Report to
The International Niagara Board of Control
On the 2009-10 Operation of
The Lake Erie-Niagara River Ice Boom

By the International Niagara Working Committee

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Cover:
Transporting the Ice Boom
(NYPA 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 . . . . . http://www.ijc.org/conseil_board/niagara/en/niagara_home_accueil.htm

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 . . . . . http://www.ec.gc.ca/grandslacs-greatlakes/

1. Highlights

Installation of the Lake Erie - Niagara River ice boom's 22 spans started on 17 December 2009 and was completed on 19 December.

An ice cover began forming behind the boom in early January 2010.

Ice boom span removal began on 22 March and was completed on 24 March.

The Board's International Niagara Working Committee conducted two helicopter flights to measure ice thickness and one fixed-wing flight to observe ice conditions during the 2009-10 ice season.

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

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 2009-10 Ice Season

2.1 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:

http://www.iceboom.nypa.gov

In accordance with Condition (d) of the Commission's 5 October 1999 supplementary Order of Approval, installation of the Lake Erie-Niagara River Ice Boom's spans commenced on 17 December. The Lake Erie water temperature, as measured at the Buffalo Water Intake, reached 4° Celsius (39° Fahrenheit) on 12 December. Installation may begin when the Lake Erie water temperature at Buffalo reaches 4°C (39°F) or on 16 December, whichever occurs first.

Beginning on 2 December, the junction plates were raised from the bottom of the lake and floatation barrels attached. This first phase of installation was completed on 8 December. The strings of pontoons were pulled from their summer storage area and placed inside the Buffalo Harbor breakwall on 14 and 15 December, completing the second phase.

Installation of the ice boom's spans began on 17 December when 6 spans were placed, starting from the Canadian side. A further 12 spans, continuing on towards the US shore, were installed on 18 December, with the final 4 spans placed on 19 December.

2.2 Ice and Hydrometeorological Conditions

The average monthly air temperature data for November 2009 through April 2010, as measured by the National Weather Service at the Buffalo/Niagara International Airport, are shown in Table 2-2. This average was about 0.9°C (1.6°F) above normal for the six-month period.

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

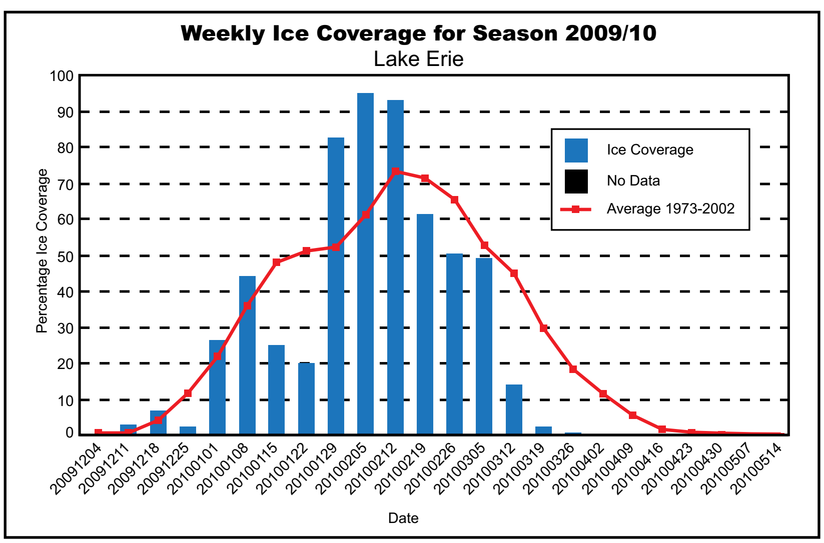
Buffalo's December weather was considered typical for western New York. It was a bit on the cold side with the average monthly temperature of -1.9°C (28.6°F), 0.7°C (1.2°F) below the normal of -1.2°C (29.8°F).

The New York Power Authority's Flood Warning Notification Plan in the Event of Ice-Affected Flooding on the Upper Niagara River was tested on 15 December. A drill was conducted that simulated a flood event along the U.S. shore triggered by an ice jam upstream of the NYPA intakes, in the vicinity of the north Grand Island Bridges.

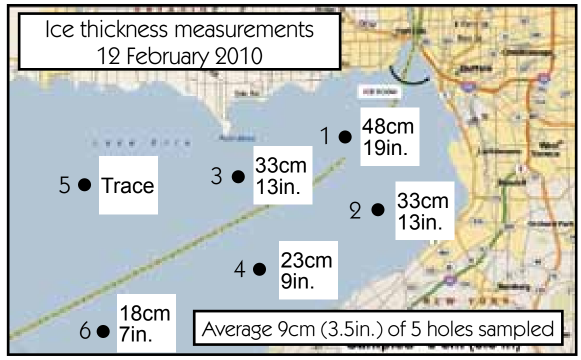
The average temperature for January of -4.9°C (23.2°F) was 0.7°C (1.3°F) below normal. Ice first appeared in the Chippawa-Grass Island Pool on 3 January. The Lake Erie at Buffalo water temperature fell to 0.0°C (32.0°F) by 10 January. An ice bridge formed in the Maid-of-the-Mist Pool, below the Falls, on 12 January. Ice began to accumulate behind the boom during the second week of the month. Strong southwest winds caused a large release of lake ice on 13 January. The ice run stopped early the next day. A subsequent inspection showed that all boom spans were intact. Ice cover on the lake declined during the second and third weeks of January and then increased with the return of below normal temperatures at the end of the month. Ice management measures were undertaken in the Pool (at times including ice breaker activity) throughout much of January.

The drill scenario of 15 December became reality during the early morning of 28 January when a warning was issued as the water level rose slightly above the Zero Damage Elevation at the LaSalle Gauge for an hour and a half. However, no flood damage was reported.

February did not experience the usual swings from deep cold to brief thaws. The average temperature was -4.1°C (24.6°F) or 0.7°C (1.3°F) below normal. As shown in this Canadian Ice Service graph, ice cover on the lake peaked by the end of the first week of February when it was about 95% compared to the average for that point of around 65%. The extent of cover reduced to about 60% by the end of the month.

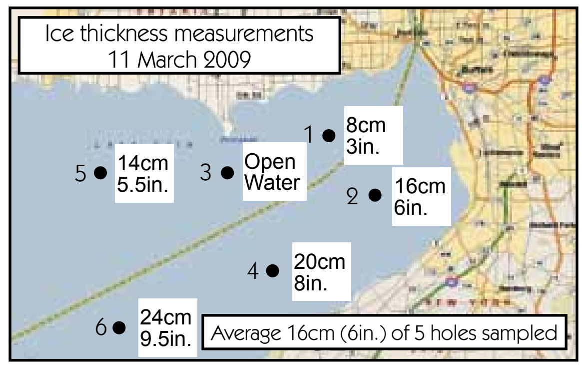


A helicopter flight was conducted on 12 February to measure ice thickness at six sites on the eastern end of Lake Erie. Average thickness was 9 centimetres (3.5 inches). Similar measurements, taken on 13 February of the previous year, averaged 34 centimetres (13 inches).



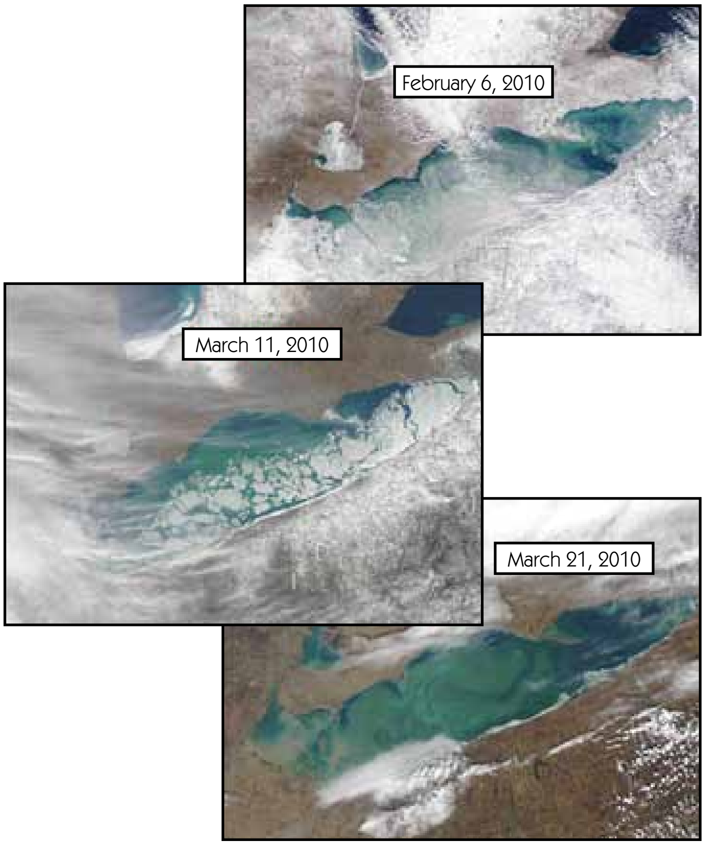
March was mild, dry and sunny, with a complete lack of snow at Buffalo. Average temperature for the month was 3.4°C (38.1°F) or 2.1°C (3.8°F) above normal.

On 11 March, another helicopter flight was conducted to measure ice thickness on the eastern part of Lake Erie. Average thickness, of the 5 sites sampled, was 16 centimetres (6 inches). Similar measurements taken in mid-March 2009 resulted in an average of 27 centimetres (11 inches).



As seen in this 11 March picture, there was open water in the area of the lake upstream of the boom.

The following 3 MODIS images from the U.S. National Oceanic and Atmospheric Administration (NOAA) CoastWatch Great Lakes Program show the eastern basin of Lake Erie on 6 February that is about the time when the most extensive cover was on the lake. Also shown is the cover on 11 March, and on 21 March which is just before ice boom removal began. The ice cover rapidly diminished as it broke apart and moved westward towards the central part of the lake due to wind action.



On 11 March, ice cover on the eastern portion of Lake Erie was 4340 square kilometres (1675 square miles). The ice bridge in the Maid-of-the-Mist Pool below the Falls, which could impede ice moving down the Niagara River towards Lake Ontario, broke apart and moved downstream on 13-14 March. Based on observations during a fixed-wing reconnaissance flight on 18 March, this ice cover had diminished to about 570 square kilometres (220 square miles). Considering the quantity and quality of the ice remaining, the International Niagara Board of Control issued a media advisory on 18 March that, with favourable conditions, boom removal was about to begin.

2.3 Ice Boom Opening

Boom opening begin on 22 March with four spans removed. Eight more spans were removed on 23 March and the remaining ten spans were removed on 24 March.

Flotation barrels were removed from the lake on 25 and 26 March.

On 29 March, the New York Power Authority crew began towing the individual spans up the Buffalo River to the boom's new storage site, where the ground crew pulled them on shore. This operation was completed on

6 April. Movement of the spans along the Buffalo River and placement onto the new storage site went very well. There was good coordination and communication with both the US Coast Guard and the City of Buffalo Harbor Master.

Both the Canadian and U.S. Coast Guards were notified that ice boom removal had been completed.

The date of last ice in Lake Erie, based on satellite information, was 29 March.

The voyages of the Maid of the Mist Steamboat Company for the 2010 season began on 10 April. Last year's operations began on 23 April.

As indicated in Section 2.2, two helicopter (thickness) and one fixed-wing (area) observation flights were conducted by the Board's representatives during 2009-10.

2.4 Estimated Power Losses

Some reduction in hydropower generation occurs virtually every year due to ice problems. 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 2009-10 ice season losses of hydroelectric power generation for the Power Entities were 39,700 Megawatt Hours (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

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

3 DATA ANALYSES 2009-10

3.1 Purpose

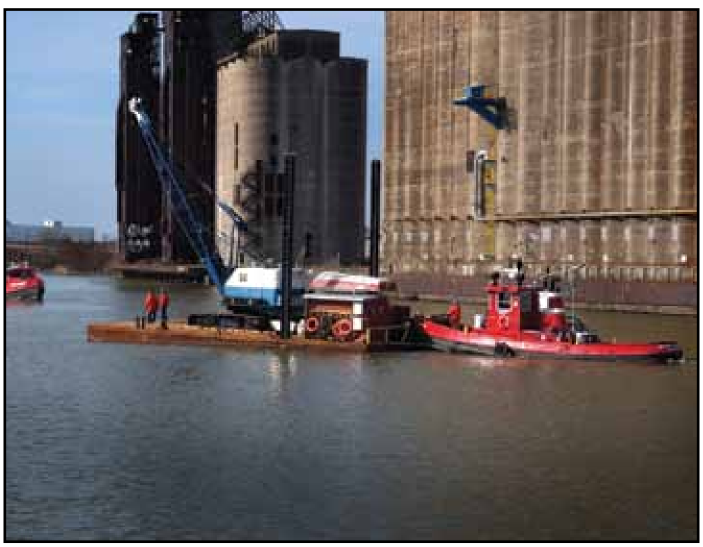
During the 2009-10 winter, the International Niagara Working Committee continued its program of collecting data and information related to ice boom operations to monitor conditions and determine when opening should begin. As part of the usual program, satellite imagery and mapping was analysed and meteorological 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 2009-10 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

The Welland Canal opened to commercial shipping this season on 25 March, for its 182nd consecutive year of service, with the passage of the tug/barge MarineLink Explorer.

Opening dates for the ice boom and commencement of navigation at the Welland Canal for the period 1965 to 2010 are shown in Table 3-4.



4 FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Findings and Conclusions

Water temperature at Buffalo reached 4°C (39°F) on 12 December.

The ice boom spans were installed during the period 17-19 December and removed during the 22-24 March period in accordance with the International Joint Commission's 1999 Supplementary Order of Approval.

During the 2009-10 season, the ice boom functioned as intended.

The Board's water temperature and ice condition monitoring program, with the use of satellite images and observations using both helicopter and fixed-wing flights, is adequate.

The new ice boom storage site works well.

4.2 Recommendations for the 2010-11 Operation

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

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, use of the maps will assist in determining when to remove the boom.

The Working Committee should continue to store ice area maps produced following aerial ice reconnaissance flights or determined from the composite ice maps. The computer generated maps are maintained in a storage and retrieval database structure for future use of the data. The most recent ice reconnaissance map is posted on the Internet at:

http://www.lrb.usace.army.mil/levels/levels.html

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

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

Date Water Temperature Reached 4°C (39°F)	Decade	Installation of the Ice Boom
7 Dec 1964	1960's	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
15 Dec 1970	1970's	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*
14 Dec 1980	1980's	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
27 Dec 1990	1990's	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
18 Dec 2000	2000's	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

* 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

	°C (Celsius)			°F (Fahrenheit)		
Month	**Normal* 1971-2000**	**Recorded 2009-10**	**Departure**	**Normal* 1971-2000**	**Recorded 2009-10**	**Departure**
Nov. 2009	4.6	6.7	2.1	40.2	44.0	3.8
Dec. 2009	-1.2	-1.9	-0.7	29.8	28.6	-1.2
Jan. 2010	-4.2	-4.9	-0.7	24.5	23.2	-1.3
Feb. 2010	-3.4	-4.1	-0.7	25.9	24.6	-1.3
Mar. 2010	1.3	3.4	2.1	34.3	38.1	3.8
Apr. 2010	7.4	10.6	3.2	45.3	51.1	5.8
Average			0.9			1.6

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

Table 2-3 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

* No Data Published

Note: No data available for period 1964-74

Table 3-1 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (Dec 2009-May 2010)												
Month	**December**		**January**		**February**		**March**		**April**		**May**	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	8.3	47	2.2	36	0.0	32	0.0	32	2.2	36	6.7	44
2	8.3	47	0.6	33	0.0	32	0.0	32	2.8	37	6.7	44
3	8.3	47	0.6	33	0.0	32	0.0	32	2.8	37	7.2	45
4	7.8	46	0.6	33	0.0	32	0.0	32	3.3	38	7.2	45
5	7.8	46	1.1	34	0.0	32	0.0	32	3.9	39	8.3	47
6	7.8	46	0.6	33	0.0	32	0.0	32	3.9	39	8.9	48
7	7.2	45	0.6	33	0.0	32	0.0	32	3.9	39	9.4	49
8	6.7	44	0.6	33	0.0	32	0.0	32	3.9	39	9.4	49
9	6.7	44	0.6	33	0.0	32	0.0	32	3.9	39	9.4	49
10	6.7	44	0.0	32	0.0	32	0.0	32	3.9	39	10.0	50
11	3.9	39	0.0	32	0.0	32	0.0	32	3.9	39	9.4	49
12	3.9	39	0.0	32	0.0	32	0.0	32	3.9	39	9.4	49
13	3.9	39	0.0	32	0.0	32	0.0	32	3.9	39	8.9	48
14	4.4	40	0.0	32	0.0	32	0.0	32	4.4	40	9.4	49
15	5.0	41	0.0	32	0.0	32	0.0	32	5.0	41	8.9	48
16	4.4	40	0.0	32	0.0	32	0.0	32	5.0	41	8.9	48
17	3.3	38	0.0	32	0.0	32	0.0	32	5.0	41	10.0	50
18	3.3	38	0.0	32	0.0	32	0.0	32	5.0	41	10.0	50
19	3.3	38	0.0	32	0.0	32	0.0	32	4.4	40	9.4	49
20	2.8	37	0.0	32	0.0	32	1.1	34	5.0	41	10.0	50
21	2.2	36	0.0	32	0.0	32	1.7	35	5.6	42	10.0	50
22	2.2	36	0.0	32	0.0	32	1.7	35	5.6	42	10.6	51
23	2.8	37	0.0	32	0.0	32	1.1	34	5.6	42	10.6	51
24	2.8	37	0.0	32	0.0	32	1.1	34	5.6	42	11.1	52
25	3.3	38	0.0	32	0.0	32	1.1	34	5.6	42	11.7	53
26	3.3	38	0.0	32	0.0	32	1.1	34	6.1	43	11.7	53
27	3.9	39	0.0	32	0.0	32	1.1	34	5.6	42	12.2	54
28	3.3	38	0.0	32	0.0	32	1.1	34	5.6	42	15.0	59
29	2.2	36	0.0	32			1.1	34	5.6	42	16.7	62
30	1.7	35	0.0	32			1.7	35	6.1	43	16.1	61
31	2.2	36	0.0	32			1.7	35			16.7	62
Avg:	4.6	40	0.2	32	0.0	32	0.5	33	4.6	40	10.3	51

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

* 1965 First year ice boom was used

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

	Areas of Ice in Eastern Lake Erie			Opening of Ice Boom	
Year	Date of Observation	Square Kilometres	Square Miles	Start	Completed
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

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

	Opening of Ice Boom			
Year	**Start***	**Completed**	**Welland****	**NOTES**
1965	21-Mar	27-Mar	1-Apr	
1966	20-Mar	1-Apr	4-Apr	* Denotes opening of first boom span. Mobilization time precedes this date.
1967	22-Mar	29-Mar	1-Apr	
1968	18-Mar	20-Mar	1-Apr	
1969	26-Mar	3-Apr	1-Apr	
1970	23-Apr	30-Apr	1-Apr	1970 Commencement of flexible date for boom opening.
1971	3-May	14-May	29-Mar	
1972	20-Apr	25-Apr	29-Mar	
1973	16-Mar	21-Mar	28-Mar	
1974	26-Mar	1-Apr	29-Mar	
1975	25-Mar	28-Mar	25-Mar	
1976	19-Apr	19-Apr	1-Apr	** Usually, scheduled date is established well in advanced and could be related to Welland Canal repair schedule.
1977	18-Apr	20-Apr	4-Apr	
1978	1-May	8-May	28-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	
2000	23-Mar	24-Mar	28-Mar	
2001	17-Apr	20-Apr	30-Mar	
2002	7-Mar	7-Mar	26-Mar	
2003	10-Apr	11-Apr	26-Mar	
2004	6-Apr	7-Apr	23-Mar	
2005	5-Apr	6-Apr	23-Mar	
2006	20-Mar	21-Mar	21-Mar	
2007	10-Apr	18-Apr	20-Mar	
2008	15-Apr	19-Apr	20-Mar	
2009	6-Apr	13-Apr	31-Mar	
2010	22-Mar	24-Mar	25-Mar	
1965-2010	4-Apr	8-Apr	29-Mar	Average for post-ice boom period
1970-2010	5-Apr	9-Apr	29-Mar	Average for the flexible boom opening period.

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 1860-2009, the average Niagara River flow at Queenston, Ontario has been 5861 cubic metres per second (m^3/s) (206,980 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

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 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^3/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^3/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 fro 0.6 to 0.9 m^3/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^3/s (2 to 3 ft/s).
At the 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 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 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 (Figure 4). The Canadian or Horseshoe Falls is so named because the crest is horseshoe shaped. During the 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 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 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 hydroelectric 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. 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 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 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 lever 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. 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 Maid-of-the-Mist Steamboat Company facilities, located downstream of the Falls. Heavy ice runs in the upper river, if added to a large volume of ice already in the Maid –of-the-Mist Pool, may, and on occasions have, severely damaged this installation.

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 review, 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 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 covers 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 week 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 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.

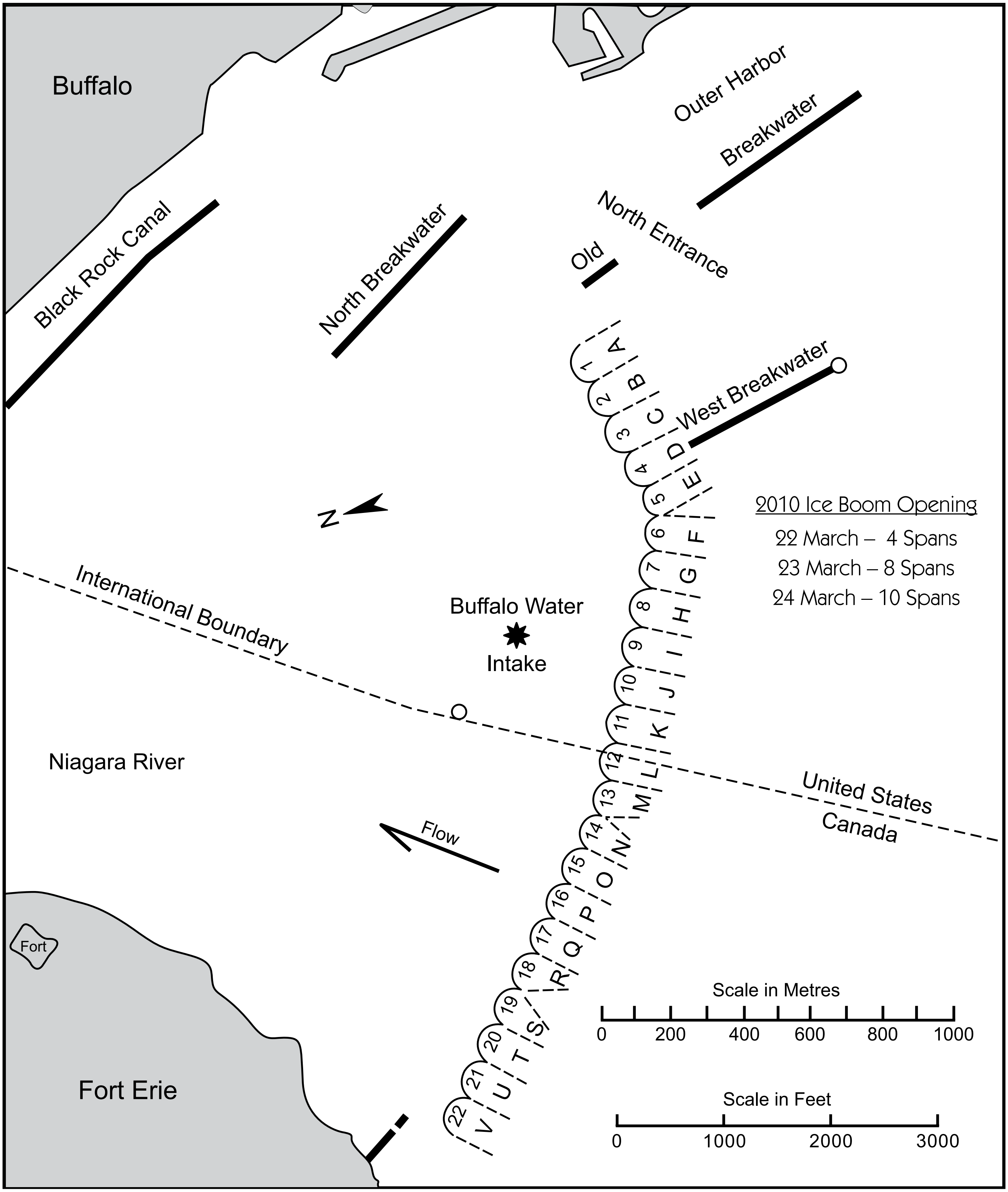
Once the ice arch is formed, it bears the pressure of upstream ice. Subsequent storms may overcome the stability of the arch and force large masses of ice against the boom. The boom was designed to then submerge and allow the ice to override it until the pressure is relieved. After storm conditions subside, 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. Spans are anchored to the lake bed at 122 metre (400 foot) intervals by 6.4 centimetres (2.5 inch) diameter steel cables. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 centimetres (30 inch) diameter, 9 metre (30 foot) long 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. 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



Great Lakes - St. Lawrence River Drainage Basin

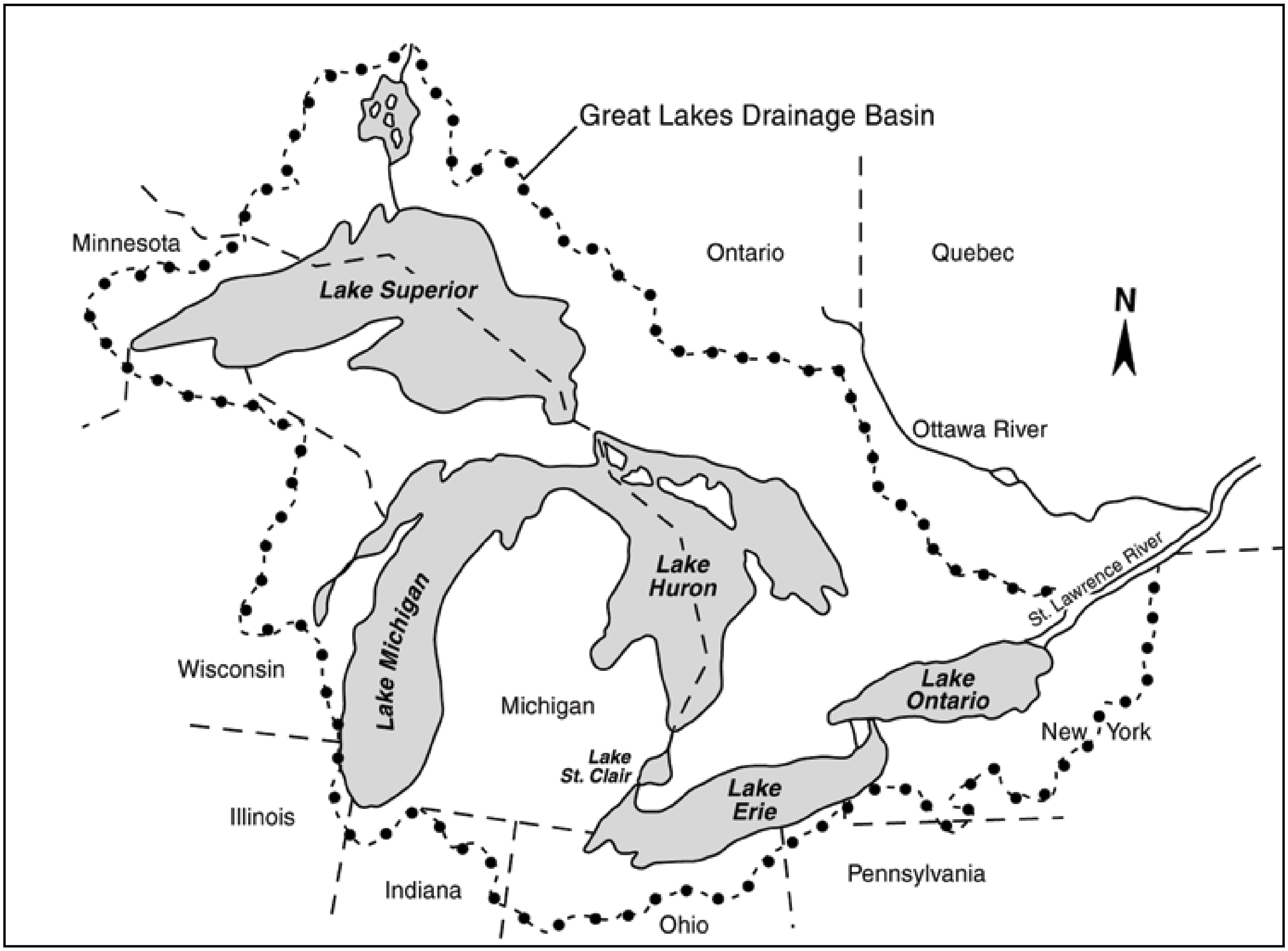


Figure 2

Niagara River - Location Map

Figure 3

Niagara River Diversion Structures and Power Plants

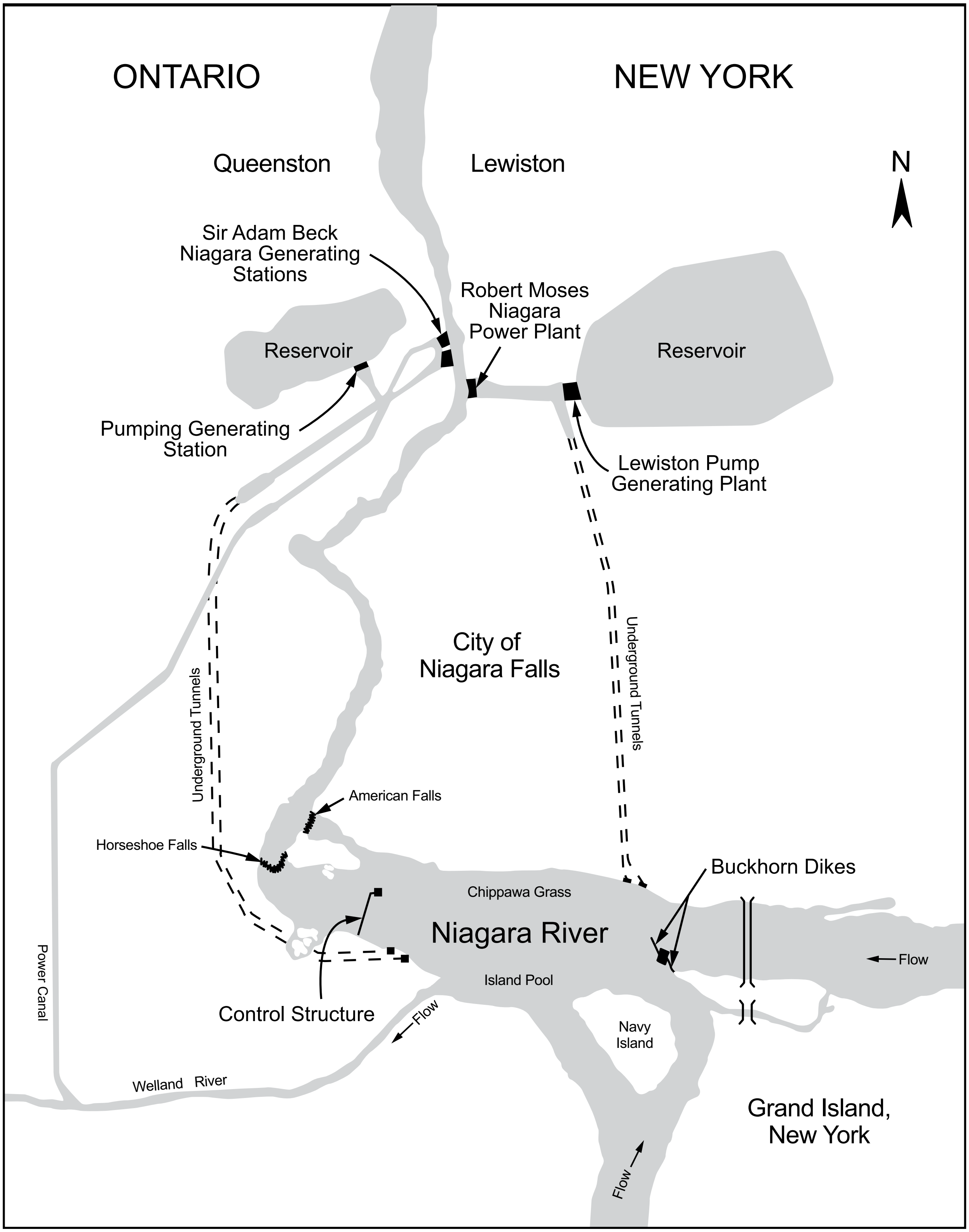
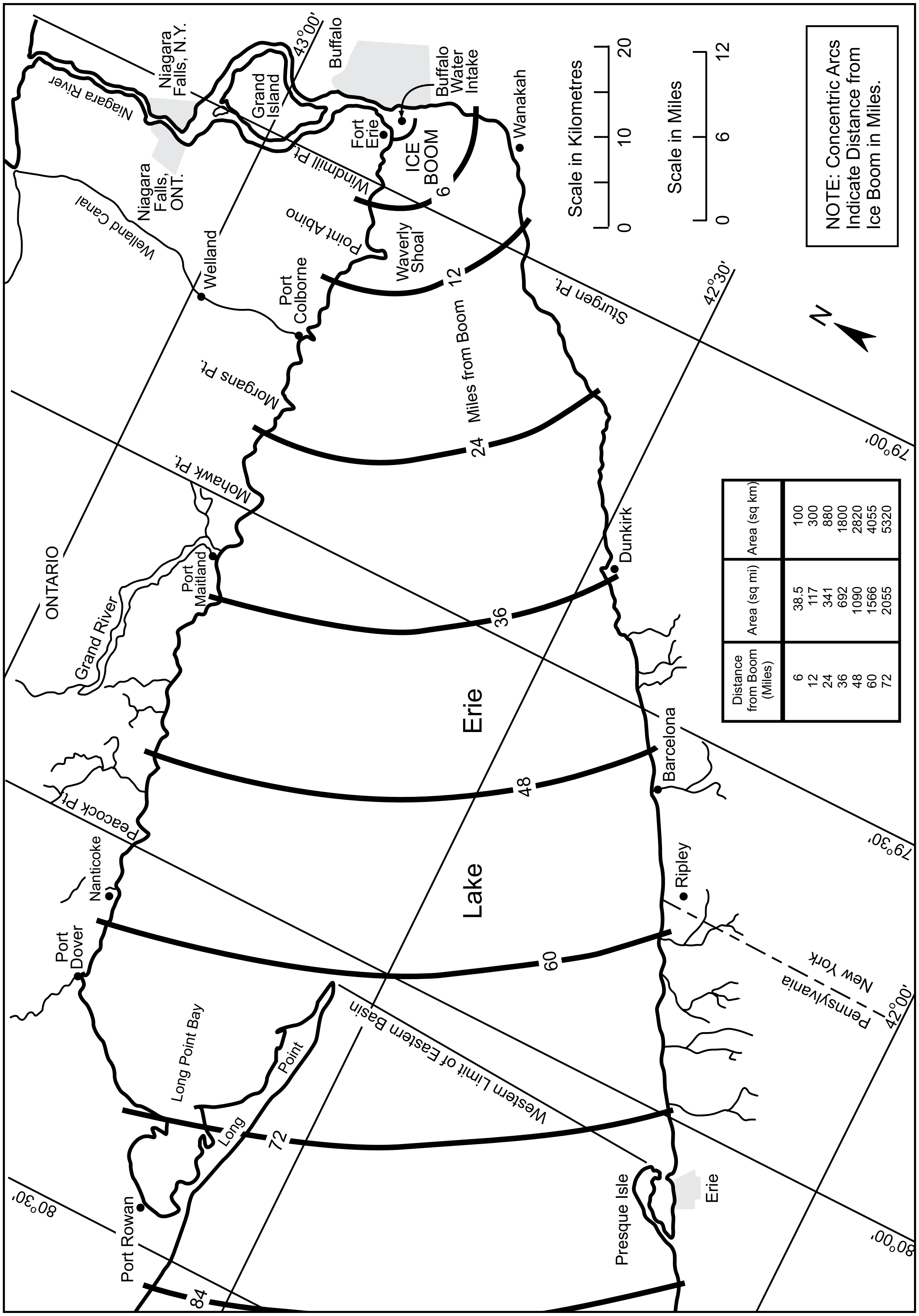


Figure 4

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

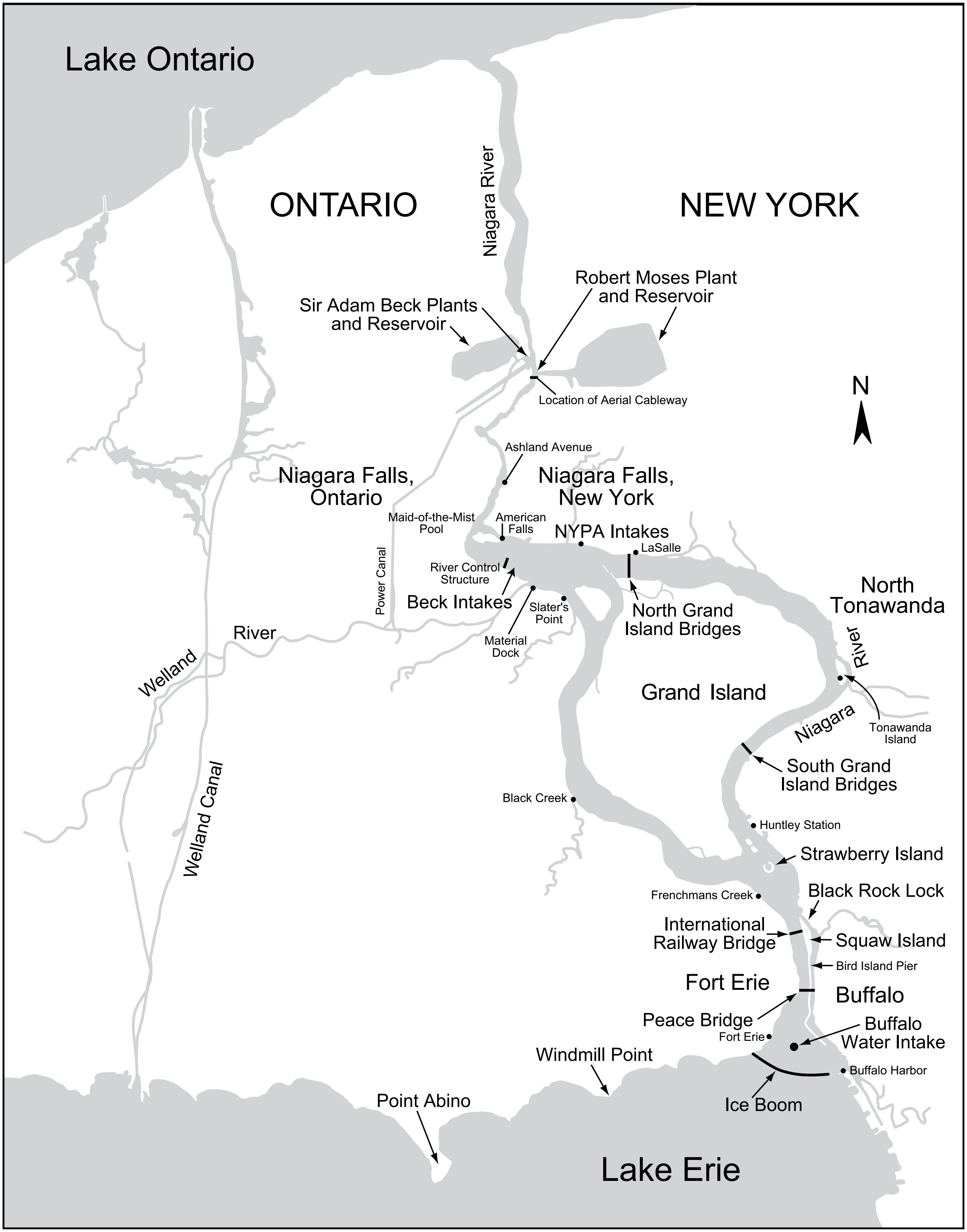


Figure 6

Structural Details of the Ice Boom

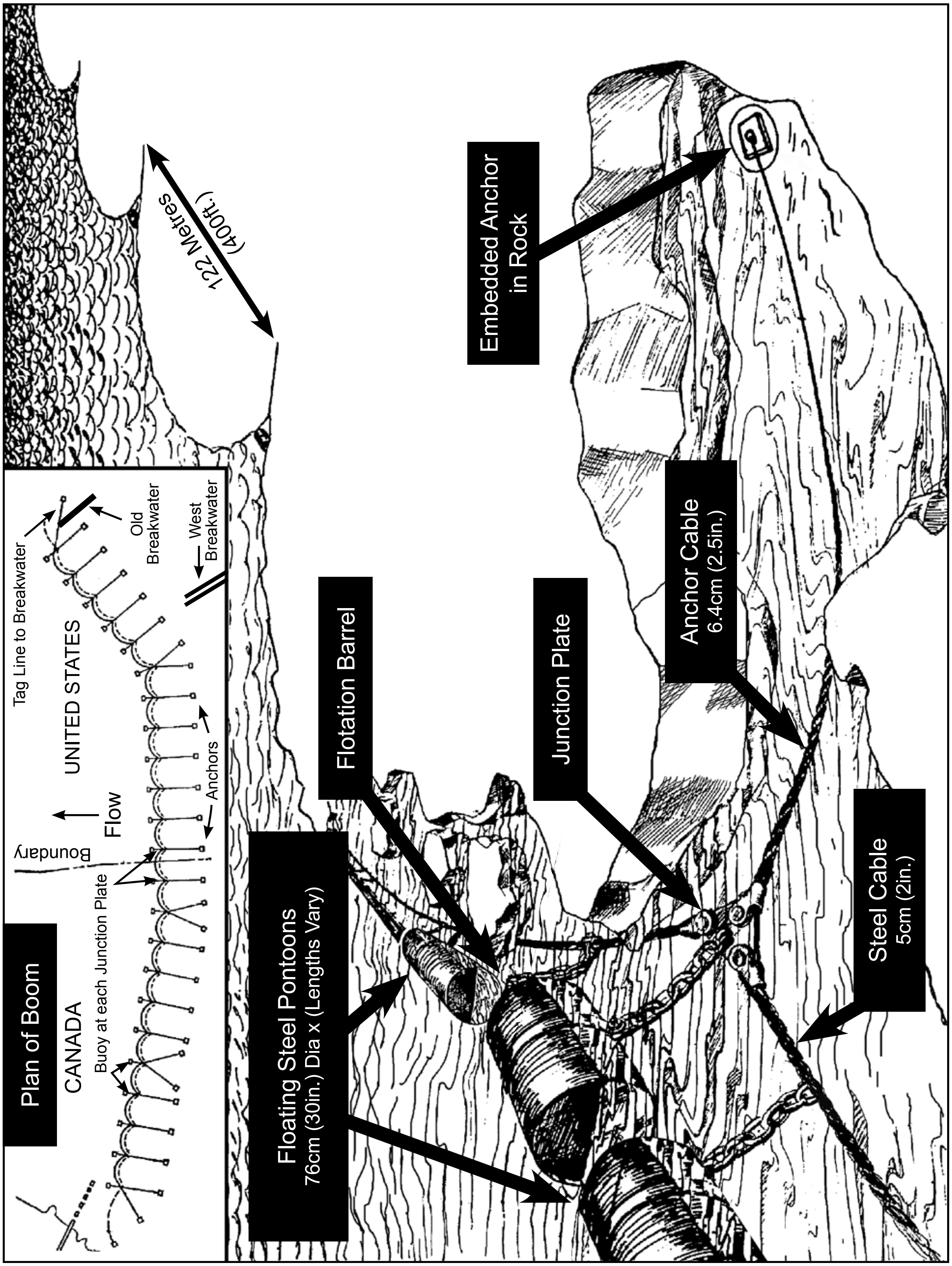


Figure 7