2014 – 2015 Operation of the Lake Erie – Niagara River Ice Boom

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

September 2015

Report to
The International Niagara Board of Control
On The 2014–15 Operation of
The Lake Erie–Niagara River Ice Boom

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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 hydro power production and reduces ice damages to shoreline property. The Power Entities, New York Power Authority (NYPA) and Ontario Power Generation (OPG) are authorized to use the ice boom by the International Joint Commission (IJC) with its International Niagara Board of Control (the Board) overseeing its installation, operation and removal. This report is prepared by the Board's International Niagara Working Committee (INWC) based on information provided by the Power Entities and information collected by the INWC to inform the Board of operation of the ice boom in the 2014-15 ice season. Further description of the Lake Erie – Niagara River system can be found in Appendix A.

2. HIGHLIGHTS

Western New York experienced below average temperatures from November 2014 through April 2015, making the winter of 2014–2015 one of the coldest in the region's recorded history for the second year in a row, with February being the coldest month on record for the City of Buffalo.

The Lake Erie water temperature, as measured at the Buffalo Water Intake, was 3.9°C (39°F) on 5 December 2014, satisfying the criteria for start of boom installation. The installation of the ice boom's 22 spans began on Lake Erie on 15 December 2014 and was completed by 16 December 2014.

A thick lake ice cover formed behind the ice boom during the 2014–15 ice season. The ice cover on Lake Erie peaked during the first week of March, covering nearly 98% of Lake Erie's surface area.

On 9 January 2015, the NYPA were made aware of possible breaks in the ice boom. An ice boom inspection was performed on 12 January 2015 revealing spans D, E, J, K and M were either trailing or broken. Repairs to the ice boom began on 12 January 2015 and were completed on 18 January 2015.

The INWC conducted two helicopter flights to measure ice thickness during the winter. The INWC also used satellite images and two fixed-wing flights in order to observe the ice conditions during the 2014–15 ice season and to ensure removal of the ice boom was in accordance with the Ice Boom Order of Approval. Removal of the Lake Erie Ice Boom began on 20 April 2015, the day after INWC members conducted the final fixed-wing ice flight of the season. The final spans of the ice boom were removed and tied off to the Buffalo break wall on 25 April 2015. They were then pulled onto shore on 6 May 2015 ending the 2014–15 ice boom season. In response to public concern on timing of ice boom removal and INWC efforts to monitor Lake Erie ice cover, regular updates were provided on the Board's website at 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 2014-2015, 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 2014 through April 2015, as measured by the National Weather Service at the Buffalo Niagara International Airport, are displayed in Table 1.

During the month of November 2014 the Buffalo/Niagara region was hit by several cold air masses that caused a historic lake effect snow event. Persistent storms throughout a five day period dumped over 2 m (7.5 ft) of snow in some parts of the region. Air temperatures for the Niagara region in the month of November were 1.6°C (2.9°F) degrees below average.

Air temperatures for the Niagara region in the month of December were 1.9°C (3.4°F) degrees above average. Snowfall was minimal and 75% of total precipitation for the month was contributed by rainfall.

The new year began with an arctic air mass dipping into the Eastern Great Lakes region bringing with it lake effect snow. By mid-January temperatures returned to near normal with typical light snowfalls. The cold air returned at the end of January with consistent temperatures below -12.2°C (10°F). The average temperature for the month was 2.5°C (4.5°F) below the Long Term Average (LTA) for the month.

February 2015 was the coldest month in the region's recorded history, and with 117 cm (46.2 in) of snow it was the third snowiest February on record. The average temperature for the month was -11.7°C (10.9°F), which is 8.5°C (15.4°F) below average. The cold weather continued into March with temperatures well below normal during the first and last week of the month. On 6 March, a reading of -18.4°C (-1.0°F) set a record daily low. Average air temperatures for March were 2.6°C (4.8°F) below average. A slow warming allowed for a manageable snowmelt following a harsh winter with temperatures well below normal.

Following a bitterly cold record breaking winter, April arrived bringing more seasonal temperatures to Western New York. On 2 April, a warm front lifted across New York State and brought the first taste of spring to the area. The average temperature for the month of April was 7.7°C (45.8°F), which was slightly lower than normal. By mid-April, a ridge of high pressure allowed temperatures to reach 25.5°C (78°F). The total snowfall from November 2014 to April 2015 was 286 cm (112.9 in) as recorded at the Buffalo Niagara International Airport, which was 46 cm (18.2 in) above normal. The average temperature for the six-month period was 2.2°C (4.0°F) below the long-term average.

The daily Lake Erie water temperatures, as measured at the Buffalo Water Intake, for the period December 2014 through May 2015 are provided in Table 2. By early January 2015, Lake Erie water temperatures had dipped to 0°C (32°F) and held steady until 9 April 2015.

The first ice of the season was observed in the Grass Island Pool on 6 January 2015. On 9 January 2015, noticeable ice began to form in the Maid-of-the-Mist-Pool (MOMP) just below the falls. By 14 January 2015, a complete ice bridge had formed in the MOMP. As shown in Figure 1, ice cover on Lake Erie peaked during the first week of March, covering nearly 98% of Lake Erie's surface area, as compared to the average peak coverage of 71% that usually occurs during the second week of February. The extent of the coverage was reduced to below 2% by 23 April 2015.

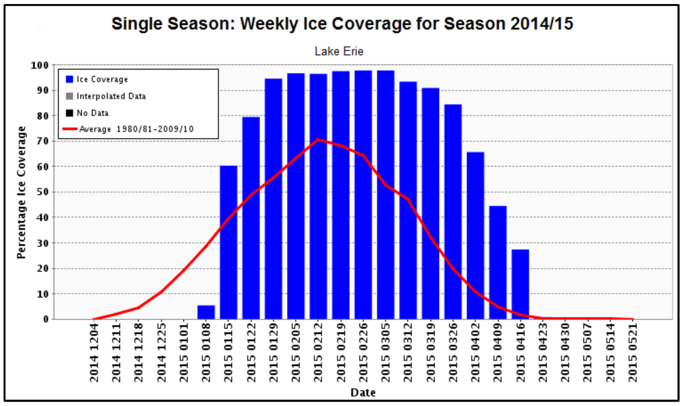


Figure 1: Single Season: Weekly Ice Coverage for 2014/15 provided by the Canadian Ice Service

The Canadian Ice Service reported that very thick ice covered Lake Erie for a majority of the 2014–15 ice season. Helicopter flights to gather ice thickness data were performed on 13 February and 13 March 2015. Figures 2 and 3 show the depth of ice measured at six measurement sites. A fixed-wing ice observation flight to determine the extent of ice cover over the eastern part of Lake Erie was performed on 15 April 2015. The flight showed 2,176 km^2 (840 mi^2) of ice coverage on the eastern end of the lake. A second fixed-wing ice observation flight occurred on 19 April 2014. This flight revealed that only 218 km^2 (84 mi^2) of eastern lake ice remained. From 24 March 2015 to 19 April 2015, satellite imagery from the National Oceanic and Atmospheric Administration (NOAA) and the Canadian Ice Service was also used to monitor the extent of ice cover.

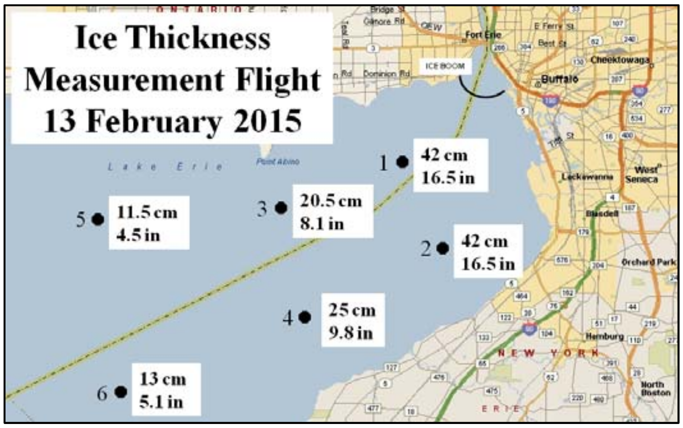


Figure 2: Ice Thickness Measurements Flight, 13 February 2015

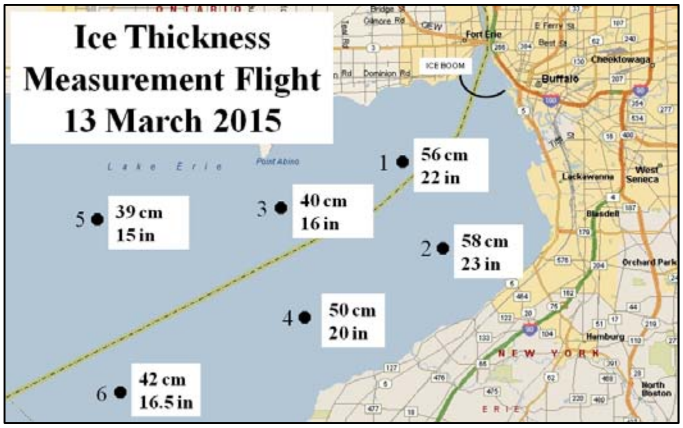


Figure 3: Ice Thickness Measurements Flight, 13 March 2015

Based on available satellite-based imagery and information provided by the Canadian Ice Service the date of last ice was determined as 20 April 2015. Historical dates of last ice can be seen in Table 3.

MODIS Satellite Imagery from the U.S. National Oceanic and Atmospheric Administration (NOAA) Coast Watch Great Lakes Program, 5 February 2015

MODIS Satellite Imagery from the (NOAA) Coast Watch Great Lakes Program, 2 March 2015

MODIS Satellite Imagery from the (NOAA) Coast Watch Great Lakes Program, 12 April 2015

4. OPERATION OF THE ICE BOOM DURING THE 2014–15 ICE SEASON

The following sections provide a description of key operations of the ice boom in the 2014-15 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 system is used to monitor the ice boom. The web cam and the information on the ice boom is available at:

www.iceboom.nypa.gov

Phase 1 of the ice boom installation (raising of the junction plates and attaching of the floatation buoy barrels) was set to begin on 3 December 2014. However, high winds and rough waters created unsafe conditions. On 4 December 2014 the ice boom crew installed 12 of the 23 junction plate buoy barrels, completing just over half of Phase 1. The remaining eleven 11 junction plate buoy barrels were installed on the following day, 5 December 2014, completing Phase 1 of the Lake Erie-Niagara River Ice Boom installation. From 6 to 12 December 2014, boom spans were pulled 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 were placed inside the Buffalo Harbor breakwall, completing Phase 2 of the boom's 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 Lake Erie water temperature was 3.9°C (39°F) on 23 November 2014 as a result of the aforementioned historic lake effect snow event, but was back up to 6.1°C (43°F) the very next day. This event was considered an anomaly by the INWC and installation of the ice boom was not initiated. Lake Erie's water temperature again reached 3.9°C (39°F) on 5 December 2014. The Board issued a media advisory on 12 December 2014, indicating that Phase 3 of the ice boom installation was scheduled to begin on 15 December 2014, following the completion of Phases 1 & 2. Installation began on schedule and ice boom crews were able to install 8 spans (Spans O through V) on the Canadian side (refer to Enclosure 6 for span layout).

On 16 December 2014 the remaining 14 Spans (N through I) were installed to complete the installation of the ice boom for the season.

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 5 December 2014.

4.2 Ice Boom Operation

By the beginning of January an ice arch began to form behind the ice boom. On 9 January 2015, the NYPA was made aware of potentially broken spans along the ice boom. A field inspection was conducted by the NYPA on 12 January 2015 from the B-1 Ice Breaker confirming that spans D, E, J, K and M had broken and were trailing. On 14 January, the ice boom crew began repairs by clearing ice from the leading edge of the boom in order to expose the buoy barrels and hardware. During this operation the B-1 Breaker lost a rudder shaft and required repairs before it could be further utilized. No repairs to the boom were able to be made until the ice breaker, the William H. Latham, was able to clear a path through the Buffalo River allowing access for the barge and tug to reach Lake Erie and the ice boom on 16 January. Working diligently through the weekend the ice boom crew successfully re-connected the trailing spans D, E, J, K and M by splicing them. The entire boom was back in service 18 January 2015. No buoy barrels or pontoons were lost during repair operations and no ice issues were identified in the Niagara River.

On 11 March 2015 a partial inspection of the ice boom was undertaken by the William H. Latham icebreaker. The ice boom was found to be encapsulated in ice due to significant ice build-up. In order to prevent breaks in the boom due to ice pressure, the ice breaker was used to free the leading edge and create stress cracks in the ice by nosing into it, allowing the ice boom hardware to break free of the encapsulating ice.

On 12 March 2015 the William H. Latham was once again employed for ice boom operations, nosing it into the leading edge of the ice encapsulated boom to create stress relief cracks.

4.3 Ice Boom Opening

Two helicopter flights to measure ice thickness on the eastern end of Lake Erie occurred this ice season. The flights provided valuable information on ice conditions for operation of the boom. The first helicopter flight occurred 13 February 2015. The average thickness of the six sites sampled during the flight was 26 cm (10 in). The second helicopter flight occurred 13 March 2015. The average ice thickness observed was 48 cm (19 in). This was the sixth highest average thickness since the helicopter flights were first done in 1984; the highest average was 96 cm (38 in) on 16 February 1985.

MODIS images from the first week of March showed ice coverage to be near 98 percent on the eastern end of Lake Erie. The Board advised the Commission on 25 March 2015 that the extent of ice cover would likely cause a delay in the ice boom opening beyond 1 April and issued a media advisory on 26 March 2015.

A fixed wing ice observation flight that occurred on 15 April 2015 revealed 2176 km^2 (840 mi^2) of ice remained on the eastern end of Lake Erie. After warming temperatures over the following week, MODIS satellite imagery showed that large dense ice packs had broken up and the thin surface ice had dissipated.

Fixed Wing Ice Observation Flight, 15 April 2015

Another ice survey flight on 19 April 2015 revealed that 218 km^2 (84 mi^2) of ice remained on the eastern basin of Lake Erie. Considering the amount of ice remaining and the absence of ice in the MOMP below Niagara Falls, the Board issued a Media Advisory on 20 April 2015 that preparations for the boom opening were underway.

Fixed Wing Ice Observation Flight, 19 April 2015

Ice boom crews began Phase 1 of the ice boom removal by removing three spans on 20 April 2014. Spans A, B and C on the U.S. side were removed and tied to the break wall. On 21 April 2015, Phase 1 came to a halt as high winds created unsafe working conditions. The high winds lasted over the next few days creating 1.2 to 1.5 m (4 to 5 ft) waves on 22 and 23 April 2015. On the morning of 24 April 2015, the waves had subsided, allowing crews to resume work. Spans S, T, U and V from the Canadian side were moved and secured to the break wall. The winds picked up again for the afternoon creating waves and making working conditions unsafe. Thus far 7 of 22 spans had been removed. Crews removed the remaining 15 spans on 25 April 2015 and secured them to the break wall. This completed Phase 1 of the ice boom removal.

Phase 2 was initiated on 27 April 2015 beginning with the removal of 11 out of 23 buoy barrels. After removing 1 buoy barrel on 28 April 2015, work was interrupted by high waves creating hazardous working conditions leaving 11 buoy barrels yet to be removed from Lake Erie. On 29 April, ice boom crews proceeded to complete Phase 2 of the ice boom removal by removing the remaining 11 buoy barrels. NYPA informed the INWC and both the US and Canadian Coast Guards that the boom was open.

Phase 3 of the ice boom removal began on 30 April 2015 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. Five spans were towed up the Buffalo River and pulled on shore the first day. On 1 May 2015 ice boom crews towed another 4 spans to the maintenance facility bringing the total to 9 out of 22 working spans on shore, with the addition of 2 spare spans at the U.S. Coast Guard (USCG) station. Ice boom removal work resumed on 4 May 2015 with spans towed onto shore after heavy fog delayed removal in the morning. Heavy fog enveloped the lakeshore on 5 May 2015 but crews were able to retrieve the 2 spare spans from the USCG station. That afternoon crews were able to retrieve 3 more spans from the break wall. The final 5 spans were pulled onto the Katherine Street storage site on 6 May 2015, marking the end of the 2014–15 ice-boom season. The IJC was informed that the 2015 removal operations were complete on 7 May 2015. 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 DURINGTHE 2014-15 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 of the ice boom or where ice floes are 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 39,000 MWh loss of hydroelectric power generation due to ice during the 2014–15 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 in the Event of Ice-Affected Flooding on the Upper Niagara River (FWNP) was tested on 3 December 2014. A drill was conducted that simulated a flood event along the U.S. shoreline in the vicinity of the North Grand Island Bridge, which was triggered by a postulated ice stoppage and jam between NYPA's intakes and the Buckhorn dikes, downstream of the North Grand Island Bridge.

Activation of the FWNP was not required in the 2014-2015 ice season.

5.3 Navigation at the Welland Canal

The Welland Canal opened to commercial shipping this season on 2 April 2015 for its 186th consecutive year of service. This marks the first time since 1997 that the Welland Canal opening has been pushed to April. A comparison of the dates of boom opening and the commencement date of navigation at the Welland Canal for the period 1965 to 2015 is shown in Table 7.

6. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Findings and Conclusions

Western New York experienced below average temperatures from November 2014 through April 2015, with February being the coldest month on record. The winter of 2014-15 was one of the coldest in the regions history. This cold weather resulted in heavy ice conditions on Lake Erie and the Niagara River for 2014-15.

On 9 January 2015 the NYPA was informed of a possible break in the ice boom which was subsequently repaired during the following week.

On 11 March 2015 the ice breaker William.H.Latham was used to create stress cracks in the ice by nosing into it allowing the ice boom hardware to break free of the encapsulating ice.

The two helicopter-based (for ice thickness measurements) and two fixed-wing (for lake ice area assessment) flights conducted by members and associates of the Board's Working Committee during the winter of 2014–15, supplemented by ice information available from satellite imagery, were adequate to make decisions on the operation and removal of the ice boom.

6.2 Recommendations for the 2015–16 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 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 2014-15**	**Departure**	**Average* 1981-2010**	**Recorded 2014-15**	**Departure**
Nov. 2014	4.8	3.2	-1.6	40.7	37.8	-2.9
Dec. 2014	-1.1	0.8	1.9	30.1	33.5	3.4
Jan. 2015	-3.9	-6.4	-2.5	24.9	20.4	-4.5
Feb. 2015	-3.2	-11.7	-8.5	26.3	10.9	-15.4
Mar. 2015	1.1	-1.6	-2.6	34.0	29.2	-4.8
Apr. 2015	7.7	7.7	0.0	45.9	45.8	-0.1
Average	0.9	-1.3	-2.2	33.7	29.6	-4.0

* 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 2014 - May 2015)

Month	**December**		**January**		**February**		**March**		**April**		**May**	
Date	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**
1	4.4	40	2.8	37	0.0	32	0.0	32	0.0	32	3.9	39
2	4.4	40	1.1	34	0.0	32	0.0	32	0.0	32	3.9	39
3	4.4	40	1.1	34	0.0	32	0.0	32	0.0	32	4.4	40
4	4.4	40	2.2	36	0.0	32	0.0	32	0.0	32	5.0	41
5	3.9	39	2.2	36	0.0	32	0.0	32	0.0	32	5.6	42
6	5.6	42	1.1	34	0.0	32	0.0	32	0.0	32	5.6	42
7	5.0	41	1.1	34	0.0	32	0.0	32	0.0	32	5.6	42
8	5.0	41	0.6	33	0.0	32	0.0	32	0.0	32	5.6	42
9	4.4	40	0.6	33	0.0	32	0.0	32	0.0	33	7.2	45
10	5.0	41	0.0	32	0.0	32	0.0	32	0.0	33	5.6	42
11	3.9	39	0.0	32	0.0	32	0.0	32	0.0	33	10.6	51
12	3.9	39	0.0	32	0.0	32	0.0	32	0.0	32	6.7	44
13	3.3	38	0.0	32	0.0	32	0.0	32	0.0	32	11.7	53
14	3.3	38	0.0	32	0.0	32	0.0	32	0.0	32	11.1	52
15	3.9	39	0.0	32	0.0	32	0.0	32	0.0	32	10.0	50
16	3.9	39	0.0	32	0.0	32	0.0	32	0.0	32	9.4	49
17	4.4	40	0.0	32	0.0	32	0.0	32	0.6	33	11.7	53
18	3.3	38	0.0	32	0.0	32	0.0	32	1.1	34	12.2	54
19	3.9	39	0.0	32	0.0	32	0.0	32	1.1	34	12.8	55
20	3.3	38	0.0	32	0.0	32	0.0	32	1.7	35	13.3	56
21	3.9	39	0.0	32	0.0	32	0.0	32	2.2	36	12.2	54
22	3.9	39	0.0	32	0.0	32	0.0	32	2.2	36	12.8	55
23	3.9	39	0.0	32	0.0	32	0.0	32	2.8	37	12.8	55
24	3.9	39	0.0	32	0.0	32	0.0	32	2.2	36	12.2	54
25	3.9	39	0.0	32	0.0	32	0.0	32	2.2	36	13.3	56
26	2.8	37	0.0	32	0.0	32	0.0	32	2.2	36	13.3	56
27	2.8	37	0.0	32	0.0	32	0.0	32	2.2	36	13.3	56
28	3.9	39	0.0	32	0.0	32	0.0	32	2.8	37	13.3	56
29	3.3	38	0.0	32			0.0	32	3.3	38	15.0	59
30	3.3	38	0.0	32			0.0	32	3.9	39	15.0	59
31	3.3	38	0.0	32			0.0	32			15.6	60
Average:	4.0	39	0.4	33	0	32	0.0	32	1.0	34	10.0	50
Hi:	5.6	42	2.8	37	0	32	0.0	32	3.9	39	15.6	60
Low:	2.8	37	0.0	32	0	32	0.0	32	0.0	32	3.9	39

* 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	1942	30-Apr	1979	3-May
1906	22-Apr	1943	20-May	1980	23-Apr
1907	30-Apr	1944	15-Apr	1981	30-Apr
1908	9-May	1945	9-Apr	1982	20-May
1909	26-Apr	1946	No data	1983	23-Feb
1910	30-Apr	1947	No data	1984	25-Apr
1911	6-May	1948	No data	1985	1-May
1912	29-Apr	1949	No data	1986	26-Apr
1913	30-Apr	1950	No data	1987	9-Mar
1914	28-Apr	1951	15-Apr	1988	27-Apr
1915	2-May	1952	27-Mar	1989	9-Apr
1916	11-May	1953	Ice-free	1990	10-Apr
1917	30-Apr	1954	27-Mar	1991	28-Mar
1918	20-Apr	1955	5-Apr	1992	15-Apr
1919	15-Mar	1956	20-Apr	1993	16-Apr
1920	20-May	1957	11-Mar	1994	1-May
1921	14-Mar	1958	10-Apr	1995	18-Apr
1922	11-Apr	1959	8-May	1996	6-May
1923	16-May	1960	5-May	1997	29-Apr
1924	20-Apr	1961	15-Apr	1998	Ice-free
1925	26-Apr	1962	30-Apr	1999	2-Apr
1926	31-May	1963	11-May	2000	28-Mar
1927	9-Apr	1964	27-Apr	2001	27-Apr
1928	19-May	1965*	14-May	2002	Ice-free
1929	2-May	1966	27-Apr	2003	22-Apr
1930	7-May	1967	13-Apr	2004	30-Apr
1931	7-Apr	1968	4-May	2005	11-Apr
1932	21-Apr	1969	26-Apr	2006	5-Apr
1933	23-Apr	1970	30-Apr	2007	29-Apr
1934	23-Apr	1971	31-May	2008	23-Apr
1935	13-Apr	1972	5-May	2009	16-Apr
1936	31-May	1973	15-Mar	2010	29-Mar
1937	14-Apr	1974	6-Apr	2011	24-Apr
1938	14-Apr	1975	8-Apr	2012	Ice-free
1939	14-May	1976	19-Apr	2013	9-Apr
1940	19-May	1977	13-May	2014	8-May
1941	21-Apr	1978	14-May	2015	20-Apr

* 1965 First year ice boom used.

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 Jan to 14 Jan 1993
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*	1-Jan-1999		2 Jan to 9 Jan 1999
25-Dec-1971		30 Nov to 10 Dec 1971	27-Nov-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	5-Dec-2008		10 Dec to 11 Dec 2008
11-Dec-1981		19 Dec to 23 Dec 1981	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			

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	1-Apr	1220	470	18-Apr	22-Apr
1982	1-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-Apr	130	50	6-Mar	6-Mar
1988	8-Apr	700	270	9-Apr	10-Apr
1989	27-Mar	340	130	30-Mar	6-Apr
1990	26-Mar	230	90	26-Mar	30-Mar
1991	25-Mar	50	20	27-Mar	30-Mar
1992	31-Mar	160	60	30-Mar	2-Apr
1993	3-Apr	540	210	5-Apr	6-Apr
1994	19-Apr	620	240	21-Apr	28-Apr
1995	28-Mar	410	160	30-Mar	17-Apr
1996	17-Apr	730	280	19-Apr	3-May
1997	24-Apr	60	25	25-Apr	28-Apr
1998	Ice-free			5-Mar	5-Mar
1999	30-Mar	Trace	Trace	30-Mar	30-Mar
2000	21-Mar	410	160	23-Mar	24-Mar
2001	14-Apr	390	150	17-Apr	20-Apr
2002	Ice-free			7-Mar	7-Mar
2003	10-Apr	490	190	10-Apr	11-Apr
2004	5-Apr	1110	430	6-Apr	7-Apr
2005	4-Apr	210	80	5-Apr	6-Apr
2006	20-Mar	80	30	20-Mar	21-Mar
2007	7-Apr	620	240	10-Apr	18-Apr
2008	14-Apr	310	120	15-Apr	19-Apr
2009	6-Apr	100	40	6-Apr	13-Apr
2010	18-Mar	570	220	22-Mar	24-Mar
2011	11-Apr	230	90	12-Apr	22-Apr
2012	Ice-free			28-Feb	2-Mar
2013	25-Mar	228	88	25-Mar	28-Mar
2014	28-Apr	622	240	29-Apr	7-May
2015	19-Apr	218	84	20-Apr	25-April

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

*No Data Published

Note: No Data available for period 1964-74.

Table7: Comparative Data for Years Ice Boom Has Been in Place

	Opening of Ice Boom			
Year	**Start***	**Completed**	**Welland****	
1965	21-Mar	27-Mar	1-Apr	
1966	20-Mar	1-Apr	4-Apr	
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	
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	
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	
2011	12-Apr	22-Apr	22-Mar	
2012	28-Feb	2-Mar	22-Mar	
2013	25-Mar	28-Mar	22-Mar	
2014	29-Apr	7-May	28-Mar	
2015	20-Apr	25-Apr	2-Apr	
1965-2012	2-Apr	4-Apr	29-Mar	Average for post-ice boom period
1970-2012	4-Apr	7-Apr	29-Mar	Average for the flexible boom opening period

1970 commencement of a flexible date for boom openings.
* Denotes opening of first boom span. Mobilization time precedes this date.
** Opening date is usually established in advance and may relate to Welland Canal repair schedule.

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

A.1 Hydraulics and Hydrology

The Niagara River, about 58 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 1860-2012, the average Niagara River flow at Queenston, Ontario has been 5766 m^3/s (203,624 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 Squaw 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 Squaw 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% 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 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 m (5 ft), 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 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.

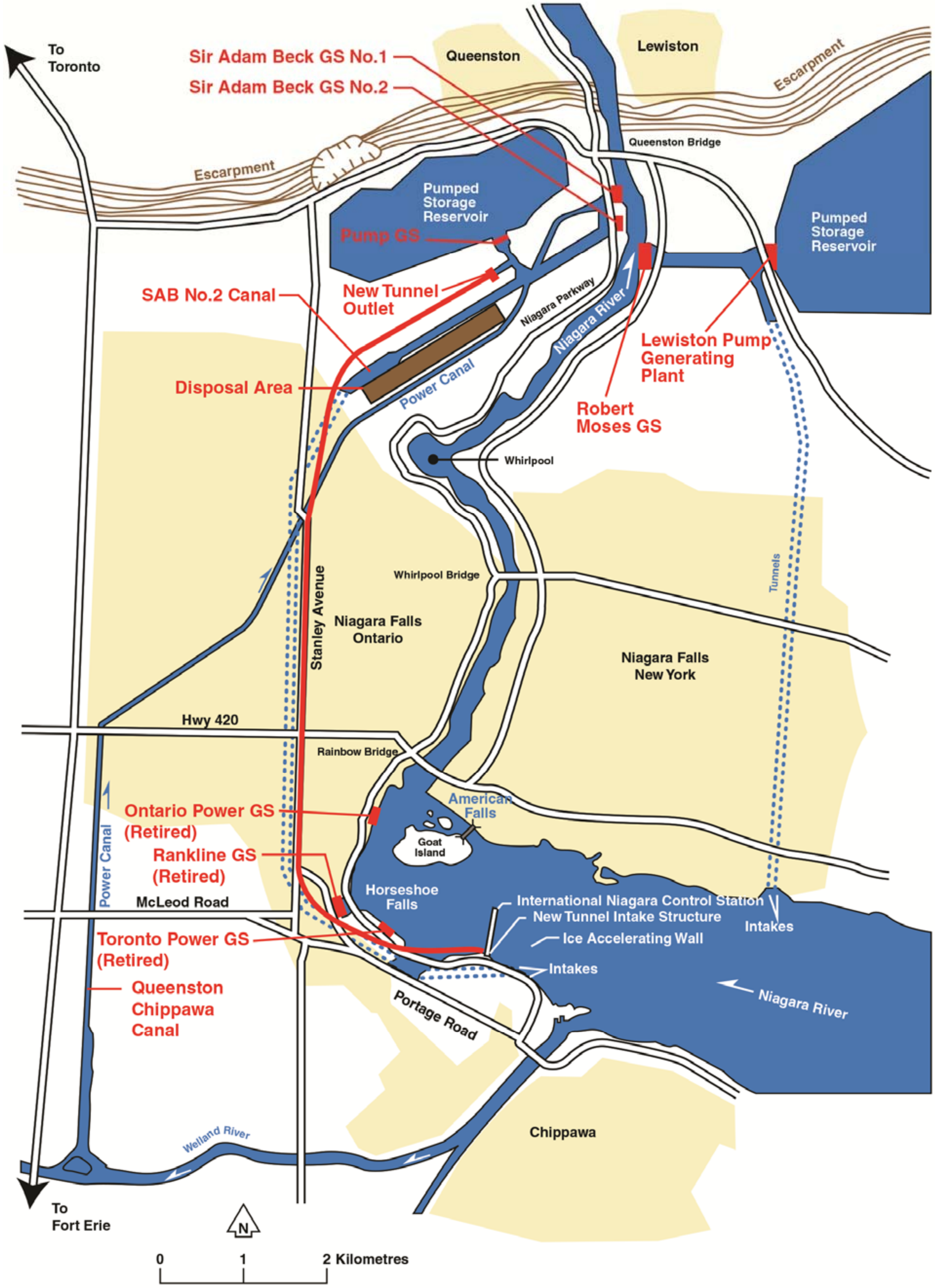
To further reduce the pontoon end cap damage and reduce the fatigue of the span cables between the inner and outer break walls (i.e. Spans A through D), the number and length of pontoons were changed to sixteen 4.6 m (15 ft) long mini pontoons per 152 m (500 ft) span, during the 2000-01 ice season. As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

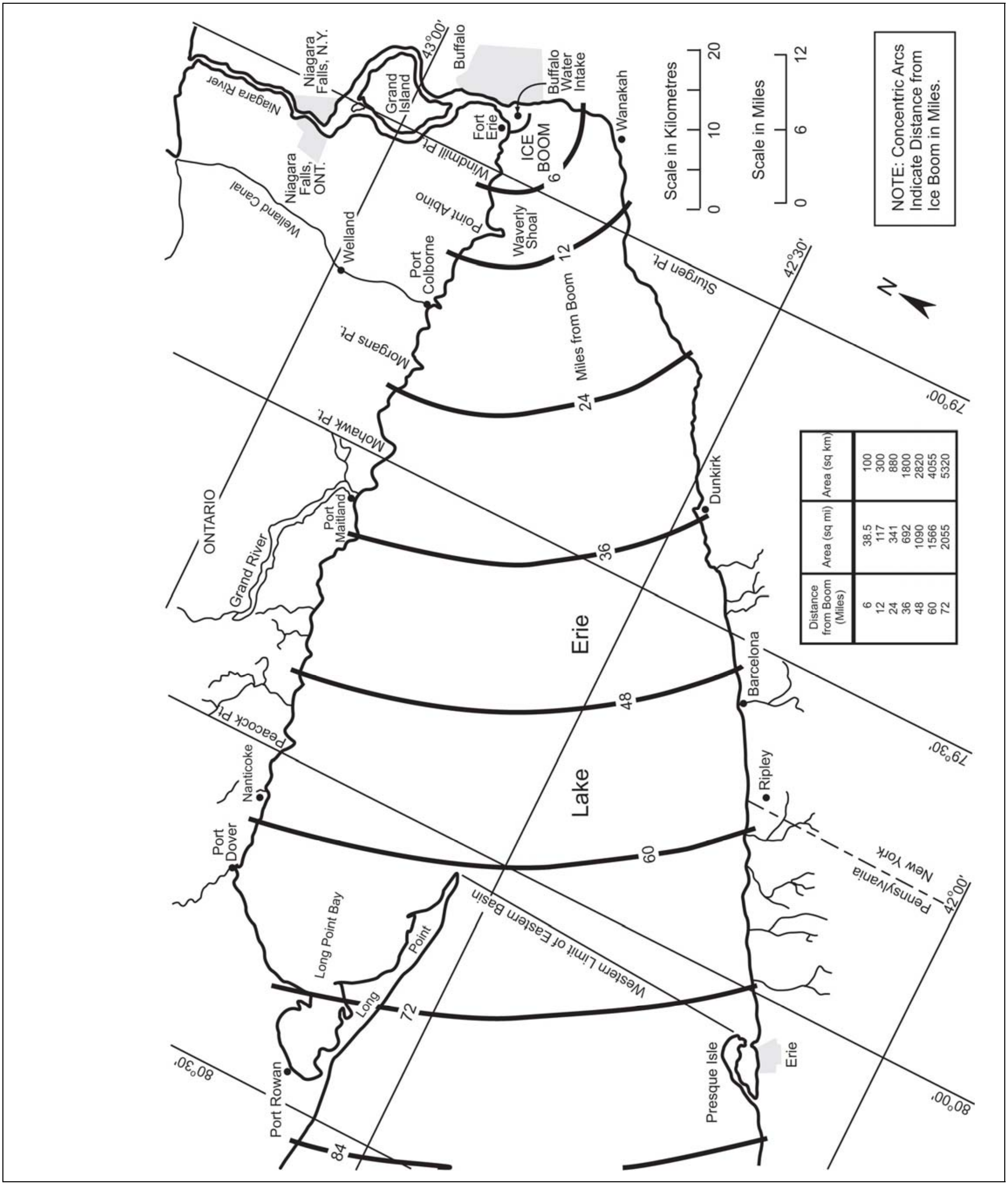
Notes

Enclosure 1: Great Lakes – St. Lawrence Drainage Basin

Enclosure 2: Niagara River Water Level Gauge Locations



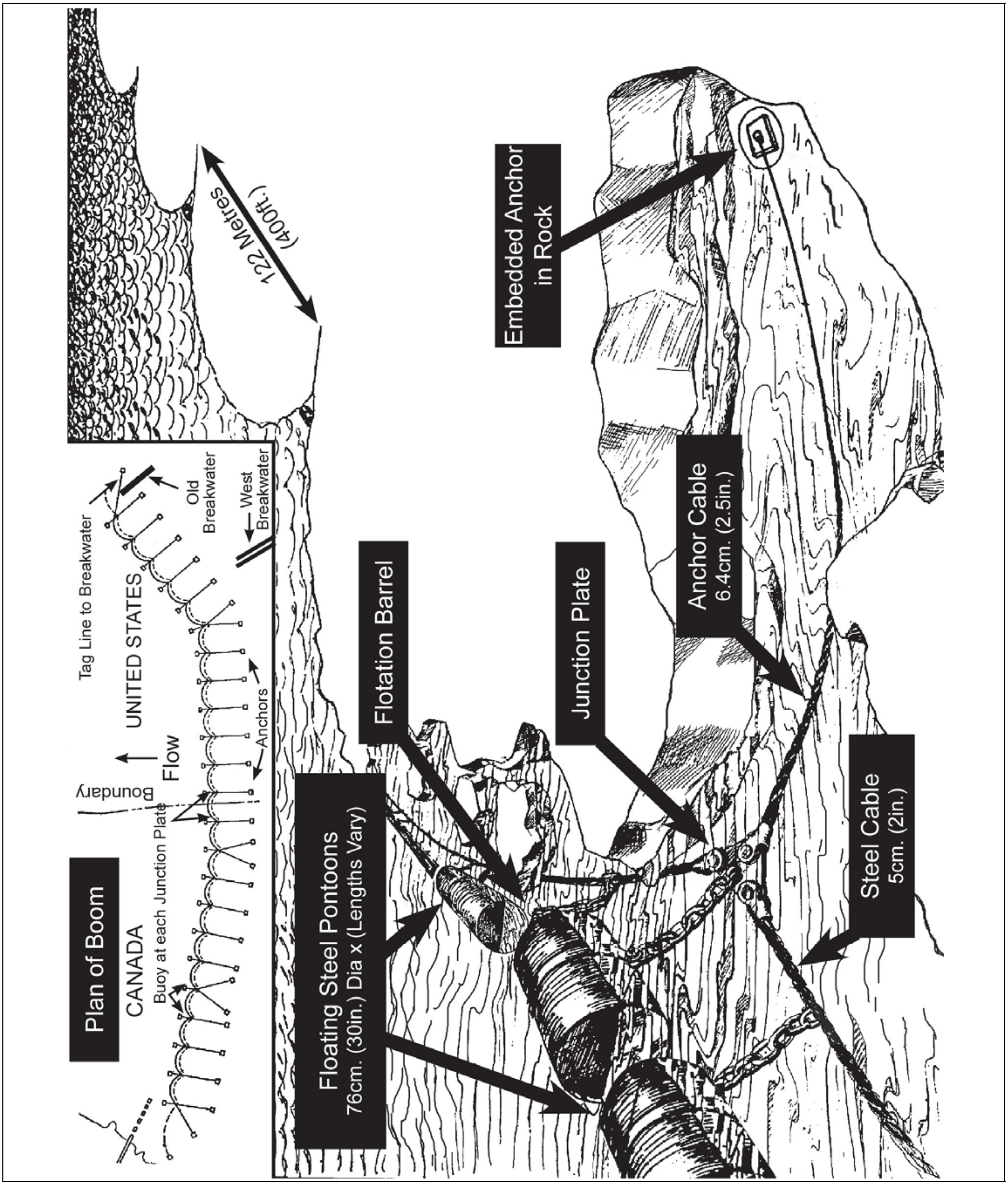
Enclosure 3: NYPA and OPG Power Projects



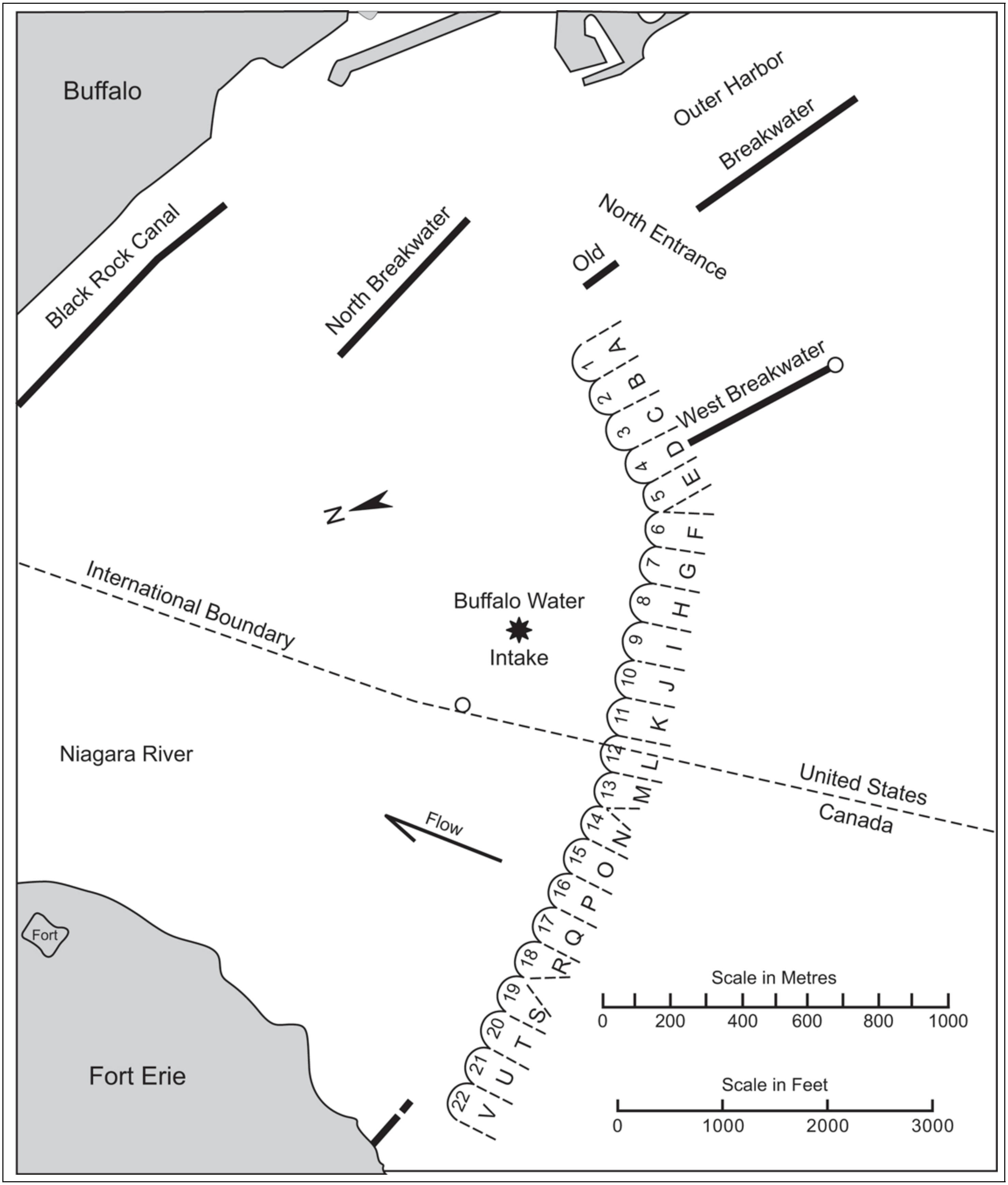
NOTE: Concentric Arcs Indicate Distance from Ice Boom in Miles.

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

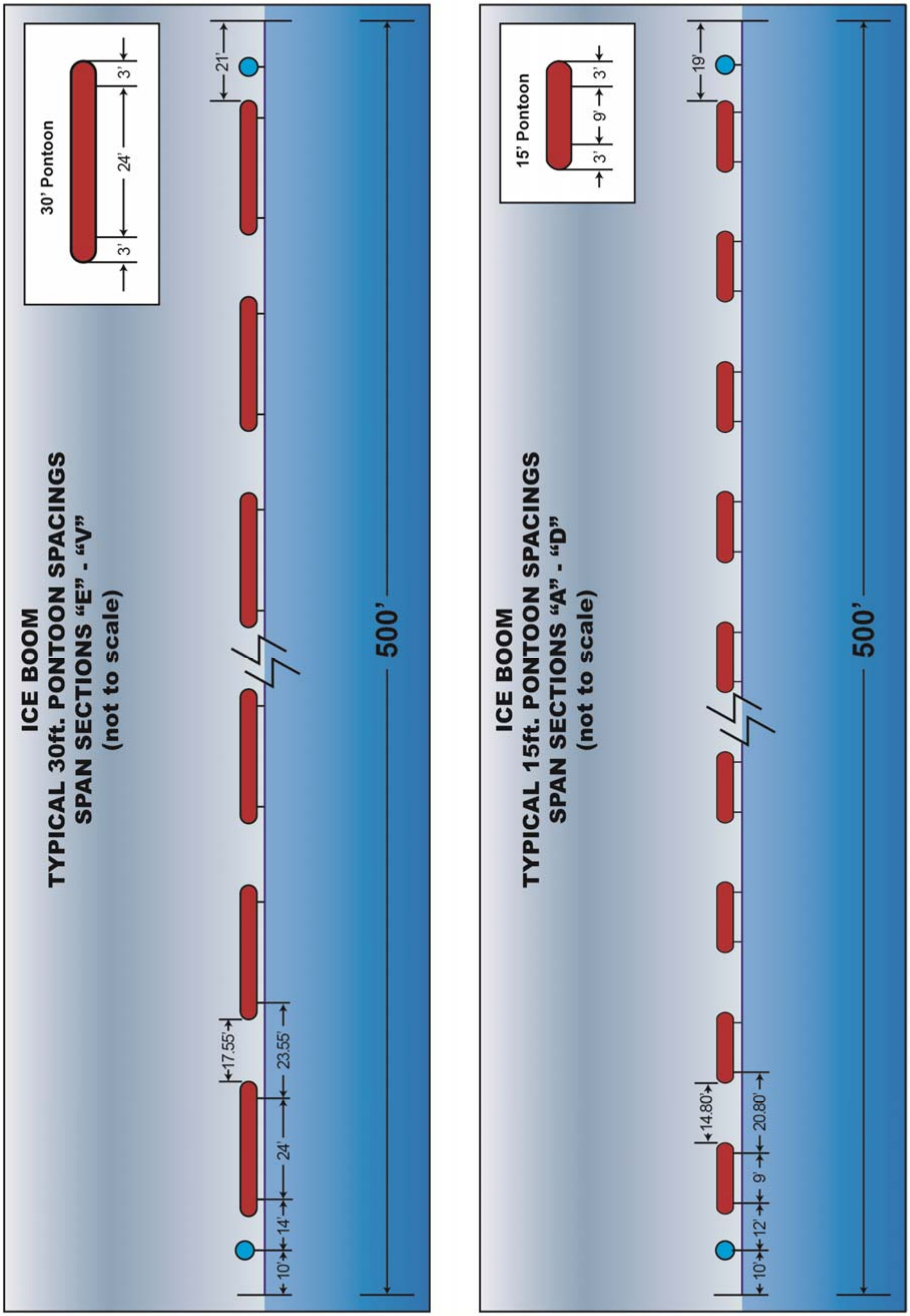
Enclosure 4: Map of Eastern End of Lake Erie



Enclosure 5: Ice Boom Detail



Enclosure 6: Plan View of Ice Boom



Enclosure 7: Typical Pontoon Spacing and Lengths

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