, the date of last ice on Lake Erie was 22 April.

The Welland Canal opened to commercial shipping, on a limited basis, on 26 March.

The voyages of the Maid-of-the-Mist Steamboat Company for the 2003 season began on 26 April. Last year's operations began on 8 April.

2.4 Estimated Power Losses

Some reduction in hydropower generation occurs virtually every year due to ice problems. However, the Power Entities estimate that the average annual savings to the existing hydropower facilities resulting from the use of the ice boom are approximately 414,000 megawatt-hours (MWH) of electric energy.

The losses of hydroelectric power generation for the Power Entities due to ice during the 2002-2003 season were 48,000 MWH. A summary of estimated loss of energy due to ice for the Period of Record 1975 to present is shown in Table 2-3.

2.5 Niagara River Shore Property Damages

There were no reports of damages to shore properties from ice along the Niagara River.

2.6 Maintenance of the Ice Boom

The installation, removal and maintenance of the Lake Erie-Niagara River ice boom is undertaken by NYPA staff on behalf of both Power Entities. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 centimetre (30 inch) diameter steel pontoons. This was done to improve the ice-overtopping resistance of the ice boom and reduce its maintenance costs. The replacement of timbers with steel pontoons was completed in the fall of 1997 and the first all-steel-pontoon ice boom was used in the 1997-1998 ice season.

Based on experience gained during the 1997-1998 ice season, it was recommended that, in order to reduce the potential for damage to the ends of the pontoons from collisions due to storm induced wave action during open water periods, one steel pontoon from each of spans A through J of the ice boom be removed. Therefore, spans A through J contain 10 instead of 11 steel pontoons beginning with the 1998-1999 ice season. This modification greatly reduced damage to the pontoons in this reach.

Due to the severe conditions encountered during the 4 February 2003 storm and the resulting damage to the Ice Boom and its components, the maintenance required this summer was much more than normal. Thirteen span cables and numerous hardware components (clamps, shackles, etc.) needed replacement, and several floatation barrels were repaired. A Power Enities' study is also underway to investigate the factors involved in the failure of twelve spans during the early February event.

Table 2-1 Dates Water Temperature Reached 4° C (39° F) and Dates of Ice Boom Installation

Decade	Date Water Temperature Reached 4º C (39º F)	Installation of the Ice Boom
1960's	7 Dec 1964	9 Nov to 15 Dec 1964
	15 Dec 1965	19 Nov to 8 Dec 1965
	19 Dec 1966	8 Nov to 6 Dec 1966
	29 Nov 1967	17 Nov to 5 Dec 1967
	10 Dec 1968	25 Nov to 5 Dec 1968
	9 Dec 1969	15 Nov to 10 Dec 1969
1970's	15 Dec 1970	Completed 15 Dec 1970*
	25 Dec 1971	30 Nov to 10 Dec 1971
	11 Dec 1972	11 Dec to 14 Dec 1972
	18 Dec 1973	19 Dec 1973 to 9 Jan 1974
	10 Dec 1974	11 Dec to 30 Dec 1974
	20 Dec 1975	24 Dec 1975 to 8 Jan 1976
	24 Nov 1976	30 Nov to 18 Dec 1976
	8 Dec 1977	13 Dec to 31 Dec 1977
	11 Dec 1978	Completed 19 Dec 1978*
	17 Dec 1979	Completed 22 Dec 1979*
1980's	14 Dec 1980	22 Dec to 30 Dec 1980
	11 Dec 1981	19 Dec to 23 Dec 1981
	4 Jan 1983	6 Jan to 8 Jan 1983
	18 Dec 1983	19 Dec to 21 Dec 1983
	26 Dec 1984	27 Dec to 30 Dec 1984
	17 Dec 1985	20 Dec to 21 Dec 1985
	15 Dec 1986	16 Dec to 17 Dec 1986
	19 Dec 1987	19 Dec to 26 Dec 1987
	12 Dec 1988	12 Dec to 17 Dec 1988
	6 Dec 1989	7 Dec to 8 Dec 1989
1990's	27 Dec 1990	27 Dec to 30 Dec 1990
	19 Dec 1991	20 Dec to 27 Dec 1991
	6 Dec 1992	13 Dec to 14 Dec 1992
	16 Dec 1993	17 Dec to 28 Dec 1993
	2 Jan 1995	7 Jan to 10 Jan 1995
	7 Dec 1995	13 Dec to 16 Dec 1995
	4 Dec 1996	8 Dec to 11 Dec 1996
	13 Dec 1997	17 Dec to 18 Dec 1997
	1 Jan 1999	2 Jan to 9 Jan 1999
	27 Dec 1999	19 Dec to 29 Dec 1999
2000's	18 Dec 2000	16 Dec to 28 Dec 2000
	27 Dec 2001	17 Dec to 22 Dec 2001
	3 Dec 2002	11 Dec to 12 Dec 2002

* starting date unknown

Note: Prior to the 1980-81 Ice Season, the International Joint Commission Orders required that complete closure of the ice boom shall not be accomplished before the first Monday in December.

Table 2-2 Air Temperature at Buffalo Niagara International Airport

	ºC (Celsius)			ºF (Fahrenheit)		
Month	Average* 1971-2000	Recorded 2002-2003	Departure	Average* 1971-2000	Recorded 2002-2003	Departure
Nov. 2002	4.6	4.1	-0.5	40.2	39.4	-0.8
Dec. 2002	-1.2	-2.0	-0.8	29.8	28.4	-1.4
Jan. 2003	-4.2	-7.2	-3.0	24.5	19.0	-5.5
Feb. 2003	-3.4	-6.2	-2.8	25.9	20.8	-5.1
Mar. 2003	1.3	0.8	-0.5	34.3	33.5	-0.8
Apr. 2003	7.4	6.1	-1.3	45.3	43.0	-2.3
Avg =		-0.7			30.7	

* Official U.S. National Weather Service averages are based on 30 years of record, 1971-2000.

Table 2-3 Estimated Loss of Energy Due to Ice for Period of Record 1975 to Present

Winter Season of:	POWER LOSSES (in MWH) December	January	February	March	April	May	Totals
1974-1975	*	*	*(2/14-3/5) 150,000	*(3/7-3/26) 15,100	*	*	165,100
1975-1976	*	78,700	36,500	45,800	32,000	*	193,000
1976-1977	*	54,000	23,500	0	0	0	77,500
1977-1978	*	88,000	600	600	0	0	89,200
1978-1979	*	30,000	3,700	0	1,600	0	35,300
1979-1980	*	6,000	30,000	13,000	10,500	0	59,500
1980-1981	14,000	9,000	3,900	1,100	4,100	0	32,100
1981-1982	*	58,000	27,000	10,000	13,000	5,000	113,000
1982-1983	0	0	0	0	0	0	0
1983-1984	53,000	57,000	4,000	25,000	0	0	139,000
1984-1985	0	65,000	25,000	11,000	29,000	0	130,000
1985-1986	10,000	65,000	8,000	5,000	6,000	0	94,000
1986-1987	0	28,000	32,000	4,000	0	0	64,000
1987-1988	0	13,000	24,000	0	4,000	0	41,000
1988-1989	0	0	30,000	1,000	2,000	0	33,000
1989-1990	6,000	7,000	5,000	5,000	0	0	23,000
1990-1991	0	14,000	11,000	6,000	0	0	31,000
1991-1992	0	21,000	3,000	14,000	0	0	38,000
1992-1993	0	0	2,000	2,000	0	0	4,000
1993-1994	0	11,000	12,000	0	1,000	0	24,000
1994-1995	0	0	11,000	2,000	7,000	0	20,000
1995-1996	0	45,000	4,000	13,000	0	0	62,000
1996-1997	0	80,000	4,000	3,000	16,000	0	103,000
1997-1998	0	0	0	0	0	0	0
1998-1999	0	17,000	700	0	0	0	17,700
1999-2000	0	0	1,200	0	0	0	1,200
2000-2001	700	3,600	500	100	0	0	4,900
2001-2002	0	0	0	0	0	0	0
2002-2003	0	35,000	11,500	1,500	0	0	48,000

* No Data Published

Note: No Data Available for Period 1964-1974.

3. DATA ANALYSIS 2002-2003

3.1 Purpose

During the 2002-2003 winter season, the International Niagara Working Committee continued its program of collecting data and information related to ice boom operations, to monitor conditions and determine when opening should begin. As part of the usual program, satellite imagery and mapping was analyzed and meteorological data from the U.S. National Weather Service Station at Buffalo were collected.

Lake Erie water temperatures, as recorded at the Buffalo water intake, for the 2002-2003 ice boom reporting period, are contained in Table 3-1. Observed dates of last ice for the period 1905 to present are contained in Table 3-2. Comparison of ice areas at the time of ice boom opening is shown in Table 3-3.

3.2 Navigation at the Welland Canal in Ontario

The Welland Canal opened to commercial shipping, on a limited basis, on 26 March.

Both U.S. and Canadian Coast Guards provided ice breaker assistance to commercial shipping on Lake Erie during the late March and early April period.

Opening dates for the ice boom and commencement of navigation at the Welland Canal for the period 1965 to 2003 are shown in Table 3-4.

4. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Findings and Conclusions

a) Water temperature at Buffalo reached 4°C (39°F) on 3 December.

b) The ice boom was installed on 11 - 12 December 2002 in accordance with the International Joint Commission's 1999 Supplementary Order of Approval.

c) Lake Erie became ice covered by the end of January 2003.

d) A major breach of the ice boom occurred during a storm event on 4 February with 12 of the boom's 22 spans opened.

e) Removal of the ice boom spans was accomplished on 10 - 11 April. The average length of time required to open and remove the ice boom spans for the period of record 1965 through 2003 is five days

4.2 Recommendations for the 2003-2004 Operation

a) The International Niagara Board of Control and its Working Committee should continue to monitor and assess the performance of the ice boom.

b) Utilization of Great Lakes ice cover maps prepared by the National Ice Center, Maryland and Canadian Ice Centre, Ottawa supplemented by ice thickness measurements and aerial ice surveys to evaluate ice conditions throughout the winter should continue. In particular, this will assist in determining when to remove the ice boom.

c) The Working Committee continues to produce ice area maps following aerial ice reconnaissance flights or determined from the composite ice maps.

d) The Working Committee should continue to liaise with the United States and Canadian Coast Guards regarding ice boom installation and removal operations.

Table 3-1 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (2002-2003).

Month	December		January		February		March		April		May	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	5.0	41	1.1	34	0.0	32	0.0	32	0.0	32	5.0	41
2	4.4	40	1.1	34	0.0	32	0.0	32	0.0	32	5.0	41
3	3.9	39	1.1	34	0.0	32	0.0	32	0.0	32	5.0	41
4	3.9	39	1.1	34	0.0	32	0.0	32	0.0	32	5.0	41
5	3.9	39	1.1	34	0.0	32	0.0	32	0.0	32	5.0	41
6	3.9	39	0.6	33	0.0	32	0.0	32	0.0	32	5.0	41
7	3.3	38	1.1	34	0.0	32	0.0	32	0.0	32	5.6	42
8	2.2	36	0.6	33	0.0	32	0.0	32	0.0	32	6.1	43
9	1.7	35	0.6	33	0.0	32	0.0	32	0.0	32	6.7	44
10	1.7	35	0.6	33	0.0	32	0.0	32	0.0	32	6.1	43
11	1.7	35	0.6	33	0.0	32	0.0	32	0.0	32	6.1	43
12	1.7	35	0.6	33	0.0	32	0.0	32	0.0	32	7.2	45
13	1.1	34	0.6	33	0.0	32	0.0	32	0.0	32	7.8	46
14	2.2	36	0.6	33	0.0	32	0.0	32	1.1	34	7.2	45
15	3.9	39	0.0	32	0.0	32	1.1	34	1.1	34	7.2	45
16	3.3	38	0.0	32	0.0	32	0.0	32	2.2	36	7.8	46
17	2.2	36	0.0	32	0.0	32	0.0	32	2.2	36	7.2	45
18	2.2	36	0.0	32	0.0	32	0.0	32	1.7	35	7.2	45
19	2.2	36	0.0	32	0.0	32	0.0	32	2.2	36	7.2	45
20	1.7	35	0.0	32	0.0	32	0.0	32	2.2	36	7.2	45
21	1.1	34	0.0	32	0.0	32	0.0	32	3.3	38	7.2	45
22	1.1	34	0.0	32	0.0	32	0.0	32	3.9	39	7.8	46
23	1.7	35	0.0	32	0.0	32	0.0	32	3.9	39	8.3	47
24	2.2	36	0.0	32	0.0	32	0.0	32	3.3	38	7.8	46
25	3.3	38	0.0	32	0.0	32	0.0	32	3.9	39	7.8	46
26	2.8	37	0.0	32	0.0	32	0.0	32	3.3	38	8.9	48
27	2.8	37	0.0	32	0.0	32	0.0	32	3.9	39	9.4	49
28	2.2	36	0.0	32	0.0	32	0.0	32	4.4	40	10.0	50
29	1.7	35	0.0	32			0.0	32	4.4	40	10.6	51
30	1.7	35	0.0	32			0/0	32	4.4	40	11.1	52
31	1.7	35	0.0	32			0.0	32			12.2	54
Avg.	2.5	36.5	0.3	32.6	0.0	32.0	0.0	32.0	2.3	36.2	7.3	45.2

Table 3-2 Observed Dates of Last Ice, 1905 to Present

Year	Observed Date of Last Ice	Year	Observed Date of Last Ice	Year	Observed Date of Last Ice
1905	7 May	1941	21 April	1976	19 April
1906	22 April	1942	30 April	1977	13 May
1907	30 April	1943	20 May	1978	14 May
1908	9 May	1944	15 April	1979	3 May
1909	26 April	1945	9 April	1980	23 April
1910	30 April	1946	No Data	1981	30 April
1911	6 May	1947	No Data	1982	20 May
1912	29 April	1948	No Data	1983	23 Feb
1913	30 April	1949	No Data	1984	25 April
1914	28 April	1950	No Data	1985	1 May
1915	2 May	1951	15 April	1986	26 April
1916	11 May	1952	27 March	1987	9 March
1917	30 April	1953	Ice Free	1988	27 April
1918	20 April	1954	27 March	1989	9 April
1919	15 March	1955	5 April	1990	10 April
1920	20 May	1956	20 April	1991	28 March
1921	14 March	1957	11 March	1992	15 April
1922	11 April	1958	10 April	1993	16 April
1923	16 May	1959	8 May	1994	1 May
1924	20 April	1960	5 May	1995	18 April
1925	26 April	1961	15 April	1996	6 May
1926	31 May	1962	30 April	1997	29 April
1927	9 April	1963	11 May	1998	Ice-Free
1928	19 May	1964	27 April	1999	2 April
1929	2 May	1965*	14 May	2000	28 March
1930	7 May	1966	27 April	2001	27 April
1931	7 April	1967	13 April	2002	Ice-free
1932	21 April	1968	4 May	2003	22 April
1933	23 April	1969	26 April		
1934	23 April	1970	30 April		
1935	13 April	1971	31 May		
1936	31 May	1972	5 May		
1937	14 April	1973	15 March		
1938	14 April	1974	6 April		
1939	14 May	1975	8 April		
1940	19 May				

* 1965 First year the ice boom was used.

Table 3-3 Comparison of Ice Areas Near Time of Boom Opening

		Areas of Ice in Eastern Lake Erie		Opening of Boom	
Year	Date of Observation	Square Kilometres	Square Miles	Start	Completed
1965				21 March	27 March
1966				20 March	1 April
1967	***No Data Collected***			22 March	29 March
1968				8 March	20 March
1969				26 March	3 April
1970	16 April	2590	1,000	23 April	30 April
1971	27 April	2850	1,100	3 May	14 May
1972	18 April	1300	500	20 April	25 April
1973	14 March	260	100	16 March	21 March
1974	18 March	320	125	26 March	1 April
1975	21 March	80	30	25 March	28 March
1976	15 April	130	50	19 April	21 April
1977	14 April	520	200	18 April	20 April
1978	27 April	710	275	1 May	8 May
1979	10 April	390	150	13 April	17 April
1980	1 April	700	270	2 April	7 April
1981	15 April	1220	470	18 April	22 April
1982	26 April	1090	420	27 April	2 May
1983	2 March	Trace	Trace	7 March	8 March
1984	5 April	780	300	7 April	10 April
1985	12 April	780	300	13 April	15 April
1986	7 April	1010	390	12 April	14 April
1987	5 March	130	50	6 March	6 March
1988	8 March	70	270	9 April	10 April
1989	27 March	340	130	30 March	6 April
1990	26 March	230	90	26 March	30 March
1991	25 March	50	20	27 March	30 March
1992	31 March	160	60	30 March	2 April
1993	3 April	540	210	5 April	6 April
1994	19 April	620	240	21 April	28 April
1995	28 March	420	160	30 March	17 April
1996	17 April	720	280	19 April	3 May
1997	24 April	65	25	25 April	28 April
1998	Ice-Free			5 March	5 March
1999	30 March	Trace	Trace	30 March	30 March
2000	21 March	160	160	23 March	24 March
2001	14 April	390	150	17 April	20 April
2002	Ice-Free			7 March	7 March
2003	10 April	490	190	10 April	11 April

Table 3-4 Comparative Data for Years Ice Boom Has Been in Place

	Opening of Boom		Navigation Season Opened at:	
Year	Start*	Completed	Welland**	NOTES
1965	21 March	27 March	1 April	* Denotes opening of first boom
1966	20 March	1 April	4 April	span. Mobilization time
1967	22 March	29 March	1 April	precedes this date.
1968	18 March	20 March	1 April	
1969	26 March	3 April	1 April	
1970	23 April	30 April	1 April	1970 Commencement of flexible
1971	3 May	14 May	29 March	date for boom opening.
1972	20 April	25 April	29 March	
1973	16 March	21 March	28 March	
1974	26 March	1 April	29 March	
1975	25 March	28 March	25 March	** Usually, scheduled date is
1976	19 April	21 April	1 April	established well in advance and
1977	18 April	20 April	4 April	could be related to the Welland
1978	1 May	8 May	28 March	Canal repair schedule.
1979	13 April	17 April	28 March	
1980	2 April	7 April	24 March	
1981	18 April	22 April	25 March	
1982	27 April	2 May	5 April	
1983	7 March	8 March	5 April	
1984	7 April	10 April	28 March	
1985	13 April	15 April	1 April	
1986	12 April	14 April	3 April	
1987	6 March	6 March	1 April	
1988	9 April	10 April	31 March	
1989	30 March	6 April	31 March	
1990	26 March	30 March	28 March	
1991	27 March	30 March	26 March	
1992	30 March	2 April	30 March	
1993	5 April	6 April	30 March	
1994	21 April	28 April	5 April	
1995	30 March	17 April	24 March	
1996	19 April	3 May	29 March	
1997	25 April	28 April	2 April	
1998	5 March	5 March	24 March	
1999	30 March	30 March	31 March	
2000	23 March	24 March	28 March	
2001	17 April	20 April	30 March	
2002	7 March	7 March	26 March	
2003	10 April	11 April	26 March	
1965 - 2003	4 April	9 April	30 March	Average of the 39 year post-ice boom period.
1970 - 2003	6 April	10 April	30 March	Average 34 year flexible boom opening date.

Appendix A - Description of the Lake Erie-Niagara River Area

A.1 Hydraulics and Hydrology

The Niagara River, about 58 kilometres (36 miles) in length, is the natural outlet from Lake Erie to Lake Ontario (Figures 2 and 3). The elevation difference between the two lakes is about 99 metres (326 feet); half of this occurs at Niagara Falls. Over the period 1860-2001, the average Niagara River flow at Queenston, Ontario has been 5872 cubic metres per second (m^3/s) (207,370 cubic feet per second (cfs)). The Welland Canal carries a small portion of the Lake Erie outflow. The total upper Great Lakes drainage basin upstream of the Niagara River is approximately 684,000 square kilometres (264,000 square miles). Figure 3 is a map of the Niagara River.

The Niagara River, as described in the following paragraphs, consists of three major reaches: the upper Niagara River, the Niagara Cascades and Falls, and the lower Niagara River.

(a) *Upper Niagara River*

The upper Niagara River extends about 35 kilometres (22 miles) from Lake Erie to the Cascade Rapids which begin 1 kilometre (0.6 mile) upstream from the Horseshoe Falls. From Lake Erie to Strawberry Island, a distance of approximately 8 kilometres (5 miles), the channel width varies from 2740 metres (9,000 feet) at its funnel-shaped entrance to 460 metres (1,500 feet) at Squaw Island below the Peace Bridge. The average fall over this reach is around 1.8 metres (6 feet). In the upper 3.2 kilometres (2 miles) of the river, the maximum depth is approximately 6 metres (20 feet), with velocities as high as 3.7 metres per second (m/s) (12 feet per second (ft/s)) in the vicinity of the Peace Bridge. Below Squaw Island, the river widens to approximately 610 metres (2,000 feet), with velocities in the order of 1.2 to 1.5 m/s (4 to 5 ft/s).

At Grand Island, the river divides into the west channel, known as the Canadian or Chippawa Channel, and the east channel, known as the American or Tonawanda Channel. The Chippawa Channel is approximately 17.7 kilometres (11 miles) in length and varies from 610 to 1220 metres (2,000 to 4,000 feet) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 ft/s). The Chippawa Channel carries approximately 60% of the total river flow. The Tonawanda Channel is 24 kilometres (15 miles) long and varies from 460 to 610 metres (1,500 to 2,000 feet) in width above Tonawanda Island. Downstream thereof, the channel varies from 460 to 1220 metres (1,500 to 4,000 feet) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 ft/s).

At the north end of Grand Island, the channels unite to form the 4.8 kilometre (3 mile) long Chippawa-Grass Island Pool. At the downstream end of the pool is the International Niagara Control Works. This structure extends from the Canadian shoreline about halfway across the width of the river. The Niagara Falls are located about 1370 metres (4,500 feet) downstream of the structure. The average fall from Lake Erie to the Chippawa-Grass Island Pool is 2.7 metres (9 feet).

(b) *Niagara Cascades and Falls*

Below the control structure, the river falls 15 metres (50 feet) through the Cascade area and is divided into two channels by Goat Island. These channels convey the flow to the brink of the Canadian and American Falls. The Canadian or Horseshoe Falls is so named because the crest is horseshoe shaped. During non-tourist hours, the minimum Falls flow is 1416 m^3/s (50,000 cfs). This produces a fall of about 57 metres (188 feet). Minimum Falls flow for tourist hours is 2832 m^3/s (100,000 cfs) which results in a fall of about 54 metres (177 feet). These minimum values are combined Horseshoe and American Falls flows. There are small accumulations of talus (rock debris) at the flanks. At the American Falls, water plunges vertically ranging from 21 to 34 metres (70 to 110 feet) to a talus slope at its base.

(c) *Lower Niagara River*

The Niagara Gorge extends from the Falls for 11 kilometres (7 miles) downstream to the foot of the escarpment at Queenston, Ontario. The upper portion of this reach is known as the Maid-of-the-Mist Pool, with an average fall of approximately 1.5 metres (5 feet). This reach is navigable for practically its entire length. The Maid-of-the-Mist Pool is bounded downstream by the Whirlpool Rapids, which extend a further 1.6 kilometres (1 mile). The water surface profile drops 15 metres (50 feet) in the Whirlpool Rapids, where velocities can reach as high as 9 m/s (30 ft/s). The Whirlpool, a basin 518 metres (1,700 feet) long and 365 metres (1,200 feet) wide, with depths up to 38 metres (125 feet), is where the river makes a near right-angled turn. Below the Whirlpool, there is another set of rapids, which drop approximately 12 metres (40 feet). The river emerges from the gorge at Queenston, Ontario and subsequently drops 1.5 metres (5 feet) to Lake Ontario. At Queenston, the river widens to 610 metres (2,000 feet) and is navigable to Lake Ontario.

A.2 Hydro-Electric Installations and Remedial Works

A major portion of the Lake Erie outflow is utilized for power production and is diverted to hydro-electric plants by intake structures located above the Falls (Figure 4). A lesser portion is diverted for power via the Welland Canal. The high head plants, Sir Adam Beck Nos. 1 and 2 in Canada and the Robert Moses Niagara Power Project in the United States, withdraw water from the Chippawa-Grass Island Pool and return it to the lower Niagara River at Queenston, Ontario and Lewiston, New York, respectively. The Ontario Power Generating Station, which was taken out of service on 26 November 1999, and the Fortis Ontario's Rankine Power Plant, both located in Canada, divert water from the Cascade area and return it to the Maid-of-the-Mist-Pool. The Ontario Power Plant (out of service) is located at the base of the gorge near the head of the Maid-of-the-Mist Pool. The Rankine Plant is located just upstream of the Horseshoe Falls. Figure 4 shows the location of these diversion structures and hydro-electric power plants.

The amount of water that can be diverted for power generation is determined by a 1950 Treaty between the Governments of Canada and the United States concerning "The Diversion of the Niagara River," generally referred to as the "1950 Niagara Treaty." The Treaty requires the flow over Niagara Falls to be not less than 2832 m^3/s (100,000 cfs) during the daylight hours of the tourist season (0800 to 2200 hours local time 1 April to 15 September and 0800 to 2000 local time 16 September to 31 October). At all other times, the flow must be not less than 1416 m^3/s (50,000 cfs). The Treaty also specifies that all water in excess of that required for domestic and sanitary purposes, navigation, and the Falls flow requirements, may be diverted for power generation.

Remedial works were constructed by the Power Entities in the 1950's, with the approval of the International Joint Commission, to maintain the Falls flows required by the Treaty and to facilitate power diversions. The remedial works consist of excavation and fill on both flanks of the Horseshoe Falls and a control structure extending about 0.8 kilometre (0.5 mile) into the river from the Canadian shore at the downstream end of the Chippawa-Grass Island Pool. The control structure has 13 gates, completed in 1957, and 5 additional gates completed in 1963. The Chippawa-Grass Island Pool control structure is operated jointly by the Power Entities and regulates the water level in the Chippawa-Grass Island Pool within limits set by the International Joint Commission. It also functions to adjust the Falls flow promptly from 2832 m^3/s (100,000 cfs) to 1416 m^3/s (50,000 cfs) and vice-versa during the tourist season. The operation of the control structure is under the supervision of the International Joint Commission's International Niagara Board of Control.

In 1964, with the International Joint Commission's approval, the Power Entities installed a floating ice boom in Lake Erie, near the head of the Niagara River. The boom has been installed early each winter and removed in the spring every year since. Its main purpose is to reduce the frequency and duration of heavy ice runs into the Niagara River which may lead to ice jams that could seriously hamper power diversions and damage shoreline installations. A more detailed description of the boom is contained in Section B.3.

A.3 Other Shore Installations

The Black Rock Canal parallels the upper reach of the Niagara River from Buffalo Harbor to the downstream end of Squaw Island. The canal provides an alternate route around the constricted, shallow and high velocity Peace Bridge reach of the upper Niagara River. Extending from Buffalo Harbor to above Strawberry Island, the canal is separated from the river at the upstream end by the Bird Island Pier, a stone and concrete wall and by Squaw Island at the downstream end. The Black Rock Lock, which has a lift of 1.5 metres (5 feet), is located near the lower end of the canal. A navigation channel extends from Squaw Island, via the Tonawanda Channel, to Niagara Falls, New York. The channel and canal are maintained to a depth of 6.4 metres (21 feet) below low water datum to North Tonawanda and then to a depth of 3.7 metres (12 feet) below low water datum to the city of Niagara Falls, New York.

The U.S. Government in 1985 and 1986 rehabilitated a portion of the Bird Island Pier. Prior to rebuilding, most of the pier was overtopped by water passing from the canal into the river at times of storm surge and/or high outflow from Lake Erie. Although the rebuilding raised the level of the pier slightly, culverts were incorporated into the structure to ensure unimpeded pre-project flow conditions that occurred over and through the pier.

Two bridges linking the Province of Ontario and State of New York span the upper Niagara River. The Peace Bridge (highway) crosses the head of the river and the Black Rock Canal near Lake Erie. The International Railway Bridge crosses the river and the canal 2.4 kilometres (1.5 miles) downstream from the Peace Bridge. The South and North Grand Island highway bridges traverse the Tonawanda Channel at Tonawanda and Niagara Falls, New York, respectively.

Docks for recreational craft are located at many points along the Niagara River, with a high concentration along the Tonawanda Channel. There are a few commercial docks for bulk commodities along the United States shoreline between the lower end of the Black Rock Canal and North Tonawanda, New York. A commercial operation for storing and distributing dredged sand is located at Queenston, Ontario. Several municipal and industrial water intakes and waste outfalls are located in the upper river. Some of these have structures extending above the water surface.

A.4 Ice Problems

Flow retardation due to ice in the Niagara River is a common winter event. During periods of high southwest winds, ice from Lake Erie sometimes enters the Niagara River and becomes grounded in shallow areas, such as the shoals near the head of the river and in the Chippawa-Grass Island Pool. During severe winter weather, ice originating in the river often adds to the problems caused by ice runs from the lake. These ice conditions can retard the flow in the Niagara River and occasionally lead to shore property damage and flooding. Accumulations of ice at the hydroelectric power intakes above Niagara Falls, or ice jams upstream, can reduce the amount of water diverted into these intakes. At times, a combination of reduced diversions, manipulated water elevations in the Chippawa-Grass Island Pool and ice breaker activity is necessary to facilitate ice passage.

Ice accumulations in the Maid-of-the-Mist Pool may pose potential hazards to the Ontario Power Plant and the Maid-of-the-Mist Steamboat Company facilities, both located downstream of the Falls on the Canadian shore. Heavy ice runs in the upper river, if added to a sizable volume of ice already in the Maid-of-the-Mist Pool, may, and on occasions have, severely damaged these installations.

Appendix B - Background Information on the Ice Boom

B.1 Authorization for Placement of the Ice Boom

The International Joint Commission authorized the Power Entities to install the ice boom on a test basis under an Order of Approval dated 9 June 1964. This Order has subsequently been modified by Supplementary Orders. The operation of the ice boom is reviewed by the International Joint Commission when circumstances require, but no less than once every five years. The most recent review was completed in 1999 and resulted in the Commission issuing a Supplementary Order which modified condition (d). A Supplementary Order was issued in 1997 to remove any reference to the material required for the ice boom's pontoons.

Condition (d) regarding installation and Condition (e) regarding boom removal state, respectively:

> "(d) Installation of the floating sections of the boom shall not commence prior to December 16 or prior to the water temperature at the Buffalo water intake reaching 4° C (39° F), whichever occurs first, unless otherwise directed by the Commission."

> "(e) All floating sections of the ice boom shall be opened by April 1, unless ice cover surveys on or about that date show there is more than 250 square miles (650 square kilometres) of ice east of Long Point. The ice boom opening may be delayed until the amount of ice east of Long Point has diminished to 250 square miles (650 square kilometres). Complete disassembly and removal of all remaining flotation equipment shall be completed within two weeks thereafter. Not with-standing any other provisions of this Order, the Commission retains the right to require retention, opening or removal of all or any part of the boom at any time because of the existence of an emergency situation."

B.2 Purpose of the Ice Boom

The ice boom accelerates the formation of the natural ice arch that forms most winters near the head of the Niagara River and stabilizes the arch once it has formed. The boom reduces the severity and duration of ice runs from Lake Erie into the Niagara River, thereby lessening the probability of large-scale ice blockages in the river. Such blockages could lead to both hydropower generation reductions and shoreline property flooding. In addition, it reduces the probability of ice damage to docks and other shore structures.

Once the ice arch is formed, it bears the pressure of upstream ice. Subsequent storms may overcome the stability of the arch and force large masses of ice against the boom. The boom was designed to then submerge and allow the ice to override it until the pressure is relieved. After storm conditions subside,
the boom resurfaces and restrains ice which otherwise would flow downriver. In the winter season, the ice boom facilitates stabilization of the broken ice cover during the refreezing process. In the spring, it minimizes the severity of ice runs by reducing the quantity of loose ice floes which enter the river.

B.3 Description of the Ice Boom

When in position, the 2700 metre (8,800 foot) ice boom spans the outlet of Lake Erie and is located approximately 300 metres (1,000 feet) southwest of the water intake crib for the city of Buffalo. The boom is made up of 22 spans. Starting with the 1997-1998 season, the boom spans consisted of a series of 11 floating steel pontoons. Spans are anchored to the lake bed at 122 metre (400 foot) intervals by 6.4 centimetre (2.5 inch) diameter steel cables. Each pontoon is 76 centimetres (30 inches) in diameter and 9 metres (30 feet) long. Beginning in 1998-99, spans A through J contained 10 instead of 11 pontoons to reduce the potential for collisions during open water conditions. A map of eastern Lake Erie showing the location of the ice boom is included as Figure 5. Figure 6 is a map of the upper Niagara River. Figure 7 illustrates structural details and a plan view of the ice boom.

Plan View of Ice Boom and Sequence of Removal

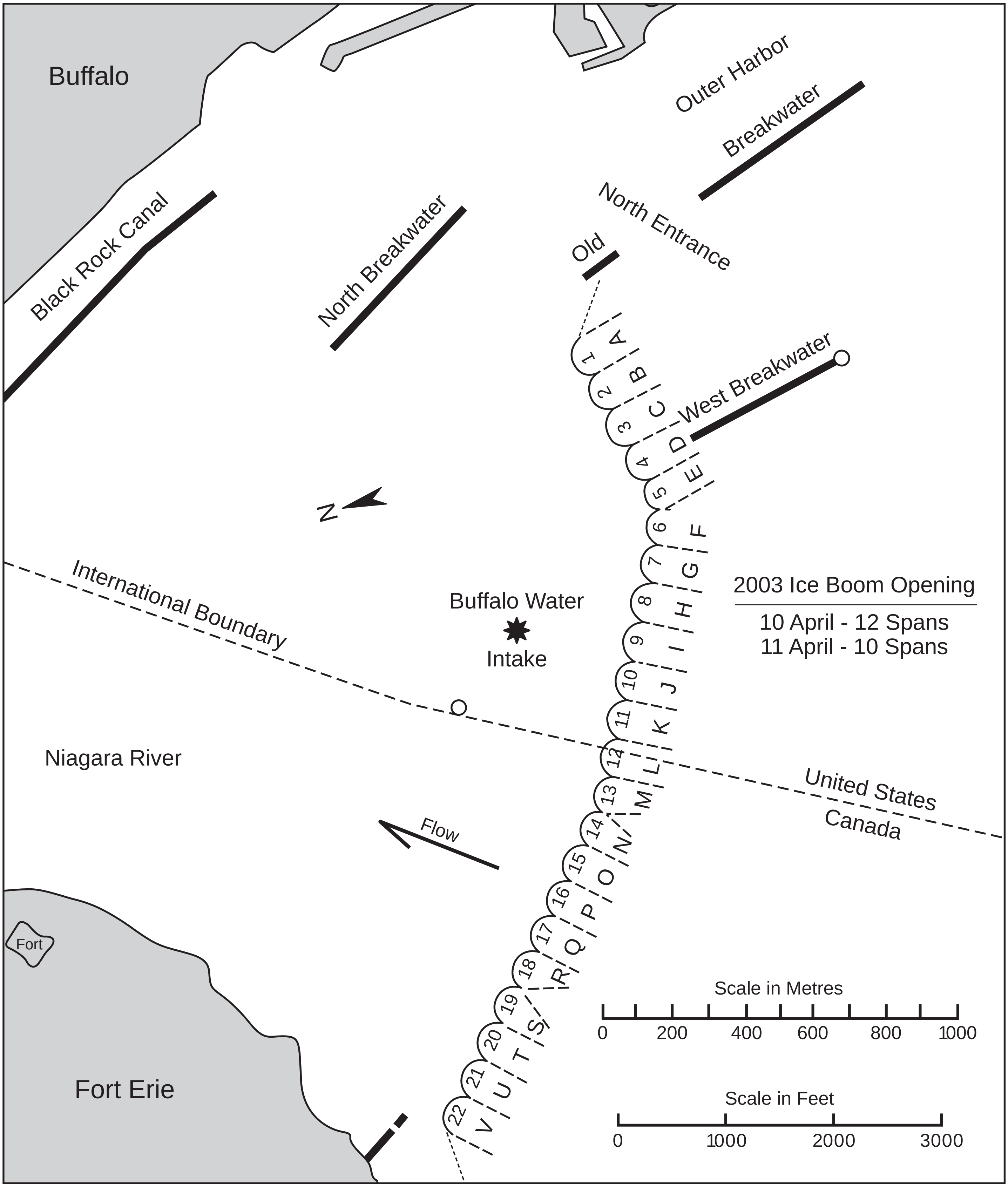


FIGURE 1

Great Lakes - St. Lawrence River Drainage Basin

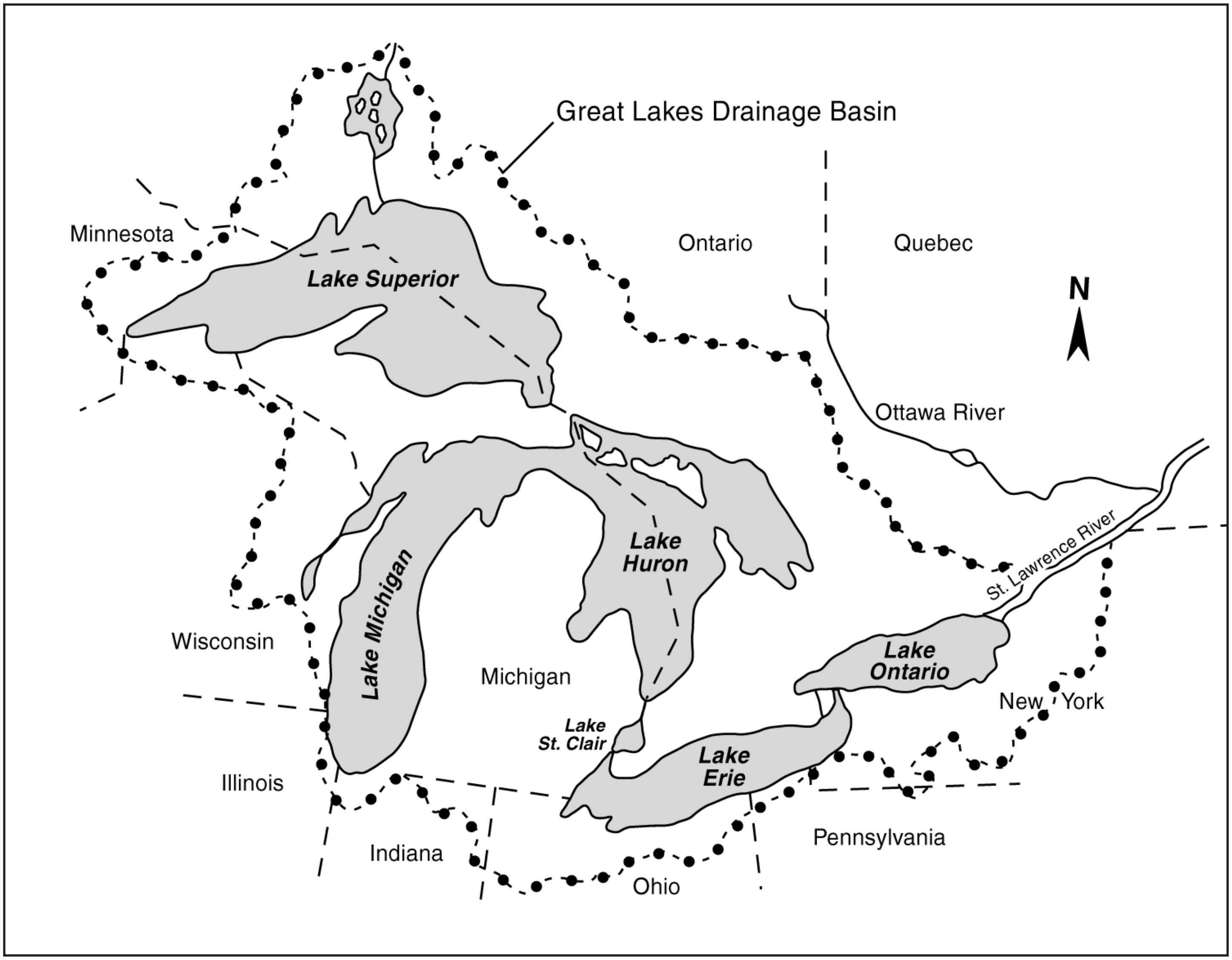


FIGURE 2

Niagara River - Location Map

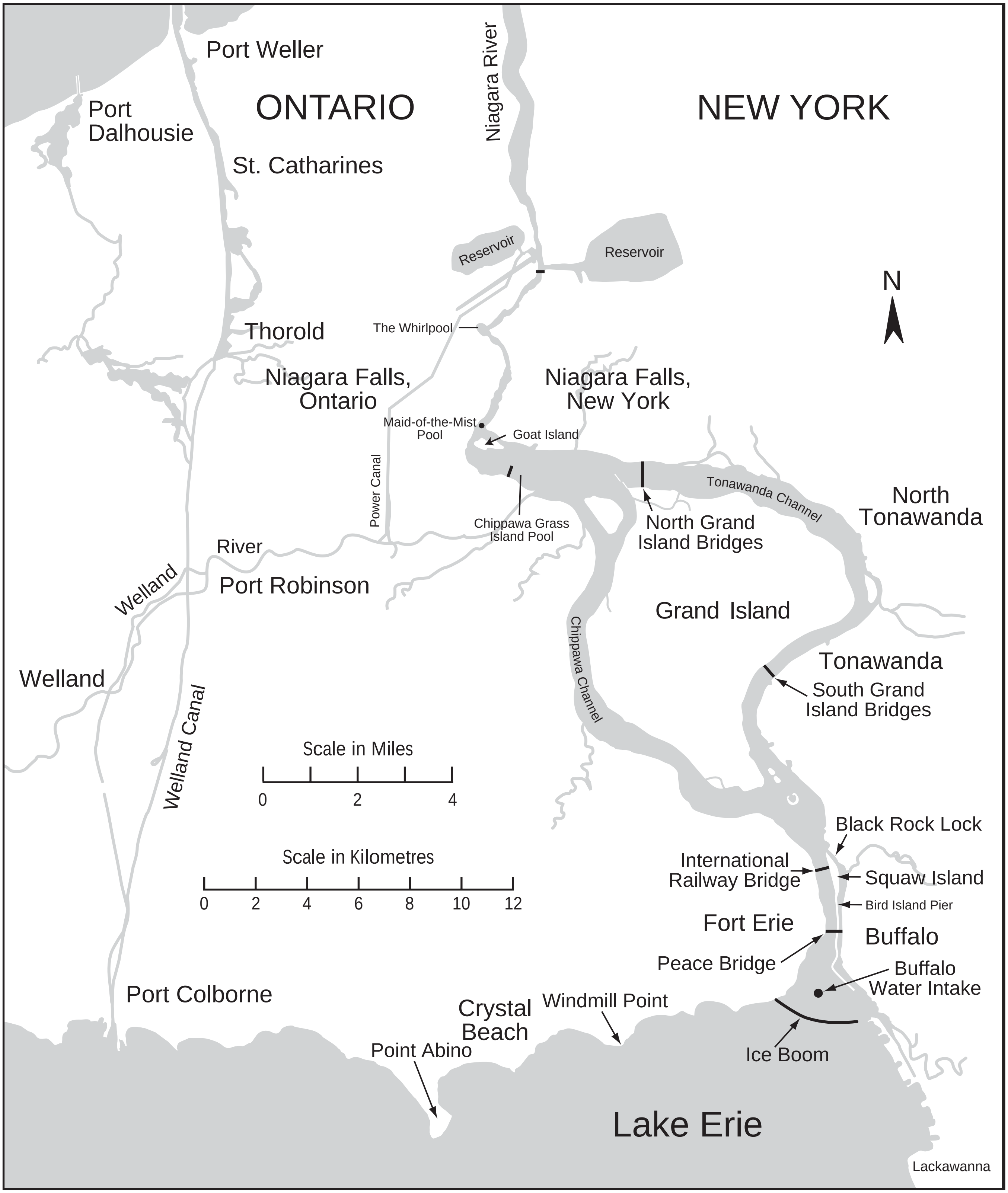


FIGURE 3

Niagara River Diversion Structures and Power Plants

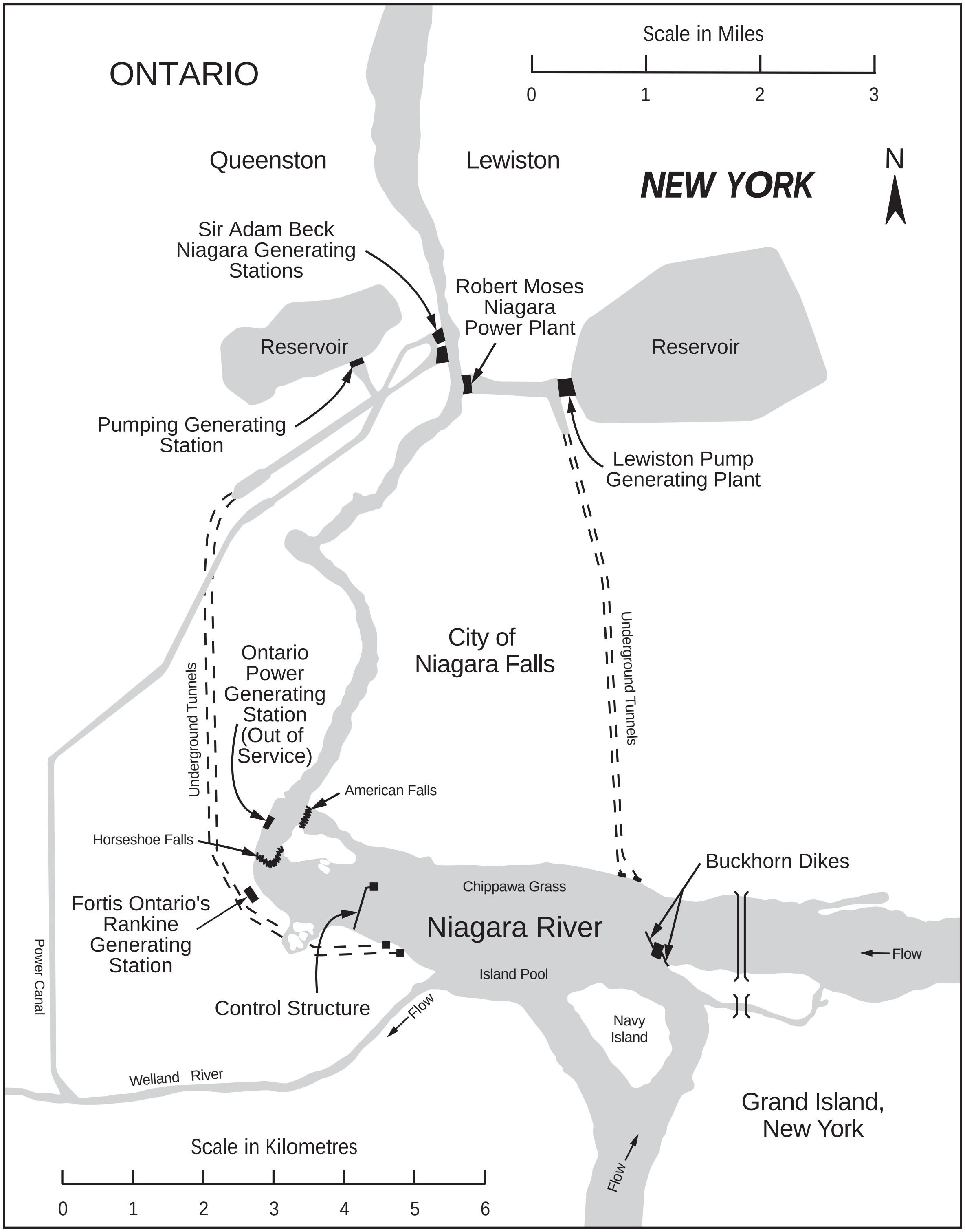
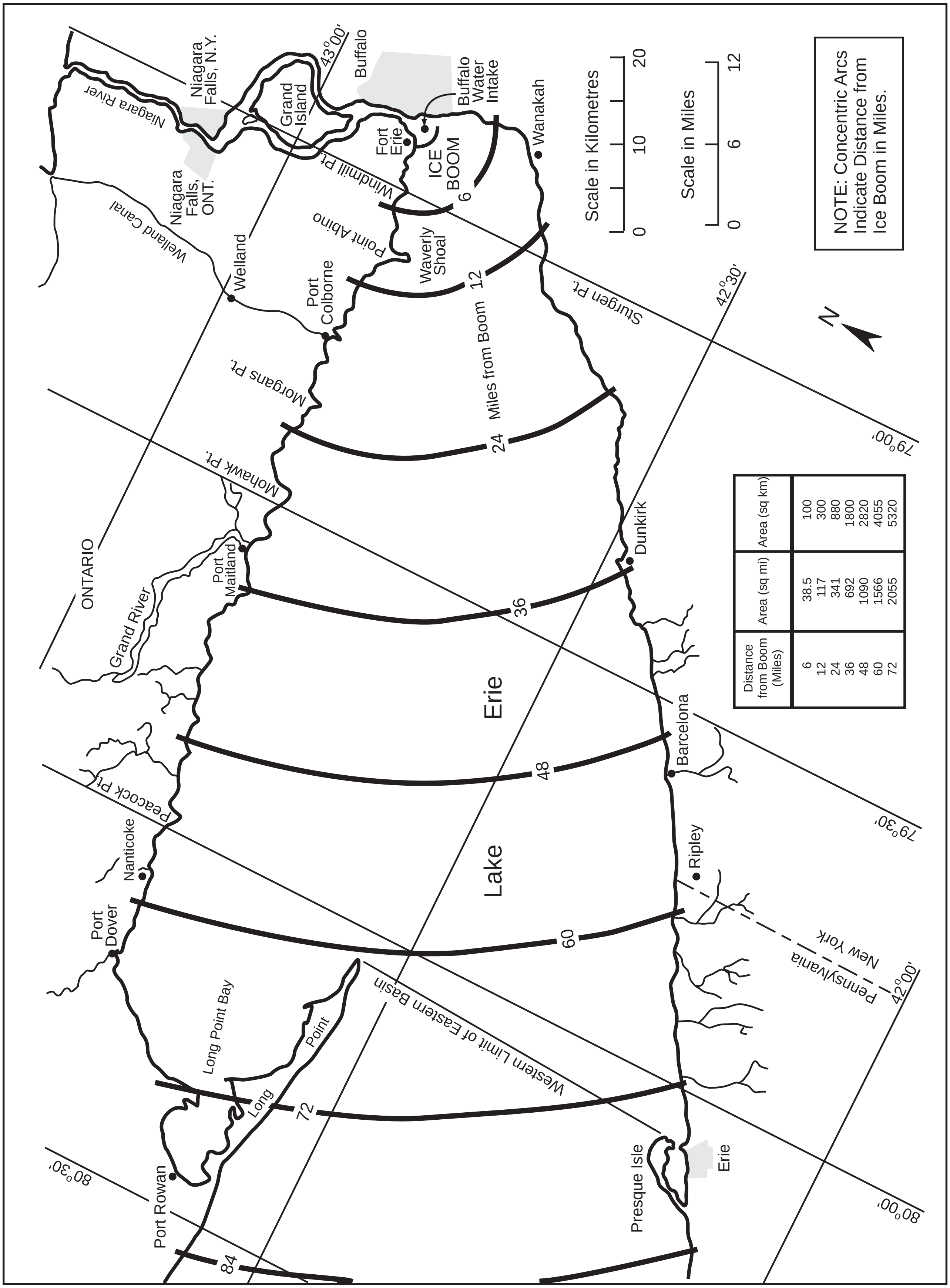


FIGURE 4

Map of Eastern Lake Erie



Distance from Boom (Miles)	Area (sq mi)	Area (sq km)
6	38.5	100
12	117	300
24	341	880
36	692	1800
48	1090	2820
60	1566	4055
72	2055	5320

FIGURE 5

Map of Upper Niagara River Showing Water Level Gauge Locations

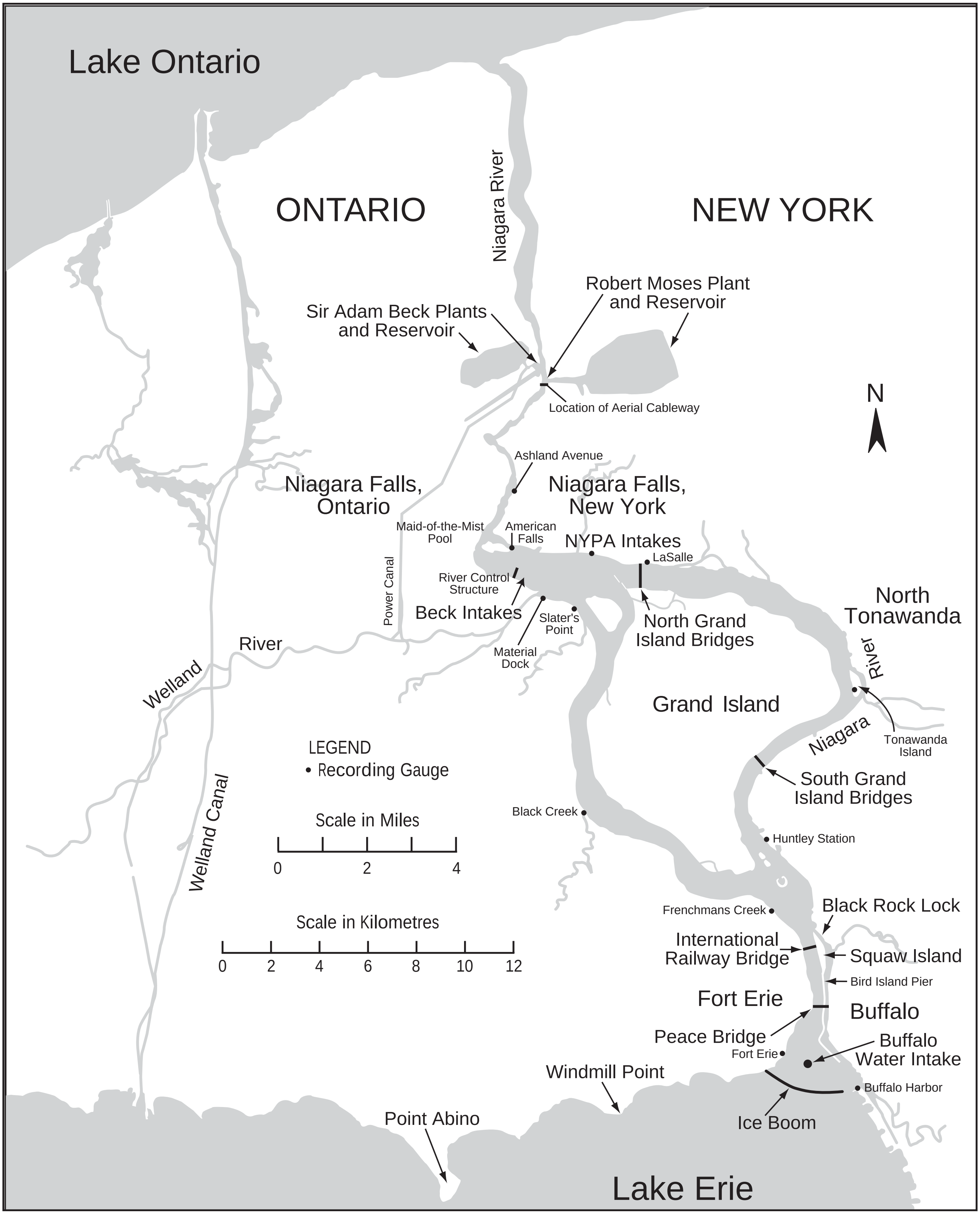


FIGURE 6