A Report

On 1994 Water Levels of the Great Lakes and St. Lawrence River

Peter P. Yee
Great Lakes-St. Lawrence Regulation Office
Water Issues Division
Environmental Services Branch
Environment Canada-Ontario Region
Cornwall, Ontario K6H 6S2
January 1995

Aussi disponible en français

Other Information Available from
Water Issues Division

Environmental Services Branch
Environment Canada - Ontario Region

Booklets/Pamphlets

- ***Great Lakes Water Levels***
  20-page illustrated booklet describing Great Lakes hydraulics and hydrology.

- ***Brochure on the International Great Lakes Datum***
  Fold-out pamphlet describing Great Lakes Datum and how it is updated.

- ***Great Lakes-St. Lawrence River Regulation: What it Means and how it Works***
  12-page illustrated booklet describing history and operations of lake regulation plans

Newsletter/Bulletins

- ***Water Level Bulletin - Great Lakes & Montréal Harbour***
  Issued monthly: Graphs illustrate 12 months of recorded levels and 6-month forecast for the Great Lakes and Montréal Harbour published by the Canadian Hydrographic Service.

- ***Water Level Bulletin St. Lawrence River*** -Issued in boating season: Graphs illustrate levels and forecasts for gauges at Kingston, ON, Ogdensburg, NY, Iroquois, ON, Long Sault Dam, NY, Summerstown, ON, Pointe Claire, QC, published by Environment Canada and the U.S. Army Corps of Engineers.

- ***Level News/Info-Niveau***
  2-page newsletter on Great Lakes-St. Lawrence water levels and related topics

Reports

- ***Annual Reports on the Water Levels of the Great Lakes and St. Lawrence River: 1985-1994***
  10-15 pages (+ appendices) on water levels and water management activities by Environment Canada-Ontario Region.

Reference Documents/Information

- ***Levels Reference Study, International Joint Commission, 1986-1993 (IJC)***
- ***International Niagara Committee reports***
- ***Lake Erie-Niagara River Ice Boom reports***
- ***Lake Erie Regulation Study, 1977-1981, IJC***
- **Great Lakes *Diversions and Consumptive Uses, 1977-1985, IJC***
- ***Canada-Ontario Flood Damage Reduction Program - Maps & Reports***
- ***Great Lakes Hydraulic & Hydrologic information***

Direct Requests To:

Great Lakes Water Level Communication Centre
Water Issues Division
Environment Canada - Ontario Region
867 Lakeshore Road, Burlington, Ontario L7R 4A6
Tel. (905) 336-4581
Fax (905) 336-6250/8901
or
Great Lakes-St. Lawrence Regulation Office
Water Issues Division
Environment Canada - Ontario Region
111 Water Street East, Cornwall, Ontario K6H 6S2
Tel. (613) 938-5725
Fax (613) 937-1302

SUMMARY

This report reviews hydrologic conditions of the Great Lakes - St. Lawrence River system, and the effects of water level fluctuations during 1994.

January and February saw extensive ice formation on the Great Lakes and the St. Lawrence River. There were concerns that a rapid snow melt or ice break-up during storms would result in serious shore damage and ice jams. However, the melt was gradual and no major changes in water level conditions occurred.

The levels of Lakes Superior and Ontario were very close to their long-term averages throughout 1994. Levels on Lakes Michigan-Huron, St. Clair and Erie were above average but well within their historical ranges. Two high water level events on eastern Lake Erie during November storms did not result in any reports of damage, because the level of the lake was low enough to allow a substantial surge without serious flooding.

Near average water levels in 1994 kept flooding to a minimum.

While Lake Ontario levels were at long-term averages in October and November, some residents in the Bay of Quinte area had low water level problems in shore wells. Some marina operators on the upper St. Lawrence River had difficulties taking their sail boats out of the water in October due to declining river levels.

Near average flows from Lake Ontario and the Ottawa River in April kept spring flooding on Lac Saint-Louis (near Montréal) to a minimum.

A mild December allowed a long navigation season on the St. Lawrence Seaway. The last ship of the year transited the Lake Ontario - Montréal section of the Seaway on December 29. By the end of December, no significant amounts of ice had formed in the St. Lawrence River or other Great Lakes connecting channels.

A mild December allowed a long navigation season on the St. Lawrence Seaway.

Lakes Erie, St. Clair and Michigan-Huron were 20-25 cm above average by the end of the year. Lakes Superior and Ontario ended the year at their seasonal averages.

TABLE OF CONTENTS

1.0 INTRODUCTION

This report summarizes information about water level fluctuations in the Great Lakes - St. Lawrence River system in 1994. The format of the report is similar to those of previous years.

This report uses information from reports by the International Lake Superior Board of Control, the International St. Lawrence River Board of Control, Environment Canada's Great Lakes Water Level Communications Centre, and analysis of hydrologic data provided by other agencies.

Water level elevations are given in metres above sea level as defined at Rimouski, Quebec and are referred to International Great Lakes Datum (IGLD) of 1985. River flows are in cubic metres per second (m^3/s).

2.0 THE GREAT LAKES - ST. LAWRENCE SYSTEM

The Great Lakes-St. Lawrence River basin (including land mass and water surface) encompasses more than one million square kilometres (see Figure 1).

As illustrated in Figure 2, the Great Lakes comprise a series of natural reservoirs positioned in a step-wise manner, with Lake Superior as the highest step and Lake Ontario the lowest. Lakes Michigan and Huron are considered one lake in hydraulic terms, because they are connected by the wide and deep Straits of Mackinac. Lakes Superior and Ontario are the only two Great Lakes that have their outflows regulated by structures at their outlets.

Water levels fluctuate according to the climate of the region. Over-lake precipitation, evaporation and runoff are the main factors that affect water levels.Other factors include flow retardation due to ice in winter, or aquatic vegetation in the summer. Weather disturbances cause short-term fluctuations in water levels. Artificial effects on water levels include regulation of lake outflows, dredging of channels, water diversions, and consumption of water.

Lake outflows are directly affected by lake levels: The higher a lake's level, the higher its outflow.

Because all of the lakes are connected, water level changes in one part of the system affect the other parts. The only exception to this is change in Lake Ontario's level, which does not affect the lakes upstream due to the steep drop at Niagara Falls.

Lake outflows are directly affected by lake levels: The higher a lake's level, the higher its outflow.

3.0 HYDROLOGIC CONDITIONS IN 1994

3.1 Precipitation

On average, about 820 millimetres of precipitation falls on the Great Lakes Basin each year. Table 1 compares the 1994 monthly precipitation for each lake basin with long-term averages. Basin-wide precipitation in 1994 was slightly below average. February, March, October and December were dry months, whereas April and August had higher than average precipitation.

The Lake Superior, Lake Erie and Lake Ontario basins had slightly below average precipitation throughout the year. Near average precipitation fell on the Lakes Michigan-Huron basin.

3.2 Water Levels and Outflows

Table 2 lists 1994 monthly outflows from each of the Great Lakes. Table 3 lists the monthly average levels for the Great Lakes and Montréal Harbour in 1994 and shows how they compare with historical data. The information is also shown graphically in Figures 3 to 8.

Lake Superior outflows were very close to average, a reflection of the near average lake level conditions during 1994.

Outflows of Lakes Michigan-Huron were 4% above average in 1994 as a result of lake levels that averaged about 20 cm above the long-term mean.

A January ice jam in the St. Clair River temporarily reduced the outflow of Lakes Michigan-Huron, which caused a 50 cm drop in Lake St. Clair's level for the first half of the month. The flow reduction was estimated at 1,000 m^3/s.

The higher-than-average outflows from Lakes Michigan-Huron continued to contribute to higher-than average levels on Lake St. Clair. This, in turn, kept Lake Erie's level about 25 cm above average.

A January ice jam in the St. Clair River caused a temporary drop in Lake St. Clair's level.

Lake Erie's 1994 outflow exceeded the long-term average by 7%. This extra inflow to Lake Ontario represented additional water supplies equivalent to 70 cm on that lake. However, higher-than-average outflows through Lake Ontario's regulation structures offset the impacts of these high supplies.

Outflows from Lake Ontario in 1994 averaged 7,470 m^3/s, about 8% higher than average.

Cold weather in late February and early March delayed the snow melt in Lake Ontario's drainage basin; thus, the timing of the seasonal rise in the levels was also delayed. The lake's level was slightly below average in March and slightly above average in May. Except

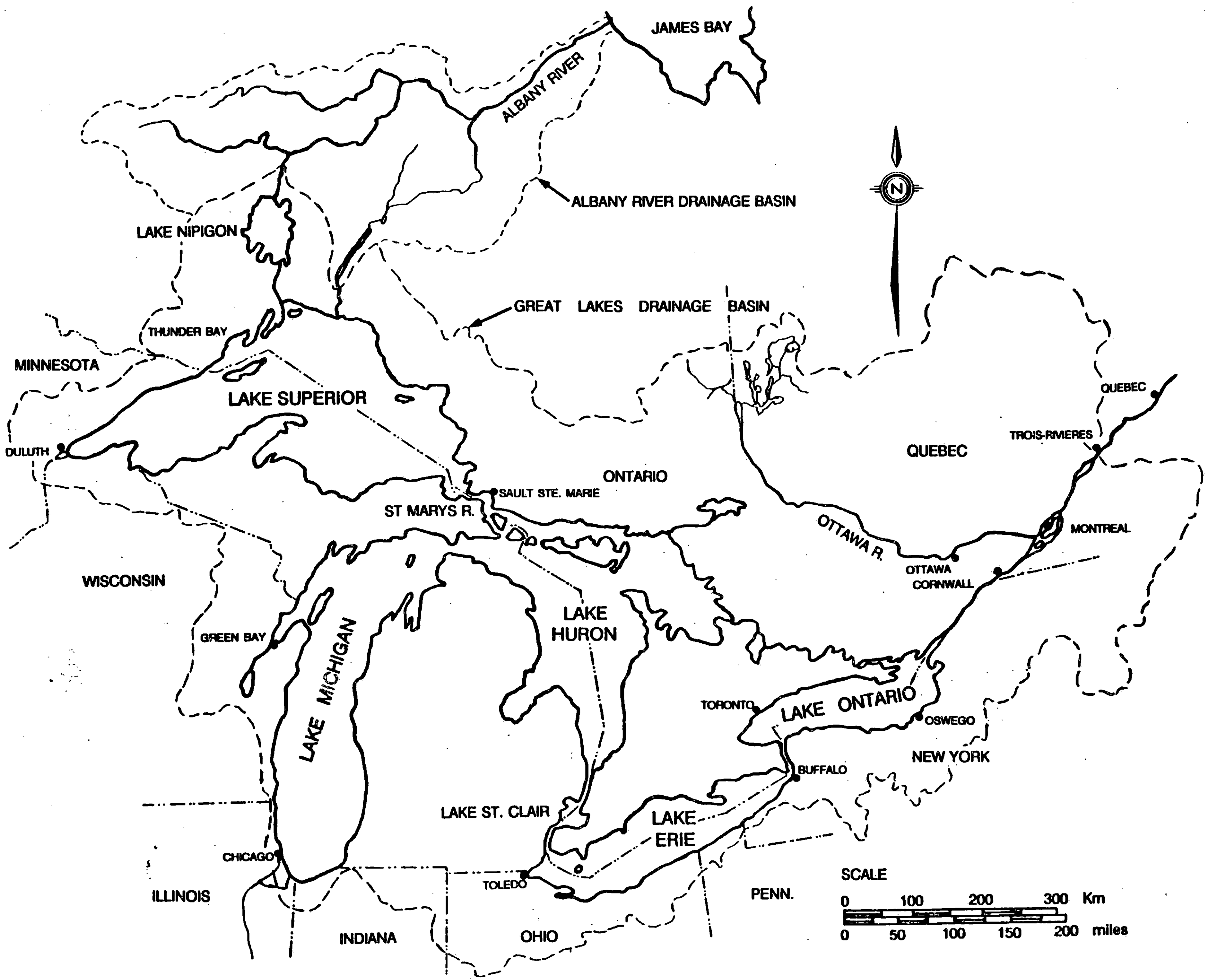


FIGURE 1. **Great Lakes-St. Lawrence River Basin**

for these two months, Lake Ontario levels in 1994 followed the seasonal average very closely.

Supplies to Lakes Superior, Michigan-Huron and Erie were slightly below average; supplies to Lake Ontario were slightly above.

Communities in the Lac Saint-Louis and Montréal areas reported no serious flooding during 1994. The peak flow of the Ottawa River during the spring freshet on the Ottawa River basin was not sufficiently high to cause serious problems to the area.

Montréal Harbour levels declined sharply in August and September due to normal declines in Lake Ontario and Ottawa River outflows. Very low flows of the Ottawa River and other local tributaries kept the summer level in the harbour below its average value.

Moderate precipitation in early November and an increase in the Ottawa River flow at that time raised the harbour levels slightly for the rest of the year.

3.3 Water Supplies

The net basin supply to a lake is the net effect of precipitation over the lake, drainage basin runoff to the lake, and evaporation from the lake. Net basin supplies for all the lakes are listed in Tables 4 through 7.

The net basin supplies to Lakes Superior, Michigan-Huron and Erie for 1994 were slightly below average. Lake Ontario received slightly above average supplies in 1994.

4.0 WATER MANAGEMENT ACTIVITIES

4.1 Lake Superior Regulation

The outflow of Lake Superior is regulated by structures and hydropower dams across the St. Marys River between Sault Ste. Marie, Ontario and Sault Ste. Marie, Michigan.

Lake Superior's Regulation Plan 1977-A specifies monthly outflows from the lake, based upon this lake's level and that of Lakes Michigan-Huron downstream. The practise of taking downstream lake levels into account is referred to as systemic regulation. This is a requirement by the International Joint Commission, whose International Lake Superior Board of Control oversees the operations of the regulation structure.

A number of structures combine to regulate the outflow of Lake Superior. Water leaving the lake flows through three hydropower plants, four navigation locks, and the Lake Superior compensating works, which were built to offset the extra flow capacity added to the St. Marys River by the hydropower developments.

The International Joint Commission requires a minimum setting of one-half gate open at the compensating works in order to supply water to the St.

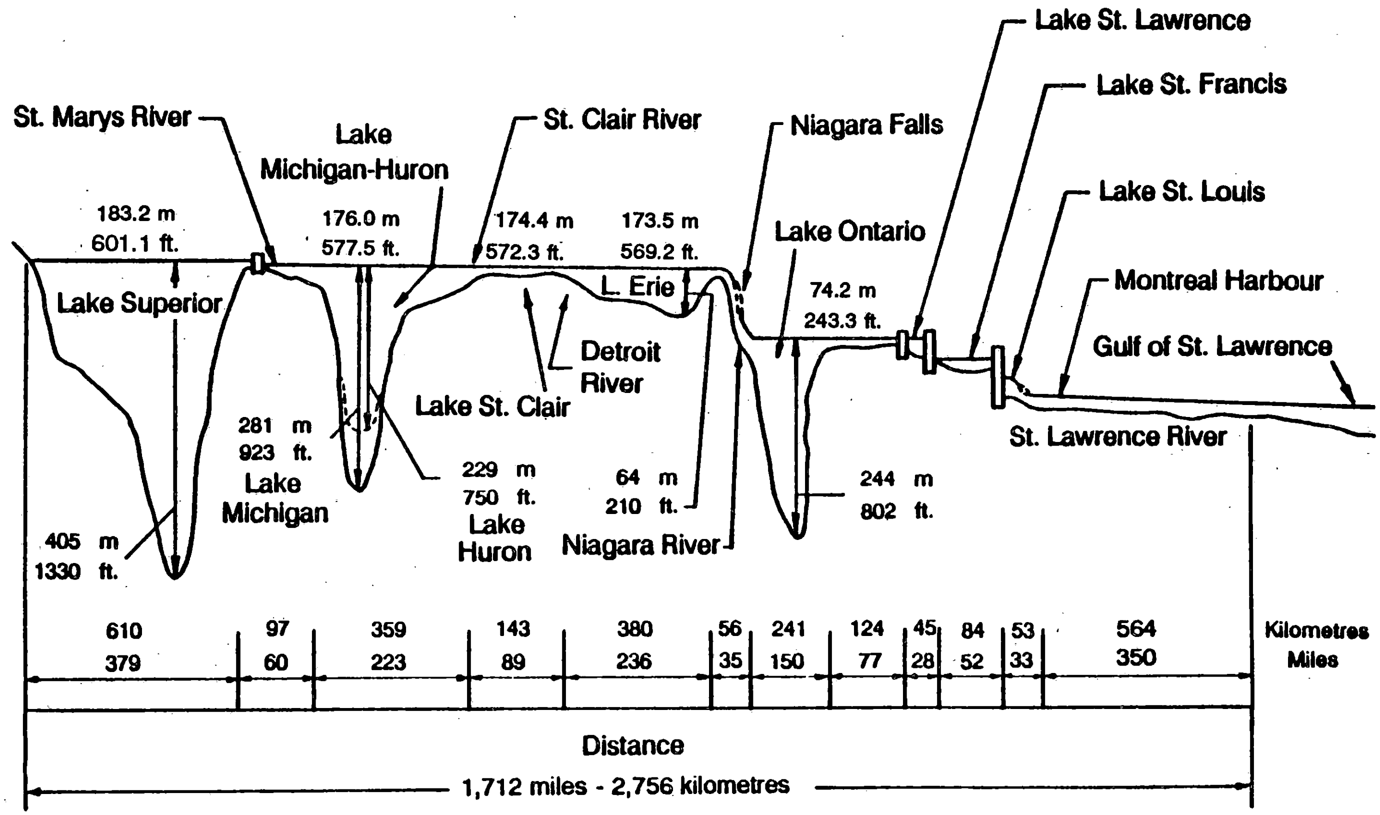


FIGURE 2. **Profile of Great Lakes-St. Lawrence River System**

Marys Rapids.

Changes to the lake's outflow are usually made by adjusting the amount of water used by the hydropower plants. When the regulation plan specifies flows larger than the capacities of the hydropower plants, additional gates at the compensating works are opened.

There were deviations from both Lake Superior's and Lake Ontario's regulation plans in 1994.

In 1994, the International Lake Superior Board of Control deviated from the regulation plan between June and October to allow for repairs to hydro plants. During this period, water designated for hydropower purposes could not be fully used. As a result, some water was retained on Lake Superior. This caused a 2 cm water level rise on Lake Superior by the end of October, and 1 cm lowering on Lakes Michigan-Huron. A further deviation from the plan in December allowed slightly higher outflows from the lake to help offset the earlier flow reductions.

As noted earlier, Lake Superior ended 1994 at its average level for the time of year. The temporary deviations from the regulation plan had little impact on Lake Michigan-Huron's above-average level.

On June 14, the Lake Superior Board held a meeting with the public in Duluth, Minnesota to provide information and receive feedback on the Board's operations.

4.2 Lake Ontario Regulation

The outflow of Lake Ontario is regulated by a hydropower dam and spillway in the St. Lawrence River near Cornwall, Ontario and Massena, New York. Lake Ontario Regulation Plan 1958-D specifies weekly outflows based upon the lake's levels and trends in water supplies.

Lake Ontario outflow regulation is overseen by the International Joint Commission's International St. Lawrence River Board of Control. The regulation plan helps prevent water level extremes both upstream and downstream of the regulation structure, and it attempts to balance the interests of shoreline property owners, navigation and hydropower interests. The plan also includes procedures to help prevent ice jams in the St. Lawrence River.

Every winter, flows through the regulation structure are reduced to promote formation of a stable ice cover and lessen the risk of ice jams. A smooth ice cover also reduces headloss, which occurs when ice retardation increases the slope of the river between Lake Ontario and Lake St. Lawrence.

Extremely cold weather in January and February of 1994 led to extensive ice formation in the St. Lawrence River. This ice cover retarded the river's flow, and lowered the level of Lake St.

Lawrence, but not to the extent that there were significant problems with municipal water intakes or hydropower generation.

Extensive ice cover caused concerns as spring approached, but no ice jams or flooding resulted.

The extensive snow cover on Lake Ontario's basin in 1994, coupled with heavy ice cover on the lake and St. Lawrence River led to concerns that a sudden spring thaw could rapidly raise lake levels and cause ice jams in the river. However, a gradual melt proved these concerns unnecessary. Lake Ontario's level reached its seasonal peak in May, after which there was a gradual decline through December.

While Lake Ontario levels in the fall of 1994 were very close to the seasonal average, some residents in the Bay of Quinte area experienced low water problems in their shore wells. At this time of year, Lake Ontario levels are near their annual low.

When the recreational boating season ended in October, some marina operators had difficulties bringing boats out of the water due to declining water levels in the St. Lawrence River. The problem was most acute in the St. Lawrence River above Iroquois. Some boaters who moored their boats in one location but stored them for the winter in another found that river levels were too low to sail back to their point of origin.

At the beginning of 1994, the International St. Lawrence River Board of Control reduced outflows from Lake Ontario to less than the amounts specified by the regulation plan. These flow reductions in April through June served several purposes. One was to reduce the flood damage on Lake St. Louis during the Ottawa River freshet in April. The second was to reduce water use at the hydropower dam at Cornwall due to a temporary energy surplus in Ontario Hydro's system. The third was to slightly increase Lake Ontario's levels for the benefit of recreational boaters on the lake and in the Thousand Islands area.

Some marina operators had trouble bringing boats out of the St. Lawrence River in the fall.

The result of the reductions was 6 cm of additional water in the lake by the end of July. At that time, the actual lake level was 74.98 m, about 5 cm higher than the seasonal average. In December, flows higher than those specified by the regulation plan offset the impacts of the previous flow reductions. By December 31, the Lake Ontario level was at 74.46 m, which is near the long-term average for that time of year and 9 cm below that at the beginning of the year.

In early 1994, the Board began assessing the performance of two potential regulation plans in order to identify improvements to Lake Ontario regulation. One plan, called Plan 35-P, is a product of the IJC Levels Reference Study completed in 1993. This plan is a modification of the lake's current regulation plan. The other, called Plan IS-4, was originally developed by a researcher at the U.S. Army Corps of Engineers. The IS-4 plan uses an "optimization" technique that attempts to achieve the best possible compromise to serve a combination of purposes.

The International St. Lawrence Board of Control is assessing potential new regulation plans.

Both plans take into consideration the needs and preferences of interests (hydropower, navigation, recreational boating, riparian, environmental) upstream and downstream of Cornwall. Over the next three years, the Board will simulate water levels and flows that could be generated by each of these plans. The existing regulation plan (1958-D) will remain in effect for this period.

On June 21, the International St. Lawrence River Board of Control hosted a meeting with the public in Oswego, New York. The purpose was to provide information and receive feedback on the operations of the Board.

4.3 Environment Canada Activities

Throughout 1994, Environment Canada's Great Lakes-St. Lawrence Regulation Office in Cornwall continued to issue six-month water level forecasts for the Great Lakes and Montréal Harbour. The forecasts appeared monthly in the water level bulletins published by Fisheries and Oceans Canada.

A similar bulletin is issued by the U.S. Army Corps of Engineers. In the past, slight differences between the two bulletins have caused reader confusion. Beginning with the January 1994 issue, the bulletins in both countries contain consistent information. This fulfilled a recommendation in the recent IJC water level study which recommended improvements in information for the public.

The Canadian and U.S. Water Level Bulletins were harmonized in 1994.

As in previous years,the Cornwall office also issued monthly water level bulletins during the recreational boating season designed specifically for Lake Ontario and the St. Lawrence River. The bulletins, issued jointly with the U.S. Army Corps of Engineers, give water level conditions and forecasts for six sites from Kingston, Ontario to Point Claire on Lac Saint-Louis in Quebec. The bulletins were distributed to local media, shore property owners and marinas to advise citizens of changing levels and flows in the river.

Environment Canada also installed staff gauges at several marinas along the St. Lawrence River to show changing water level conditions in the river as they occur.

The Great Lakes-St. Lawrence Office continued as the Canadian focal point for Lake Ontario and Lake Superior regulation operations.

Staff gauges were installed at marinas along the St. Lawrence River.

The unusually heavy ice cover on the Great Lakes and St. Lawrence River in January 1994 provoked a considerable amount of media and public interest. Questions focused on the extent of the ice and possible implications for shoreline damage and ice jams in the spring. Environment Canada monitored the ice conditions closely and responded to a number of media and citizen inquiries.

In January 1994, the Great Lakes Water Level Communications Centre coordinated procedures with the Ontario Weather Centre in Toronto and the Ice Centre in Ottawa for issuing advisories about the potential for damage due to ice problems on the Great Lakes.

In November, the Centre, together with the Great Lakes-St. Lawrence Regulation Office, formed a link with Environment Canada's new Weather and Environmental Services Regional Centre in Ottawa.

In addition, the Communications Centre initiated a strategy to respond to the International Joint Commission's recommendations for improving communications with the general public.

The Centre plans to increase its public outreach and education efforts with regard to the Great Lakes-St. Lawrence River system, how it functions and the risks that are associated with changing water levels and flows. The Centre expects to work with provincial, U.S. and private sector partners, where possible, to undertake communications and educational initiatives in 1995.

The Communications Centre also became a founding participant in the Great Lakes Information Management Resource (GLIMR), a pilot project to make Great Lakes environmental information available on the Internet and World-Wide Web. Great Lakes water level and related publications will be accessible in GLIMR's user-friendly format, and will be complemented by corresponding U.S. publications, which are available through the Great Lakes Information Network (GLIN), GLIMR's U.S. counterpart. The Communications Centre will provide a public access point to GLIMR when the project goes officially on line in 1995. The GLIMR pilot project is led by Environment Canada-Ontario Region's Water Issues Division.

5.0 Water Levels Reference Study

Environment Canada, together with other federal departments, the Québec and Ontario governments, drafted a formal response to the International Joint Commission's final report on Great Lakes-St. Lawrence water levels, which was transmitted to the Governments of Canada and the United States in the spring of 1994.

In addition, Environment Canada initiated discussions with potential partners to explore responses to a number of recommendations in the Commission's report.

6.0 EFFECTS OF WATER LEVEL FLUCTUATIONS

6.1 Impacts on Shore Properties

No serious flood or erosion damage was reported on the Great Lakes and St. Lawrence River in 1994.

The Great Lakes-St. Lawrence Regulation office received several calls from residents in the Bay of Quinte area of Lake Ontario expressing concern about low water levels at the shore wells. Many of these wells are shallow and located on bedrock. Thus, they are easily affected by declining water levels as the lake falls toward its annual low.

6.2 Impacts on Commercial Navigation

An unusually cold winter in 1993-1994 led to near record ice conditions on all of the Great Lakes. Although the freeze up came a few days later than usual and added extra days to the navigation season, ice formed quickly once temperatures did drop.

A delay in ice formation in the St. Lawrence River allowed vessels to transit the Lake Ontario - Montréal section of the St. Lawrence River until December 25, 1993. Ice began forming in the river the next day, and by mid-winter all of the lakes, with the exception of Lakes Michigan and Ontario were almost completely ice covered. The heavy ice caused local navigation problems on the upper lakes throughout the winter. There were reports of boats becoming stuck in ice on Lake Erie and in the St. Clair-Detroit Rivers. These ice conditions delayed the 1994 start of the shipping season, which began on April 5.

Once the 1994 shipping season started, however, shipping operations were essentially trouble-free for the year. Vessels transiting the Lake Ontario - Montréal section of the St. Lawrence River experienced no adverse water levels or cross currents during the year. In October, levels on Lake St. Lawrence immediately above Cornwall were near the minimum required for navigation.

Relatively mild weather persisted in much of November and early December. This delayed the ice freeze-up which normally begins in the latter part of December. The 1994 navigation season in the international section of the St. Lawrence River ended on December 28 when the last down bound ocean vessel cleared the Snell Lock at Massena, New York. The St. Lambert Lock, located at Montréal, cleared the last ocean vessel on December 29.

The Welland Canal, which links Lake Erie and Lake Ontario, continued to operate until December 30. The locks at Sault Ste. Marie, Michigan (between Lake Superior and Lake Huron) were expected to continue operations until mid-January 1995. The Black Rock Lock, located at the head of the Niagara River at Buffalo, N.Y., was expected to close in early January, 1995.

6.3 Impacts on Recreational Boating

There were no reports by boaters of water level problems on Lake Erie and the upper Great Lakes. However, as Lake Ontario levels followed their seasonal decline in September and October, boaters in the Thousand Island area began to encounter low water level problems. Some marina operators in the upper St. Lawrence River had difficulties bringing large sail boats on shore in October due to declining river levels.

6.4 Impacts on Hydro Power Generation

Hydro-electric facilities at Sault Ste. Marie in the St. Marys River continued to use amounts of water specified by the regulation plan for power generation. However, repairs at times reduced the plants' capacities to use their full share of the water (see details in section 4.1).

Higher-than-average flows in the Niagara and St. Lawrence Rivers resulted in above average power production on the two waterways (see section 3.2).

The Long Sault Spillway near Cornwall normally remains closed because the power dam can accommodate the entire Lake Ontario outflow. While this capacity existed during 1994, there were several days in the year when a small portion of the flow was released at the spillway. This occurred when a temporary energy surplus existed in Ontario Hydro's system and the utility did not use its full share of the water for power generation.

7.0 FORECAST OF FUTURE WATER LEVEL CONDITIONS

A six-month water level forecast for the Great Lakes and Montréal Harbour (prepared on January 4, 1995) is shown in Figures 3-8. Water levels of the Great Lakes fluctuate according to the weather conditions. Since it is not possible to accurately forecast weather conditions several months in advance, these forecasts are made assuming average, wet, and dry weather conditions for the next six months.

Assuming most probable (average) water supplies over the next six months, the levels of Lakes Michigan-Huron, St. Clair and Erie would remain above their respective seasonal average levels throughout the forecast period. Lake Superior and Lake Ontario levels would remain close to their seasonal values.

The levels of Lakes Superior and Michigan-Huron are expected to continue their usual seasonal declines and fall a further few centimetres by late winter. The levels of Lakes Erie and Ontario will likely begin their annual rises in January.

Montréal Harbour is expected to be below its average level (1967-1993) for the next six months but above chart datum.

8.0 CONCLUSION

1. Conditions on the Great Lakes and St. Lawrence River were relatively trouble-free in 1994. This can be attributed to the near average water level conditions on the Great Lakes.

2. Two high water level events on Lake Erie in November did not cause serious shoreline damage, because the lake's level was sufficiently low to allow for resulting storm surges.

3. The very severe ice conditions on the Great Lakes and in the St. Lawrence River in January and February 1994 posed a risk of severe shore damage and ice jams. But a gradual melting of the snow and ice in March prevented any large, sudden water level fluctuations.

4. Deviations from the regulation plan to allow for repairs to hydropower facilities in the St. Marys River resulted in 2 cm of stored water on Lake Superior and a one cm. lowering of Lakes Michigan-Huron by the end of October. Deviations from Lake Ontario's regulation plan resulted in 6 cm of stored water on that lake by the end of July. Higher outflows toward the end of the year offset these deviations.

5. While low St. Lawrence River levels in October caused some problems with late removal of pleasure boats in October, recreational boating on the Great Lakes was generally good throughout the season.

6. Declining Lake Ontario levels in the Fall of 1994 were a concern to some Bay of Quinte residents who depend on shore wells.

7. The mild weather towards the end of 1994 delayed the start of ice formation in the Great Lakes - St. Lawrence River. This made extension of the shipping season possible.

8. At the end of 1994, Lakes Superior and Ontario were at their long-term average levels for the time of year; Lakes Michigan-Huron, St. Clair and Erie were 20-25 cm above their long-term averages. The six-month forecasts suggest the lakes will continue to follow these patterns for the first half of 1995.

Table 1 Comparison of 1994 Great Lakes Basin Precipitation and Long-Term Average (millimetres)

Superior Basin

	1994	Percentage of average	Average 1900-1992	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	46.0	93	49.4	91.4 (1935)	22.5 (1961)
Feb	18.0	49	37.2	84.4 (1939)	12.3 (1912)
Mar	34.0	76	44.4	101.6 (1979)	9.6 (1910)
Apr	75.2	152	49.2	105.6 (1960)	17.4 (1949)
May	61.0	88	68.6	129.4 (1970)	21.1 (1948)
Jun	73.2	88	83.3	151.4 (1943)	22.7 (1910)
Jly	87.4	107	82.1	141.7 (1952)	27.7 (1936)
Aug	96.3	118	81.6	185.9 (1988)	26.3 (1930)
Sep	81.3	91	89.4	163.5 (1941)	32.7 (1967)
Oct	53.8	78	69.0	122.4 (1982)	15.6 (1947)
Nov	58.7	92	63.8	119.5 (1985)	11.0 (1939)
Dec	17.8	35	51.6	90.1 (1984)	9.0 (1913)
Sum	702.7	91	769.6		

Michigan-Huron Basin

	1994	Percentage of average	Average 1900-1992	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	56.6	108	52.6	91.8 (1950)	20.5 (1956)
Feb	38.1	87	43.8	86.2 (1908)	14.3 (1969)
Mar	35.0	63	55.2	116.2 (1976)	15.1 (1958)
Apr	71.4	110	65.1	125.6 (1929)	25.6 (1946)
May	60.7	80	75.6	141.6 (1983)	31.0 (1925)
Jun	97.3	124	78.5	143.8 (1969)	29.3 (1988)
Jly	112.5	150	75.6	132.2 (1952)	29.9 (1936)
Aug	117.6	151	77.8	136.1 (1972)	23.8 (1927)
Sep	66.8	75	88.2	213.3 (1986)	29.6 (1979)
Oct	54.1	75	72.0	147.4 (1954)	13.9 (1924)
Nov	83.3	119	70.2	127.8 (1985)	18.6 (1904)
Dec	26.7	45	59.0	105.6 (1971)	14.4 (1913)
Sum	820.1	101	813.6		

Erie Basin

	1994	Percentage of average	Average 1900-1992	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	72.6	119	61.1	160.5 (1950)	14.3 (1961)
Feb	33.5	63	52.9	117.1 (1990)	10.4 (1987)
Mar	54.6	77	70.6	170.6 (1913)	11.0 (1910)
Apr	108.5	137	79.1	152.1 (1961)	23.5 (1946)
May	54.1	64	83.8	175.8 (1943)	16.8 (1934)
Jun	105.9	112	86.6	167.9 (1937)	19.0 (1988)
Jly	67.1	80	84.6	190.5 (1992)	29.3 (1930)
Aug	101.1	125	81.0	179.7 (1975)	33.1 (1969)
Sep	48.5	60	79.8	176.0 (1926)	19.3 (1908)
Oct	38.9	56	69.6	196.2 (1954)	11.2 (1924)
Nov	73.2	102	71.8	191.8 (1985)	9.8 (1904)
Dec	68.4	102	66.7	160.0 (1990)	21.1 (1943)
Sum	826.4	93	887.6		

Table 1 (continued)

Ontario Basin

	1994	Percentage of average	Average 1900-1992	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	69.1	103	67.3	137.2 (1978)	27.6 (1981)
Feb	39.6	66	60.2	112.5 (1971)	22.9 (1969)
Mar	68.1	101	67.8	143.4 (1936)	18.2 (1915)
Apr	97.0	134	72.9	126.6 (1929)	28.6 (1915)
May	85.1	109	78.2	144.7 (1943)	15.9 (1920)
Jun	67.6	87	77.6	159.1 (1972)	30.3 (1912)
Jly	60.4	77	79.4	159.5 (1992)	31.7 (1933)
Aug	101.6	129	79.3	142.3 (1977)	32.1 (1907)
Sep	60.7	75	80.8	159.2 (1945)	24.3 (1964)
Oct	33.5	44	76.8	211.5 (1955)	12.9 (1963)
Nov	100.6	128	78.5	168.0 (1927)	15.4 (1904)
Dec	58.9	80	74.1	139.9 (1990)	27.0 (1943)
Sum	843.1	94	892.9		

Great Lakes Basin

	1994	Percentage of average	Average 1900-1992	Previous Maxima and Minima (Year of Occurrence) Maximum	Minimum
Jan	57.4	105	54.6	100.5 (1950)	21.9 (1961)
Feb	32.3	71	45.1	80.1 (1908)	16.8 (1969)
Mar	41.2	74	55.6	110.7 (1976)	15.4 (1910)
Apr	80.5	127	63.5	106.0 (1929)	28.6 (1915)
May	62.7	83	75.0	116.1 (1983)	32.7 (1934)
Jun	88.4	109	80.6	121.1 (1968)	36.5 (1910)
Jly	93.2	119	78.9	123.7 (1992)	31.7 (1936)
Aug	107.7	136	79.4	128.1 (1977)	28.7 (1930)
Sep	67.6	78	86.4	166.2 (1986)	38.9 (1948)
Oct	49.5	68	71.4	127.0 (1954)	20.7 (1924)
Nov	77.2	111	69.6	136.7 (1985)	18.0 (1904)
Dec	33.6	56	59.8	92.5 (1983)	16.9 (1913)
Sum	791.3	97	820.0		

Source: NOAA, Corps of Engineers
R denotes new record
All figures are in millimetres rounded to one decimal place.

Table 2 **Outflows from the Great Lakes in 1993 and 1994 (cubic metres per second)**

Lake Superior

	1994	1993	Average 1900-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	2120	2260	1950	2630	(1971)	1250	(1922)
Feb	2150	2290	1910	2610	(1969)	1270	(1922)
Mar	2130	2040	1880	2690	(1969)	1290	(1982)
Apr	2050	2110	1950	2940	(1951)	1300	(1922)
May	2390	2190	2120	3450	(1951)	1250	(1931)
Jun	2340	2430	2200	3480	(1951)	1220	(1922)
Jul	2190	2230	2280	3570	(1938)	1270	(1922)
Aug	2210	2210	2370	3600	(1950)	1270	(1926)
Sep	2140	2110	2360	3570	(1950)	1160	(1955)
Oct	2210	2130	2300	3510	(1968)	1250	(1926)
Nov	2250	2130	2260	3750	(1985)	1250	(1981)
Dec	2190	2050	2070	3170	(1950)	1310	(1981)
Annual	2200	2180	2140				

Lakes Michigan-Huron

	1994	1993	Average 1900-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	4200	5070	4500	6060	(1987)	3060	(1934)
Feb	4960	4760	4370	5720	(1974)	3000	(1942)
Mar	5380	4870	4820	5830	(1986)	3510	(1931)
Apr	5460	5070	5140	6260	(1986)	3600	(1901)
May	5580	5440	5360	6370	(1986)	4390	(1964)
Jun	5580	5630	5460	6430	(1985)	4420	(1964)
Jly	5630	5780	5520	6570	(1974)	4500	(1964)
Aug	5680	5790	5520	6630	(1986)	4530	(1964)
Sep	5690	5760	5480	6600	(1986)	4470	(1933)
Oct	5620	5680	5430	6740	(1986)	4420	(1933)
Nov	5550	5620	5370	6650	(1986)	4390	(1934)
Dec	5430	5580	5190	6230	(1986)	3990	(1935)
Annual	5400	5420	5180				

(Continued on next page)

Table 2 (Continued)

Lake Erie

	1994	1993	Average 1900-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	5850	7040	5600	7420	(1987)	4050	(1936)
Feb	5820	6640	5480	7050	(1987)	3340	(1936)
Mar	6160	6690	5640	7480	(1986)	4110	(1934)
Apr	6440	7130	5920	7700	(1974)	4390	(1935)
May	6800	7060	6210	7760	(1974)	4590	(1934)
Jun	6450	6680	6240	7820	(1986)	4560	(1934)
Jly	6590	6760	6120	7670	(1986)	4450	(1934)
Aug	6550	6480	6020	7420	(1986)	4470	(1934)
Sep	6350	6410	5910	7140	(1986)	4450	(1934)
Oct	6140	6290	5810	7450	(1986)	4420	(1934)
Nov	6420	6240	5810	7280	(1986)	4280	(1934)
Dec	6190	6300	5800	7620	(1985)	4330	(1934)
Annual	6310	6640	5880				

Lake Ontario

	1994	1993	Average 1900-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	6440	7130	6290	8470	(1987)	4700	(1935)
Feb	7030	7560	6350	8160	(1986)	4360	(1936)
Mar	7090	8290	6650	8890	(1991)	5010	(1935)
Apr	7370	8340	7080	9200	(1973)	5070	(1964)
May	8020	10100R	7330	10100	(1993)	4980	(1965)
Jun	8150	10010R	7430	10010	(1993)	5350	(1965)
Jly	7900	8990	7370	9910	(1976)	5520	(1934)
Aug	7690	8650	7210	9340	(1974)	5300	(1934)
Sep	7660	7870	7020	9230	(1986)	5100	(1934)
Oct	7550	7560	6840	9170	(1986)	4960	(1934)
Nov	7440	7270	6720	9570	(1986)	4810	(1934)
Dec	7250	7320	6600	9260	(1986)	4810	(1934)
Annual	7470	8260	6910				

Source: Environment Canada, Ontario Region

Table 3 **Great Lakes Water Levels in 1993 and 1994 and Their Comparison with Previous Records (Metres, IGLD-1985)**

Lake Superior Water Levels

	1994	1993	1918-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	183.39	183.41	183.35	183.70	(1986)	182.83	(1926)
Feb	183.32	183.32	183.29	183.63	(1986)	182.76	(1926)
Mar	183.28	183.24	183.26	183.61	(1986)	182.74	(1926)
Apr	183.30	183.24	183.29	183.68	(1986)	182.72	(1926)
May	183.40	183.38	183.39	183.74	(1986)	182.76	(1926)
Jun	183.46	183.48	183.47	183.76	(1986)	182.85	(1926)
Jul	183.53	183.56	183.54	183.82	(1950)	182.96	(1926)
Aug	183.56	183.62	183.57	183.86	(1950)	183.02	(1926)
Sep	183.59	183.62	183.57	183.86	(1985)	183.12	(1926)
Oct	183.56	183.58	183.54	183.91	(1985)	183.10	(1925)
Nov	183.50	183.52	183.50	183.89	(1985)	183.01	(1925)
Dec	183.42	183.46	183.43	183.81	(1985)	182.92	(1925)

Lakes Michigan-Huron Levels

	1994	1993	1918-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	176.57	176.54	176.35	177.18	(1987)	175.60	(1965)
Feb	176.56	176.51	176.33	177.11	(1986)	175.59	(1964)
Mar	176.59	176.48	176.35	177.12	(1986)	175.58	(1964)
Apr	176.63	176.58	176.43	177.23	(1986)	175.61	(1964)
May	176.70	176.70	176.53	177.28	(1986)	175.74	(1964)
Jun	176.72	176.82	176.59	177.33	(1986)	175.76	(1964)
Jul	176.81	176.91	176.62	177.39	(1986)	175.78	(1964)
Aug	176.81	176.88	176.60	177.39	(1986)	175.77	(1964)
Sep	176.78	176.83	176.55	177.38	(1986)	175.76	(1964)
Oct	176.71	176.76	176.49	177.50	(1986)	175.70	(1964)
Nov	176.65	176.70	176.43	177.38	(1986)	175.65	(1964)
Dec	176.59	176.64	176.38	177.26	(1986)	175.62	(1964)

Lake St. Clair Water Levels

	1994	1993	1918-1993	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum		Minimum	
Jan	175.05	175.40	174.82	175.80	(1986)	173.88	(1936)
Feb	175.16	175.26	174.76	175.80	(1986)	173.89	(1926)
Mar	175.18	175.34	174.89	175.80	(1986)	174.05	(1934)
Apr	175.31	175.42	175.04	175.82	(1986)	174.32	(1926)
May	175.37	175.43	175.12	175.83	(1986)	174.42	(1934)
Jun	175.40	175.48	175.17	175.92	(1986)	174.45	(1934)
Jul	175.49	175.56	175.18	175.93	(1986)	174.50	(1934)
Aug	175.48	175.51	175.15	175.90	(1986)	174.41	(1934)
Sep	175.39	175.44	175.08	175.84	(1986)	174.34	(1934)
Oct	175.29	175.30	175.00	175.96	(1986)	174.27	(1934)
Nov	175.18	175.21	174.91	175.82	(1986)	174.18	(1934)
Dec	175.16	175.22	174.91	175.80	(1986)	174.24	(1964)

(Continued on next page)

Table 3 (Continued)

Lake Erie Water Levels

Previous Recorded Maxima & Minima (Year of Occurrence)

	1994	1993	1918-1993	Maximum	Minimum
Jan	174.21	174.59	173.98	174.86 (1987)	173.21 (1935)
Feb	174.18	174.54	173.96	174.78 (1987)	173.18 (1936)
Mar	174.28	174.55	174.05	174.88 (1986)	173.20 (1934)
Apr	174.48	174.70	174.20	174.98 (1985)	173.38 (1934)
May	174.54	174.67	174.29	174.97 (1986)	173.44 (1934)
Jun	174.53	174.66	174.32	175.04 (1986)	173.45 (1934)
Jul	174.58	174.65	174.30	175.03 (1986)	173.45 (1934)
Aug	174.53	174.53	174.24	174.94 (1986)	173.43 (1934)
Sep	174.42	174.42	174.15	174.83 (1986)	173.38 (1934)
Oct	174.31	174.31	174.05	174.94 (1986)	173.30 (1934)
Nov	174.24	174.25	173.98	174.85 (1986)	173.20 (1934)
Dec	174.21	174.29	173.98	174.90 (1986)	173.19 (1934)

Lake Ontario Water Levels

Previous Recorded Maxima & Minima (Year of Occurrence)

	1994	1993	1918-1993	Maximum	Minimum
Jan	74.55	75.04	74.55	75.16 (1946)	73.81 (1935)
Feb	74.52	75.16	74.58	75.27 (1952)	73.78 (1936)
Mar	74.55	75.14	74.66	75.37 (1952)	73.94 (1935)
Apr	74.87	75.42	74.87	75.65 (1973)	74.03 (1935)
May	75.10	75.61	75.00	75.73 (1973)	74.11 (1935)
Jun	75.08	75.46	75.04	75.76 (1952)	74.19 (1935)
Jul	75.02	75.24	74.98	75.66 (1947)	74.14 (1934)
Aug	74.93	75.01	74.87	75.58 (1947)	74.00 (1934)
Sep	74.78	74.75	74.74	75.41 (1947)	73.91 (1934)
Oct	74.62	74.60	74.61	75.22 (1945)	73.82 (1934)
Nov	74.54	74.52	74.54	75.18 (1945)	73.75 (1934)
Dec	74.50	74.56	74.52	75.20 (1945)	73.74 (1934)

Montréal Harbour (Jetty No.1)

Previous Recorded Maxima & Minima (Year of Occurrence)

	1994	1993	Average 1967-1993	Maximum	Minimum
Jan	6.48	6.82	6.95	8.96 (1968)	6.18 (1992)
Feb	6.87	8.16	7.13	9.04 (1967)	6.34 (1989)
Mar	6.58	7.34	7.13	8.36 (1973)	6.13 (1989)
Apr	7.18	8.24	7.66	8.82 (1976)	6.44 (1989)
May	7.02	7.32	7.42	8.93 (1974)	6.42 (1968)
Jun	6.79	7.26	6.84	8.12 (1974)	5.93 (1988)
Jul	6.81	6.70	6.58	7.49 (1973)	5.72 (1988)
Aug	6.46	6.53	6.49	7.27 (1972)	5.93 (1991)
Sep	6.18	6.27	6.43	7.08 (1986)	5.85 (1991)
Oct	6.02	6.50	6.50	7.16 (1986)	5.82 (1991)
Nov	6.19	6.55	6.62	7.31 (1967)	5.64 (1991)
Dec	6.20	6.50	6.68	7.24 (1972)	5.87 (1978)

R denotes new record.

Table 4 **Lake Superior Supply Summary**

	1900-1993 Average	1994 N.B.S. (m³/s)	1994 Accu difference Storage (m)	1993 N.B.S. (m³/s)	1993 Accu difference Storage (m)
Jan	-380	-1170	-0.03	-390	0
Feb	260	770	-0.01	-1600	-0.06
Mar	1290	1410	-0.01	680	-0.08
Apr	4210	4810	0.01	4850	-0.06
May	5240	4490	-0.01	6460	-0.02
Jun	4440	4100	-0.02	4180	-0.03
Jul	3680	3560	-0.02	4920	0.01
Aug	2820	2920	-0.02	3300	0.03
Sep	2070	2630	0	200	-0.03
Oct	1110	190	-0.03	870	-0.04
Nov	540	-410	-0.06	-650	-0.08
Dec	-640	-460	-0.06	600	-0.04
Sum	24600	22800		23400	

Table 5 **Lakes Michigan-Huron Supply Summary**

	1900-1993 Average	1994 N.B.S. (m³/s)	1994 Accu difference Storage (m)	1993 N.B.S. (m³/s)	1993 Accu difference Storage (m)
Jan	1530	830	-0.02	3350	0.04
Feb	2450	3350	0	1220	0.01
Mar	5240	5130	0	2470	-0.05
Apr	8120	6180	-0.04	11090	0.02
May	7070	5070	-0.09	6470	0
Jun	5780	5120	-0.10	9540	0.09
Jul	3610	6660	-0.03	4530	0.11
Aug	1560	2670	-0.01	2330	0.13
Sep	850	1410	0	610	0.12
Oct	90	-970	-0.02	70	0.12
Nov	1140	1600	-0.01	1350	0.13
Dec	850	-240	-0.03	490	0.12
Sum	38300	36800		43500	

Source: International Lake Superior Board of Control
31380 m^3/s-month is equivalent to 1 metre storage on Lake Superior
44670 m^3/s-month is equivalent to 1 metre storage on Lakes Mich-Huron

Table 6 **Lake Erie Supply Summary**

	1900-1993 Average	1994 N.B.S. (m^3/s)	1994 Accu difference Storage (metres)	1993 N.B.S. (m^3/s)	1993 Accu difference Storage (metres)
Jan	720	60	-0.07	2380	0.17
Feb	1010	330	-0.14	360	0.10
Mar	2030	1860	-0.15	2930	0.20
Apr	1880	2680	-0.07	2420	0.25
May	1290	590	-0.14	360	0.16
Jun	830	1410	-0.09	1500	0.22
Jul	130	110	-0.09	-250	0.19
Aug	-340	270	-0.02	-560	0.16
Sep	-520	-650	-0.04	-1040	0.11
Oct	-640	-710	-0.05	-980	0.07
Nov	-110	-540	-0.09	730	0.16
Dec	510	950	-0.04	210	0.13
Sum	6790	6360		8060	

Source: Environment Canada, Ontario Region
9750 m^3/s-months is equivalent to 1 metre storage on Lake Erie

Table 7 **Lake Ontario Supply Summary**

	1900-1993 Average	1994 N.B.S. (m^3/s)	1994 Accu difference Storage (metres)	1993 N.B.S. (m^3/s)	1993 Accu difference Storage (metres)
Jan	940	220	-0.10	2330	0.19
Feb	1060	780	-0.13	910	0.17
Mar	2140	1940	-0.16	1750	0.11
Apr	2670	3740	-0.02	4600R	0.37
May	1710	1860	0	2060	0.42
Jun	1180	1220	0.01	2120	0.55
Jul	680	710	0.01	590	0.54
Aug	240	400	0.03	100	0.52
Sep	140	20	0.02	0	0.50
Oct	230	240	0.02	380	0.52
Nov	590	480	0	1010	0.57
Dec	790	1010	0.03	1040	0.61
Sum	12400	12600		16900	

Source: International St. Lawrence River Board of Control
7430 m^3/m-months is equivalent to 1 metre storage on Lake Ontario

LAKE SUPERIOR MONTHLY MEAN LEVEL

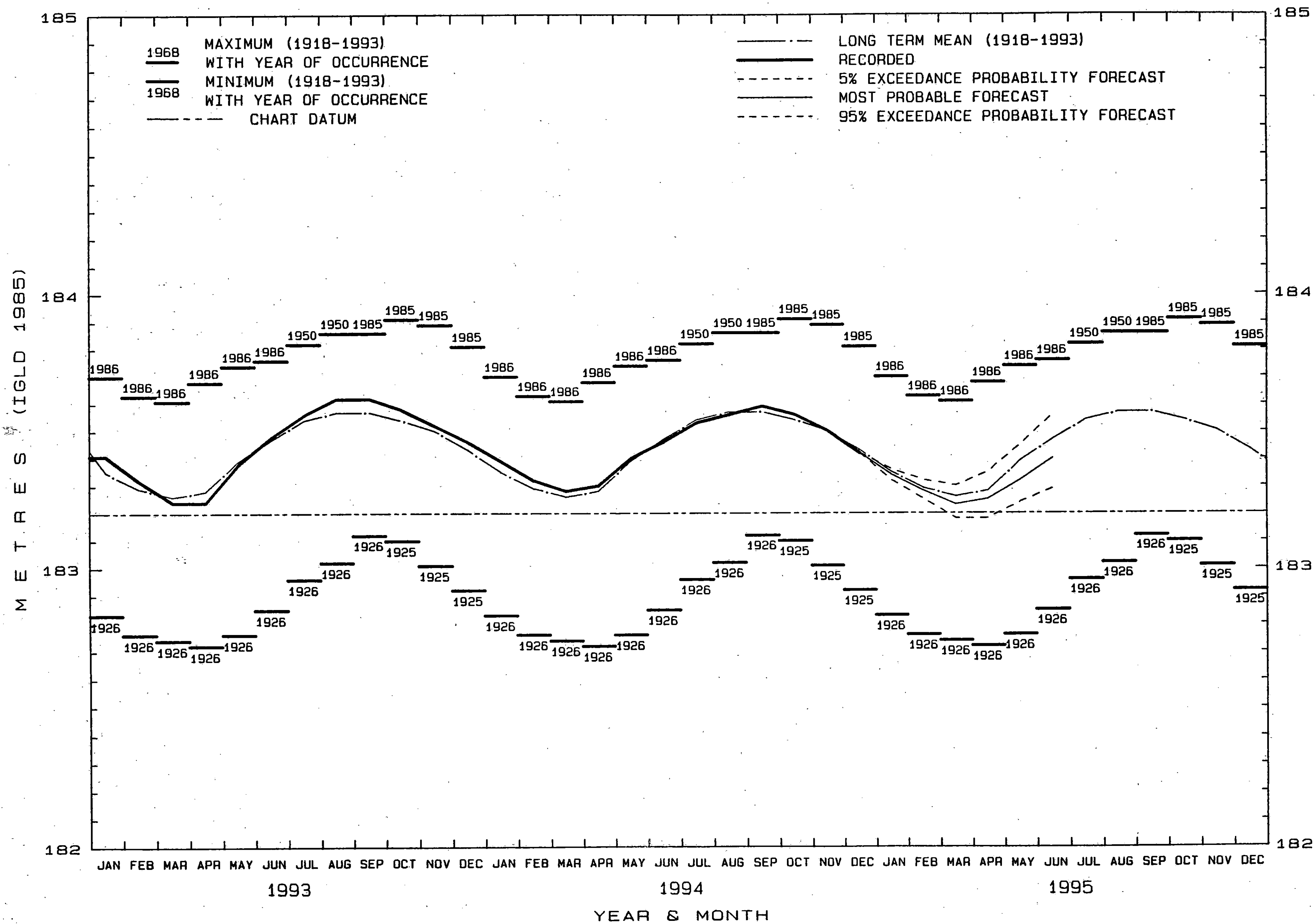
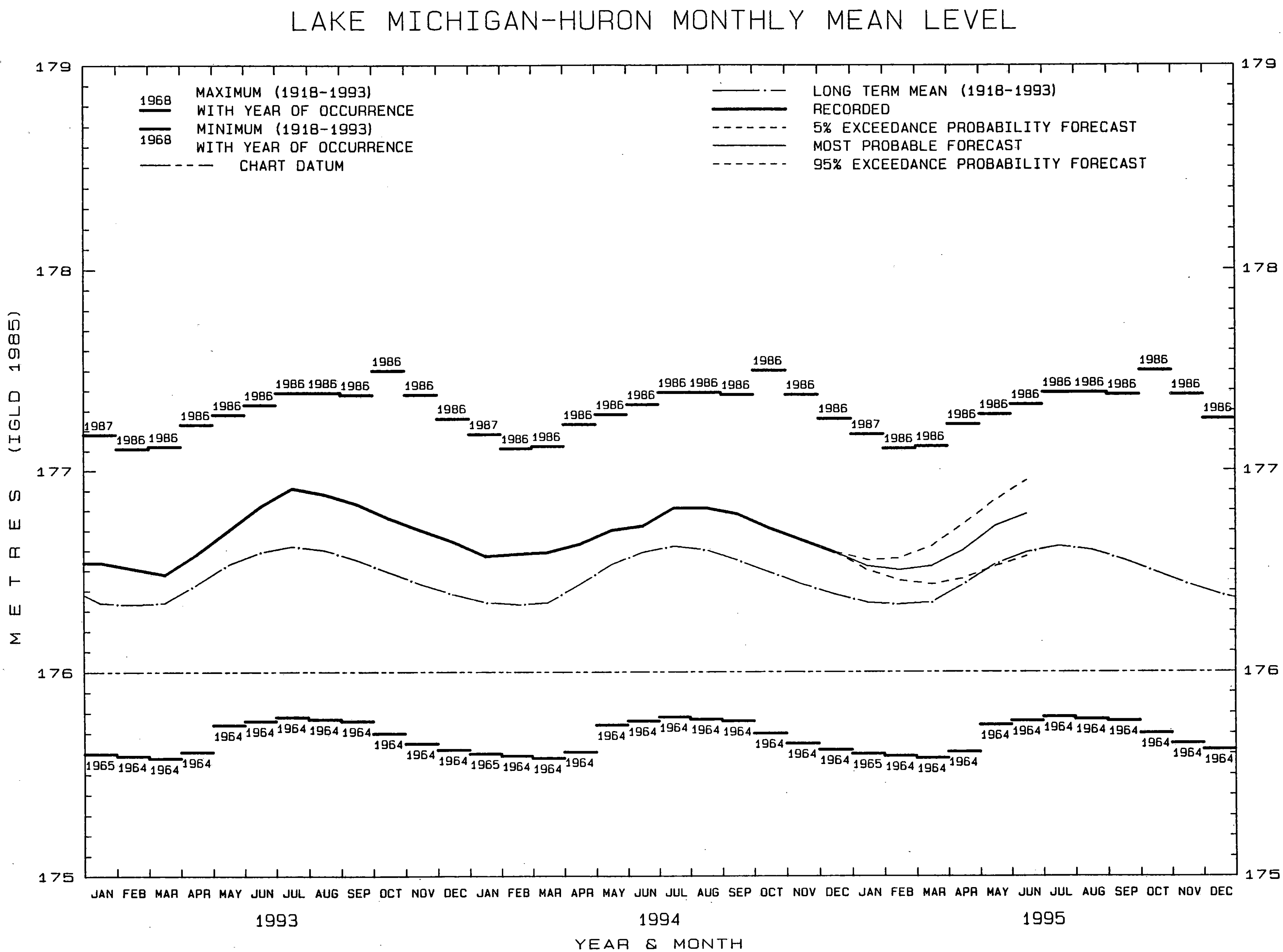


FIGURE 3.



LAKE MICHIGAN-HURON MONTHLY MEAN LEVEL
MAXIMUM (1918-1993) WITH YEAR OF OCCURRENCE
MINIMUM (1918-1993) WITH YEAR OF OCCURRENCE
CHART DATUM
LONG TERM MEAN (1918-1993)
RECORDED
5% EXCEEDANCE PROBABILITY FORECAST
MOST PROBABLE FORECAST
95% EXCEEDANCE PROBABILITY FORECAST
METRES (IGLD 1985)
179
178
177
176
175
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1993
1994
1995
YEAR & MONTH

FIGURE 4.

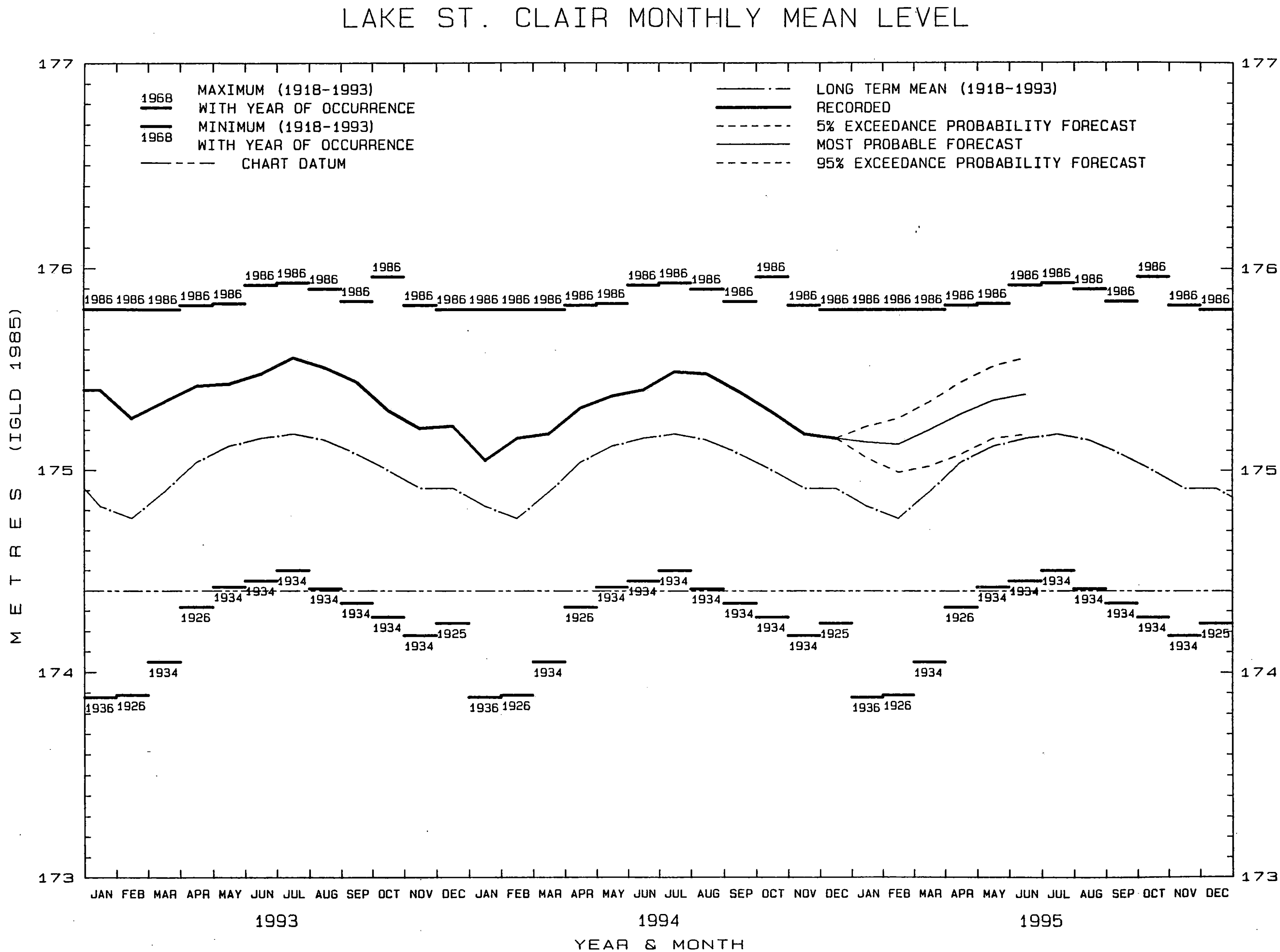

LAKE ST. CLAIR MONTHLY MEAN LEVEL
MAXIMUM (1918-1993) WITH YEAR OF OCCURRENCE
MINIMUM (1918-1993) WITH YEAR OF OCCURRENCE
CHART DATUM
LONG TERM MEAN (1918-1993)
RECORDED
5% EXCEEDANCE PROBABILITY FORECAST
MOST PROBABLE FORECAST
95% EXCEEDANCE PROBABILITY FORECAST
METRES (IGLD 1985)
YEAR & MONTH
1993
1994
1995

FIGURE 5.

LAKE ERIE MONTHLY MEAN LEVEL

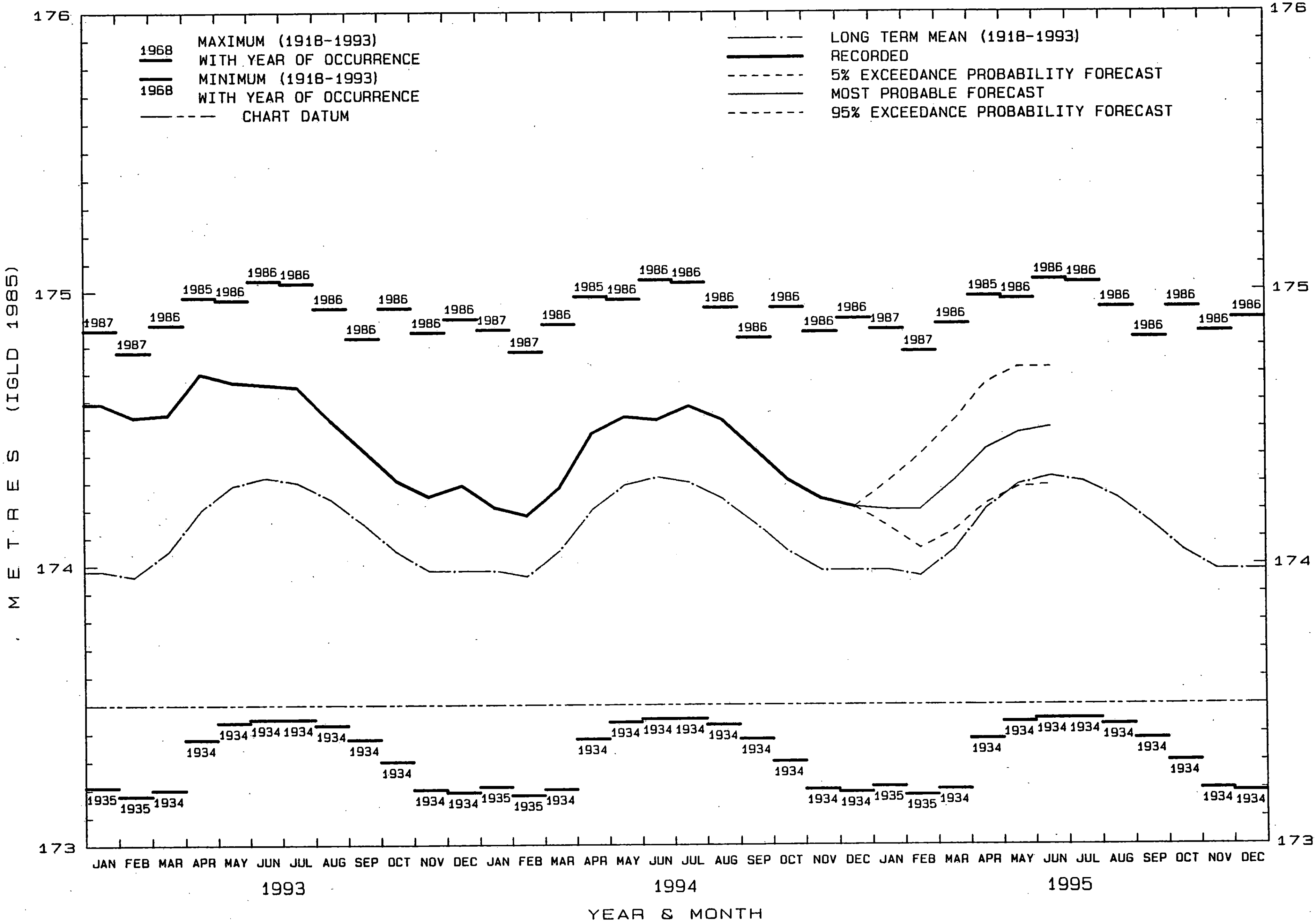


FIGURE 6.

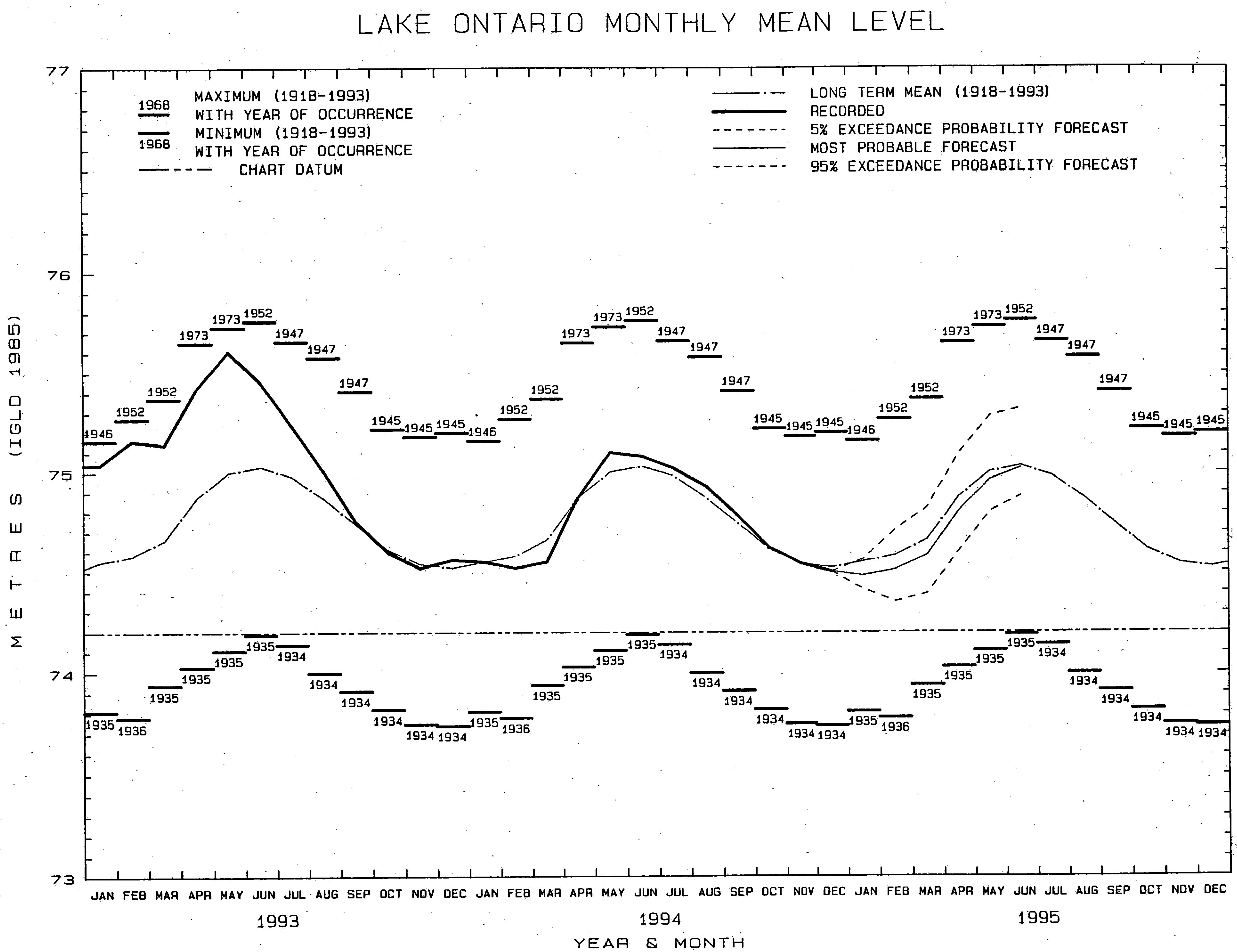

LAKE ONTARIO MONTHLY MEAN LEVEL
MAXIMUM (1918-1993) WITH YEAR OF OCCURRENCE
MINIMUM (1918-1993) WITH YEAR OF OCCURRENCE
CHART DATUM
LONG TERM MEAN (1918-1993)
RECORDED
5% EXCEEDANCE PROBABILITY FORECAST
MOST PROBABLE FORECAST
95% EXCEEDANCE PROBABILITY FORECAST
METRES (IGLD 1985)
77
76
75
74
73
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1993
1994
1995
YEAR & MONTH

FIGURE 7.

MONTREAL HARBOUR (JETTY NO. 1)

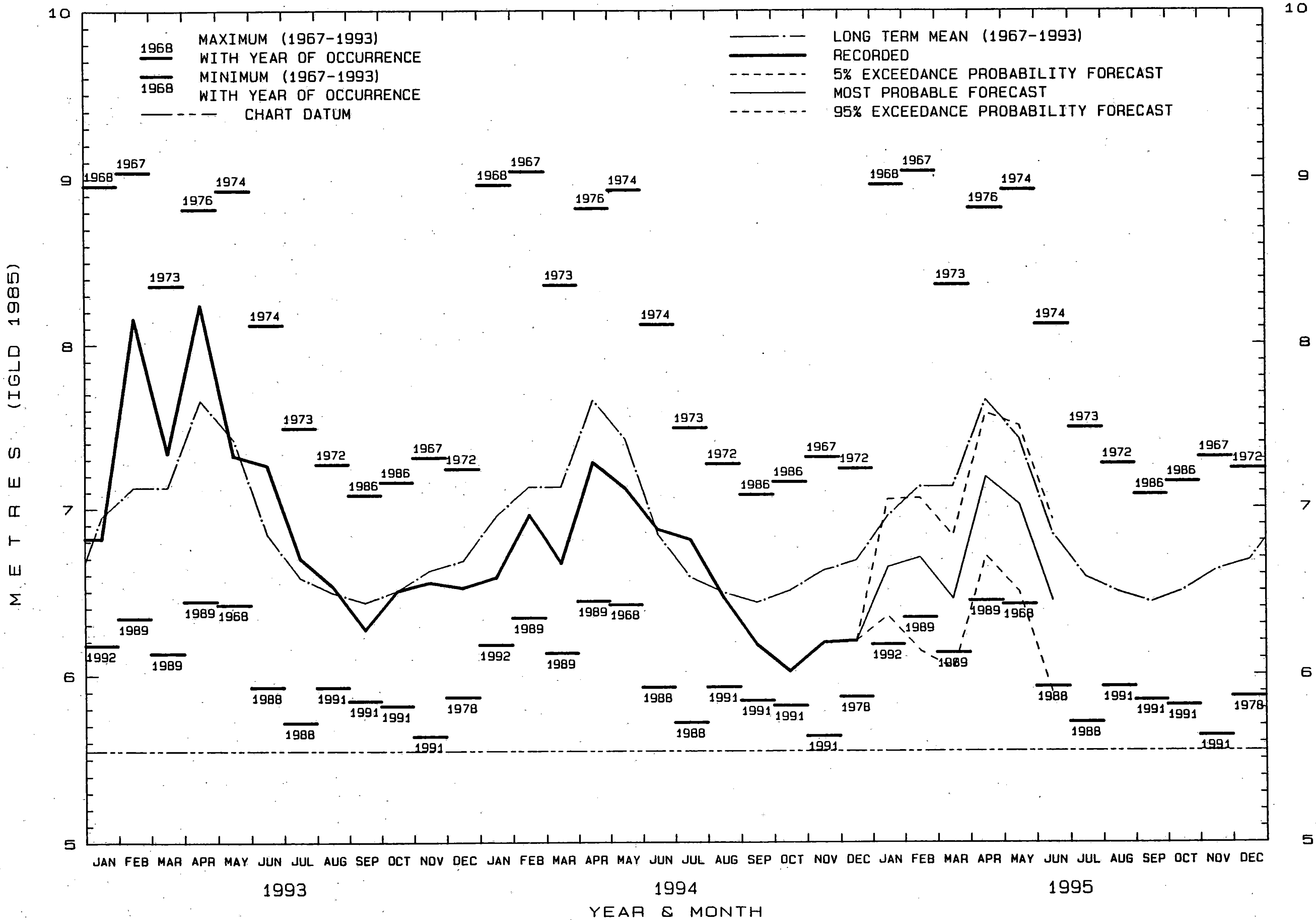


FIGURE 8.