2015-2016 Operation of the Lake Erie-Niagara River Ice Boom

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

October 2016

Report to
The International Niagara Board of Control
On The 2015–16 Operation of
The Lake Erie–Niagara River Ice Boom

By the International Niagara Working Committee

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1. PURPOSE

The Lake Erie–Niagara River Ice Boom (ice boom) reduces the amount of ice passing from Lake Erie to the Niagara River. This prevents ice blockages from reducing hydropower production and reduces ice damage to shoreline property. The Power Entities, New York Power Authority (NYPA) and Ontario Power Generation (OPG) are authorized by the International Joint Commission (IJC) to use the ice boom. The International Niagara Board of Control (the Board) oversees the installation, operation and removal of the ice boom. This report is prepared by the Board's International Niagara Working Committee (INWC) based on information provided by the Power Entities. Information collected by the INWC is used to inform the Board of ice boom operation for the 2015-2016 ice season. Further description of the Lake Erie–Niagara River system can be found in Appendix A.

2. HIGHLIGHTS

The winter of 2015–2016 was one of the warmest winters recorded for the Buffalo/Niagara area. The meteorological winter of December, January, and February tied for third warmest on record, with only 100 cm (39.4 in) of snow.

The water temperature, as measured at the Buffalo Water Intake, did not reach 4°C (39°F) until 6 January 2016. In accordance with condition (d) of the International Joint Commission Order of Approval, installation of the Lake Erie-Niagara River ice boom may begin when the Lake Erie water temperature reaches 4°C (39°F) or on 16 December, whichever occurs first.

On 16 December 2015, ice boom crews began installation of the ice boom's 22 spans and completed installation by 28 December.

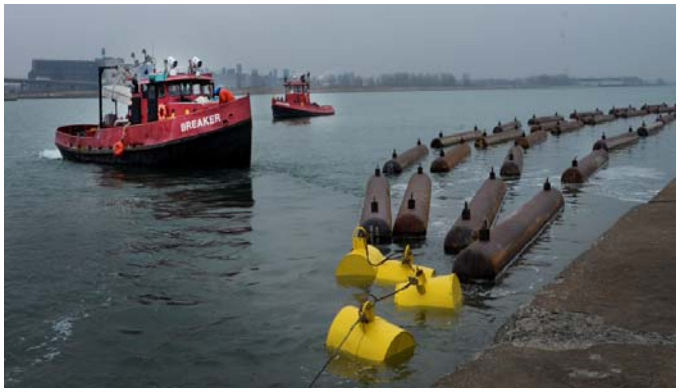
A solid ice formation did not occur on Lake Erie for the 2015–2016 ice season. Lake Erie ice cover peaked at 75 percent by mid-February but rapidly melted due to unseasonably warm temperatures over the next few days.

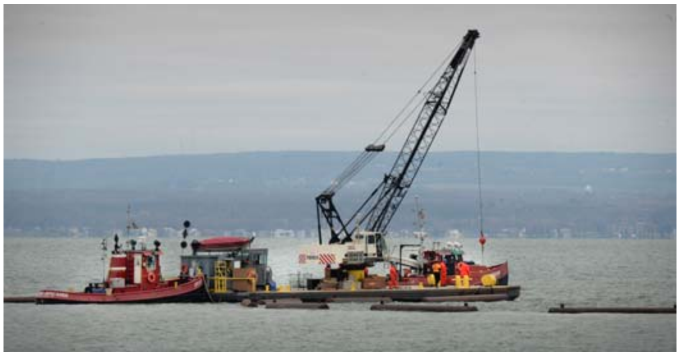
On 11 February 2016, NYPA was made aware that span D had broken. The following week, they were informed that span F was also broken and trailing. On 23 February 2016, repairs began to the ice boom and were completed the same day. Following the repairs, an inspection was completed revealing that span I had two trailing pontoons which were subsequently removed.

The INWC scheduled a helicopter flight to measure ice thickness on 17 February 2016 but the flight was cancelled because of unsafe landing conditions. The INWC did not perform any of the fixed-wing or helicopter ice survey flights due to lack of ice coverage in the eastern basin of Lake Erie.

Removal of the Lake Erie-Niagara River Ice Boom began on 8 March 2016. The final spans of the ice boom were removed and tied off to the Buffalo break wall on 23 March 2016. The last of the ice boom spans were then pulled onto shore on 1 April 2016 ending the 2015–2016 ice boom season. The INWC continues efforts to monitor Lake Erie ice cover, and regular updates are provided on the Board's website at http://ijc.org/en_/inbc/ice_boom.

Data in this report are in metric units followed by the 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).





3. HYDROMETEOROLOGICAL AND ICE CONDITIONS

During the winter of 2015-2016, the INWC continued its program of collecting data and information related to ice boom operations. These data were used to monitor conditions of the ice boom and Lake Erie, as well as determining 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.

The average monthly air temperature data for November 2015 through April 2016, as measured by the National Weather Service at the Buffalo Niagara International Airport, are displayed in Table 1.

The Buffalo/Niagara region saw mild temperatures throughout the month of November 2015. The average air temperature for the month was 7.9°C (46.2°F), which is 3.1°C (5.5°F) above average, making November 2015 the 7th warmest on record. This, in combination with consistently warm temperatures throughout the previous months, made the autumn season of 2015 the 5th warmest on record. November 2015 was a dry month with only 3.4 cm (1.3 in) of precipitation.

The above-average air temperatures continued through December 2015. The average air temperature was 6.7°C (12°F) above normal. The average air temperature for December 2015 was 5.6°C (42.1°F) setting the record for the warmest December on record. This surpassed the old record by a margin of 2.5°C (4.5°F) set back in 1923. Two century-old records were broken in December 2015. The latest, first measurable snowfall occurred on 18 December 2015, breaking the old record of 3 December set back in 1899. December 2015 recorded the least monthly snowfall for any December, with only 2.5 cm (1.0 in) of total snowfall for the entire month, breaking the record of 2.8 cm (1.1 in) set back in 1891 and 1899.

January of 2016 brought more familiar temperatures to the Buffalo/Niagara Region. The average temperature for the month was -2.8°C (26.9°F), which was 1.1°C (2.0°F) above the Long Term Average (LTA). Three lake effect snow events, between 11 and 19 January 2016, brought several inches of snow to the region. Above average temperatures at the end of the month generated a thaw, melting any remaining snow.

February began with mild temperatures well above normal before a cold front moved into the area. From 10 to 18 February 2016, temperatures dropped, bringing winter-like conditions to the region. On 14 February, the mercury plunged to -24.4°C (-12°F). This temperature was recorded as the coldest day in the region since 17 January 1982. Above normal temperatures returned for the end of the month. The average temperature for February 2016 was -1.3°C (29.7°F), which is 1.9°C (3.4°F) above normal. It presents a stark contrast to the record-setting cold of February 2015. The average temperature for February 2015 was -11.7°C (10.9°F), which was 10.4°C (18.8°F) colder than 2016.

March started with wintry conditions but by the end of the first week, spring-like weather had begun. The average temperature was 4.4°C (39.9°F), which is 3.3°C (5.9°F) above average.

Following a mild winter, April arrived with cold temperatures and above average snowfall. Snowfall for April was measured at 18 cm (7.1 in), all falling within the first ten days of the month. By mid-April, spring temperatures had returned. The average temperature for April was 6.2°C (43.1°F), which was -1.5°C (-2.8°F) below LTA.

The total snowfall from November 2015 to April 2016 was 140 cm (55.1 in) as recorded at the Buffalo Niagara International Airport, which is 100 cm (39.4 in) below normal. The average temperature for the six-month period was 2.4°C (4.3°F) above the LTA.

The daily Lake Erie water temperature, as measured at the Buffalo Water Intake, for the period December 2015 through May 2016, are provided in Table 2. By mid-January 2016, the Lake Erie water temperature had dipped to 0.6°C (33°F) and never reached 0°C (32°F), reflecting the mild winter temperatures for the winter of 2015-2016.

The first ice of the season was observed in the Chippewa Grass Island Pool on 19 January 2016. On 20 January 2016, sheet and shale ice were present along the NYPA intake wall and was subsequently cleared by icebreaker action. As shown in Figure 1, ice cover on Lake Erie peaked at 75 percent mid-February as reported by the Canadian Ice Service. With above average temperatures, the thin shale ice melted by the end of the month.

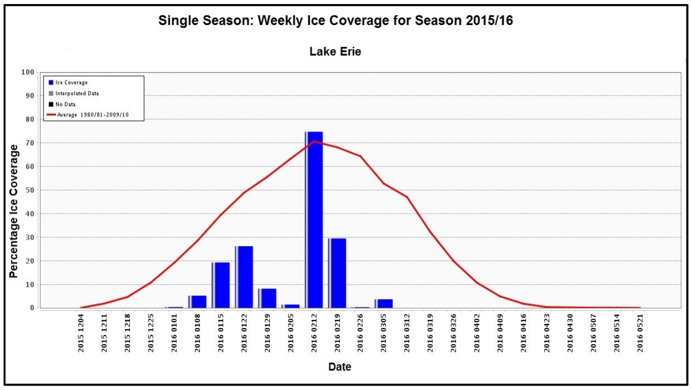


Figure 1: Single Season: Weekly Ice Coverage for 2015/16 provided by the Canadian Ice Service

Usually, the INWC carries out two helicopter ice thickness measurement flights, one in February and one in March. Figure 2 shows the six ice thickness measurement locations. With very little ice formation for the 2015-16 season, the flight scheduled for 17 February was cancelled and no March flight was scheduled. No fixed wing ice survey flights were necessary by the International Niagara Working Committee before the opening of the ice boom due to lack of ice formation in the eastern basin of Lake Erie.

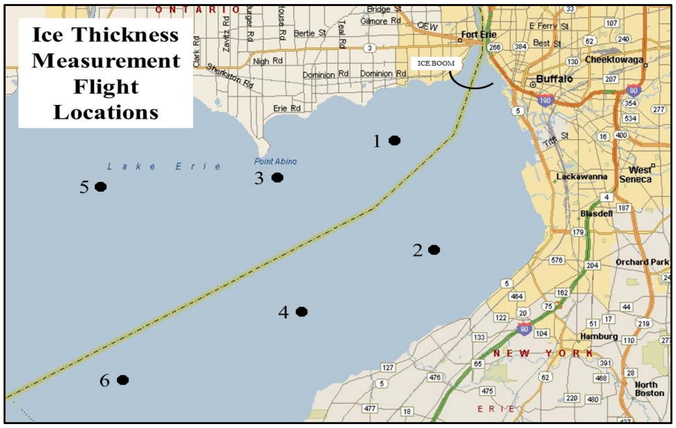


Figure 2: Ice Thickness Measurements Flight – Cancelled

Based on available satellite imagery and information provided by the Canadian Ice Service, the date of last ice was determined as 6 March 2016. Historical dates of last ice can be seen in Table 3.


MODIS Satellite Imagery from the (NOAA) Coast Watch Great Lakes Program, 28 February 2016

4. OPERATION OF THE ICE BOOM DURING THE 2015–16 ICE SEASON

The following sections provide a description of key operations of the ice boom in the 2015-16 ice season as they relate to the Order of Approval. Further background information on the ice boom can be found in Appendix B.

4.1 Installation of the Boom

A video surveillance system is used to monitor the ice boom. The web cam and information on the ice boom is available at:

www.iceboom.nypa.gov and the International Niagara Board of Control web site http://www.ijc.org/en_/inbc/ice_boom.

Phase 1 of the ice boom installation (raising of the junction plates and attaching of the floatation buoy barrels) was completed on 1 December 2015 for the entire length of the boom.

With Phase 1 of the ice boom installation complete, crews began Phase 2 on 3 December 2015, towing four boom spans from their storage area at 100 Katherine Street, Buffalo, NY, (along the shore of the Buffalo River about 3 km [2 mi] upstream from Lake Erie) and securing them to the Buffalo Harbor breakwall. By 10 December 2015, ice boom crews had pulled all 22 boom spans and secured them to the breakwall with 2 spare spans at the Coast Guard station. This work completed Phase 2 of the ice boom installation.

The Lake Erie water temperature is taken at the Buffalo Water Treatment Plant located at the head of the Niagara River. The reading is taken at a depth of 9.1 m (30 ft). 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 (i.e. Phase 3 which is the placement of ice boom spans on Lake Erie as shown in Enclosure 6) will not begin before the Lake Erie water temperature reaches 4°C (39°F) or before 16 December, whichever occurs first. The Board issued a media advisory on 15 December 2015, indicating that Phase 3 of the ice boom installation was scheduled to begin on 16 December 2015, following the completion of Phases 1 & 2.

Installation began on schedule and ice boom crews were able to install 6 spans (Spans Q through V) on the Canadian side (refer to Enclosure 6 for span layout). On 17 December 2015, crews were able to install 3 more spans (N-P) before high winds forced them off the water. On 18 December 2015, weather conditions worsened. Crews were not able to continue installation until 22 December, installing another 4 spans (Spans J through M). Work continued on 23 December 2015 with 6 additional spans installed (Spans D through I). Following the Christmas break, on 28 December 2015, ice boom crews installed the remaining 3 spans (A through C) completing Phase 3 ice boom installation.

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 3.9°C (39°F) on 6 January 2016.

4.2 Ice Boom Operation

Typically, an ice sheet will form behind the ice boom, stabilizing the structure for a significant portion of the ice season. During the 2015-2016 ice season, the ice sheet formed for only brief periods behind the ice boom. Due to above average temperatures, there were extended lengths of time that the ice boom was exposed to the stress of wave action during high wind events. On 11 February, span D was reported broken. The following week while ice boom crews were completing repairs on the dry docked vessel, span F was also reported open and trailing. On 23 February, after necessary repairs to the vessel were completed, ice boom crews mobilized. Splice repairs to spans D and F were completed. Following the repairs, span I was observed as having two trailing sections, which were subsequently removed. A complete inspection of the ice boom was completed and all sections were found to be in good working order.

4.3 Ice Boom Opening

MODIS images from the first week of March showed only trace amounts of ice coverage on the eastern end of Lake Erie. A fixed-wing ice survey flight is typically carried out to determine the extent and condition of ice coverage on the eastern basin of Lake Erie and in the Maid-of-the-Mist-Pool (MOMP). With very little ice coverage, the flight was deemed unnecessary prior to the decision to begin removal of the ice boom.

Considering the amount of ice remaining in the eastern basin and in the MOMP, the Board issued a media advisory on 8 March 2016, stating that ice boom removal preparations were underway. Ice boom crews began Phase 1 of the Lake Erie-Niagara River Ice Boom opening.

On 8 March, ice boom crews removed 8 spans (O through V) and secured them to the Buffalo Harbor Breakwall. On the following day, poor conditions on Lake Erie halted removal proceedings, but ice boom crews were back out on 10 March removing 2 additional spans (M & N). Removal continued on 11 March as ice boom crews encountered one sunken pontoon and a sunken span but worked diligently to remove 8 more spans (E through L) and secure them to the breakwall.

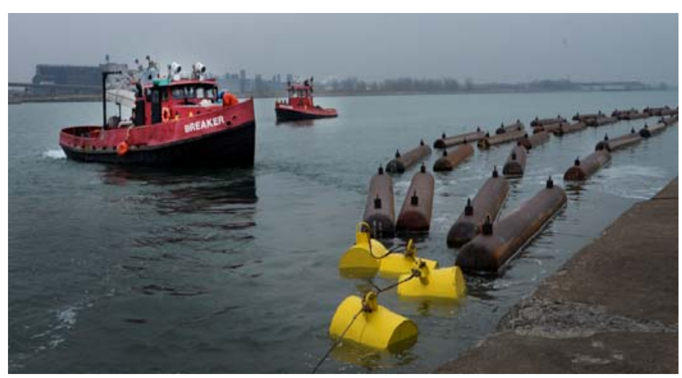
On 14 March 2016, ice boom crews were back on the water removing the four remaining spans (A through D) and towing them to the Buffalo Harbor breakwall. With all 22 spans (A through V) secured to the break wall, Phase 1 of the opening of the ice boom was now complete.

Phase 2, removal of the buoy barrels, was scheduled to begin 15 March, but work was interrupted for the next few days as inclement weather created unsafe working conditions. On 18 March, crews began Phase 2, removing 11 of the 23 buoy barrels. The removal process continued on 21 March as crews were able to remove an additional 9 buoy barrels before high winds halted work. Phase 2 was completed 23 March as crews removed the remaining 3 buoy barrels. With Phases 1 & 2 complete, NYPA informed the INWC and both the Canadian and U.S. Coast Guards that the ice boom was now open.

Phase 3 of the ice boom removal process started on 24 March when ice boom crews began towing the 152-metre (500-foot) long spans to the Katherine Street storage site, where they were pulled onto shore. Four spans were towed up the Buffalo River and pulled onto shore on the first day. On 29 March, work resumed and six additional spans were towed to the maintenance facility, bringing the total to 10 out of 22 working spans on shore, with the addition of 2 spare spans at the U.S Coast Guard (USCG) station. Work continued over the next few days as ice boom crews towed six spans to shore on 30 March and four spans on 31 March. The final four spans were pulled onto the Katherine Street storage site on 1 April 2016, marking the end of the 2015-2016 ice boom season. The IJC was informed that the 2016 ice boom removal operations were complete. Historical data, from 1970 to present, on the ice area remaining in eastern Lake Erie and the boom opening dates, are shown in Table 5.

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 2015-16 ICE SEASON

5.1 Estimated Power Losses

Even with the installation of the ice boom, some reduction in hydropower generation can be expected virtually every year due to ice conditions where ice flows over top the ice boom or when ice is generated in the river itself. The Power Entities estimate that the ice boom provides an average annual savings to the hydropower facilities of approximately 414,000 Megawatt Hours (MWh) of electric energy.

The Power Entities experienced a 10,500 MWh loss of hydroelectric power generation due to ice during the 2015–2016 ice season. A summary of estimated loss of energy due to ice for the period of record, 1975 to present, is shown in Table 6.

5.2 Niagara River Shore Flooding and Property Damages

The NYPA's Flood Warning Notification Plan (FWNP) in the Event of Ice-Affected Flooding on the Upper Niagara River was tested on 5 December 2015 at 1300 hrs. A drill was conducted that simulated a flood event along the U.S. shoreline downstream of the North Grand Island Bridge. The water level gauge located at the LaSalle Yacht Club read 15 cm (0.5 ft) below the zero damage elevation, with potential flooding of low lying areas along the Robert Moses Parkway under the Grand Island Bridge. These simulated conditions were caused by a postulated ice stoppage and jam between NYPA's intakes and the Buckhorn dikes.

Activation of the FWNP was not required in the 2015-2016 ice season.

5.3 Navigation at the Welland Canal

The Welland Canal opened to commercial shipping this season on 21 March 2016 for its 187th consecutive year of service. A comparison of the dates of boom opening and the commencement date of navigation at the Welland Canal for the period 1965 to 2016 is shown in Table 7.

6. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Findings and Conclusions

Western New York experienced temperatures well above average for the winter of 2015-16. The meteorological winter period of December, January, and February tied for the third warmest on record.

On 11 February 2016, the NYPA was informed of a possible break in the ice boom at span D. During the following week, span F was reported open and trailing. On 23 February 2016, ice boom crews completed repairs. Upon further inspection, it was noticed that span I had two trailing pontoons, which were subsequently removed.

Helicopter (for ice thickness measurements) and fixed-wing (for lake ice area assessment) flights were not required to assess ice conditions in the eastern basin of Lake Erie as a result of the ice conditions during the winter of 2015-2016.

6.2 Recommendations for the 2016–17 Operation

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

The Power Entities should continue to ensure that they monitor the ice boom and have adequate materials to repair multiple breakages in a timely manner, if they occur.

Utilization of Great Lakes ice information maps prepared by the Canadian Ice Centre and the United States National Ice Center, NOAA satellite imagery, and helicopter and fixed-wing aerial ice surveys should continue to be used, as required, to evaluate ice conditions throughout the winter. In addition, the availability and applicability of additional, alternate forms of satellite-based remote sensing information should be investigated.

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

	ºC (Celsius)			ºF (Fahrenheit)		
Month	**Average* 1981-2010**	**Recorded 2015-16**	**Departure**	**Average* 1981-2010**	**Recorded 2015-16**	**Departure**
Nov. 2015	4.8	7.9	3.1	40.7	46.2	5.5
Dec. 2015	-1.1	5.6	6.7	30.1	42.1	12.0
Jan. 2016	-3.9	-2.8	1.1	24.9	26.9	2.0
Feb. 2016	-3.2	-1.3	1.9	26.3	29.7	3.4
Mar. 2016	1.1	4.4	3.3	34.0	39.9	5.9
Apr. 2016	7.7	6.2	-1.5	45.9	43.1	-2.8
Average	0.9	3.3	2.4	33.7	38.0	4.3

* 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 2015 - May 2016)*

Month	December		January		February		March		April		May	
Date	ºC	ºF	ºC	ºF	ºC	ºF	ºC	ºF	ºC	ºF	ºC	ºF
1	7.8	46	5.0	41	1.7	35	1.1	34	5.0	41	6.1	43
2	7.8	46	5.0	41	1.7	35	1.1	34	5.6	42	6.1	43
3	8.3	47	5.0	41	1.7	35	1,1	34	5.0	41	6.1	43
4	7.8	46	4.4	40	2.2	36	1.1	34	5.0	41	6.7	44
5	7.2	45	4.4	40	2.2	36	1.1	34	4.4	40	7.2	45
6	7.8	46	3.9	39	2.2	36	1.1	34	3.9	39	7.2	45
7	7.2	45	3.3	38	2.2	36	1.1	34	4.4	40	6.7	44
8	7.8	46	2.8	37	2.2	36	1.7	35	4.4	40	7.2	45
9	7.2	45	3.3	38	2.8	37	1.7	35	4.4	40	7.2	45
10	7.2	45	2.2	36	1.7	35	2.2	36	4.4	40	7.8	46
11	7.2	45	1.7	35	1.7	35	2.2	36	3.9	39	7.8	46
12	7.8	46	1.1	34	1.1	34	2.2	36	3.9	39	8.3	47
13	7.8	46	1.1	34	0.6	33	2.2	36	4.4	40	8.3	47
14	7.8	46	1.1	34	0.6	33	2.2	36	4.4	40	10.0	50
15	7.8	46	1.7	35	0.6	33	2.2	36	4.4	40	10.0	50
16	7.8	46	2.2	36	0.6	33	2.8	37	4.4	40	10.6	51
17	7.8	46	0.6	33	0.6	33	3.3	38	5.0	41	10.6	51
18	7.2	45	0.6	33	0.6	33	3.9	39	5.0	41	10.0	50
19	6.7	44	0.6	33	0.6	33	3.3	38	5.0	41	10.0	50
20	6.1	43	0.6	33	0.6	33	2.8	37	5.6	42	10.6	51
21	5.6	42	0.6	33	0.6	33	2.8	37	5.6	42	11.1	52
22	6.7	44	0.6	33	1.1	34	2.8	37	5.6	42	10.6	51
23	6.7	44	0.6	33	1.1	34	2.8	37	6.1	43	10.6	51
24	6.7	44	0.6	33	1.1	34	2.8	37	6.1	43	11.7	53
25	6.7	44	0.6	33	1.1	34	2.8	37	6.1	43	13.3	56
26	6.7	44	0.6	33	0.6	33	3.3	38	5.6	42	13.9	57
27	6.1	43	0.6	33	0.6	33	3.3	38	6.1	43	14.4	58
28	5.6	42	0.6	33	0.6	33	4.4	40	6.1	43	14.4	58
29	6.1	43	1.1	34	1.1	34	4.4	40	6.1	43	17.2	63
30	6.1	43	1.1	34			3.9	39	6.1	43	17.8	64
31	5.6	42	1.1	34			4.4	40			18.3	65
Average:	7.2	45	1.7	35	1.1	34	2.8	37	5.0	41	10.0	50.0
Hi:	8.3	47	5.0	41	2.8	37	4.4	40	6.1	43	15.6	65
Low:	5.6	42	0.6	33	0.6	33	1.1	34	3.9	39	3.9	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		1943	20-May		1981	30-Apr
1906	22-Apr		1944	15-Apr		1982	20-May
1907	30-Apr		1945	9-Apr		1983	23-Feb
1908	9-May		1946	No data		1984	25-Apr
1909	26-Apr		1947	No data		1985	1-May
1910	30-Apr		1948	No data		1986	26-Apr
1911	6-May		1949	No data		1987	9-Mar
1912	29-Apr		1950	No data		1988	27-Apr
1913	30-Apr		1951	15-Apr		1989	9-Apr
1914	28-Apr		1952	27-Mar		1990	10-Apr
1915	2-May		1953	Ice-free		1991	28-Mar
1916	11-May		1954	27-Apr		1992	15-Apr
1917	30-Apr		1955	5-Apr		1993	16-Apr
1918	20-Apr		1956	20-Apr		1994	1-May
1919	15-Mar		1957	11-Apr		1995	18-Apr
1920	20-May		1958	10-Apr		1996	6-May
1921	14-Mar		1959	8-May		1997	29-Apr
1922	11-Apr		1960	5-May		1998	Ice-free
1923	16-May		1961	15-Apr		1999	2-Apr
1924	20-Apr		1962	30-Apr		2000	28-Mar
1925	26-Apr		1963	11-May		2001	27-Apr
1926	31-May		1964	27-Apr		2002	Ice-free
1927	9-Apr		1965*	14-May		2003	22-Apr
1928	19-May		1966	27-Apr		2004	30-Apr
1929	2-May		1967	13-Apr		2005	11-Apr
1930	7-May		1968	4-May		2006	5-Apr
1931	7-Apr		1969	26-Apr		2007	29-Apr
1932	21-Apr		1970	30-Apr		2008	23-Apr
1933	23-Apr		1971	31-May		2009	16-Apr
1934	23-Apr		1972	5-May		2010	29-Mar
1935	13-Apr		1973	15-Mar		2011	24-Apr
1936	31-May		1974	6-Apr		2012	Ice-free
1937	14-Apr		1975	8-Apr		2013	9-Apr
1938	14-Apr		1976	19-Apr		2014	8-May
1939	14-May		1977	13-May		2015	20-Apr
1940	19-May		1978	14-May		2016	6-Mar
1941	21-Apr		1979	3-May			
1942	30-Apr		1980	23-Apr			

Table 4: Dates Water Temperature Reached 4˚C (39˚F) and Dates of Ice Boom Installation

Date Water Temperature Reached 4°C (39°F)		Installation of the Ice Boom	Date Water Temperature Reached 4°C (39°F)		Installation of the Ice Boom
7-Dec-1964	1960's	9 Nov to 15 Dec 1964	27-Dec-1990	1990's	27 Dec to 30 Dec 1990
15-Dec-1965		19 Nov to 8 Dec 1965	19-Dec-1991		20 Dec to 27 Dec 1991
19-Dec-1966		8 Nov to 6 Dec 1966	6-Dec-1992		13 Dec to 14 Dec 1992
29-Nov-1967		17 Nov to 5 Dec 1967	16-Dec-1993		17 Dec to 28 Dec 1993
10-Dec-1968		25 Nov to 5 Dec 1968	2-Jan-1995		7 Jan to 10 Jan 1995
9-Dec-1969		15 Nov to 10 Dec 1969	7-Dec-1995		13 Dec to 16 Dec 1995
15-Dec-1970	1970's	Completed 15 Dec 1970*	4-Dec-1996		8 Dec to 11 Dec 1996
25-Dec-1971		3 Dec to 10 Dec 1971	13-Dec-1997		17 Dec to 18 Dec 1997
11-Dec-1972		11 Dec to 18 Dec 1972	1-Jan-1999		2 Jan to 9 Jan 1999
7-Jan-1974		19 Dec 1973 to 9 Jan 1974	27-Dec-1999		19 Dec to 29 Dec 1999
10-Dec-1974		11 Dec to 30 Dec 1974	18-Dec-2000	2000's	16 Dec to 28 Dec 2000
20-Dec-1975		24 Dec 1975 to 8 Jan 1976	27-Dec-2001		17 Dec to 22 Dec 2001
24-Dec-1976		30 Nov to 18 Dec 1976	3-Dec-2002		11 Dec to 12 Dec 2002
8-Dec-1977		13 Dec to 31 Dec 1977	15-Dec-2003		16 Dec to 20 Dec 2003
11-Dec-1978		Completed 19 Dec 1978*	20-Dec-2004		17 Dec to 20 Dec 2004
17-Nov-1979		Completed 22 Dec 1979*	9-Dec-2005		14 Dec to 15 Dec 2005
14-Dec-1980	1980's	22 Dec to 30 Dec 1980	19-Jan-2007		18 Dec to 19 Dec 2006
11-Dec-1981		19 Dec to 23 Dec 1981	9-Dec-2007		13 Dec to 17 Dec 2007
4-Jan-1982		6 Jan to 8 Jan 1983	5-Dec-2008		10 Dec to 11 Dec 2008
18-Dec-1983		19 Dec to 21 Dec 1983	12-Dec-2009		17 Dec to 19 Dec 2009
26-Dec-1984		27 Dec to 30 Dec 1984	8-Dec-2010	2010's	12 Dec to 16 Dec 2010
17-Dec-1985		20 Dec to 21 Dec 1985	28-Dec-2011		17 Dec to 18 Dec 2011
15-Dec-1986		16 Dec to 17 Dec 1986	28-Dec-2012		18 Dec to 20 Dec 2012
19-Dec-1987		19 Dec to 26 Dec 1987	10-Dec-2013		14 Dec to 16 Dec 2013
12-Nov-1988		12 Dec to 17 Dec 1988	5-Dec-2014		15 Dec to 16 Dec 2014
6-Dec-1989		7 Dec to 8 Dec 1989	6-Jan-2016		16 Dec to 28 Dec 2015

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.
* Starting date unknown.

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	No Data Collected			21-Mar	27-Mar
1966				20-Mar	1-Apr
1967				22-Mar	29-Mar
1968				8-Mar	20-Mar
1969				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	980	300	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	160	60	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
2014	28-Apr	622	240	29-Apr	7-May
2015	19-Apr	218	84	20-Apr	25-Apr
2016	Ice-free			8-Mar	23-Mar

Table 6: Estimated Power Losses In MW-hours 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
1999-00	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	31,800
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	15,500	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
2013-14	0	93,300	0	0	0	0	93,300
2014-15	0	32,800	6,200	0	0	0	39,000
2015-16	0	0	10,500	0	0	0	10,500

*No Data Published
Note: No Data available for period 1964-74.

Table 7: Ice Boom and Welland Canal Opening Dates*

	Opening Date				Opening Date		
Year	Ice Boom Start**	Ice Boom Completed	Welland***	Year	Ice Boom Start**	Ice Boom 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	21-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	30-Mar	2013	25-Mar	28-Mar	22-Mar
1979	13-Apr	17-Apr	28-Mar	2014	29-Apr	7-May	28-Mar
1980	2-Apr	7-Apr	24-Mar	2015	20-Apr	25-Apr	2-Apr
1981	18-Apr	22-Apr	25-Mar	2016	8-Mar	23-Mar	21-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				
1965-2016	3-Apr	7-Apr	28-Mar	Average for post-ice boom period			
1970-2016	5-Apr	9-Apr	28-Mar	Average for the flexible boom opening period			

1970 commencement of a flexible date for boom openings.
*For years that ice boom has been in operation.
**Denotes opening of first boom span. Mobilization time precedes this date. Total time for removal is dependent on wind, wave and other safety considerations for removal crews.
*** 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 km (36 mi) in length, is the natural outlet from Lake Erie to Lake Ontario (Enclosure 3). The elevation difference between the two lakes is about 99 m (326 ft); and about half of this occurs at Niagara Falls. Over the period 1860-2015, the average Niagara River flow at Queenston, Ontario has been 5857 m^3/s (206,852 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 km^2 (264,000 mi^2). Enclosure 2 shows a detailed 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 km (22 mi) from Lake Erie to the Cascade Rapids, which begin 1 km (0.6 mi) upstream from the Horseshoe Falls. From Lake Erie to Strawberry Island, a distance of approximately 8 km (5 mi), the channel width varies from 2,740 m (9,000 ft) at its funnel-shaped entrance to 460 m (1,500 ft) at Unity Island below the Peace Bridge. The fall over this reach is around 1.8 m (6 ft). In the upper 3.2 km (2 mi) of the river, the maximum depth is approximately 6 m (20 ft), with velocities as high as 3.7 m/s (12 ft/s) in the vicinity of the Peace Bridge. Below Unity Island, the river widens to approximately 610 m (2,000 ft), 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 km (11 mi) in length and varies from 610 to 1,220 m (2,000 to 4,000 ft) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 ft/s). The Chippawa Channel carries approximately 60 percent of the total river flow. The Tonawanda Channel is 24 km (15 mi) long and varies from 460 to 610 m (1,500 to 2,000 ft) in width above Tonawanda Island. Downstream thereof, the channel varies from 460 to 1,220 m (1,500 to 4,000 ft) 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 km (3 mi) long Chippawa-Grass Island Pool (CGIP). At the downstream end of the CGIP is the International Niagara Control Works (INCW). 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 m (4,500 ft) downstream of the structure. The average fall from Lake Erie to the CGIP is 2.7 m (9 ft).

(b) Niagara Cascades and Falls

Below the INCW, the river falls 15 m (50 ft) 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 (Enclosure 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 m (188 ft). Minimum Falls flow for tourist hours is 2,832 m^3/s (100,000 cfs), which results in a fall of about 54 m (177 ft). 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 m (70 to 100 ft), to a talus slope at its base.

(c) Lower Niagara River

The Niagara Gorge extends from the Falls for 11 km (7 mi) 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 (M-O-M Pool), with an average fall of approximately 1.5 m (5 ft). This reach is navigable for practically its entire length. The M-O-M Pool is bounded downstream by the Whirlpool Rapids, which extends a further 1.6 km (1 mi). The water surface profile drops 15 m (50 ft) in the Whirlpool Rapids, where velocities can reach as high as 9 m/s (30 ft/s). The Whirlpool, a basin 518 m (1,700 ft) long, 365 m (1,200 ft) wide and depths up to 38 m (125 ft), is where the river makes a near right-angled turn. Below the Whirlpool, there is another set of rapids which drop approximately 12 m (40 ft). The river emerges from the gorge at Queenston, Ontario and subsequently drops 1.5 m (5 ft) to Lake Ontario. At Queenston, the river widens to 610 m (2,000 ft) 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 (Enclosure 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 CGIP and return it to the lower Niagara River at Queenston, Ontario and Lewiston, New York, respectively. (Enclosure 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 defined as 8:00 a.m. to 10:00 p.m. local time from 1 April to 15 September and 8:00 a.m. to 8:00 p.m. local time from 16 September to 31 October. 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 Enclosure 2.

Remedial works were constructed by the Power Entities in the 1950's, with the approval of the International Joint Commission (IJC), 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 INCW structure extending about 0.8 km (0.5 mi) into the river from the Canadian shore at the downstream end of the CGIP. The INCW has 13 gates that were completed in 1957 and 5 additional gates which were completed in 1963. The INCW is operated jointly by the Power Entities and regulates the water level in the CGIP 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 vice- versa during the tourist season. In 1964, with the IJC's approval, the Power Entities installed a floating ice boom in Lake Erie, near the head of the Niagara River. The ice 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 Unity 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 Unity Island at the downstream end. The Black Rock Lock, which has a lift of 1.5 m (5 ft), is located near the lower end of the canal. A navigation channel extends from Unity Island via the Tonawanda Channel to Niagara Falls, New York. The channel and canal are maintained to a depth of 6.4 m (21 ft) below low water datum to North Tonawanda and then to a depth of 3.7 m (12 ft) 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 km (1.5 mi) 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 CGIP. 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 CGIP and ice breaker activity is necessary to facilitate ice passage. Ice accumulations in the M-O-M Pool may pose potential hazards to the boat tour companies' 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 M-O-M Pool, have occasionally damaged these facilities.

Appendix B – Background Information on the Ice Boom

B.1 Authorization for Placement of the Ice Boom

The IJC 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 IJC when circumstances require, but no less than once every five years. The most recent review was completed in 2014. 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 by 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 December 16 or prior to the water temperature at the Buffalo Water intake reaching 4º C (39º 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 mi^2 (650 km^2) 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 mi^2 (650 km^2). Complete disassembly and removal of all remaining flotation equipment shall be completed within two weeks thereafter. Notwithstanding 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 Enclosure 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 arch 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 m (8,800 ft) ice boom spans the outlet of Lake Erie and is located approximately 300 m (1,000 ft) 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 m (400 ft) intervals by 6.4 cm (2.5 in) diameter steel cables. Enclosure 5 illustrates structural details and a plan view of the ice boom is shown in Enclosure 6. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 cm (30 in) diameter, 9 m (30 ft) 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.

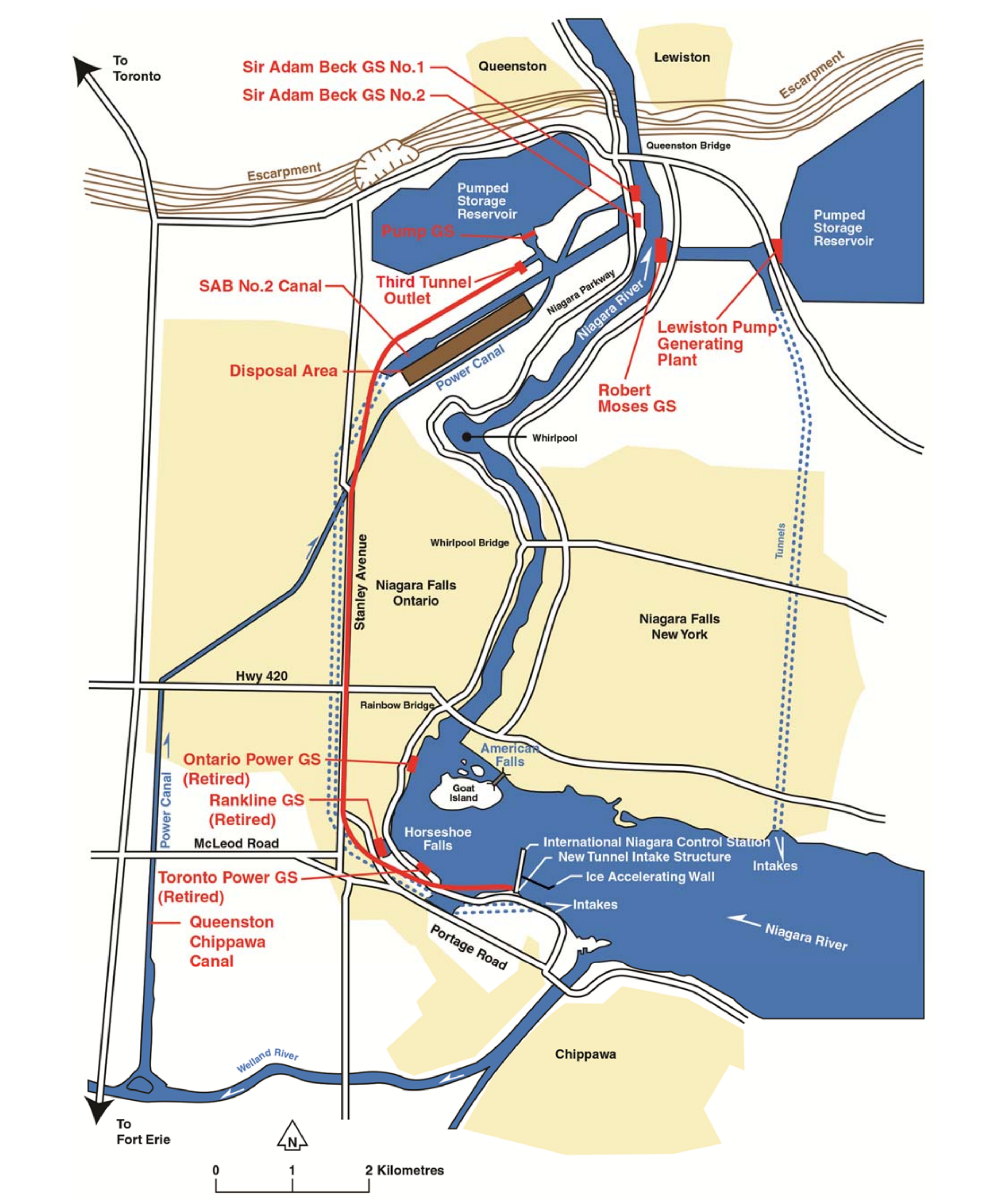
To further reduce the pontoon end cap damage and reduce the fatigue of the span cables between the inner and outer break walls (i.e. Spans A through D), the number and length of pontoons were changed to sixteen 4.6 m (15 ft) long mini pontoons per 152 m (500 ft) span, during the 2000-01 ice season. As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

Enclosure 6 shows the plan view of the ice boom on Lake Erie. Enclosure 7 shows the span configuration using the typical 9 m (30 ft) pontoon and the 4.6 m (15 ft) mini pontoons.

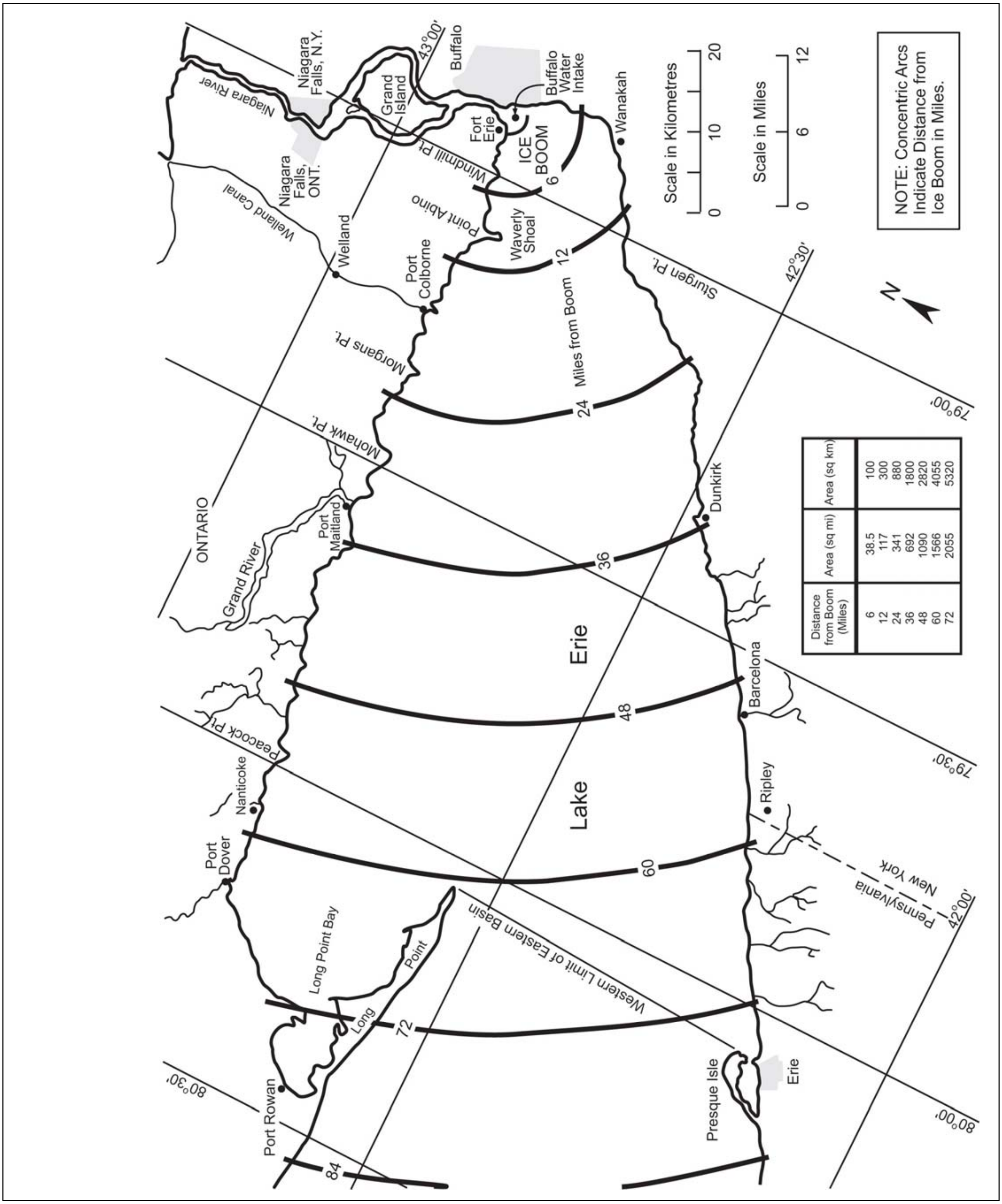
Notes

Enclosure 1: Great Lakes – St. Lawrence Drainage Basin

Enclosure 2: Niagara River Water Level Gauge Locations

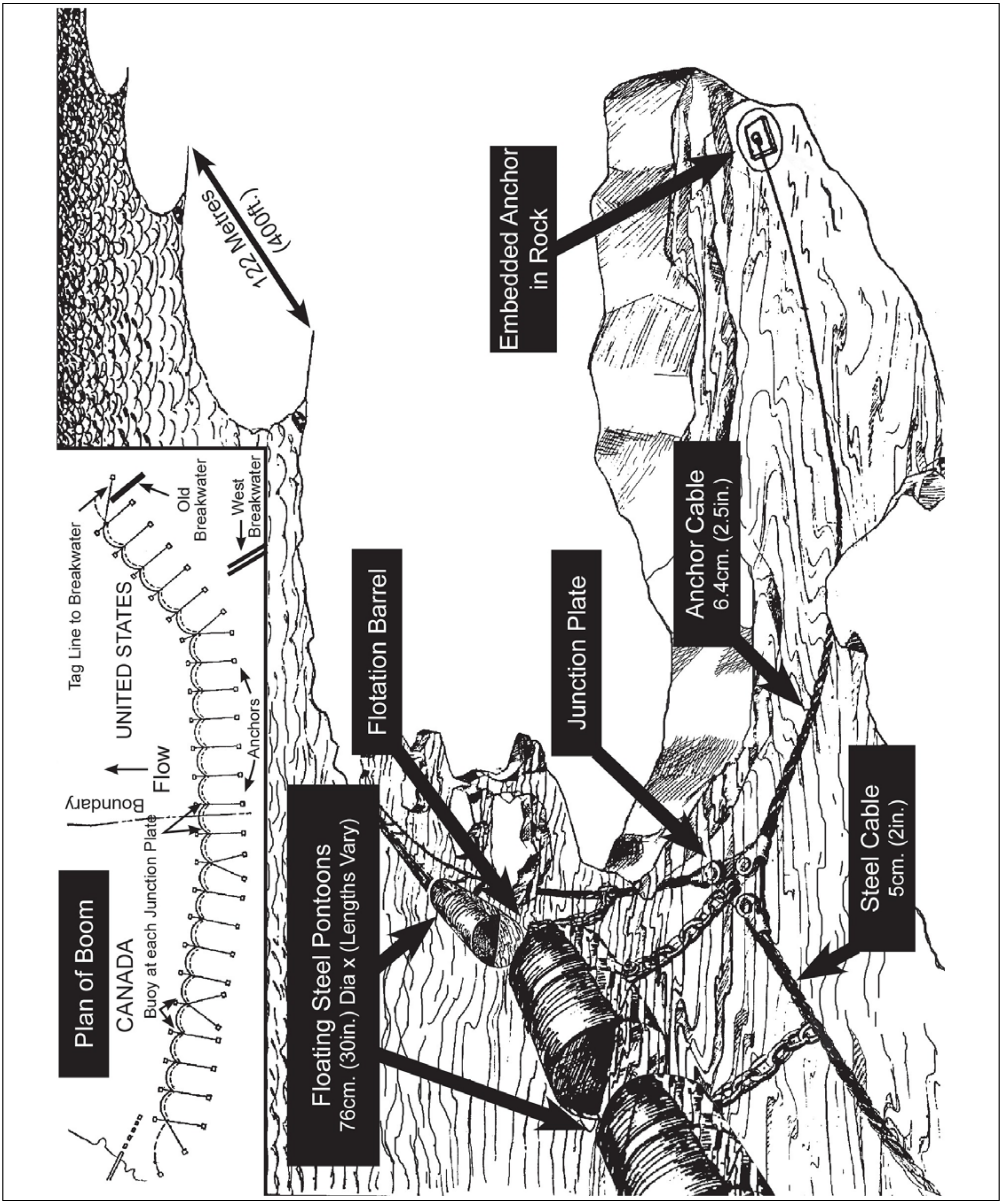


Enclosure 3: NYPA and OPG Power Projects

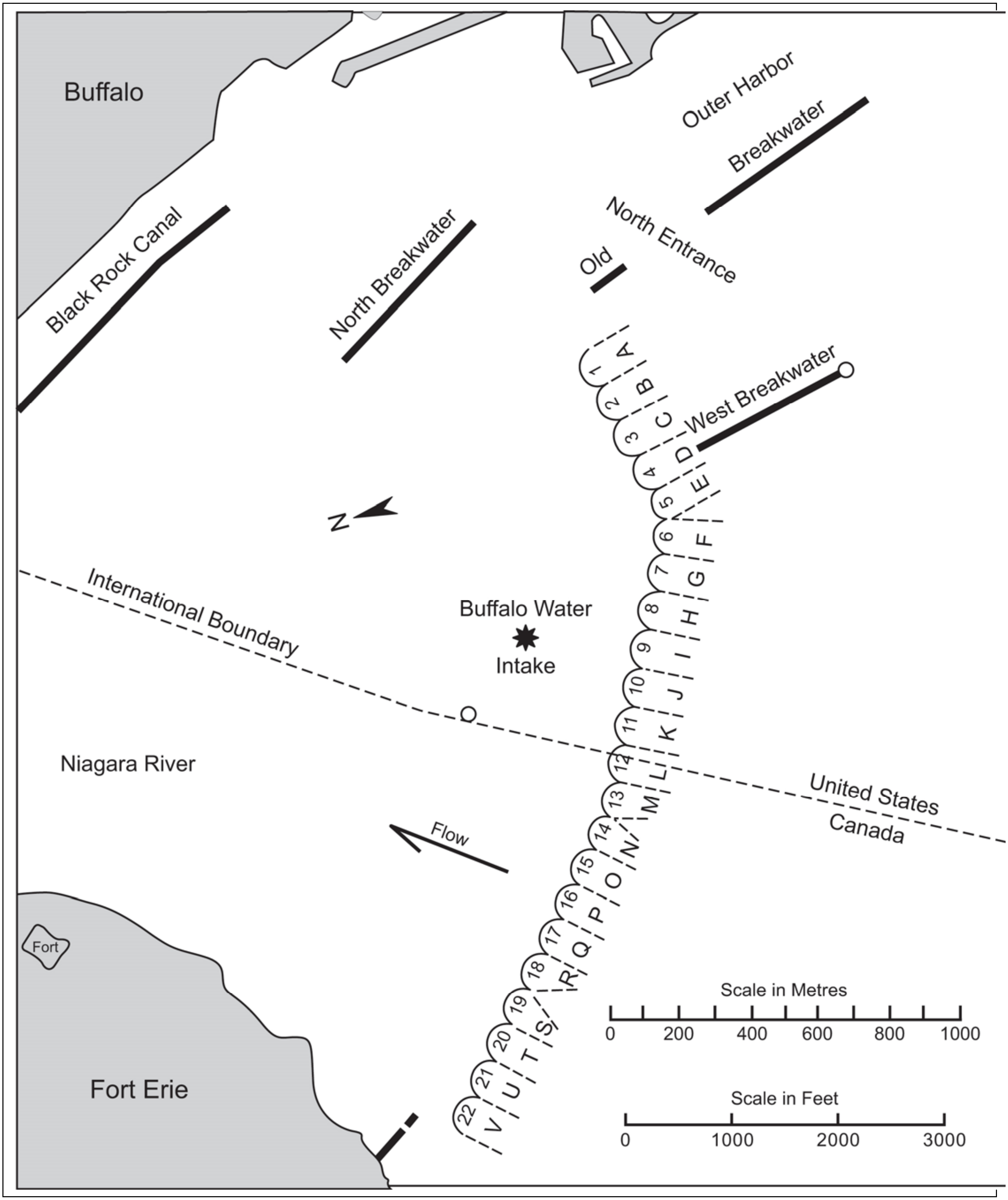


Distance from Boom (Miles)	Area (sq mi)	Area (sq km)
6	38.5	100
12	117	300
24	341	880
36	692	1800
48	1090	2820
60	1566	4055
72	2055	5320

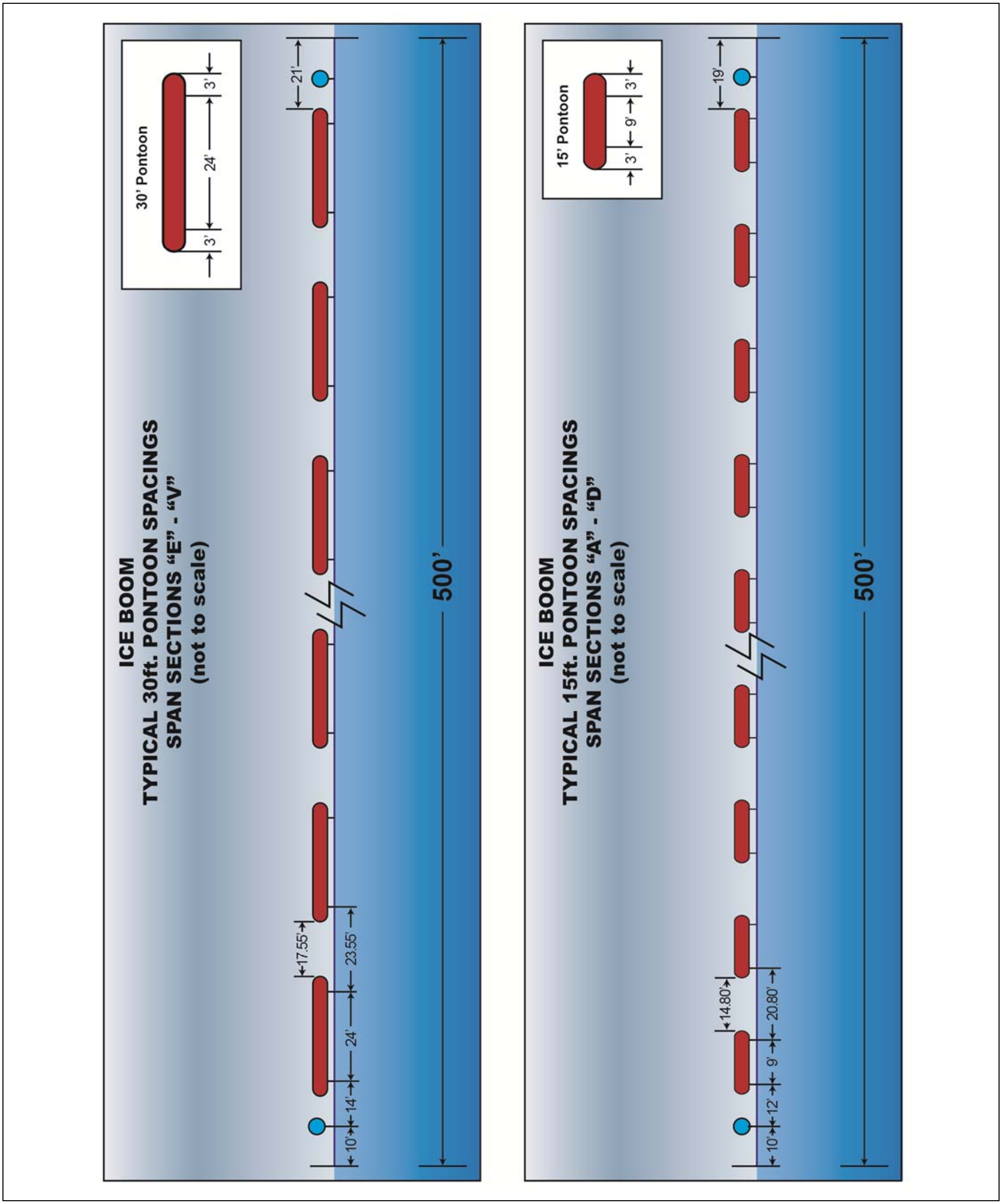
Enclosure 4: Map of Eastern End of Lake Erie



Enclosure 5: Ice Boom Detail



Enclosure 6: Plan View of Ice Boom



Enclosure 7: Typical Pontoon Spacing and Lengths

Notes