Report to
The International Niagara Board of Control
On the 2012-13 Operation of
The Lake Erie-Niagara River Ice Boom

By the International Niagara Working Committee

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Cover:
Photos of Ice Boom Installation
(USACE Photos)

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RELATED INTERNET SITES

International Joint Commission . . . . . www.ijc.org

New York Power Authority . . . . . www.iceboom.nypa.gov

International Niagara Board of Control . . . . . www.ijc.org/en_/inbc

COE, Buffalo District . . . . . www.lrb.usace.army.mil

COE, Detroit District . . . . . www.lre.usace.army.mil

Great Lakes Information Network . . . . . www.great-lakes.net

Environment Canada . . . . . www.ec.gc.ca/grandslacs-greatlakes/

1 . PURPOSE

The purpose of the ice boom is to reduce the amount of ice passing from Lake Erie to the Niagara River. Thereby preventing ice blockages from reducing power production. The ice boom also reduces ice damages to shoreline property.

2. HIGHLIGHTS

Western New York experienced a warm December and January. This winter was similar to the previous year, however, temperatures and snowfall returned to near average in February.

The Lake Erie water temperature, as measured at the Buffalo Water Intake, was 6°C (43°F) on 15 December 2012. As a result, installation of the Lake Erie - Niagara River ice boom's 22 spans started on 18 December 2012. It was completed by 20 December 2012.

A thin to medium ice cover formed behind the ice boom during the 2012-2013 ice season. The ice cover on Lake Erie peaked during the last week of February, covering nearly 78% of Lake Erie's surface area.

The ice boom experienced two span breaks during the season as a result of high winds and strong ice pressure.

Towards the end of the 2012-13 ice season, representatives of the International Niagara Working Committee (INWC) agreed that the ice formed in the eastern basin of Lake Erie was very thin and therefore unsafe for landing an aircraft. As a result, the INWC cancelled both helicopter flights that are typically carried out during the season to measure ice thickness. A fixed-wing aircraft flight was performed over Lake Erie during the morning of 25 March 2013 to determine the extent and condition of the ice cover.

Removal of the Lake Erie – Niagara River Ice Boom began during the afternoon on 25 March 2013 following the fixed-wing ice observation flight earlier that day. The final spans of the ice boom were removed and tied off to the Buffalo break wall on 28 March. Removal of the buoy barrels was delayed by unfavorable weather. However, the work was completed safely without incident on 8 and 9 April. 17 April 2013 marked the end of the 2012-13 ice-boom season when the final spans of the ice boom were brought to and pulled onto its Katherine Street (Buffalo, NY) storage site.

Data in this report are in metric units followed by the approximate customary units (in parentheses). The latter are provided for information purposes only.

3. HYDROMETEOROLOGICAL AND ICE CONDITIONS

During the 2012-13 winter, the INWC continued its program of collecting data and information related to ice boom operations. This data is used to monitor conditions regarding the ice boom and Lake Erie, as well as to determine the installation and removal dates of the ice boom. As part of the program, satellite imagery and mapping were analyzed and meteorological data from the U.S. National Weather Service Station at Buffalo were collected.

Air temperatures for the Niagara region in the month of December were well above average, making it the eighth warmest December on record. As a result, Lake Erie water temperatures hovered above freezing for the entire month. The region experienced erratic temperature swings in the month of January 2013 ranging from a low of -17°C (1°F) to a record high of 19°C (66°F). By the end of January, Lake Erie water temperatures dipped close to 0°C (32°F). Although typical winter conditions returned for the month of February, a thick ice cover did not form. With only 2.7 cm (1.06 in) of precipitation, March 2013 came in as the 2nd driest March on record and average temperatures were 0.6°C (1.1°F) below average. No major lake-effect snow events occurred near the City of Buffalo during the winter of 2012-13.

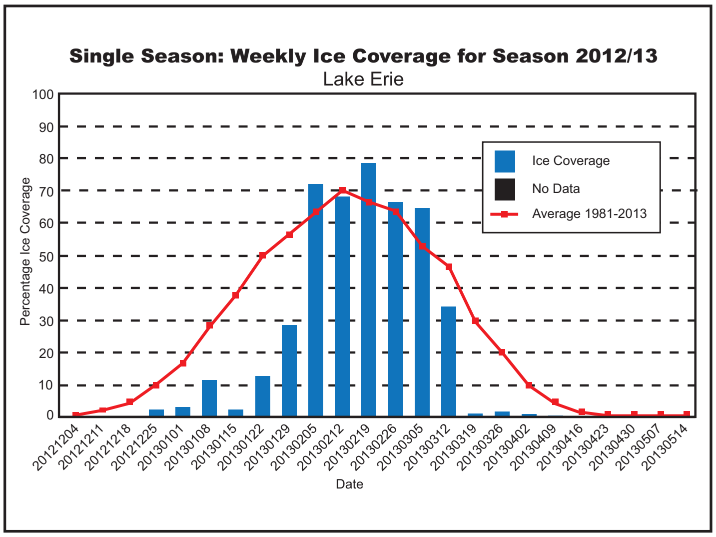
The average monthly air temperature data for November 2012 through April 2013, as measured by the National Weather Service at the Buffalo Niagara International Airport, are displayed in Table 1. The average temperature for the six-month period was 0.9°C (1.5°F) above the long-term average, while the season total for snowfall was 148.6 cm (58.5 in), and 84.3 cm (33.2 in) below the long-term average snowfall .

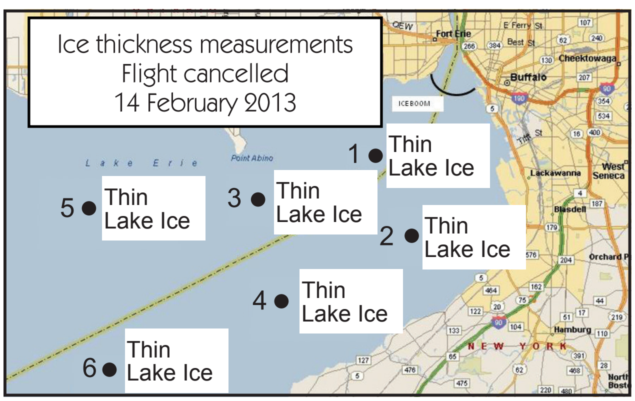
The daily Lake Erie water temperatures, as measured at the Buffalo Water Intake, for the period December 2012 through May 2013 are provided in Table 2. The Lake Erie water temperature fell to 0°C (32°F) in early February 2013 where it remained until the first week of April. However, the cold weather arrived too late in the winter to form a solid and stable ice cover over Lake Erie.

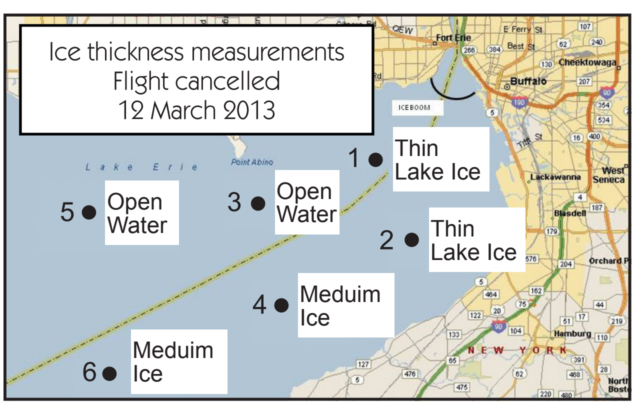
As shown in the Canadian Ice Service graph, ice cover on Lake Erie peaked by the end of the third week of February at about 78% coverage, as compared to the average of 67%. The extent of the coverage was reduced to nearly 3% by the end of the third week of March. Although the plot does not indicate ice thickness, the Canadian Ice Service reported that the ice thickness during the 2012-13 ice season was consistently thin to medium. Helicopter flights are typically carried out during early February and March to gather ice thickness data. However, representatives of INWC agreed that the thin ice would be unsafe for landing. Maps provided below show the extent of ice cover and the six standard measurement sites on 14 February and 12 March 2013. A single fixed-wing ice observation flight to determine the extent of ice cover over the eastern part of Lake Erie was performed during the morning of 25 March 2013. The flight showed less than 230 square kilometres (89 square miles) of ice coverage on the eastern end of the lake.

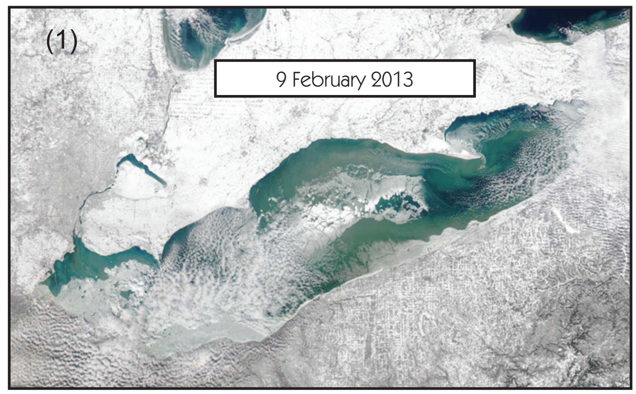
The following MODIS satellite images from the U.S. National Oceanic and Atmospheric Administration (NOAA) Coast Watch Great Lakes program show the eastern portion of Lake Erie on 9 February and 17 March 2013, respectively.

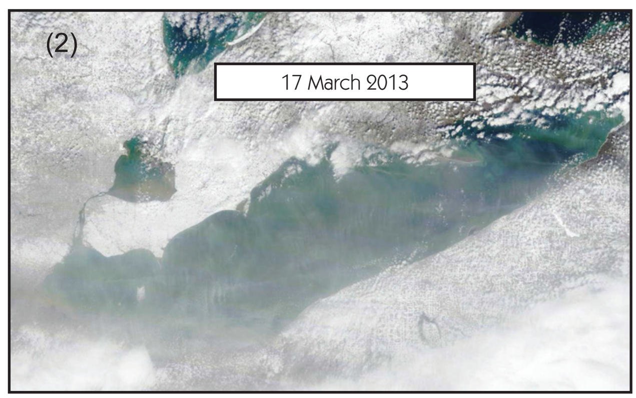
Based on satellite and available imagery and information provided by the Canadian Ice Service, the date of last ice was determined as 9 April 2013.











4. OPERATION OF THE ICE BOOM DURING THE 2012-13 ICE SEASON

4.1 Installation of the Ice Boom

A video system is used to monitor the ice boom. The Internet address for information on the ice boom as well as current images is:

www.iceboom.nypa.gov

Phase 1 of the ice boom installation began 27 November 2012. On that day, 10 junction plates were raised from the bottom of the lake and 10 buoy barrels were attached. Phase 1 of the installation of the ice boom was delayed on 28 and 29 November as a result of high winds and high waves. The remaining 13 junction plates and buoy barrels were installed on 30 November, completing Phase 1 of the ice boom installation. From 4 to 10 December 2012, boom spans were pulled from their storage area at 100 Katherine Street, Buffalo, NY, located on the shore of the Buffalo River about 3 kilometres (2 miles) upstream from Lake Erie, and were placed inside the Buffalo Harbor break wall, completing Phase 2 of the boom's installation.

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 will not begin before the Lake Erie water temperature reaches 4°C (39°F) or on 16 December, whichever occurs first. As noted above, Lake Erie's water temperature, as measured at the Buffalo Water Intake, was 6°C (43°F) on 14 December. Given the lake's water temperature and that 16 December was on a Sunday, installation of the ice boom was planned to begin on Monday, 17 December. However, unfavorable weather conditions on 17 December did not allow ice boom installation to begin. A break in the weather allowed for installation to begin on 18 December. Starting from the Canadian side, 6 spans of the boom (V through Q) were installed on 18 December. Ten (10) additional spans (P through G) were installed on 19 December. Phase 3 of the ice boom was complete on 20 December when the remaining 6 spans (F through A) were placed out on the lake.

Table 4 provides the dates from 1964 to the present year when the Lake Erie water temperature as measured at the Buffalo Water Intake reached 4°C (39°F) and the dates of ice boom installation. As indicated in both Tables 2 and 4, the Lake Erie water temperature reached 4°C (39°F) on 28 December 2012.

4.2 Ice Boom Operation

An ice sheet formed behind the ice boom for a significant portion of the ice season. On 12 February 2013, span F was observed to be trailing in images provided by the ice boom camera mounted atop the First Niagara tower in Buffalo. The breakage occurred as a result of a combination of strong winds and strong ice pressure. The broken span was repaired by NYPA's ice boom crew on 13 February 2013. Based on images provided by the ice boom camera on 15 February 2013, it appeared to New York Power Authority (NYPA) staff that several spans were broken. An inspection performed by the ice boom crew revealed that spans A and B were facing upstream as a result of stream flow direction changes near the inner break wall, which is typical at times with changing wind direction. The only single open and trailing span encountered was span D. The ice boom crew was able to repair span D by performing a splice repair the same day.

4.3 Ice Boom Opening

The fixed-wing observation flight performed during the morning of on 25 March 2013 revealed less than 230 square kilometres (89 square miles) of ice remained on the eastern part of Lake Erie, and a limited amount of ice buildup in the Maid-of-the Mist Pool below Niagara Falls. Given the limited ice cover, and the limited potential for significant ice to form in either location, preparations for the removal of the ice boom began immediately after the fixed wing flight. Comparison of ice areas near the time of ice boom opening since 1970 are shown in Table 5.

With favourable weather conditions, removal of the Ice boom began on 25 March 2013 with 6 spans removed from the Canadian side and tied against the break wall. The ice boom crew continued Phase 1 of the removal process on 26 March 2013, and removed 4 spans, (A through D from between the break walls along the American side), 2 spans (O and P from the Canadian side), and opened span N leaving it trailing. During the night of 26 March, two pontoons were stripped off span N during ice flow past the boom. NYPA recovered one pontoon the following day. The second pontoon had not been recovered at the time of this report. Only two spans were removed on 27 March and one was left trailing, due to difficulties encountered with the ice field exerting tension on the spans. The final 6 spans were removed and tied off to the break wall on 28 March, completing Phase 1 of the removal process.

Weather was not favourable for the ice boom crew to safely retrieve buoy barrels at the beginning of Phase 2 of the removal process. For many days, high west winds and continual ice accumulation persisted at the east section of the Buffalo harbour. Finally, with favourable weather conditions, 12 out of 23 buoy barrels were removed from the Canadian side on 8 April 2013. Phase 2 of the ice boom removal process was completed on 9 April 2013 when the remaining 11 junction plate buoy barrels were removed.

Phase 3, the final phase, of the ice boom removal process began on 10 April 2013 when ice boom crews began towing the 152-metre (500-ft) long ice boom spans to the Katherine Street storage site where they were pulled onto shore. Four (4) spans were towed and pulled onto shore on 10 April. Four (4) spans were towed and pulled onto shore on 11 April for a total of eight (8) spans. Three (3) spans were towed from the inner break wall to the ice boom storage facility on 12 April 2013. Another five (5) spans were pulled to shore on 15 April. 17 April 2013 marked the end of another ice-boom season when the final six (6) spans were pulled onto the Katherine Street storage site in Buffalo NY.

4.4 Ice Boom Maintenance

As part of a routine summer maintenance program, hardware will be replaced where necessary.

5. POWER LOSSES, FLOODING, AND NAVIGATION DURING THE 2012-13 ICE SEASON

5.1 Estimated Power Losses

The ice boom expedites the formation of the natural ice arch near the outlet of Lake Erie into the Niagara River and helps to sustain it through the winter. This aids the Power Entities (Ontario Power Generation and the New York Power Authority) by reducing the amount of ice flow into the river, minimizing power losses at the intakes in the Chippawa-Grass Island Pool. However, even with the installation of the ice boom, some reduction in hydropower generation can be expected virtually every year due to ice conditions when ice passes overtop of the ice boom or when ice floes are generated in the river itself. The Power Entities estimate that the use of the ice boom results in the benefit of an average annual savings to the hydropower facilities of approximately 414,000 Megawatt Hours (MWh) of electric energy.

The power entities experienced a 33,600 (MWh) loss of hydroelectric power generation due to ice during the 2012-13 ice seasons. A summary of estimated loss of energy due to ice for the period of record 1974-75 to present is shown in Table 6.

5.2 Niagara River Shore Flooding and Property Damages

NYPA's Flood Warning Notification Plan in the Event of Ice-Affected Flooding on the Upper Niagara River was tested on 18 December 2012. A drill was conducted that simulated a flood event along the U.S. shoreline in the vicinity of the North Grand Island Bridge, which was triggered by an ice jam upstream of the NYPA intakes. No ice-affected flood watch or flood warning alerts were issued under the flood warning notification plan during the 2012-13 ice season.

There were no reports of damages to shore properties due to ice or flooding along the Niagara River during the 2012-2013 ice season.

5.3 Navigation at the Welland Canal.

The Welland Canal opened to commercial shipping this season 22 March 2013 for its 184th consecutive year of service with the passage of the Great Lakes shipping freighter Cuyahoga. A comparison of the dates of boom opening and the commencement date of navigation at the Welland Canal for the period 1965 to 2013 is shown in Table 7.

6. FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Findings and Conclusions

During the winter of 2012-13, Eastern Lake Erie experienced a continual variation of temperatures ranging from average to well above average. The ice that formed behind the ice boom was classified by the Canadian Ice Service as thin to medium throughout the 2012-2013 ice season.

The ice boom experienced two breakages during the 2012-13 ice season due to high winds and high ice pressure. In both cases, splice repairs were required.

The use of satellite images and one fixed-wing aerial ice survey was adequate during the winter of 2012-13 to make decisions on the operation and removal of the ice boom as a result of very thin ice coverage in Eastern Lake Erie. However, during more typical ice seasons, helicopter flights to estimate ice thicknesses should still be conducted by members and associates of the INWC as appropriate to supplement the ice information available from remote sensing technology.

6.2 Recommendations for the 2013-14 Operation

The International Niagara Board of Control and the INWC should continue to monitor and assess the performance of the ice boom.

The Power Entities should ensure they have adequate materials to repair multiple breakages if they occur.

Utilization of Great Lakes ice cover maps prepared by the Canadian Ice Centre in Ottawa, ON and the United States National Ice Center in Suitland, MD, supplemented by ice thickness measurements and fixed-wing aerial ice surveys should continue to be used, as required, to evaluate ice conditions throughout the winter.

The INWC should continue to store ice area maps produced from aerial ice reconnaissance flight data or composite ice maps. The computer generated maps are maintained in a storage and retrieval database structure for future use of the data.

The INWC should continue to liaise with both the United States and Canadian Coast Guards regarding ice boom installation and removal operations.

Table 1 Air Temperature at Buffalo Niagara International Airport						
	°C (Celsius)			°F (Fahrenheit)		
Month	Average* 1981-2010	Recorded 2012-13	Departure	Average* 1981-2010	Recorded 2012-13	Departure
Nov. 2012	4.8	4.1	-0.7	40.7	39.3	-1.4
Dec. 2012	-1.1	2.4	3.5	30.1	36.3	6.2
Jan. 2013	-3.9	-1.1	2.8	24.9	30.0	5.1
Feb. 2013	-3.2	-3.3	-0.1	26.3	26.0	-0.3
Mar. 2013	1.1	0.5	-0.6	34.0	32.9	-1.1
Apr. 2013	7.7	7.9	0.2	45.9	46.3	0.4
Average	0.9	1.8	0.9	33.7	35.1	1.5

* Official U.S. National Weather Service averages are based on 30 years of record, 1981-2010.

Table 2 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (Dec 2012-May 2013)												
Month	**December**		**January**		**February**		**March**		**April**		**May**	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	6.7	44	3.3	38	0.6	33	0.0	32	0.0	32	6.7	44
2	6.7	44	2.8	37	0.0	32	0.0	32	0.0	32	7.2	45
3	6.7	44	3.3	38	0.0	32	0.0	32	0.6	33	7.8	46
4	6.7	44	1.7	35	0.0	32	0.0	32	0.6	33	7.8	46
5	6.7	44	1.1	34	0.0	32	0.0	32	1.1	34	7.8	46
6	6.7	44	2.2	36	0.0	32	0.0	32	1.7	35	7.2	45
7	6.1	43	2.2	36	0.0	32	0.0	32	1.7	35	7.8	46
8	6.1	43	2.2	36	0.0	32	0.0	32	2.2	36	8.9	48
9	6.1	43	1.7	35	0.0	32	0.0	32	2.2	36	6.1	43
10	6.1	43	1.7	35	0.0	32	0.0	32	2.2	36	10.0	50
11	6.1	43	2.2	36	0.0	32	0.0	32	2.8	37	10.0	50
12	6.1	43	2.8	37	0.0	32	0.0	32	2.2	36	10.6	51
13	5.6	42	2.8	37	0.0	32	0.0	32	3.3	38	10.0	50
14	6.1	43	2.8	37	0.0	32	0.0	32	3.3	38	9.4	49
15	6.1	43	2.2	36	0.0	32	0.0	32	3.3	38	10.0	50
16	6.1	43	2.2	36	0.0	32	0.0	32	3.9	39	10.0	50
17	6.7	44	2.2	36	0.0	32	0.0	32	3.9	39	10.0	50
18	6.7	44	2.2	36	0.0	32	0.0	32	3.9	39	10.6	51
19	6.1	43	2.8	37	0.0	32	0.0	32	4.4	40	11.1	52
20	6.1	43	2.2	36	0.0	32	0.0	32	4.4	40	11.1	52
21	6.1	43	2.2	36	0.0	32	0.0	32	6.1	43	12.8	55
22	5.6	42	1.7	35	0.0	32	0.0	32	4.4	40	13.9	57
23	5.0	41	0.6	33	0.0	32	0.0	32	4.4	40	13.3	56
24	5.6	42	0.6	33	0.0	32	0.0	32	5.0	41	13.3	56
25	5.0	41	0.6	33	0.0	32	0.0	32	5.0	41	10.0	50
26	5.6	42	0.6	33	0.0	32	0.0	32	5.6	42	9.4	49
27	4.4	40	0.6	33	0.0	32	0.0	32	6.1	43	11.1	52
28	3.9	39	0.6	33	0.0	32	0.0	32	6.1	43	12.8	55
29	3.3	38	0.6	33			0.0	32	6.1	43	13.3	56
30	3.3	38	0.6	33			0.0	32	6.7	44	14.4	58
31	3.3	38	0.6	33			0.0	32			14.4	58
Avg	5.7	42	1.8	35	0.0	32	0.0	32	3.4	38	10.3	51
Hi:	6.7	44	3.3	38	0.6	33	0.0	32	6.7	44	14.4	58
Low:	3.3	38	0.6	33	0.0	32	0.0	32	0.0	32	6.1	43

Water temperatures at Buffalo are reported in Fahrenheit. The Celsius values provided are based on the equivalent values in Fahrenheit converted to Celsius and given to the nearest tenth of a degree.

Table 3 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-Apr	1978	14-May
1906	22-Apr	1942	30-Apr	1979	3-May
1907	30-Apr	1943	20-May	1980	23-Apr
1908	9-May	1944	15-Apr		
1909	26-Apr	1945	9-Apr	1981	30-Apr
1910	30-Apr	1946	No data	1982	20-May
		1947	No data	1983	23-Feb
1911	6-May	1948	No data	1984	25-Apr
1912	29-Apr	1949	No data	1985	1-May
1913	30-Apr	1950	No data	1986	26-Apr
1914	28-Apr			1987	9-Mar
1915	2-May	1951	15-Apr	1988	27-Apr
1916	11-May	1952	27-Mar	1989	9-Apr
1917	30-Apr	1953	Ice-free	1990	10-Apr
1918	20-Apr	1954	27-Mar		
1919	15-Mar	1955	5-Apr	1991	28-Mar
1920	20-May	1956	20-Apr	1992	15-Apr
		1957	11-Mar	1993	16-Apr
1921	14-Mar	1958	10-Apr	1994	1-May
1922	11-Apr	1959	8-May	1995	18-Apr
1923	16-May	1960	5-May	1996	6-May
1924	20-Apr			1997	29-Apr
1925	26-Apr	1961	15-Apr	1998	Ice-free
1926	31-May	1962	30-Apr	1999	2-Apr
1927	9-Apr	1963	11-May	2000	28-Mar
1928	19-May	1964	27-Apr		
1929	2-May	1965*	14-May	2001	27-Apr
1930	7-May	1966	27-Apr	2002	Ice-free
		1967	13-Apr	2003	22-Apr
1931	7-Apr	1968	4-May	2004	30-Apr
1932	21-Apr	1969	26-Apr	2005	11-Apr
1933	23-Apr	1970	30-Apr	2006	5-Apr
1934	23-Apr			2007	29-Apr
1935	13-Apr	1971	31-May	2008	23-Apr
1936	31-May	1972	5-May	2009	16-Apr
1937	14-Apr	1973	15-Mar		
1938	14-Apr	1974	6-Apr	2010	29-Mar
1939	14-May	1975	8-Apr	2011	24-Apr
1940	19-May	1976	19-Apr	2012	Ice-Free
		1977	13-May	2013	9-April

1965 First year ice boom was used

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

Decade	Date Water Temperature Reached 4°C (39°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 Dec 1976	30 Nov to 18 Dec 1976
	8 Dec 1977	13 Dec to 31 Dec 1977
	11 Dec 1978	Completed 19 Dec 1978*
	17 Nov 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 Dec 1982	6 Jan to 8 Jan 1983
	18 Nov 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 Nov 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 Jan to 14 Jan 1993
	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 Jan 1997	17 Dec to 18 Dec 1997
	1 Dec 1999	2 Jan to 9 Jan 1999
	27 Nov 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
	15 Dec 2003	16 Dec to 20 Dec 2003
	20 Dec 2004	17 Dec to 20 Dec 2004
	9 Dec 2005	14 Dec to 15 Dec 2005
	19 Jan 2007	18 Dec to 19 Dec 2006
	9 Dec 2007	13 Dec to 17 Dec 2007
	5 Dec 2008	10 Dec to 11 Dec 2008
	12 Dec 2009	17 Dec to 19 Dec 2009
2010's	8 Dec 2010	12 Dec to 16 Dec 2010
	28 Dec 2011	17 Dec to 18 Dec 2011
	28 Dec 2012	18 Dec to 20 Dec 2012

* 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 5 Comparison of Ice Areas Near Time of Ice Boom Opening

	Areas of Ice in Eastern Lake Erie			Opening of Ice Boom	
Year	Date of Obser-vation	Square KMs	Square Miles	Start	Com-pleted
1965				21-Mar	27-Mar
1966				20-Mar	1-Apr
1967				22-Mar	29-Mar
1968				8-Mar	20-Mar
1969	No Data Collected			26-Mar	3-Apr
1970	16-Apr	2590	1000	23-Apr	30-Apr
1971	27-Apr	2850	1100	3-May	14-May
1972	18-Apr	1300	500	20-Apr	25-Apr
1973	14-Mar	260	100	16-Mar	21-Mar
1974	18-Mar	320	125	26-Mar	1-Apr
1975	21-Mar	80	30	25-Mar	28-Mar
1976	15-Apr	130	50	19-Apr	21-Apr
1977	14-Apr	520	200	18-Apr	20-Apr
1978	27-Apr	710	275	1-May	8-May
1979	10-Apr	390	150	13-Apr	17-Apr
1980	1-Apr	700	270	2-Apr	7-Apr
1981	15-Apr	1220	470	18-Apr	22-Apr
1982	26-Apr	1090	420	27-Apr	2-May
1983	2-Mar	Trace	Trace	7-Mar	8-Mar
1984	5-Apr	780	300	7-Apr	10-Apr
1985	12-Apr	780	300	13-Apr	15-Apr
1986	7-Apr	1010	390	12-Apr	14-Apr
1987	5-Mar	130	50	6-Mar	6-Mar
1988	8-Apr	700	270	9-Apr	10-Apr
1989	27-Mar	340	130	30-Mar	6-Apr
1990	26-Mar	230	90	26-Mar	30-Mar
1991	25-Mar	50	20	27-Mar	30-Mar
1992	31-Mar	160	60	30-Mar	2-Apr
1993	3-Apr	540	210	5-Apr	6-Apr
1994	19-Apr	620	240	21-Apr	28-Apr
1995	28-Mar	410	160	30-Mar	17-Apr
1996	17-Apr	730	280	19-Apr	3-May
1997	24-Apr	60	25	25-Apr	28-Apr
1998	Ice-free			5-Mar	5-Mar
1999	30-Mar	Trace	Trace	30-Mar	30-Mar
2000	21-Mar	410	160	23-Mar	24-Mar
2001	14-Apr	390	150	17-Apr	20-Apr
2002	Ice-free			7-Mar	7-Mar
2003	10-Apr	490	190	10-Apr	11-Apr
2004	5-Apr	1110	430	6-Apr	7-Apr
2005	4-Apr	210	80	5-Apr	6-Apr
2006	20-Mar	80	30	20-Mar	21-Mar
2007	7-Apr	620	240	10-Apr	18-Apr
2008	14-Apr	310	120	15-Apr	19-Apr
2009	6-Apr	100	40	6-Apr	13-Apr
2010	18-Mar	570	220	22-Mar	24-Mar
2011	11- Apr	230	90	12-Apr	22-Apr
2012	Ice-free			28-Feb	2-Mar
2013	25-Mar	228	88	25-Mar	28-Mar

Table 6 Estimated Power Losses Due to Ice for Period of Record 1975 to Present

Winter Season of:	December	January	February	March	April	May	Totals
1974-75	*	*	150,000	15,100	*	*	165,100
1975-76	*	78,700	36,500	45,800	32,000	*	193,000
1976-77	*	54,000	23,500	0	0	0	77,500
1977-78	*	88,000	600	600	0	0	89,200
1978-79	*	30,000	3,700	0	1,600	0	35,300
1979-80	*	6,000	30,000	13,000	10,500	0	59,500
1980-81	14,000	9,000	3,900	1,100	4,100	0	32,100
1981-82	*	58,000	27,000	10,000	13,000	5,000	113,000
1982-83	0	0	0	0	0	0	0
1983-84	53,000	57,000	4,000	25,000	0	0	139,000
1984-85	0	65,000	25,000	11,000	29,000	0	130,000
1985-86	10,000	65,000	8,000	5,000	6,000	0	94,000
1986-87	0	28,000	32,000	4,000	0	0	64,000
1987-88	0	13,000	24,000	0	4,000	0	41,000
1988-89	0	0	30,000	1,000	2,000	0	33,000
1989-90	6,000	7,000	5,000	5,000	0	0	23,000
1990-91	0	14,000	11,000	6,000	0	0	31,000
1991-92	0	21,000	3,000	14,000	0	0	38,000
1992-93	0	0	2,000	2,000	0	0	4,000
1993-94	0	11,000	12,000	0	1,000	0	24,000
1994-95	0	0	11,000	2,000	7,000	0	20,000
1995-96	0	45,000	4,000	13,000	0	0	62,000
1996-97	0	80,000	4,000	3,000	16,000	0	103,000
1997-98	0	0	0	0	0	0	0
1998-99	0	17,000	700	0	0	0	17,700
1999-2000	0	0	1,200	0	0	0	1,200
2000-01	700	3,600	500	100	0	0	4,900
2001-02	0	0	0	0	0	0	0
2002-03	0	35,000	11,500	1,500	0	0	48,000
2003-04	0	26,000	5,800	0	0	0	32,000
2004-05	0	7,000	13,100	8,500	0	0	28,600
2005-06	0	0	14,300	18,600	0	0	32,900
2006-07	0	2,500	37,600	3,800	7,800	0	51,700
2007-08	0	15,000	153,900	1,300	500	0	171,200
2008-09	0	4,700	17,600	0	2,400	0	24,700
2009-10	0	36,700	3,000	0	0	0	39,700
2010-11	0	8,400	5,800	0	15,300	0	29,500
2011-12	0	0	0	0	0	0	0
2012-13	0	0	2,900	21,600	9,100	0	33,600

* No Data Published

Note: No data available for period 1964-74

Table 7 Comparative Data for Years Ice Boom Has Been in Place

	Opening of Ice Boom				Opening of Ice Boom		
Year	Start*	Completed	Welland**	Year	Start*	Completed	Welland**
1965	21-Mar	27-Mar	1-Apr	2000	23-Mar	24-Mar	28-Mar
1966	20-Mar	1-Apr	4-Apr	2001	17-Apr	20-Apr	30-Mar
1967	22-Mar	29-Mar	1-Apr	2002	7-Mar	7-Mar	26-Mar
1968	18-Mar	20-Mar	1-Apr	2003	10-Apr	11-Apr	26-Mar
1969	26-Mar	3-Apr	1-Apr	2004	6-Apr	7-Apr	23-Mar
1970	23-Apr	30-Apr	1-Apr	2005	5-Apr	6-Apr	23-Mar
1971	3-May	14-May	29-Mar	2006	20-Mar	21-Mar	21-Mar
1972	20-Apr	25-Apr	29-Mar	2007	10-Apr	18-Apr	20-Mar
1973	16-Mar	21-Mar	28-Mar	2008	15-Apr	19-Apr	20-Mar
1974	26-Mar	1-Apr	29-Mar	2009	6-Apr	13-Apr	31-Mar
1975	25-Mar	28-Mar	25-Mar	2010	22-Mar	24-Mar	25-Mar
1976	19-Apr	19-Apr	1-Apr	2011	12-Apr	22-Apr	22-Mar
1977	18-Apr	20-Apr	4-Apr	2012	28-Feb	2-Mar	22-Mar
1978	1-May	8-May	28-Mar	2013	25-Mar	28-Mar	22-Mar
1979	13-Apr	17-Apr	28-Mar				
1980	2-Apr	7-Apr	24-Mar				
1981	18-Apr	22-Apr	25-Mar				
1982	27-Apr	2-May	5-Apr				
1983	7-Mar	8-Mar	5-Apr				
1984	7-Apr	10-Apr	28-Mar				
1985	13-Apr	15-Apr	1-Apr				
1986	12-Apr	14-Apr	3-Apr				
1987	6-Mar	6-Mar	1-Apr				
1988	9-Apr	10-Apr	31-Mar				
1989	30-Mar	6-Apr	31-Mar				
1990	26-Mar	30-Mar	28-Mar				
1991	27-Mar	30-Mar	26-Mar				
1992	30-Mar	2-Apr	30-Mar				
1993	5-Apr	6-Apr	30-Mar				
1994	21-Apr	28-Apr	5-Apr				
1995	30-Mar	17-Apr	24-Mar				
1996	19-Apr	3-May	29-Mar				
1997	25-Apr	28-Apr	2-Apr				
1998	5-Mar	5-Mar	24-Mar				
1999	30-Mar	30-Mar	31-Mar				
1965-2013	3-Apr	8-Apr	29-Mar	Average for post-ice boom period			
1970-2013	4-Apr	9-Apr	28-Mar	Average for the flexible boom opening period.			

1970 Commencement of flexible date for boom opening.

* Denotes opening of first boom span. Mobilization time precedes this date.

** Opening date is usually established in advance and may relate to Welland Canal repair schedule.

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 (Figure 1). The elevation difference between the two lakes is about 99 metres (326 feet), of which about half of this occurs at Niagara Falls. Over the period 1860-2012, the average Niagara River flow at Queenston, Ontario has been 5,859 cubic metres per second (m^3/s) (206,910 cubic feet per second (cfs)). The Welland Canal carries a small portion of the Lake Erie outflow. The total Great Lakes drainage basin upstream of the Niagara River is approximately 684,000 square kilometres (264,000 km^2). Figure 2 shows a detailed map of the Niagara region.

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 2,740 metres (9,000 feet) at its funnel-shaped entrance to 460 metres (1,500 feet) at Squaw Island below the Peace Bridge. The 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 ranging from 1.2 to 1.5 m/s (4 to 5 ft/s).

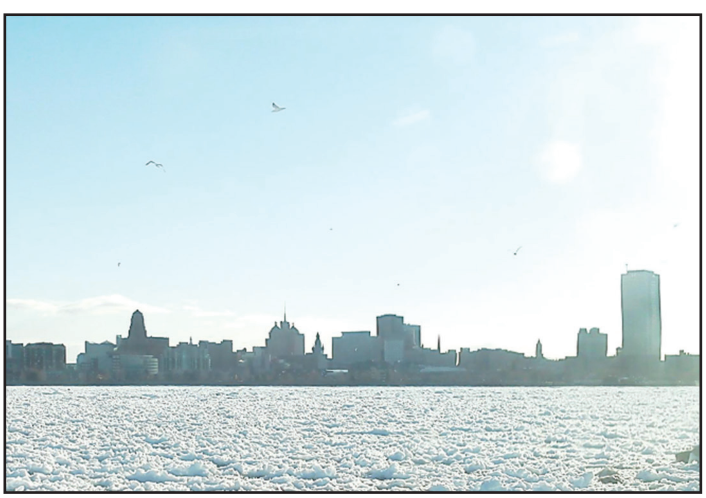
At Grand Island, the river divides into the west channel known as the Canadian or Chippawa Channel and the east channel known as the American or Tonawanda Channel. The Chippawa Channel is approximately 17.7 kilometres (11 miles) in length and varies from 610 to 1,220 metres (2,000 to 4,000 feet) in width. 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 1,220 metres (1,500 to 4,000 feet) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 ft/s). North of Grand Island, the channels unite to form the 4.8 kilometre (3 mile) long Chippawa-Grass Island Pool (Pool). At the downstream end of the Pool is the International Niagara Control Works. This gate control structure extends from the Canadian shoreline about halfway across the width of the river. The Niagara Falls are located about 1,370 metres (4,500 feet) downstream of the structure. The average fall from Lake Erie to the Pool is 2.7 metres (9 feet).

(b) Niagara Cascades and Falls

Below the gate 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 (Figure 3). The Canadian or Horseshoe Falls is so named because the crest is horseshoe shaped. During the non-tourist hours, the minimum Falls flow is 1,416 m^3/s) (50,000 cfs). This produces a fall of about 57 metres (188 feet). Minimum Falls flow for tourist hours is 2,832 m^3/s) (100,000 cfs), which results in a fall of about 54 metres (177 feet). These minimum flow 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 100 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 extends 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, 365 metres (1,200 feet) wide and 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 Lake Erie outflow is utilized for power production and is diverted to hydroelectric plants by intake structures located above the Falls (Figure 3). 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. Figure 3 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 no less than 2,832 m^3/s) (100,000 cfs) during the daylight hours of the tourist season. The tourist season is from 08:00 to 22:00 hours local time from 1 April to 15 September. From 16 September to 31 October, the hours are 08:00 to 20:00 local time. At all other times, the flow must be not less than 1,416 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. River levels are monitored using water level gauges located along the Niagara River. Gauge locations are referenced on the map in Figure 2.

Remedial works were constructed by the Power Entities in the 1950's, with the approval of the International Joint Commission, to maintain the Falls flow 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 the International Niagara Control Works (INCW) structure extending about 0.8 kilometres (0.5 miles) into the river from the Canadian shore at the downstream end of the Chippawa-Grass Island Pool. The INCW has 13 gates that were completed in 1957 and 5 additional gates which were completed in 1963. The 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 Niagara Board of Control. It also functions to adjust Falls flow promptly from 2,832 m^3/s) (100,000 cfs) to 1,416 m^3/s) (50,000 cfs) and viceversa during the tourist season. The operation of the INCW 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 then. 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 rehabilitated a portion of the Bird Island Pier in 1985 and 1986. Prior to rebuilding, most of the pier was overtopped by water passing from the Canal into the Niagara River at times of storm 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 close to 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. 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 tour boat company facilities located downstream of the Falls. In the past, heavy ice runs in the upper river, combined with a large volume of ice already in the Maid-of-the-Mist Pool, have occasionally damaged these facilities.

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 2009. A 1999 review resulted in the Commission issuing a Supplementary Order which modified condition (d). A 1984 Order of Approval established the current conditions for ice boom opening modifying condition (e). 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 16 December 2013 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 650 square kilometres (250 square miles) 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 withstanding any other provision 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 also stabilizes the arch once it has formed. A map of eastern Lake Erie indicating the location of the ice boom is shown in Figure 4. 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 blockage 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, the ice boom bears the pressure of upstream ice. Seasonal 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 again restrains the ice. Throughout 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 2,700 metre (8,800 feet) 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. Spans are anchored to the lake bed at 122 metre (400 foot) intervals by 6.4 centimetre (2.5 inch) diameter steel cables. Figure 5 illustrates structural details and a plan view of the ice boom. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 centimetre (30 inch) diameter, 9 metre (30 feet) long steel pontoons. This replacement 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 1997-98 ice season.

Based on experience gained during the 1997-98 ice season, it was recommended that 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 the spans A through J be removed. Therefore, beginning with the 1998-99 ice season, spans A through J contain 10 instead of 11 steel pontoons. This modification greatly reduced damage to the pontoons in this reach.

To further reduce the pontoon end cap damage and reduce the fatigue of the span cables between the inner and outer break walls (i.e. Spans A through D), the number and length of pontoons were changed to sixteen 4.6 metre (15 feet) long mini pontoons per 152-metre (500-foot) span, during the 2000-01 ice season.

As per maintenance protocol, and to further reduce damage to the ends of the pontoons, sections K-P were reduced from 11 to 10 pontoons per sections at the start of the 2001-02 ice season. Remaining sections Q-V were reconfigured to 10 pontoons per span at the beginning of the 2002-03 ice season.

Figure 6 shows the plan view of the ice boom on Lake Erie. Figure 7 shows the span configuration using the typical 9-metre (30 foot) pontoon and the 4.6-metre (15-foot) mini pontoons.

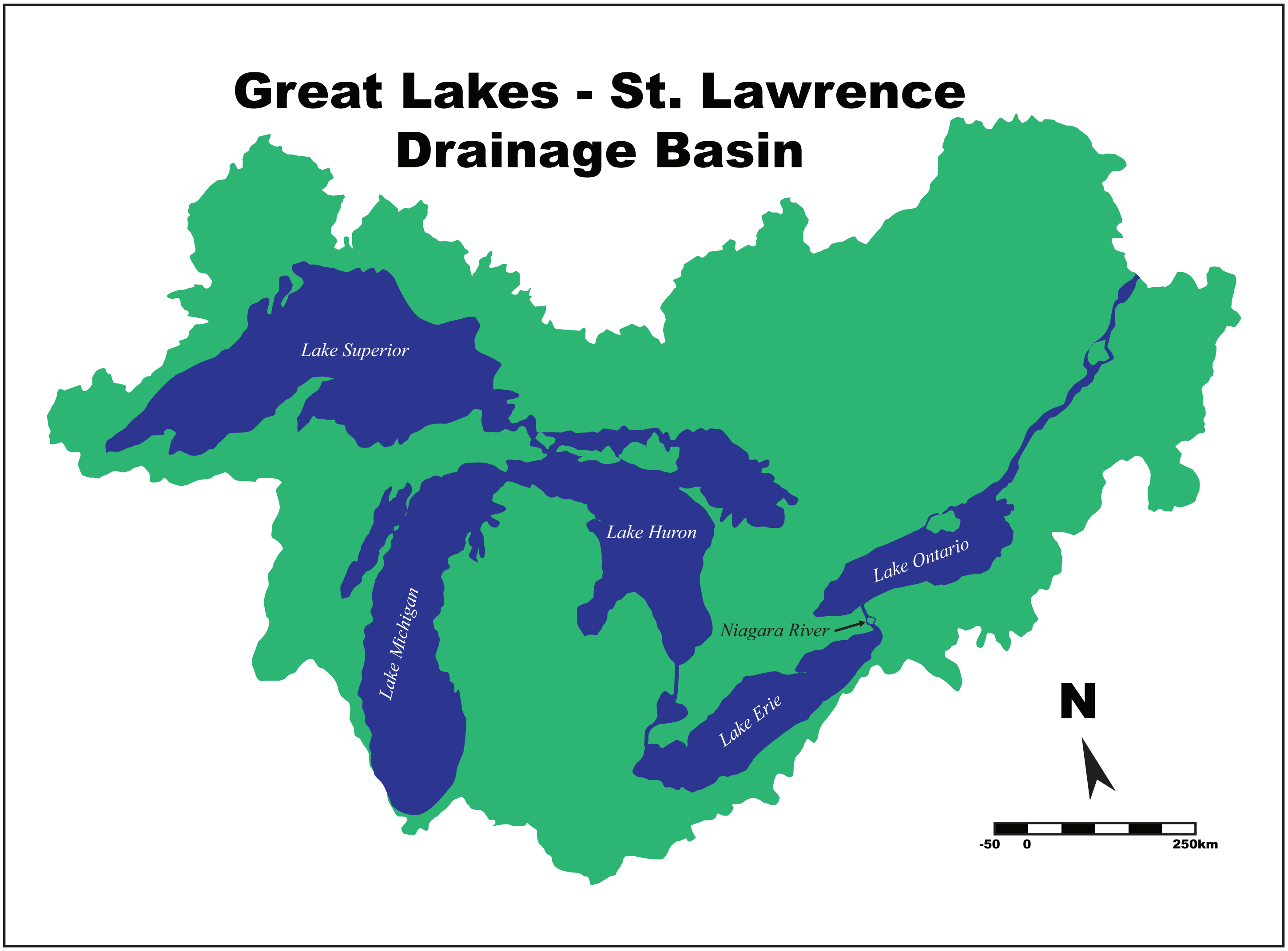

Great Lakes - St. Lawrence
Drainage Basin
Lake Superior
Lake Huron
Lake Michigan
Lake Ontario
Niagara River
Lake Erie
N
-50
0
250km

Figure 1

Map of Niagara River Showing Water Level Gauge Locations

Figure 2

Niagara River Diversion Structures and Power Plants

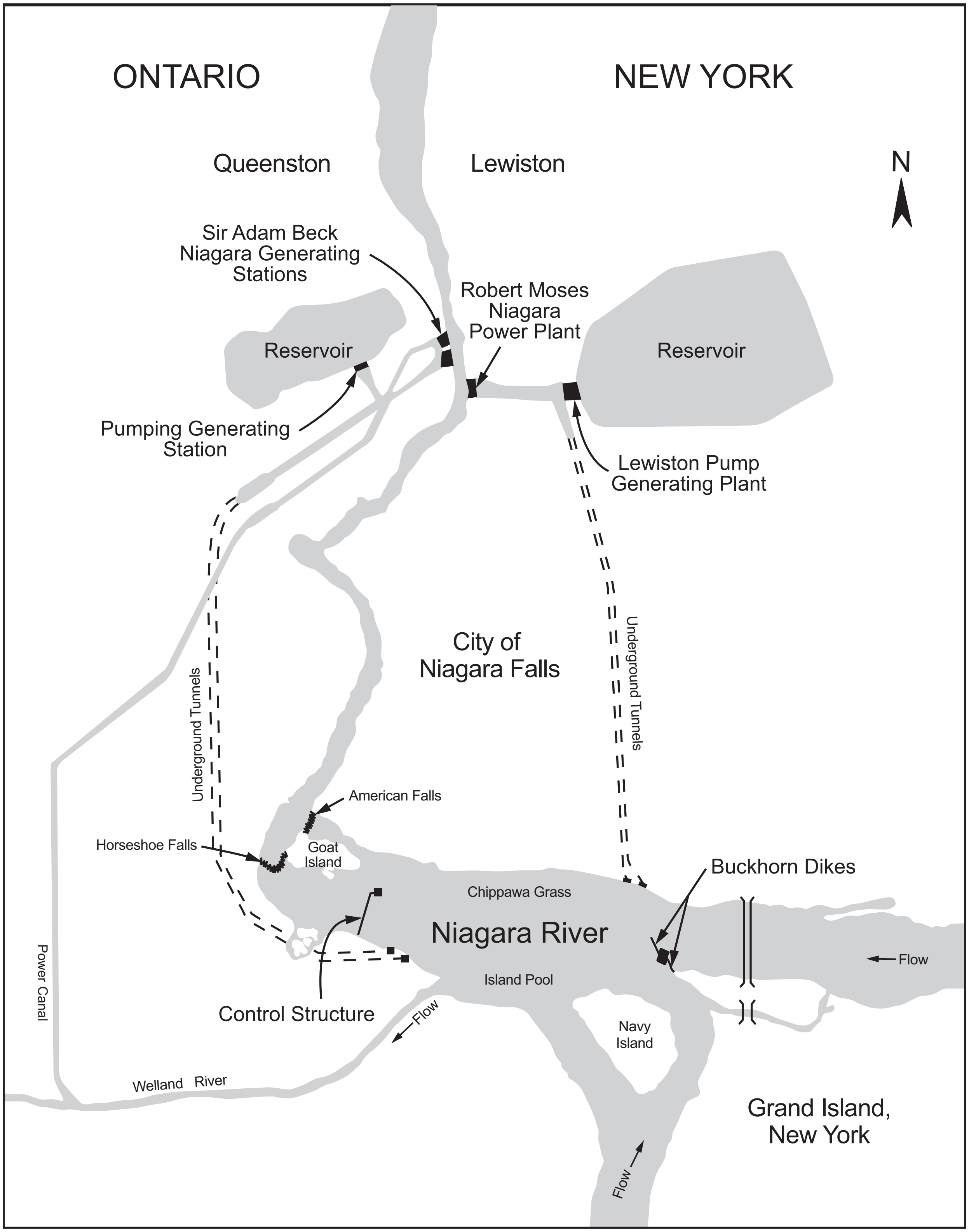


Figure 3

Structural Details of the Ice Boom

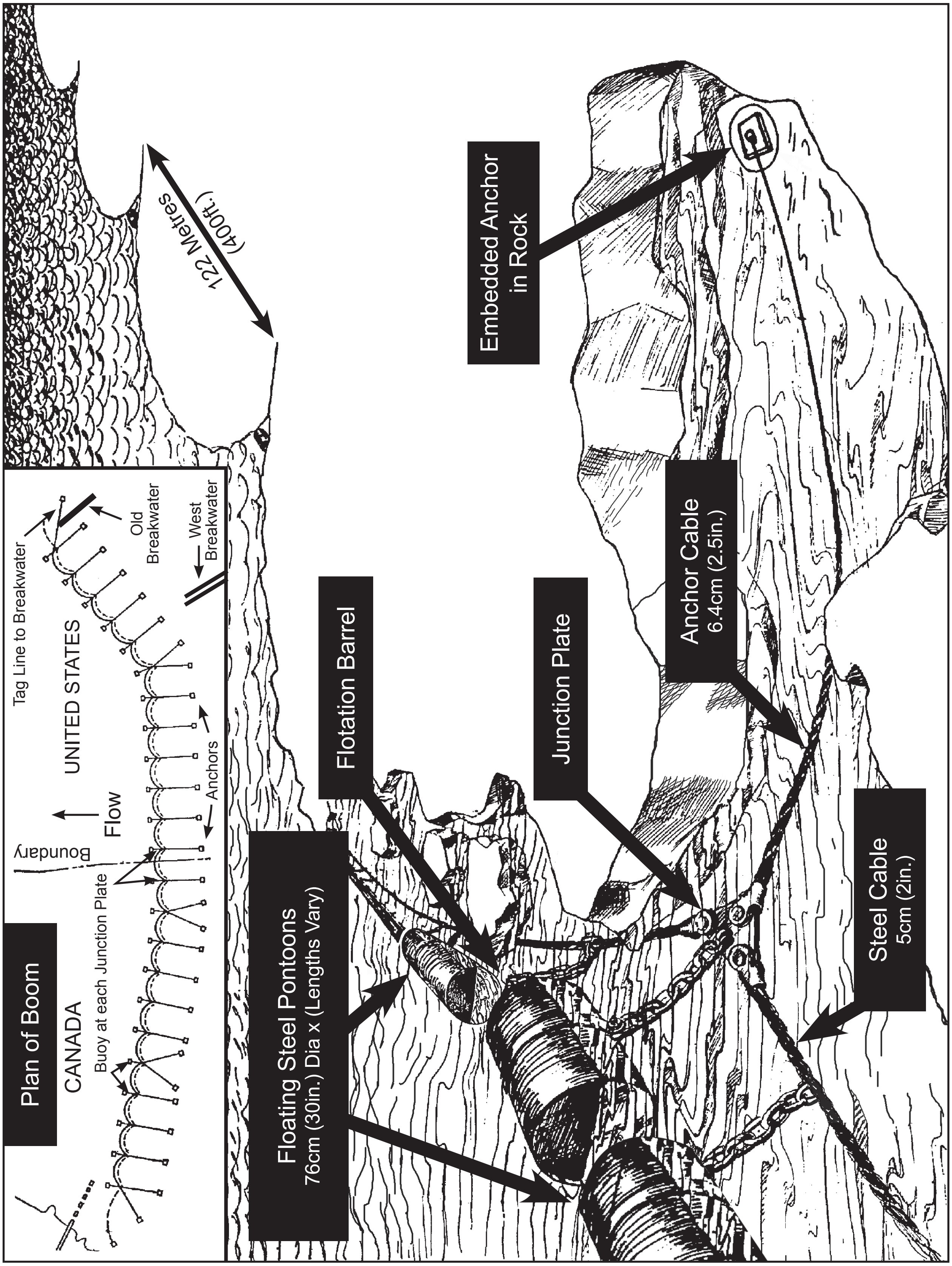
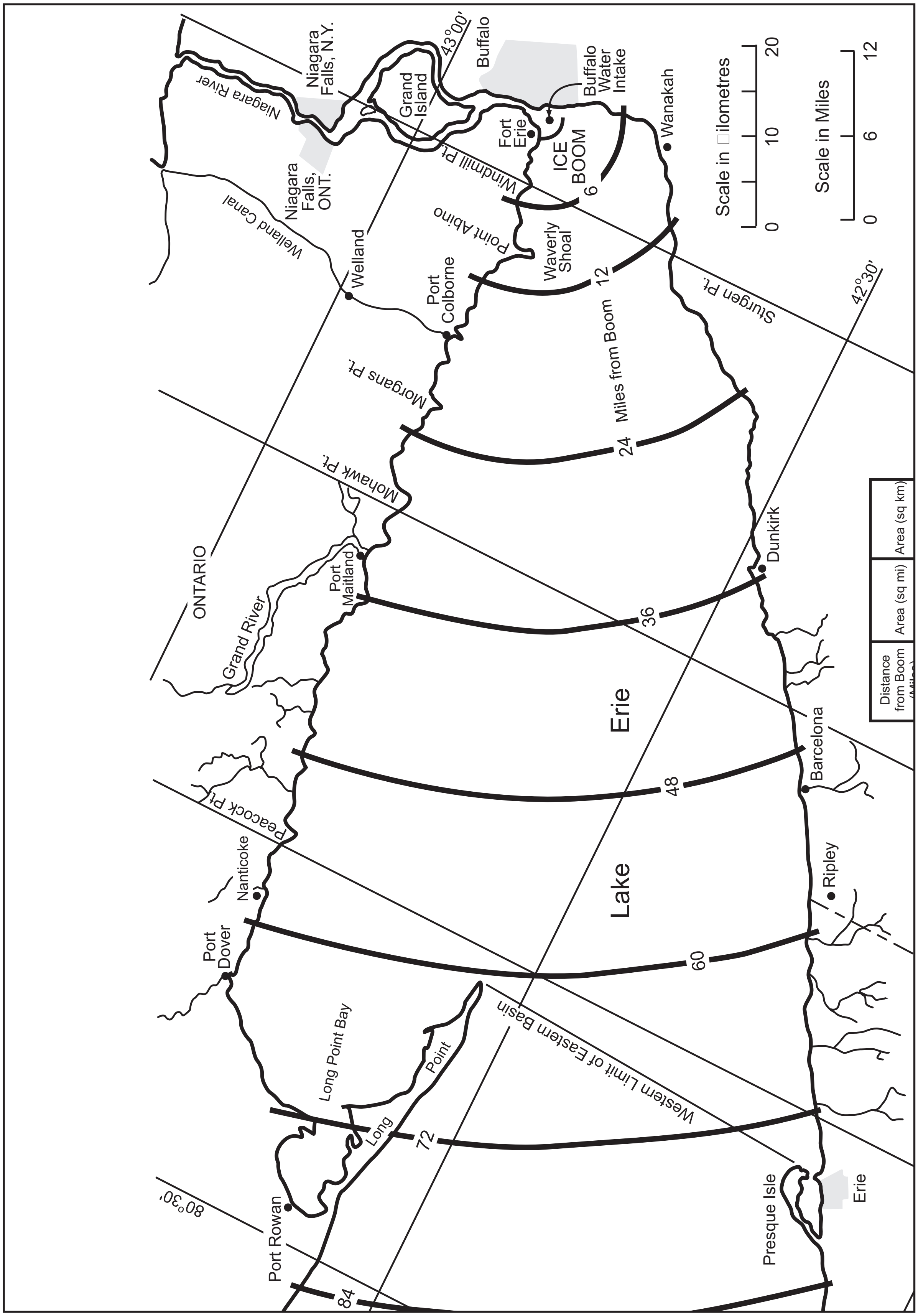


Figure 4

Map of Eastern Lake Erie



Plan View of Ice Boom

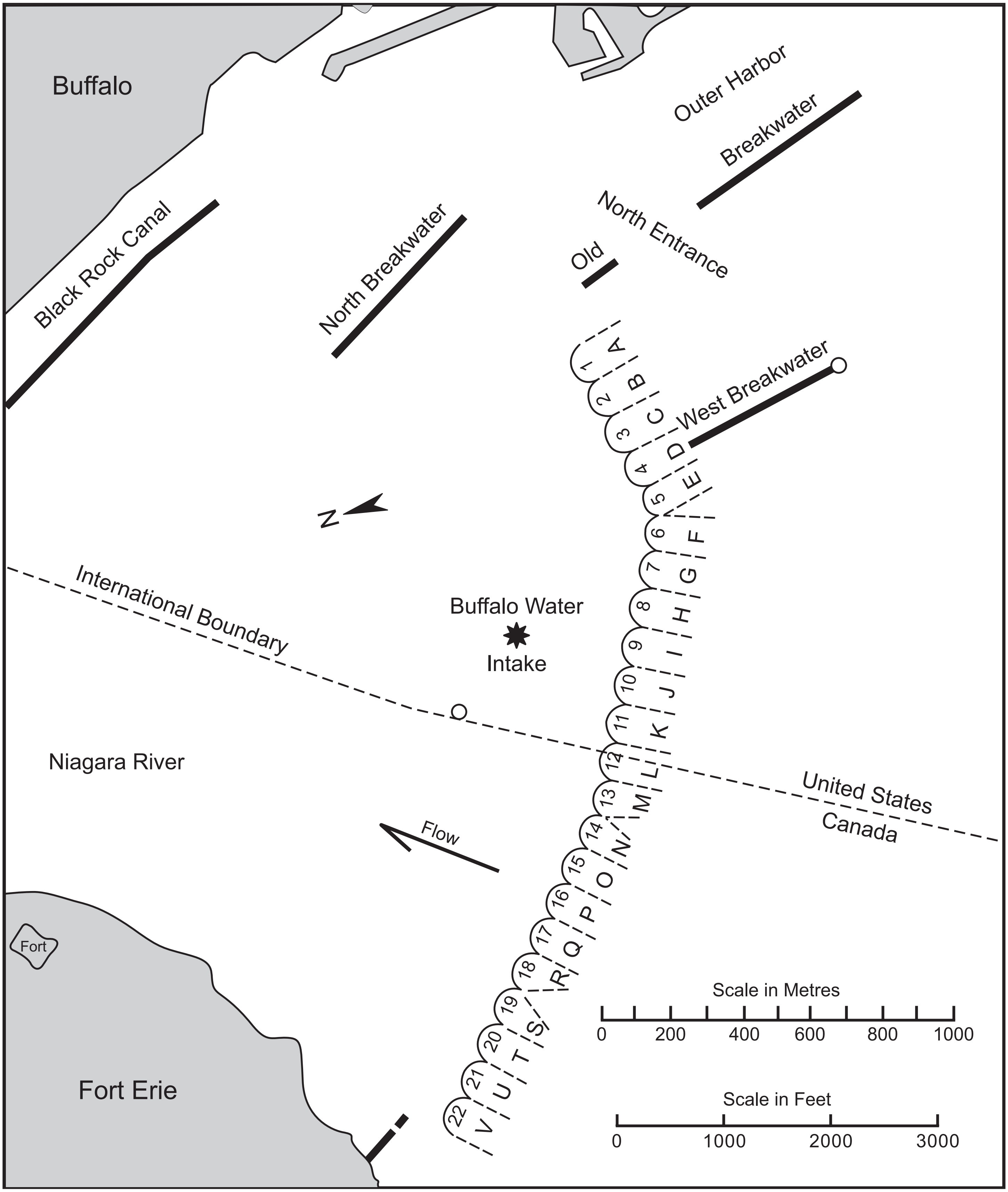


Figure 6