REPORT ON

POTENTIAL MEASURES TO ALLEVIATE PROBLEMS CREATED BY CURRENT HIGH LAKE LEVELS

TASK 3

DIVERSIONS MANAGEMENT

TO

THE INTERNATIONAL JOINT COMMISSION

FROM TASK GROUP MEMBERS

GERALD MACMILLAN	DON LEONARD
REG GOLDING	BILL DALEY
MAC ODELL	BILL ERDLE
PETER YEE	NEIL FULTON

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EXECUTIVE SUMMARY

The Governments of Canada and the United States requested, in August 1986, that the International Joint Commission study methods of alleviating the adverse consequences of fluctuating Great Lakes water levels. Part of this study entailed an immediate short-term investigation of methods of alleviating the present high water level crisis. One of the elements of the short-term investigation was a study of diversions management and the results are contained herein.

The theoretical maximum flow through the Welland Canal in an extreme crisis situation was estimated to be 12,000 cubic feet per second (cfs). The most significant physical impacts of this maximum flow would be the complete disruption of navigation between Lake Ontario and the upper lakes and the possibility of major damage to the canal itself. A reduction in Lake Erie levels of 1.3 inches would be achieved.

The Ogoki and Long Lac Diversions can be closed completely but, because of significant social impacts associated with the closure of the Long Lac Diversion, a scenario involving a combined annual diversion flow of 800 cfs was investigated to determine the benefits foregone by maintaining the log-driving operation from Long Lake. The most significant physical impacts were the direct loss of 2,500 jobs in the Terrace Bay - Longlac area resulting from the closure of the Kimberly-Clark pulp mill in Terrace Bay due to complete closure of Long Lac Diversion, and the reduction in livelihood and alteration in way of life for local populations associated with the closure of both diversions. A significant annual hydro energy loss would be replaced by thermal generation and the impacts would be spread over the entire basin population, particularly in Ontario. The maximum Lake Erie water level reduction would be 1.8 inches.

The maximum annual flow in the Lake Michigan Diversion at Chicago has been determined to be 10,000 cfs. The significant physical impacts of this maximum flow would be the interruption of navigation in the Sanitary and Ship Canal as well as flooding of extensive low-lying areas along the Illinois Waterway and even the Mississippi River if these areas are not below bankful conditions. A reduction in the level of Lake Erie of 1.5 inches could be achieved by an increase in the flow of the Lake Michigan Diversion at Chicago.

It was determined that the diversion of Niagara River water through the New York State Barge Canal has virtually no effect on Lake Erie.

SUMMARY TABLE

LAKES	MAXIMUM LAKE LEVEL REDUCTIONS DUE TO DIVERSIONS MANAGEMENT			
	OGOKI - LONG LAC		WELLAND	CHICAGO
	0 cfs	800 cfs	12,000 cfs	10,000 cfs
Michigan - Huron	0.23 ft.	0.19 ft.	0.03 ft.	0.21 ft.
St. Clair	0.18 ft.	0.15 ft.	0.06 ft.	0.16 ft.
Erie	0.15 ft.	0.13 ft.	0.11 ft.	0.14 ft.

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Introduction

As a result of record high Great Lakes levels in 1985 and 1986, the Governments of Canada and the United States issued, in August 1986, a new reference to the International Joint Commission for a comprehensive, multi-year study of methods to alleviate the adverse consequences of fluctuating Great Lakes water levels. The Governments asked for an interim report in one year and a final report by May 1, 1989. This report on "Diversions Management" forms part of the documentation which may lead to the preparation of the Commission's interim report.

The work elements under this task have been subdivided into four objectives:

> Objective A, involves the determination of the theoretical maximum flows through the Welland Canal and the identification of the significant physical effects associated with the passage of maximum flows.
>
> Objective B, is the identification of the significant physical effects of stopping the Ogoki and Long Lac diversions.
>
> Objective C, describes the facilities used for the Lake Michigan Diversion at Chicago, its limitations and identifies the impacts of increasing the diversion flow.
>
> Objective D, describes the diversion of water through the New York State Barge Canal.

The performance of the investigations into management of these four diversions was delegated to the national participants with the Canadian personnel being responsible for the Ogoki-Long Lac and Welland Canal diversions and the personnel from the United States handling the Chicago Diversion and the NY State Barge Canal. The minor variations in format are due to this division of responsibility.

OBJECTIVE A

The Welland Canal diversion is a man-made waterway between Lake Erie and Lake Ontario which by-passes the navigational obstacle of Niagara Falls and provides a transportation link between Lake Ontario and the upper lakes. The physical description and technical specifications of the canal have been reprinted from the report of the International Great Lakes Diversions and Consumptive Uses Study Board and are contained in Appendix A.

Maximum Flows: The flows through the Welland Canal unfortunately have been declining throughout the recent years leading up to and during the high water level crisis. The most recent figures indicate a decline from the theoretical operational maximum flow with navigation of 9,200 cfs on an average annual basis in 1980 down to an annual average of 7,900 cfs during 1985 and 1986. The majority of the reduction has been due to the required repair of a lock wall failure in 1985 and the beginning of a major 7-year canal rehabilitation program. In the spring of 1987 all flows in the canal had returned to normal with the completion of major concrete rehabilitation work at Lock 8 and the re-opening of the Seaway's power plant which had been inoperable since the Lock 7 wall failure. The St. Lawrence Seaway Authority has advised that the average flow through the canal should average 9,200 cfs during the 1987 navigation season and the rehabilitation program should not cause significant reductions from this figure for the next few years.

During the Diversions and Consumptive Uses study, the theoretical maximum flow through the canal with maximum water use by all sectors, including full capacity navigation traffic, was estimated to be 11,000 cfs. If a water level crisis of such proportions existed that a decision was taken to utilize the canal to remove water from Lake Erie, then all navigation would be stopped and lockages without vessels would occur. Dummy lockages would be necessary as the locks of the canal could not withstand continuous flow without complete destruction. An estimate of the possible flows under these conditions was set at 12,000 cfs.

Significant Physical Effects: A computer simulation of lake levels associated with a Welland Canal flow of 12,000 cfs was performed and compared to similar lake levels representing a normal maximum canal flow of 9,200 cfs as a base case. The other factors in the base case were: lake supplies - 20 year average, Long Lac/Ogoki - 5,600 cfs and Chicago Diversion - 3,200 cfs. The results are illustrated in case 1, tables 1, 2 and 3. The tables indicate the benefits on Lakes Michigan- Huron, St. Clair and Erie derived from such an action in terms of differences in elevations. The time period selected for the continuous flow change was from April 1, 1987 to December 31, 1989 to reflect the short-term aspect of this study. The result of this action at the end of the timeframe would be to effect a reduction of lake levels on Michigan-Huron of 0.03 foot (0.4 inch), on Lake St. Clair of 0.06 foot (0.7 inch) and on Lake Erie of 0.11 foot (1.3 inches) at the end of two and one-half years operation. There would be a reduction in the level of Lake Superior due to operation of Plan 1977 but it would be small and unidentifiable due to regulation, therefore a table for Lake Superior was not prepared.

CASE 1 - PLAN 1977 IN EFFECT - WELLAND CANAL= 12,000 CFS

Table 1: Lakes Michigan-Huron (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	WELLAND= 12,000 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	580.51	580.51	0.00
MAY	580.78	580.78	0.00
JUN	580.94	580.94	0.00
JUL	580.95	580.95	0.00
AUG	580.77	580.77	0.00
SEP	580.54	580.54	0.00
OCT	580.20	580.20	0.00
NOV	579.91	579.91	0.00
DEC	579.66	579.66	0.00
1988			
JAN	579.52	579.51	0.01
FEB	579.45	579.44	0.01
MAR	579.55	579.54	0.01
APR	579.85	579.84	0.01
MAY	580.14	580.13	0.01
JUN	580.33	580.32	0.01
JUL	580.35	580.34	0.01
AUG	580.18	580.17	0.01
SEP	579.97	579.96	0.01
OCT	579.65	579.63	0.02
NOV	579.38	579.36	0.02
DEC	579.16	579.14	0.02
1989			
JAN	579.04	579.02	0.02
FEB	579.00	578.98	0.02
MAR	579.12	579.10	0.02
APR	579.44	579.42	0.02
MAY	579.74	579.72	0.02
JUN	579.93	579.91	0.02
JUL	579.92	579.90	0.02
AUG	579.78	579.76	0.02
SEP	579.54	579.52	0.02
OCT	579.25	579.23	0.02
NOV	579.02	579.00	0.02
DEC	578.81	578.78	0.03

CASE 1 - PLAN 1977 IN EFFECT - WELLAND CANAL= 12,000 CFS

Table 2: Lake St. Clair (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	WELLAND= 12,000 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	575.92	575.91	0.01
MAY	576.08	576.06	0.02
JUN	576.10	576.07	0.03
JUL	576.01	575.98	0.03
AUG	575.74	575.70	0.04
SEP	575.46	575.42	0.04
OCT	575.13	575.09	0.04
NOV	574.89	574.85	0.04
DEC	574.82	574.78	0.04
1988			
JAN	574.63	574.58	0.05
FEB	574.48	574.43	0.05
MAR	574.96	574.90	0.06
APR	575.31	575.26	0.05
MAY	575.49	575.44	0.05
JUN	575.55	575.49	0.06
JUL	575.48	575.42	0.06
AUG	575.22	575.16	0.06
SEP	574.96	574.90	0.06
OCT	574.64	574.59	0.05
NOV	574.42	574.36	0.06
DEC	574.37	574.32	0.05
1989			
JAN	574.20	574.13	0.07
FEB	574.07	574.00	0.07
MAR	574.57	574.50	0.07
APR	574.94	574.88	0.06
MAY	575.14	575.08	0.06
JUN	575.20	575.13	0.07
JUL	575.12	575.05	0.07
AUG	574.87	574.81	0.06
SEP	574.60	574.54	0.06
OCT	574.30	574.24	0.06
NOV	574.10	574.04	0.06
DEC	574.06	574.00	0.06

CASE 1 - PLAN 1977 IN EFFECT - WELLAND CANAL= 12,000 CFS

Table 3: Lake Erie (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	WELLAND= 12,000 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	573.07	573.05	0.02
MAY	573.15	573.11	0.04
JUN	573.11	573.06	0.05
JUL	572.92	572.86	0.06
AUG	572.61	572.54	0.07
SEP	572.27	572.20	0.07
OCT	571.93	571.86	0.07
NOV	571.74	571.66	0.08
DEC	571.71	571.62	0.09
1988			
JAN	571.67	571.58	0.09
FEB	571.69	571.60	0.09
MAR	572.12	572.03	0.09
APR	572.48	572.39	0.09
MAY	572.60	572.50	0.10
JUN	572.59	572.49	0.10
JUL	572.42	572.32	0.10
AUG	572.12	572.03	0.09
SEP	571.80	571.71	0.09
OCT	571.48	571.39	0.09
NOV	571.30	571.21	0.09
DEC	571.28	571.19	0.09
1989			
JAN	571.26	571.16	0.10
FEB	571.30	571.20	0.10
MAR	571.75	571.65	0.10
APR	572.13	572.03	0.10
MAY	572.26	572.16	0.10
JUN	572.26	572.16	0.10
JUL	572.10	572.00	0.10
AUG	571.81	571.71	0.10
SEP	571.49	571.39	0.10
OCT	571.17	571.07	0.10
NOV	571.00	570.90	0.10
DEC	571.00	570.89	0.11

A decision to utilize the Welland Canal to remove excess water from Lake Erie by passing maximum flows would have several significant physical impacts over a widespread area. Firstly, there would be a complete cessation of navigation between Lake Ontario and the upper lakes for the entire period, effectively cutting the St. Lawrence Seaway in half, and the effects on trade patterns and jobs would involve a major portion of the continent. In the Great Lakes region, the impacts would be more dramatic with impacts in all industrial and agricultural sectors including the physical displacement of workers. In the canal region, the impacts would be even more physical with the possibility of major damage to the canal itself from the stress applied to the system by the increased flows. Both the supply and navigational channels are subject to erosion and bank slumping at flows in excess of 9,000 cfs. Flows at a rate of 12,000 cfs would accelerate the erosion rates with the possibility of major damage to the canal banks necessitating a closure of the canal for repair and maintenance. The higher flows would also raise the water levels in the canal beyond the "bankfull" conditions and cause flooding around the pondage basins and over the docks. The Seaway Authority has determined that even the intermittent passage of 10,000 cfs which now occurs causes vessel navigation problems and increased maintenance through bank stabilization and dredging. For any significant increase in flows in the Welland Canal to occur, some modifications to the canal would probably have to be done so that maximum vessel traffic and maximum auxiliary water use could be accomodated simultaneously.

OBJECTIVE B

The Ogoki and Long Lac Diversions are two separate projects which divert water from the Hudson Bay drainage basin to the Great Lakes drainage basin. The history and physical description of each of these diversions have been reprinted from the report of the International Great Lakes Diversions and Consumptive Uses Study Board and are contained in Appendix B.

Minimum Flows: Both the Ogoki and Long Lac Diversions are capable of being reduced to zero and the flows redirected northward. In the course of the significant impact investigation, it was realized that there was the possibility of a massive social impact to the town of Terrace Bay and surrounding area if the log-driving operation supporting the Kimberly-Clark Canada Limited pulp mill at Terrace Bay was discontinued. Therefore, two scenarios representing reductions in diversion flows were selected for simulation. These scenarios consisted of one representing a complete stoppage of both flows (0 cfs) while the other allowed the maintenance of sufficient flow to sustain the log-driving operation to the mill (800 cfs on an average annual basis). The elements of the base case were: lake supplies - 20 year average, Lake Michigan Diversion at Chicago - 3,200 cfs and Welland Canal - 9,200 cfs. These scenarios were also simulated under two regulation schemes: Case 2, which had Lake Superior regulation Plan 1977 in effect, and Case 3, which by-passed the regulation plan and passed the full flow reduction to the lower lakes.

Significant Physical Impacts: Computer simulations of lake levels associated with the varied diversion flows were performed and compared with similar lake levels representing the long-term average combined diversion flow of 5,600 cfs. The results are illustrated in Case 2, tables 4, 5 and 6 and Case 3, tables 7, 8 and 9. The tables indicate the benefits on Lakes Michigan-Huron, St. Clair and Erie derived from the diversion flow reductions in terms of differences in elevations. The time period selected for the continuous flow change was April 1, 1987 to December 31, 1989 to reflect the short-term aspect of this study. The result of these flow reductions at the end of the timeframe would be to effect reductions in lake levels on Michigan-Huron of 0.20 foot (2.4 inches), on Lake St. Clair of 0.16 foot (1.9 inches), and on Lake Erie of 0.14 foot (1.7 inches) where the diversion flow was reduced to 0 cfs and Plan 1977 was in effect. Lake level reductions of 0.16 foot (1.9 inches) on Michigan-Huron, 0.13 foot (1.6 inches) on Lake St. Clair, and 0.12 foot (1.4 inches) on Lake Erie would be achieved if the diversion flow were reduced to an annual average of 800 cfs representing the maintenance of the log-driving operation. If regulation Plan 1977 were by-passed and the full flow reduction were passed on to the downstream lakes, the comparable reductions in lake levels would be 0.23 foot (2.8 inches), 0.18 foot (2.2 inches) and 0.15 foot (1.8 inches) for a diversion flow of 0 cfs; while reductions of 0.19 foot (2.3 inches), 0.15 foot (1.8 inches) and 0.13 foot (1.6 inches) would be achieved if a diversion flow of 800 cfs were maintained through the Long Lac Diversion. If Plan 1977 were in operation, a reduction in Lake Superior levels would occur; if Plan 1977 were by-passed, there would be no effect on Lake Superior. A table for Lake Superior was deemed unnecessary.

CASE 2 - PLAN 1977 IN EFFECT - LONG LAC/OGOKI = 0 cfs, 800 cfs

Table 4: Lakes Michigan-Huron (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/0= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	580.51	580.51	0.00	580.51	0.00
MAY	580.78	580.78	0.00	580.78	0.00
JUN	580.94	580.94	0.00	580.94	0.00
JUL	580.95	580.92	0.03	580.92	0.03
AUG	580.77	580.74	0.03	580.75	0.02
SEP	580.54	580.50	0.04	580.51	0.03
OCT	580.20	580.16	0.04	580.17	0.03
NOV	579.91	579.87	0.04	579.88	0.03
DEC	579.66	579.62	0.04	579.63	0.03
1988					
JAN	579.52	579.47	0.05	579.48	0.04
FEB	579.45	579.40	0.05	579.41	0.04
MAR	579.55	579.49	0.06	579.50	0.05
APR	579.85	579.79	0.06	579.80	0.05
MAY	580.14	580.08	0.06	580.09	0.05
JUN	580.33	580.26	0.07	580.27	0.06
JUL	580.35	580.27	0.08	580.27	0.08
AUG	580.18	580.06	0.12	580.09	0.09
SEP	579.97	579.80	0.17	579.83	0.14
OCT	579.65	579.49	0.16	579.52	0.13
NOV	579.38	579.25	0.13	579.28	0.10
DEC	579.16	579.02	0.14	579.04	0.12
1989					
JAN	579.04	578.89	0.15	578.91	0.13
FEB	579.00	578.83	0.17	578.85	0.15
MAR	579.12	578.94	0.18	578.96	0.16
APR	579.44	579.25	0.19	579.27	0.17
MAY	579.74	579.52	0.22	579.54	0.20
JUN	579.93	579.69	0.24	579.71	0.22
JUL	579.92	579.69	0.23	579.71	0.21
AUG	579.78	579.52	0.26	579.55	0.23
SEP	579.54	579.30	0.24	579.33	0.21
OCT	579.25	579.03	0.22	579.07	0.18
NOV	579.02	578.83	0.19	578.87	0.15
DEC	578.81	578.61	0.20	578.65	0.16

CASE 2 - PLAN 1977 IN EFFECT - LONG LAC/OGOKI = 0 cfs, 800 cfs

Table 5: Lake St. Clair (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/0= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	575.92	575.92	0.00	575.92	0.00
MAY	576.08	576.08	0.00	576.08	0.00
JUN	576.10	576.10	0.00	576.10	0.00
JUL	576.01	576.00	0.01	576.00	0.01
AUG	575.74	575.73	0.01	575.73	0.01
SEP	575.46	575.44	0.02	575.44	0.02
OCT	575.13	575.11	0.02	575.11	0.02
NOV	574.89	574.87	0.02	574.87	0.02
DEC	574.82	574.79	0.03	574.80	0.02
1988					
JAN	574.63	574.59	0.04	574.60	0.03
FEB	574.48	574.44	0.04	574.45	0.03
MAR	574.96	574.92	0.04	574.93	0.03
APR	575.31	575.27	0.04	575.28	0.03
MAY	575.49	575.45	0.04	575.46	0.03
JUN	575.55	575.50	0.05	575.51	0.04
JUL	575.48	575.42	0.06	575.42	0.06
AUG	575.22	575.14	0.08	575.16	0.06
SEP	574.96	574.85	0.11	574.87	0.09
OCT	574.64	574.54	0.10	574.56	0.08
NOV	574.42	574.32	0.10	574.35	0.07
DEC	574.37	574.27	0.10	574.29	0.08
1989					
JAN	574.20	574.08	0.12	574.10	0.10
FEB	574.07	573.94	0.13	573.96	0.11
MAR	574.57	574.44	0.13	574.45	0.12
APR	574.94	574.80	0.14	574.82	0.12
MAY	575.14	574.98	0.16	575.00	0.14
JUN	575.20	575.03	0.17	575.04	0.16
JUL	575.12	574.94	0.18	574.96	0.16
AUG	574.87	574.69	0.18	574.71	0.16
SEP	574.60	574.42	0.18	574.44	0.16
OCT	574.30	574.12	0.18	574.15	0.15
NOV	574.10	573.94	0.16	573.97	0.13
DEC	574.06	573.90	0.16	573.93	0.13

CASE 2 - PLAN 1977 IN EFFECT - LONG LAC/OGOKI = 0 cfs, 800 cfs

Table 6: Lake Erie (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/0= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	573.07	573.07	0.00	573.07	0.00
MAY	573.15	573.15	0.00	573.15	0.00
JUN	573.11	573.11	0.00	573.11	0.00
JUL	572.92	572.92	0.00	572.92	0.00
AUG	572.61	572.60	0.01	572.60	0.01
SEP	572.27	572.26	0.01	572.26	0.01
OCT	571.93	571.92	0.01	571.92	0.01
NOV	571.74	571.72	0.02	571.72	0.02
DEC	571.71	571.68	0.03	571.69	0.02
1988					
JAN	571.67	571.64	0.03	571.65	0.02
FEB	571.69	571.66	0.03	571.67	0.02
MAR	572.12	572.09	0.03	572.10	0.02
APR	572.48	572.45	0.03	572.46	0.02
MAY	572.60	572.56	0.04	572.57	0.03
JUN	572.59	572.55	0.04	572.56	0.03
JUL	572.42	572.38	0.04	572.39	0.03
AUG	572.12	572.08	0.04	572.09	0.03
SEP	571.80	571.74	0.06	571.76	0.04
OCT	571.48	571.41	0.07	571.43	0.05
NOV	571.30	571.22	0.08	571.24	0.06
DEC	571.28	571.20	0.08	571.22	0.06
1989					
JAN	571.26	571.17	0.09	571.19	0.07
FEB	571.30	571.21	0.09	571.22	0.08
MAR	571.75	571.65	0.10	571.66	0.09
APR	572.13	572.03	0.10	572.04	0.09
MAY	572.26	572.15	0.11	572.16	0.10
JUN	572.26	572.14	0.12	572.15	0.11
JUL	572.10	571.97	0.13	571.98	0.12
AUG	571.81	571.67	0.14	571.68	0.13
SEP	571.49	571.34	0.15	571.36	0.13
OCT	571.17	571.02	0.15	571.04	0.13
NOV	571.00	570.85	0.15	570.87	0.13
DEC	571.00	570.85	0.14	570.87	0.12

The other physical impacts of altering these diversions will occur in both the Great Lakes and Hudson Bay drainage basins from reductions in flows along the diversion routes and increases in flows within the natural drainage area. Detailed information has been submitted and is enclosed in Appendix E. The data is summarized here for clarity purposes. The largest, but less direct, impact would be the loss of electrical energy production of approximately 1,332,000 Megawatt-hours annually throughout the Ontario Hydro system with some additional losses at the U.S. hydro plants at Sault Ste. Marie and Cornwall as well as the Quebec Hydro stations at Beauharnois and des Cedres. The majority of the replacement energy would be from fossil fuel sources, basically coal, with its attendant production of acid gas annually. The indirect aspect of these impacts would be that all electricity consumers in Ontario would absorb the additional costs and large areas of the Great Lakes basin would receive the additional acid gas precipitation.

The localized, more direct, impacts involve the fluctuations in local lake and river levels and flows and their effects upon the local populations. The most significant potential impact involves the complete closure of the Long Lac Diversion and the stoppage of the log-driving operation of the Kimberly-Clark pulp mill at Terrace Bay. The current mill operation can be classified as marginal at best and closure of the mill has been rumoured from possible economic losses significantly lower than those associated with alternate log transportation. Closure of the mill would result in the direct loss of approximately 2,500 jobs in the Terrace Bay - Longlac and surrounding area as well as impact on the livelihood of approximately 7,500 people indirectly throughout a wider area.

Changes in water levels and flows would be experienced in Lake Nipigon, Little Jackfish River, Ogoki reservoir and the Ogoki and Albany Rivers from closure of the Ogoki Diversion, and the Aguasabon River, Hayes Lake, Long Lake and Kenogami River from closure of the Long Lake Diversion. There would be a direct impact on the fishing and recreation industries of the area as commercial fishing, sport fishing and recreational tourism exists on various water bodies throughout the area. The levels of Lake Nipigon would probably experience more frequent and wider fluctuations as the Nipigon River power plants would be increasingly used in a peaking power operation. Both the commercial and sport fishing operations would be negatively affected as spawning grounds and traditional fishing areas are altered and physical installations become increasingly unusable. It is possible that the reservoir areas (Ogoki reservoir and Long Lake) through operation of the northern control dams could be maintained at their normal operational levels to minimize the local impacts.

The increased flows in the Ogoki River are sufficient to produce noticeable changes in the flow regime of the upper Albany River. Although there might be a small adjustment in the timing of the Albany River flows, the flows could increase by as much as 35% at the confluence of the Ogoki and Albany Rivers. Flood flows, which could be 50% higher than current levels, could affect Indian Reserve No. 65 at the confluence of the two rivers but no additional flooding problems are anticipated along the lower Albany River. A study of historical flood events on indian reserves in the Ogoki, Kenogami and Albany River basins is underway and the results of the study will be forwarded to the Commission as soon as available.

CASE 3 - PLAN 1977 BY-PASSED - LONG LAC/OGOKI = 0 cfs, 800 cfs

Table 7: Lakes Michigan-Huron (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/O= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	580.51	580.50	0.01	580.50	0.01
MAY	580.78	580.76	0.02	580.76	0.02
JUN	580.94	580.91	0.03	580.91	0.03
JUL	580.95	580.91	0.04	580.91	0.04
AUG	580.77	580.72	0.05	580.72	0.05
SEP	580.54	580.48	0.06	580.49	0.05
OCT	580.20	580.13	0.07	580.14	0.06
NOV	579.91	579.83	0.08	579.84	0.07
DEC	579.66	579.57	0.09	579.58	0.08
1988					
JAN	579.52	579.42	0.10	579.43	0.09
FEB	579.45	579.34	0.11	579.35	0.10
MAR	579.55	579.43	0.12	579.44	0.11
APR	579.85	579.72	0.13	579.73	0.12
MAY	580.14	580.01	0.13	580.02	0.12
JUN	580.33	580.19	0.14	580.21	0.12
JUL	580.35	580.20	0.15	580.23	0.12
AUG	580.18	580.02	0.16	580.05	0.13
SEP	579.97	579.80	0.17	579.83	0.14
OCT	579.65	579.47	0.18	579.50	0.15
NOV	579.38	579.19	0.19	579.22	0.16
DEC	579.16	578.96	0.20	579.00	0.16
1989					
JAN	579.04	578.84	0.20	578.88	0.16
FEB	579.00	578.79	0.21	578.83	0.17
MAR	579.12	578.91	0.21	578.95	0.17
APR	579.44	579.23	0.21	579.27	0.17
MAY	579.74	579.53	0.21	579.57	0.17
JUN	579.93	579.72	0.21	579.76	0.17
JUL	579.92	579.71	0.21	579.75	0.17
AUG	579.78	579.56	0.22	579.60	0.18
SEP	579.54	579.32	0.22	579.36	0.18
OCT	579.25	579.02	0.23	579.06	0.19
NOV	579.02	578.79	0.23	578.83	0.19
DEC	578.81	578.58	0.23	578.62	0.19

CASE 3 - PLAN 1977 BY-PASSED - LONG LAC/OGOKI= 0 cfs, 800 cfs

Table 8: Lake St. Clair (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/0= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	575.92	575.92	0.00	575.92	0.00
MAY	576.08	576.07	0.01	576.07	0.01
JUN	576.10	576.08	0.02	576.09	0.01
JUL	576.01	575.99	0.02	575.99	0.02
AUG	575.74	575.71	0.03	575.71	0.03
SEP	575.46	575.42	0.04	575.42	0.04
OCT	575.13	575.09	0.04	575.09	0.04
NOV	574.89	574.84	0.05	574.85	0.04
DEC	574.82	574.77	0.05	574.77	0.05
1988					
JAN	574.63	574.56	0.07	574.56	0.07
FEB	574.48	574.41	0.07	574.41	0.07
MAR	574.96	574.87	0.09	574.88	0.08
APR	575.31	575.22	0.09	575.23	0.08
MAY	575.49	575.40	0.09	575.41	0.08
JUN	575.55	575.45	0.10	575.46	0.09
JUL	575.48	575.37	0.11	575.38	0.10
AUG	575.22	575.11	0.11	575.12	0.10
SEP	574.96	574.84	0.12	574.85	0.11
OCT	574.64	574.51	0.13	574.54	0.10
NOV	574.42	574.29	0.13	574.31	0.11
DEC	574.37	574.23	0.14	574.25	0.12
1989					
JAN	574.20	574.04	0.16	574.07	0.13
FEB	574.07	573.91	0.16	573.94	0.13
MAR	574.57	574.41	0.16	574.44	0.13
APR	574.94	574.78	0.16	574.81	0.13
MAY	575.14	574.97	0.17	575.00	0.14
JUN	575.20	575.03	0.17	575.06	0.14
JUL	575.12	574.95	0.17	574.98	0.14
AUG	574.87	574.71	0.16	574.74	0.13
SEP	574.60	574.43	0.17	574.46	0.14
OCT	574.30	574.13	0.17	574.16	0.14
NOV	574.10	573.93	0.17	573.96	0.14
DEC	574.06	573.88	0.18	573.91	0.15

CASE 3 - PLAN 1977 BY-PASSED - LONG LAC/OGOKI= 0 cfs, 800 cfs

Table 9: Lake Erie (All elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LL/O= 0 cfs ELEVATION	DIFFERENCE IN ELEVATION	LL/0= 800 cfs ELEVATION	DIFFERENCE IN ELEVATION
APR	573.07	573.07	0.00	573.07	0.00
MAY	573.15	573.15	0.00	573.15	0.00
JUN	573.11	573.11	0.00	573.11	0.00
JUL	572.92	572.91	0.01	572.91	0.01
AUG	572.61	572.59	0.02	572.59	0.02
SEP	572.27	572.25	0.02	572.25	0.02
OCT	571.93	571.91	0.02	571.91	0.02
NOV	571.74	571.71	0.03	571.71	0.03
DEC	571.71	571.67	0.04	571.67	0.04
1988					
JAN	571.67	571.62	0.05	571.62	0.05
FEB	571.69	571.64	0.05	571.64	0.05
MAR	572.12	572.06	0.06	572.06	0.06
APR	572.48	572.42	0.06	572.42	0.06
MAY	572.60	572.53	0.07	572.53	0.07
JUN	572.59	572.51	0.08	572.51	0.08
JUL	572.42	572.34	0.08	572.34	0.08
AUG	572.12	572.04	0.08	572.04	0.08
SEP	571.80	571.71	0.09	571.72	0.08
OCT	571.48	571.38	0.10	571.39	0.09
NOV	571.30	571.19	0.11	571.21	0.09
DEC	571.28	571.17	0.11	571.19	0.09
1989					
JAN	571.26	571.14	0.12	571.16	0.10
FEB	571.30	571.18	0.12	571.20	0.10
MAR	571.75	571.62	0.13	571.64	0.11
APR	572.13	572.00	0.13	572.02	0.11
MAY	572.26	572.13	0.13	572.15	0.11
JUN	572.26	572.13	0.13	572.15	0.11
JUL	572.10	571.97	0.13	571.99	0.11
AUG	571.81	571.68	0.13	571.70	0.11
SEP	571.49	571.36	0.13	571.38	0.11
OCT	571.17	571.04	0.13	571.06	0.11
NOV	571.00	570.86	0.14	570.88	0.12
DEC	571.00	570.85	0.15	570.87	0.13

In the downstream areas, Ogoki and Kenogami Rivers, the increased flows would disrupt the fish spawning and wildlife habitat of the entire area. Although a short-term disruption would not force a change in species diversification, there would be immediate impacts on the local population through decline of the fishing, hunting and trapping industries. There would be an increase in navigational hazards due to increased water velocities and debris densities along the rivers.

OBJECTIVE C

Water from Lake Michigan and its drainage basin is diverted at Lockport, Illinois, into the Des Plaines River, a tributary of the Illinois River and a part of the Mississippi River. The City of Chicago pumps about 1,700 cfs from Lake Michigan together with other cities in the Metropolitan Sanitary District for domestic and industrial purposes. After use, most of this water is discharged into the waterways at sewage treatment plants and flows into the Mississippi River Basin. In addition, surface runoff that originally flowed into Lake Michigan and water diverted directly from Lake Michigan (an estimated total amount of 1,500 cfs), flows through the Chicago area waterways into the Mississippi River Basin.

The natural divide separating the Great Lakes drainage basin from the Mississippi River drainage basin passes about ten miles west of the Lake Michigan shoreline at Chicago. When the Sanitary and Ship Canal was constructed from Chicago to Lockport, it breached the divide near Summit at which point the divide was about ten feet above the level of Lake Michigan at LWD.

Reversing the flow of the Chicago and Calumet Rivers and intercepting certain drainage areas along the shore of Lake Michigan at Chicago has eliminated about 800 square miles from the Lake Michigan watershed. Locks and controlling works have closed the Chicago and Calumet Rivers to Lake Michigan. The Calumet River between O'Brien Lock and Lake Michigan flows either lakeward or toward Lockport depending on lake and canal stage and storm runoff. At Wilmette Harbor, a pumping station diverts Lake water to the North Shore Channel. A sluice gate at this point is used for emergency storm water releases from the channel to the lake. A detailed description of the Lake Michigan Diversion at Chicago and its physical capacities is contained in Appendix C.

Maximum Flows: Since 1925, the diversion has been controlled by U.S. Supreme Court decisions. The latest decree, issued in 1967 and amended in 1980, limits the diversion to 3,200 cfs. Studies have indicated a potential for increasing the diversion to a maximum annual diversion of 10,000 cfs.

Significant Physical Effects: As diversions flows increase, navigation decreases and all traffic in the Sanitary and Ship Canal ceases when flows exceed 10,000 cfs. Increases in diversion flow would be possible only when river stages along the Illinois Waterway and the Mississippi River are below bankful conditions. There is a 7-10 day travel time for water diverted at Chicago to transit the Illinois Waterway and flooding of extensive areas along the waterway is a constant hazard. An operating plan to minimize induced flooding on the Illinois Waterway would need to be developed in order to consider an increase in the Lake Michigan Diversion at Chicago a viable means to lower Great Lakes levels.

Computer simulations of lake levels associated with a maximum diversion of 10,000 cfs through the Lake Michigan Diversion at Chicago were compared with similar lake levels representing the long-term average flow of 3,200 cfs. The results are illustrated in Case 4, tables 10, 11 and 12. The tables indicate the benefits on Lakes Michigan-Huron, St. Clair and Erie derived from the maximum diversion flow in terms of differences in elevations. The time period selected for the continuous flow change was April 1, 1987 to December 31, 1989 to reflect the short-term aspect of this study. The results of the increased diversion at the end of the timeframe would be to effect reductions in lake levels on Michigan-Huron of 0.21 foot (2.5 inches), on Lake St. Clair of 0.16 foot (1.9 inches), and on Lake Erie of 0.14 foot (1.7 inches). There would be a small reduction in Lake Superior levels due to the operation of regulation Plan 1977, but a table for Lake Superior was deemed unnecessary. Only during extremely dry hydrologic conditions on the Illinois Waterway could a 10,000 cfs diversion be maintained for any lengthy period of time through the Lake Michigan Diversion at Chicago.

CASE 4 - PLAN 1977 IN EFFECT - LAKE MICHIGAN DIVERSION AT CHICAGO = 10,000 CFS

Table 10: Lakes Michigan-Huron (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LAKE MICHIGAN AT CHICAGO 10,000 CFS ELEVATION	DIFFERENCE IN ELEVATION
APR	580.40	580.39	0.01
MAY	580.70	580.68	0.02
JUN	580.91	580.88	0.03
JUL	581.00	580.96	0.04
AUG	580.95	580.91	0.04
SEP	580.80	580.75	0.05
OCT	580.55	580.50	0.05
NOV	580.28	580.21	0.07
DEC	580.06	579.99	0.07
1988			
JAN	579.87	579.79	0.08
FEB	579.72	579.62	0.10
MAR	579.75	579.64	0.11
APR	580.02	579.91	0.11
MAY	580.36	580.24	0.12
JUN	580.61	580.48	0.13
JUL	580.72	580.59	0.13
AUG	580.70	580.56	0.14
SEP	580.58	580.42	0.16
OCT	580.36	580.20	0.16
NOV	580.11	579.94	0.17
DEC	579.91	579.72	0.19
1989			
JAN	579.72	579.53	0.21
FEB	579.56	578.38	0.18
MAR	579.59	579.40	0.19
APR	579.87	579.67	0.20
MAY	580.21	580.01	0.20
JUN	580.46	580.26	0.20
JUL	580.58	580.37	0.21
AUG	580.55	580.34	0.21
SEP	580.43	580.22	0.21
OCT	580.21	580.00	0.21
NOV	579.95	579.75	0.20
DEC	579.76	579.55	0.21

CASE 4 - PLAN 1977 IN EFFECT - LAKE MICHIGAN DIVERSION AT CHICAGO = 10,000 CFS

Table 11: Lake St-Clair (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LAKE MICHIGAN AT CHICAGO 10,000 CFS ELEVATION	DIFFERENCE IN ELEVATION
APR	575.88	575.87	0.01
MAY	576.06	576.05	0.01
JUN	576.18	576.16	0.02
JUL	576.16	576.14	0.02
AUG	576.02	576.00	0.02
SEP	575.82	575.79	0.03
OCT	575.57	575.54	0.03
NOV	575.35	575.32	0.03
DEC	575.34	575.30	0.04
1988			
JAN	575.45	575.40	0.05
FEB	575.67	575.61	0.06
MAR	575.78	575.71	0.07
APR	575.93	575.85	0.08
MAY	576.03	575.94	0.09
JUN	576.10	576.01	0.09
JUL	576.05	575.96	0.09
AUG	575.89	575.79	0.10
SEP	575.68	575.58	0.10
OCT	575.44	575.33	0.11
NOV	575.23	575.10	0.13
DEC	575.22	575.08	0.14
1989			
JAN	575.33	575.19	0.14
FEB	575.54	575.41	0.13
MAR	575.66	575.51	0.15
APR	575.81	575.66	0.15
MAY	575.90	575.75	0.15
JUN	575.98	575.83	0.15
JUL	575.93	575.77	0.16
AUG	575.77	575.61	0.16
SEP	575.57	575.40	0.17
OCT	575.32	575.16	0.16
NOV	575.10	574.94	0.16
DEC	575.10	574.94	0.16

CASE 4 - PLAN 1977 IN EFFECT - LAKE MICHIGAN DIVERSION AT CHICAGO = 10,000 CFS

Table 12: Lake Erie (all elevations in feet above Great Lakes Datum)

1987	BASE CASE ELEVATION	LAKE MICHIGAN AT CHICAGO 10,000 CFS ELEVATION	DIFFERENCE IN ELEVATION
APR	572.94	572.94	0.00
MAY	573.17	573.17	0.00
JUN	573.25	573.25	0.00
JUL	573.18	573.17	0.01
AUG	572.96	572.94	0.02
SEP	572.70	572.69	0.01
OCT	572.41	572.40	0.01
NOV	572.21	572.20	0.01
DEC	572.29	572.26	0.03
1988			
JAN	572.45	572.42	0.03
FEB	572.68	572.64	0.04
MAR	573.02	572.98	0.04
APR	573.28	573.23	0.05
MAY	573.36	573.30	0.06
JUN	573.33	573.27	0.06
JUL	573.18	573.12	0.06
AUG	572.92	572.84	0.08
SEP	572.63	572.56	0.07
OCT	572.32	572.24	0.08
NOV	572.12	572.02	0.10
DEC	572.19	572.08	0.11
1989			
JAN	572.35	572.24	0.11
FEB	572.58	572.46	0.12
MAR	572.92	572.80	0.12
APR	573.18	573.06	0.12
MAY	573.26	573.14	0.12
JUN	573.23	573.11	0.12
JUL	573.08	572.96	0.12
AUG	572.82	572.68	0.14
SEP	572.53	572.40	0.13
OCT	572.22	572.08	0.14
NOV	572.02	571.88	0.14
DEC	572.08	571.94	0.14

OBJECTIVE D

The New York State Barge Canal is comprised of the interconnected Champlain, Erie, Oswego, and Cayuga-Seneca Canals. This system takes water for navigation purposes from the Niagara River at Tonawanda, New York, and returns all of it to Lake Ontario at several tributaries and the Oswego Canal. A detailed description of the physical layout and capacity of the New York State Barge Canal is contained in Appendix D.

Because this relatively small unregulated flow is withdrawn from the Niagara River at a point considerably downstream from Lake Erie, it has virtually no effect on the levels of the Niagara River, Lake Erie, or the other Great Lakes.

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APPENDIX A

PHYSICAL DESCRIPTION OF THE WELLAND CANAL DIVERSION

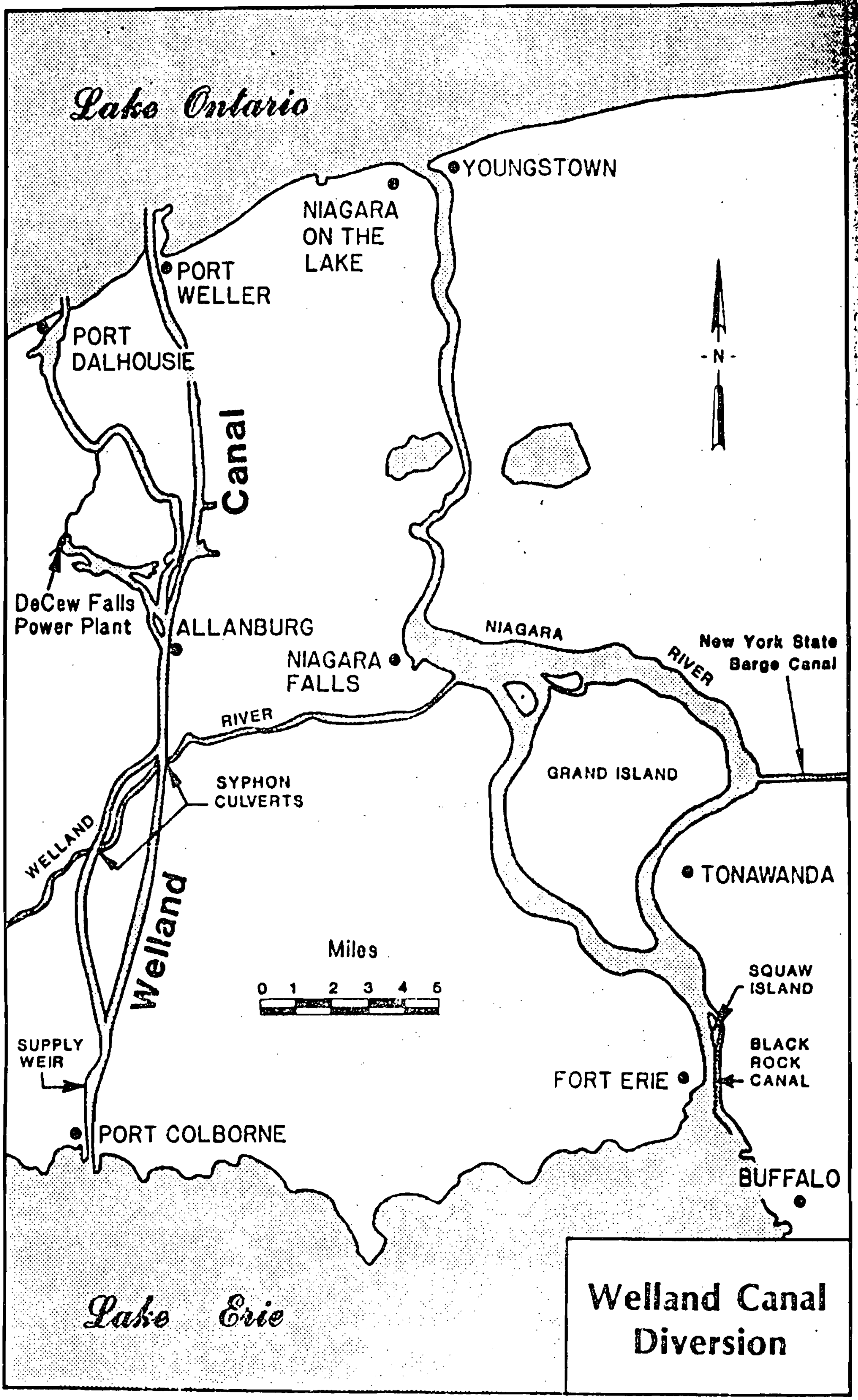
General

The Welland Canal is a deep-draft, man-made navigational waterway, totally within Ontario, Canada, which joins Lake Erie with Lake Ontario across the Niagara Peninsula (see Figure 4-5). It is the route for ocean-going vessels to gain access to Lake Erie and the upper lakes, bypassing the falls and rapids of the Niagara River which once presented the major obstacle to an uninterrupted water route.

History

The original Welland Canal was built in 1829, between Port Dalhousie on Lake Ontario and Port Robinson on the Welland River, to allow navigation between Lakes Erie and Ontario. Prior to 1881 the small water requirement of the Canal, approximately 85 cfs, was supplied through a feeder canal from the Grand River at Dunnville, Ontario, a tributary to Lake Erie. In 1881 the summit reach of the canal was cut through at Lake Erie level and the Lake Ontario end of the canal reconstructed. The improved canal required additional water and by 1887 the diversion amounted to 400 cfs. Between 1887 and 1898 the old canal was adapted for power purposes and by 1898 the total rate of diversion had reached 1,000 cfs. As hydro-power units were installed in the No. 1 plant at DeCew Falls and fed from the Welland Canal, the total diversion grew from 1,100 cfs in 1901 to 1,500 cfs by 1908 and to 2,000 cfs by 1913.

The present Welland Canal has been greatly improved since it was built between 1913 and 1932. By 1933, the total diversion was 2,500 cfs. There was little change during the remaining years of the thirties. However, to meet the power requirements due to World War II, supplementary flow was provided and the total diversion in 1942 reached



Welland Canal Diversion

Figure 4-5

3,200 cfs. The No. 2 DeCew Falls power plant was installed during the period 1943 to 1947, and by 1951 the total diversion was at a maximum rate of 7,400 cfs.

Description of the Present Canal

The Welland Canal is a deep-draft man-made waterway joining Lake Erie with Lake Ontario across the Niagara Peninsula. The Canal was constructed to allow commercial shipping to transit between Lakes Erie and Ontario. The canal lies wholly within the province of Ontario, and since 1959 has been operated by a Canadian crown corporation, the St. Lawrence Seaway Authority, as an integral part of the St. Lawrence Seaway system.

The canal runs in a nearly straight south-to-north direction between Port Colborne on Lake Erie and Port Weller on Lake Ontario, a distance of about 27 miles. The 327-foot difference in water levels between Lakes Erie and Ontario is overcome by eight lift locks spaced along the canal. Factual information concerning these locks is given in Table 4-2. The seven lower locks are located within eight miles of Port Weller, and have an average lift of 46.5 feet each. The eighth lock, at Port Colborne, serves as a shallow-lift guard lock at the upper end of the canal.

The present Welland Canal is a modified version of the fourth Welland Canal (Welland Ship Canal), which was constructed beween 1913 and 1932. Improvements have been made at various locations along the canal to enhance its efficiency. The latest major improvement was completed in 1973 with the complete upgrading and re-routing of nine miles of the canal away from downtown Welland. Most of the canal's features and equipment, however, have remained as originally installed.

Commodity traffic through the canal has increased steadily over the years. In 1932 about 8.3 million tons passed through the canal in 5,712 transits; by 1979 the traffic reached 73 million tons in 6,547 transits. About 75 percent of this traffic is U.S. and Canadian interlake trading in iron ore, coal, limestone and grains. The remainder is fuel oils, iron and steel and other domestic lakes traffic, as well as cargo destined for or arriving from overseas ports.

Until 1932 the largest vessels transiting the canal were less than 261 feet in length and carried less than 3,000 tons of cargo. The completion of the Welland Ship Canal opened the route to the 13,000-ton bulk freighters, 600 feet in length, which previously had been confined to Lake Erie and above. It also induced the construction of even larger vessels; many over 700 feet in length began to appear. Today, 50 percent of canal traffic is carried in "seaway-sized" lakers, 730 feet in length, 76 feet in breadth and carrying 28,000 tons of cargo. The seaway-sized laker is the largest vessel presently permitted to enter the canal. The limiting feature is the size of locks, as shown in Table 4-2. The maximum allowable vessel draft in the canal is 26 feet. This is limited by the controlling depth (27 feet) of the canal prism. Although it is impossible to pass larger vessels through the canal, some future gains in throughput are expected to be achieved by way of operational improvements. The Seaway Authority expects, however, that all possibilities for major gains in throughput will be exhausted by the end of the 1980s, when capacity will be reached at about 34 transits per day, or 90 million tons annually.

Table 4-2
WELLAND CANAL LOCK DATA

Lock	Normal Lift, Ft.	Usable Length of Chamber, Ft.	Usable Width of Chamber, Ft.	Minimum Depth at Sill(2), Ft.
1	46.0	730	76	30
2	46.5	730	76	30
3	46.5	730	76	30
4	47.9	730	76	30
5	47.9	730	76	30
6	43.7	730	76	30
7	46.5	730	76	30
8	2.0-11.0(1)	1148	76	30

Notes: (1) Depending upon the prevailing level of Lake Erie.
(2) The controlling channel depth is 27 feet.

The Welland Canal's success as a commercial transportation artery has led to substantial industrial development and urban settlement in its vicinity. A line of urban communities exists along the canal, some centered on the operation of the canal itself; others taking advantage of cheap transporation, abundant water supply or the opportunity to service shipping and canal needs. The attractions of a canal-side location are extended by ready accessibility to road and rail facilities, as well as cheap hydro-electric power.

Thus the Welland Canal Diversion serves several purposes, apart from navigation. Water for power generation at Ontario Hydro's DeCew Falls generating stations (located about three miles west of the canal), is diverted from the canal at Allanburg. Diversions of canal water for industrial cooling and industrial and municipal water consumption occur at numerous points along the canal. For example, a portion of canal water is diverted into the Welland River to maintain its water quality, and induce flow in the old canal channel in the city of Welland. The present total diversion down the Welland Canal is about 9,200 cfs, calculated on a mean annual basis. More detailed descriptions of the uses of canal water and the method of operating the canal to satisfy these needs are given in the following paragraphs. Also included are descriptions of the physical capacities and practical operating limitations of the various systems presently using canal water, including the canal's main lock and weir system. The summation of the capacities of each part of the canal facility will give an approximation of the absolute capacity of the canal with respect to diversion of Lake Erie water. Consideration of the practical operating limitations gives a better indication of the maximum diversion that is ever likely to occur without major modification to the facility.

Hydraulic Operations Within the Canal

Water enters the canal through a supply raceway, or channel, and through Lock 8 at Port Colborne. The main supply to the canal (which in recent years has been about 9,000 cfs on a mean annual basis) enters through the raceway, which is completely controlled by a weir. The intake through Lock 8 is the result of navigation lockages. This averages about 175 cfs during the navigation season. The lock passes no water after navigation ceases.

Supply Raceway: The present supply weir and equipment constitute the original installation completed in 1932. The weir consists of ten tainter gates, 15 feet wide by 14 feet high each. The gates work in two banks of five gates each. Each bank can be adjusted individually. Gate settings are made remotely from the Lock 8 control tower.

The principle behind the operation of the supply weir is to maintain the water level in the "summit reach" or "long reach" of the canal, i.e., the section between Lock 8 and Lock 7. This level is maintained at 568.0 feet (IGLD) at Lock 8, which provides a depth of 30.8 feet over the sill of Lock 8, and 30 feet over the sill of Lock 7 (the difference is due to the hydraulic gradient of the canal), to meet the requirement for safe navigation. The seemingly simple feat of maintaining the summit level is in fact considerably complicated by a host of factors and limitations which must be taken into account when making inflow adjustments. These factors include fluctuating water demand downstream, the presence and mode of activity of shipping at various critical points in the canal, the ever-changing level of Lake Erie, flow velocity restrictions at various points and water levels at key points in the canal, wind effects on the water surface profile in the summit reach, bank erosion concerns and so on. In this context then, the present operating mode, with respect to the water levels regime in the canal, can be considered to be "bankfull". This regime must remain intact if navigation and other canal functions are to continue. Any increase in levels would cause spillage over lock gates, coping walls and docks, and would flood considerable acreage around lock pondage basins ('pondage' is explained later in this section). Recently an automated and computerized control system was installed to assist the weir operator by providing instant analyses and information concerning conditions in key areas. However, in the final analysis, safe and efficient operation of the canal's intake still depends largely on the capability of an experienced operator.

The gate opening required to achieve a desired intake flow through the supply weir is determined using a weir calibration curve and flow equation, which convert the head on the weir and the gate opening to weir intake. In practice, the gate opening is adjusted until the desired flow is obtained. The intake flow is calculated and displayed continuously by computer for the benefit of the weir operator. The calculated flow is also recorded continuously. Also displayed and recorded continuously for the weir operator are the levels of Lake Erie and the supply channel below the weir. The gauges for these levels, which are the ones used to calculate flow through the weir, are located just upstream and downstream of the weir. The weir calibration was last checked in 1966-67. It showed very little difference from the original calibration done in 1933.

Under a head of one foot (that is, a difference of one foot between the water levels of Lake Erie and the supply channel below the weir) the supply weir is capable of passing about 12,000 cfs, which is more than the current canal requirement. Under greater head the weir can pass more water; for instance, with a three-foot head it can pass about 21,000 cfs. Since the level of Lake Erie (and thus the head on the weir) fluctuates continuously, frequent gate settings are required to maintain the desired flow through the weir. When the level of Lake Erie is very low, reducing the head on the weir to less than one foot, it becomes impossible to maintain the full required intake into the canal. During these periods, the flow to DeCew Falls is cut back in order to supply navigation requirements. If there is no head, or a negative head develops at the weir, navigation may be suspended while the condition exists. However, if the zero-head situation persists for more than a few days, other precautions are taken, depending on the magnitude of the drop in water level in the canal. This would include reducing the allowable shipping draft in the canal.

The rate of intake into the canal through the supply weir is governed mainly by velocity considerations, both in the supply channel, in which the weir is located, and in the main ship channel. Too great and too sudden a change in intake velocity at the entrance to the supply channel has drawn vessels onto the shoals in that area. Downstream of the weir, high velocity flows in the supply channel cause several serious problems. First the high cross-currents generated at the point of confluence with the main shipping channel are dangerous and disruptive to navigation; when the supply channel flow exceeds about 9,000 cfs, the resulting high current velocities produce a decrease in water depth (a hydraulic phenomenon) which becomes of serious concern to vessels berthed at the Robin Hood wharves on either side of the downstream end of the supply channel. Furthermore, any sudden change in velocity in the channel will cause a sudden, dangerous shift in vessels at these berths.

It is frequently necessary to shut down the weir to reduce velocity in the supply channel and in the main ship channel when vessels are tieing-up at the Lock 8 approach walls. Similar current velocity reductions are also required to assist in vessel passing manoeuvres when initial velocity is high, and to reduce critical velocities in the restricted portions along the canal. Many otherwise simple manoeuvres become disproportionately difficult (even for an experienced mariner) in the presence of high currents because of the hull pressures generated and loss of steering.

Another operational constraint in setting canal flow is the effect of high current velocity on bank stability in the supply channel and other locations along the canal. Even though the supply channel is protected by boulders and bedrock in places, it is difficult to control erosion. In recent years, the high velocity flows in the canal have aggravated the erosion problem, increasing the incidence of bank slumping and flushing boulders two feet and more in diameter from the bank walls of the supply channel out into the main ship channel. Through experience, the Seaway has found that this type of problem is minimized when sustained flows are kept below about 9,000 cfs. High currents in the main navigation channel itself are also a cause of erosion and bank slumping. There is evidence of this problem at various points along the canal.

Only through experience is the operator of the supply weir able to balance the numerous criteria and restraints associated with keeping the canal supplied with water. He must keep water levels constant throughout the canal; he must keep Ontario Hydro and other users supplied with uninterrupted supplies; at the same time, he must keep current velocities throughout the canal favourable to safe navigation. In spite of his efforts, however, erosion occurs, incidents happen and Ontario Hydro occasionally temporarily loses some or all of its allotted supply.

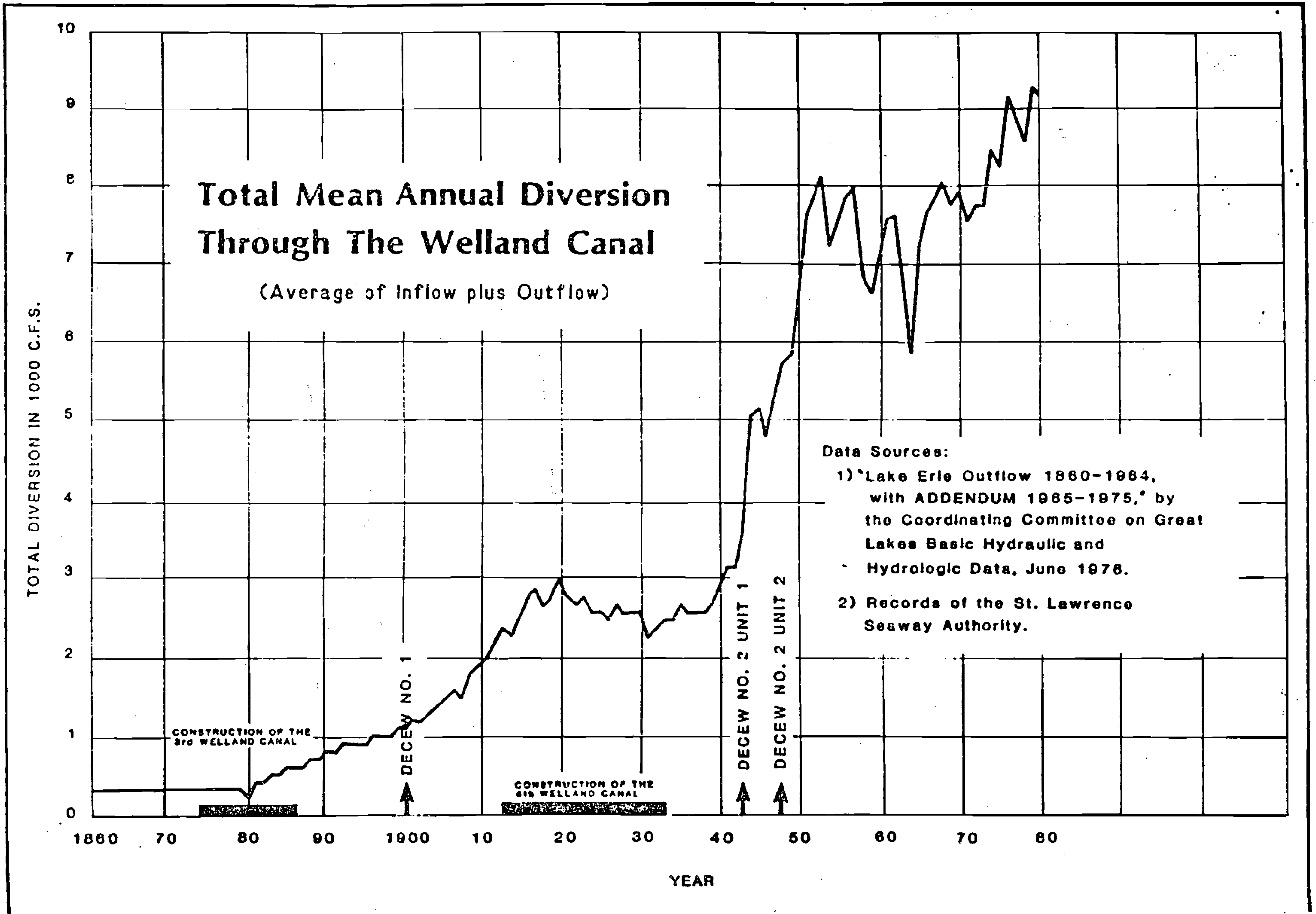
Lock 8 Intake: The amount of water entering the Welland Canal through Lock 8 is calculated from the difference in head above and below the lock at the time of lockage, the corresponding lock intake and the number of lockages. Water level gauges are situated above and below the lock for this purpose. The gauge below the lock is the same one used to monitor the water level in the summit reach. The amount of water entering the canal is the sum of the intakes through Lock 8 and the previously described supply weir at Port Colborne; it is calculated and recorded continuously and summarized daily, monthly and annually on records which date back to 1952. Figure 4-6 gives the total annual mean flow through the Welland Canal since 1860. These flows were obtained from the St. Lawrence Seaway Authority, and the report "Lake Erie Outflow 1860-1964, with addendum 1965-1975", by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, June 1976.

Uses of the Canal Water and Diversion Rates

Also included in the summary records are the amounts of the various diversions and uses of canal water which occur below Lock 8 and the supply weir. A typical mean annual distribution of canal water is shown schematically in Figure 4-7. About 70 percent of the water entering the canal is diverted out again at Allanburg for power generation. Ontario Hydro has two raceways leading from the canal to their Lake Gibson pondage area which feeds two generating stations at DeCew Falls. Intake into the raceways is completely controlled by weirs. The water diverted for the DeCew plants is not used for navigation, and is not returned to the canal; it is discharged directly into Lake Ontario through Twelve Mile Creek.

Between 1952 and 1978 the total diversion to DeCew Falls fluctuated around a mean value of about 6,000 cfs (see Figure 4-8). During that period, Ontario Hydro had a purchase agreement with the Seaway Authority for a maximum supply of 6,400 cfs on an annual mean basis. The full 6,400 cfs was rarely diverted for a variety of reasons including plant shut-downs, canal intake reductions for maintenance work and during periods of low Lake Erie levels. In the latter case, when Lake Erie levels are low, intake into the canal may be reduced (as explained earlier); after municipal, industrial and navigation water requirements (which take precedence) are satisfied, the water remaining for power generation may be less than that provided for in the purchase agreement. Ontario Hydro's current contract, in effect since 1978, allows for a maximum of 6,887 cfs as an annual mean. Under the agreement, Ontario Hydro can receive up to 7,550 cfs per month during the non-navigation season, and about 6,670 cfs per month during the navigation season. It is estimated that about 7,550 cfs is the combined maximum that can flow through the two raceways to DeCew. The estimated capacities of the raceways are about 1,500 cfs and 6,050 cfs.

Figure 4



Total Mean Annual Diversion Through The Welland Canal

(Average of Inflow plus Outflow)

Data Sources:

1) "Lake Erie Outflow 1860-1964, with ADDENDUM 1965-1975," by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, June 1976.
2) Records of the St. Lawrence Seaway Authority.

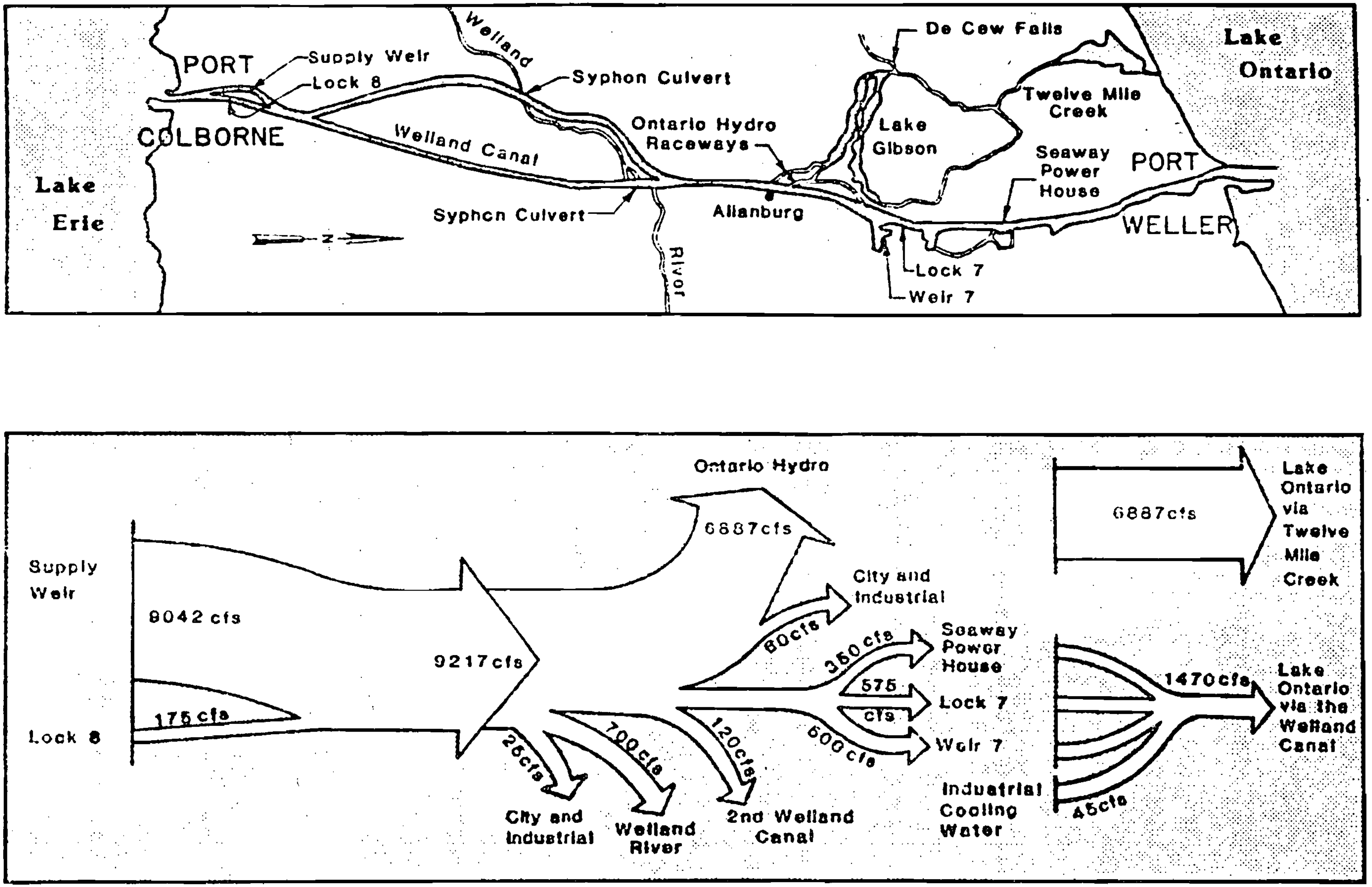


Figure 4-7

Typical Mean Annual Distribution of Welland Canal Waters

Components of the Welland Canal Diversion
1950 to 1980

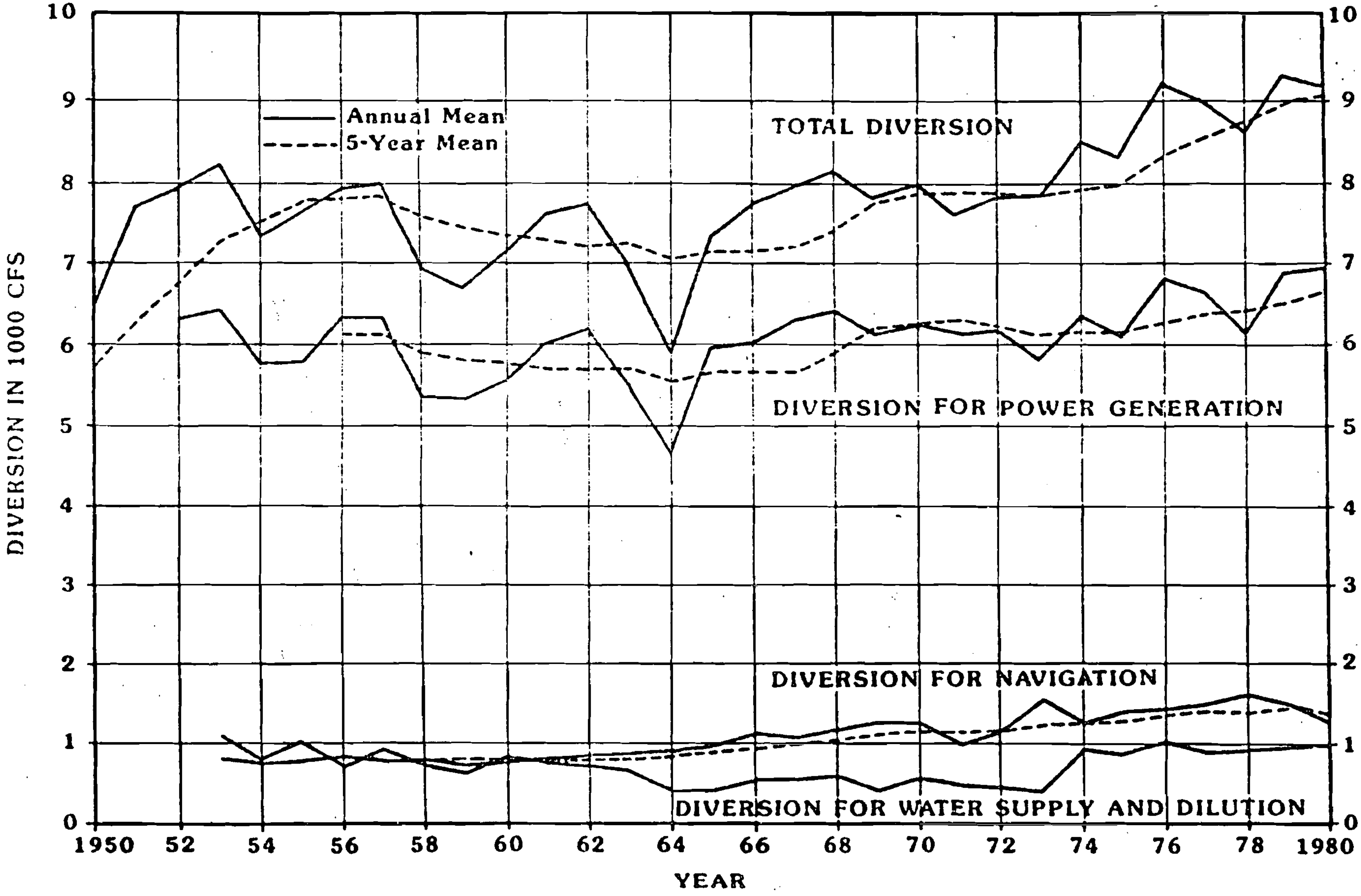


Figure 4-8

The second largest user of canal water is the St. Lawrence Seaway Authority, which requires water for navigation and power generation for the canal's navigation equipment. During the regular navigation season, lockages and lateral and hydraulic assists require about 1,100 cfs (for a seasonal average of about 24 ship transits per day). This figure varies depending on the level of shipping activity. During peak periods, when there may be as many as 30 transits per day, the average monthly requirement may be as high as 1,400 cfs. When the canal reaches traffic capacity, estimated to occur around the year 1990, the average number of transits per day during the navigation season will be about 30 and the maximum number of transits achievable in a day will be about 34; the consequent average water requirement will be about 1,400 cfs with peak requirements of 1,600 cfs.

An additional factor which could affect the annual diversion rate through the canal is an extension of the navigation season from its current nine months to nine and one-half months, as has been considered for the entire St. Lawrence Seaway. However, it has been estimated that such an extension would have an almost negligible effect on the annual mean diversion for the following reason. Under present operations, when navigation ceases in the fall, a large portion of the flow used by navigation is transferred to Ontario Hydro for power generation. As explained earlier, the maximum flow in the canal is restricted and navigation water requirements are deducted first. Therefore, during an extended navigation season, the transfer of flow to the power plants would simply be delayed by two weeks until navigation ceased. Because navigation during those two weeks would use slightly more water than would have otherwise been transferred for power generation, the net result is a minimal increase in the total annual diversion.

Each lock, or set of locks, in the Welland Canal is equipped with a by-pass or "waste" system which will pass water around the lock. These by-passes are controlled by weirs and are used to replenish downstream pondage areas. The pondage acts as a "surge tank" to prevent sudden large fluctuations in water level on the main ship channel as a result of lockages. Via the by-pass system, water can pass directly from the summit level above Lock 7 to the pondage for the flight lock system, Locks 6, 5 and 4. From the flight lock pondage it can continue on to the pondage for Lock 3, if necessary, without entering the ship channel. The flow between pondage areas is controlled by weirs. At Locks 3, 2 and 1 the by-pass weirs are located adjacent to the locks in the ship channel, and "spilled" water passes along the ship channel. The capacity of the by-pass system is set by the capacity of the weir for Lock 7, which is about 1,000 cfs. During the navigation season about 500 cfs are passed through the by-pass system for pondage water replacement. This water is used for lockages, lateral and hydraulic assists, and is included in the 1,100 cfs referred to above. This leaves a maximum reserve capacity of about 500 cfs for the system. As another 100 cfs or so will be needed for navigation in the future, the future ability of the system to draw additional water from Lake Erie will be 300 cfs to 400 cfs. However, in practical terms, this additional flow could not take place because of an adverse effect on navigation. The Seaway Authority has found that vessel manoeuvrability in the vicinity of Locks 3, 2 and 1 is dangerously impaired when the flow through the waste weirs is above 600 cfs.

The Seaway's power generation plant is located beside Lock 4. Water is taken from the canal above Lock 7 and fed by penstock to the power house. The water is returned to the canal below Lock 4 for re-use downstream. The plant presently draws about 350 cfs, both summer and winter. The maximum intake the plant can handle is about 550 cfs.

A plot of the total annual mean diversion of canal water for navigation for the period 1950 through 1980 is shown on Figure 4-8. Included are quantities for lockages, lateral and hydraulic assists, Seaway power generation and pondage.

The third largest usage of water from the canal is for water quality enhancement. About 700 cfs of dilution water is diverted from the canal year-round at the City of Welland. About 150 cfs of this is diverted by the Welland Waterworks Department to dilute sewage entering the Welland River. Another 525 cfs is drawn from the canal through holes drilled through the roof of the old Welland River syphon culvert in the abandoned ship channel at Welland. This diversion serves two purposes. One is to induce flow in the abandoned ship channel to prevent stagnation, as the only flow in the channel was cut off by causeway construction in 1973. Because this water ultimately enters the Welland River, the other purpose is to aid dilution. About 25 cfs is also diverted from the Welland Canal to the Welland River at Port Robinson and an additional small diversion of about five cfs is made from the canal into Lyons Creek, south of Welland, to replace flows in the creek which were cut off by the canal at Lyons Creek crossing. No increase in dilution water requirements is foreseen.

About 200 cfs are drawn from the system at various locations (e.g. Welland, Thorold, St. Catherines) for industrial cooling and other industrial and municipal uses. The amounts of these uses are controlled by a series of guidelines. Most of the cooling water is returned to the system. There are no known plans for major increases in industrial cooling or industrial or municipal consumptives uses.

Figure 4-8 shows the total Welland Canal diversion and its components and how they have varied since 1950. As previously discussed, water for navigation, water supply and dilution take precedence over water made available for power generation. Hence, as a result of the gradual increase in water needed for navigation and the marked increase in water supply needs (which began about 1973), there is less water available for power generation in 1980 than if these values had remained at pre-1970 level. It is estimated that this increase has reduced the water available for power generation in the order of 250 cfs. In addition, the table below indicates that the future needs of these interests could further increase. If this occurs there would be a further reduction in water available for power generation in both the Welland Canal and Niagara River.

All of the uses and routings of canal water have been described. Assuming navigation in the canal will continue as projected, the following summation of the ultimate navigation water requirement plus the maximum requirements for all other uses gives some indication of the theoretical maximum capacity for sustained diversion of Lake Erie through the Welland Canal.

	Theoretical Maximum Flow in cfs
Navigation (lockages, assists)	1,600
Seaway Power	550
Ontario Hydro Power	7,550
Dilution	700
Additional Capacity at "Waste" Weirs	400
Water Supply	200
	11,000

However, as already discussed, 11,000 cfs could not be sustained in the canal as it exists. Also, the Seaway Authority has found that the "most desirable" maximum sustained flow is about 9,000 cfs. However, due to a recent increased demand for water by Ontario Hydro, the Seaway has decided to accept the penalty of higher flows, up to about 10,000 cfs during peak-demand months. The penalty is increased maintenance of canal banks, more dredging and greater inconvenience to shipping. With 10,000 cfs as the maximum acceptable monthly mean flow, the maximum annual mean flow will likely never exceed about 9,400 cfs or 9,500 cfs. There are several reasons for this. The canal is closed to navigation for three months of the year and the supply weir must be shut down occasionally during the year to assist in canal maintenance and vessel manoeuvring. Also, the summit level must usually be lowered a few feet during the winter months to allow maintenance work. At such times the flow to DeCew Falls will be reduced. Occasional shutdowns for repair and maintenance at the DeCew plants will further reduce the amount of water which can be used there.

Environmental Conditions

The Welland Canal is a man-made channel, cut twenty-seven miles across the Niagara Peninsula between Lakes Erie and Ontario. The canal was built with an economic purpose in mind, that is, to allow ships to transit between the two lakes. To be commercially viable, it was designed just wide and deep enough to handle the largest ships expected to be required in Great Lakes trade during its economic life. Canal banks were constructed to withstand high current forces and wave energies caused by such ships. Similarly, the channel bed was built to withstand high currents and the severe scouring forces of ships' propellers. The canal was also designed to accommodate (structurally and environmentally) anticipated increases in water demand for navigation, power and other uses. In this context, the "environment" for the Welland Canal is a contrived feature which was never intended to stabilize completely. Testimony to this is a long history of continuous change, upgrading and re-routing; in fact, the canal has been completely re-built four times in its one hundred and fifty-year history. Environmental impacts on the canal have gone virtually unrecognized as such, with the minor mitigating modifications being made as part of everyday events on the canal.

Amount of Diversion and Limitations

The present diversion has averaged 7,600 cfs from 1952 to 1976, with a maximum annual average of approximately 8,500 cfs. The diversion was increased for a time in 1973-74 to offset the reduced diversion during the fall and winter period, 1972-1973, because of construction on the Welland Canal. About 700 cfs of this diversion is discharged into the Welland River for water quality purposes and thereby returned to the Niagara River above the falls. The average has increased to 7,800 cfs for the period 1952-79, with a maximum value of 9,300 cfs in 1979. As mentioned above, the maximum annual mean flow will be unlikely to exceed 9,400 to 9,500 cfs.

The International Joint Commission has not exercised control over flows in the canal. The Board has not attempted to interpret the Commission's authority to exercise such control.* However, the amounts of water diverted are reported to the two governments by the International Niagara Committee.

Hydrologic Effects of Existing Diversion

The diversion of water through the Welland Canal increases the outflow capacity of Lake Erie. With an average of 7,000 cfs, the level of Lake Erie would be lowered by about 0.32 foot. Because the level of Lake Erie to some degree affects the levels of Lakes Michigan-Huron and Superior, the levels of these lakes have dropped about 0.17 foot and 0.04 foot respectively, due to diversion of water through the Welland Canal. Increasing this average to an annual value of 9,400 cfs will lower Lake Erie by an additional 0.08 foot (a total lowering of 0.40 foot), Lakes Michigan-Huron by 0.05 foot (total 0.22 foot), and Lake Superior by 0.02 foot (total 0.06 foot).

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* The Commission, in its 1985 report to Governments, noted that it has no authority over the Welland Canal diversions.

APPENDIX B

PHYSICAL DESCRIPTION OF THE OGOKI AND LONG LAC DIVERSIONS

The Long Lac and Ogoki Diversions are entirely separate projects even though both are diversions from watersheds of the northward flowing Albany River (the Kenogami and Ogoki Rivers), and both flow into the Lake Superior drainage basin.

Both diversions date back to the early 1940s. While the Long Lac Diversion was first visualized as a southward route for log driving, its importance, and that of the Ogoki, largely arise from the electric energy generation which these flows make possible. In the case of the Long Lac Diversion, the diverted water has carried logs and augmented natural flows in the Aguasabon River since January 1941, and has justified a 40.5 MW hydro-power plant on the Aguasabon River. The Ogoki Diversion to Lake Nipigon has augmented the natural flows driving the hydro-power plants on the Nipigon River since July 1943.

During the period July 1943 to December 1979, an average of about 1,440 cfs had been diverted via the Long Lac route and about 4,150 cfs via Ogoki.

History of the Long Lac and Ogoki Diversions

The possibility of diverting the headwaters of the Kenogami and Ogoki Rivers southward into Lake Superior was recognized in the early 1920s. Feasibility studies of the Kenogami and Ogoki systems were conducted by Ontario Hydro at that time, but no action was taken for almost ten years.

In 1935, the Ontario Department of Lands and Forests (representing the Ontario Government) entered into discussions with four U.S. pulp and paper companies over the possible development of the Long Lake timber limits and the feasibility of diverting Kenogami River water southward as a means of transport for the pulpwood logs. In 1937, the Ontario Government signed an agreement with the Pulpwood Supply Company (formed as a consortium of the four companies) to develop the area. The original purpose of the diversion scheme was to facilitate the driving of pulp logs southward on Long Lake and across the height-of-land to the Aguasabon River where they would be moved by jackladder to Lake Superior for rafting.

Ontario Hydro was also interested in the diversion, as the diverted water would increase the power potential on the Aguasabon River and would provide additional benefits at the Great Lakes power sites downstream. In view of this, an agreement was also reached in 1937 between the Ontario Government and Ontario Hydro whereby the latter would construct the necessary dams and channels on a cost-sharing basis. Construction of the Aguasabon generating station began in 1946 and the plant officially commenced operation on October 15, 1948.

In 1940, by an exchange of diplomatic notes, an agreement was reached between Canada and the United States to the effect that, if Canada and Ontario agreed to proceed immediately with the Long Lac/Ogoki Diversions, the United States would not object to Canada diverting immediately an additional 5,000 cfs at Niagara for power production. Construction was started in December 1940 and the Ogoki Diversion was officially opened in July 1943. There was a further exchange of notes dated November 14, 1941, authorizing the use of this water at either Niagara or through the Welland Canal. The 1950 Niagara Diversion Treaty between Canada and the United States perpetuated the additional 5,000 cfs for Canada from the diversion by indicating in Article III that this water would continue to be governed by the earlier exchange of notes and would not be included in the waters allocated under the provisions of the treaty.

Description of the Present Long Lac Diversion

The Long Lac Diversion connects the headwaters of the Kenogami River, which originally drained north through the Kenogami and Albany Rivers into James Bay, with the Aguasabon River, which naturally discharges into Lake Superior near Terrace Bay, Ontario about 155 miles east of Thunder Bay, Ontario (Figure 4-1). It diverts the runoff from about 1,690 square miles of the Hudson Bay drainage basin into the Great Lakes.

Structurally, the Long Lac Diversion consists of the Kenogami River Control Dam, located 12 miles downstream of Longlac on the Kenogami River, and the South Regulating Dam, five miles south of the lake. Long Lac reservoir is about 52 miles long and has a surface area of about 53 square miles. The normal operating range of the reservoir is 1,021.0 to 1,028.4 feet (GSC)*. The operational procedure is to store the spring runoff in Long Lake for release primarily during the fall and winter months. As the lake approaches the maximum storage level in the spring, water is spilled northward through the Kenogami Control Dam. The

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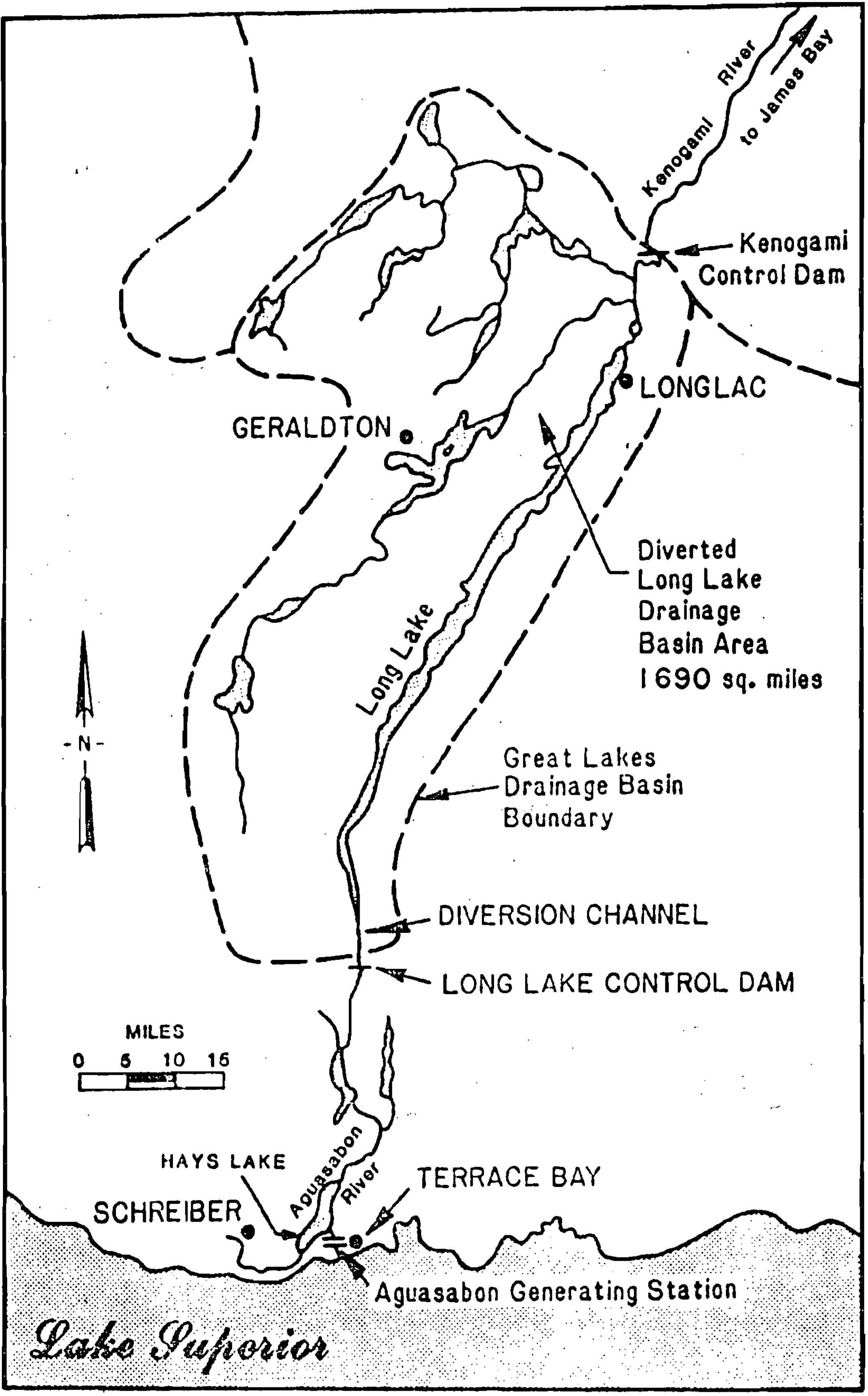
*Geological Survey of Canada datum



Long Lac Diversion

Figure 4-1

normal storage capacity of Long Lac reservoir is 4,190 cfs-months. At the south end of Long Lake a diversion channel was cut across the divide and through a series of small creeks and lakes to connect Long Lake to the Aguasabon River. The control works situated at the south end of the channel consist of three concrete structures: an auxiliary dam, a main dam with an emergency sluice and log chute, and a control dam with two 14-foot wide sluices. About 1.5 miles of the Aguasabon River, below the South Regulating Dam, was widened, deepened and straightened to permit the driving of pulpwood. The generating station, located 2.5 miles west of the Hays Lake Dam, has a 3,500-foot intake tunnel conducting water to two turbines. Normal head at the station is about 298 feet. The installed generating capacity is 40.5 Mw. The Aguasabon generating station is connected by a 70-mile 110,000-volt transmission line to the Nipigon River power plants and the provincial grid. In 1947 the Kimberly-Clark Corporation, then sole operators of the Long Lac timber rights, began construction of a 272-ton per day bleached sulphate mill and a 1,500-person townsite at what is now known as Terrace Bay. The pulpmill began operation in 1948.

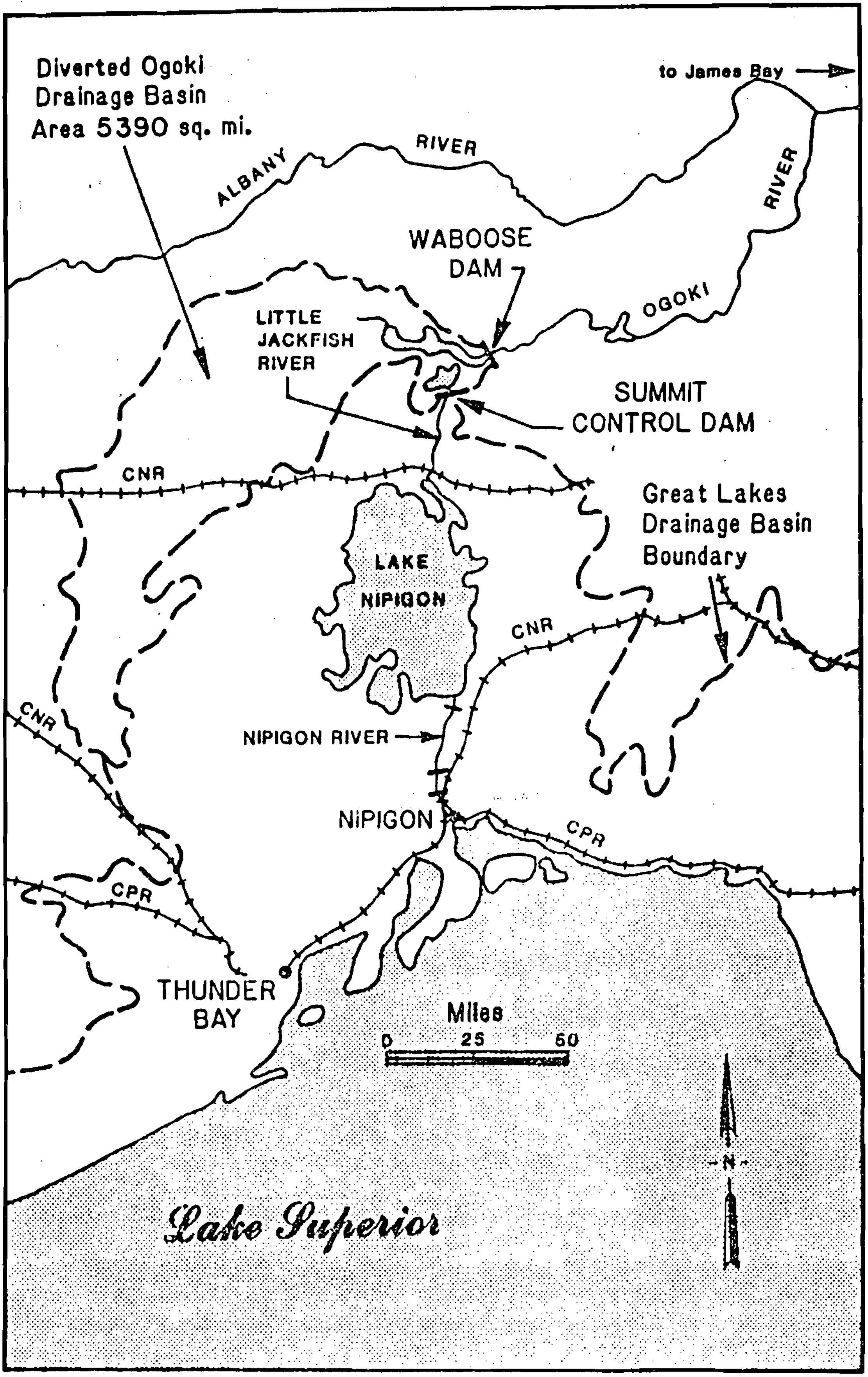
Description of the Present Ogoki Diversion

The Ogoki Diversion connects the upper portion of the Ogoki River (which originally drained through the Albany River into James Bay) with the headwaters of the Little Jackfish River, which flows into Lake Nipigon and thence, through the Nipigon River, into Lake Superior at a point about 60 miles east of Thunder Bay, Ontario (Figure 4-2). The Waboose Dam on the Ogoki River impounds the water that would normally flow northward and redirects it southward into Lake Nipigon. Summit Dam was built to control the rate of diversion into Lake Nipigon, Ontario's largest inland lake.

Located at Waboose Rapids on the Ogoki River, Waboose Dam impounds water from 5,390 square miles of the upper Ogoki River drainage basin for diversion southward. This structure, in conjunction with several earthfill side dams required to prevent flow into low areas, effectively raised the level of the river by 40 feet and flooded Mojikit Lake with an additional 10 feet of water to form the Ogoki reservoir. When at its normal maximum level of 1,073.0 feet (GSC), the Ogoki reservoir occupies an area of about 103 square miles and has a normal storage capacity of about 5,910 cfs-months, but it has relatively little retention capacity. The normal operating range is 6.0 feet. During periods of high water on Lake Nipigon, water is spilled northward through the Waboose Dam.

A channel was excavated through the height-of-land southeast of Mojikit Lake to pass water diverted from the Ogoki River southward through a string of small lakes into the Little Jackfish River. It is here that the Summit Dam controls the diversion flow through the Little Jackfish River into the second reservoir on the system, Lake Nipigon.

Lake Nipigon is 65 miles long, 40 miles wide and has a water surface area of about 1,750 square miles. The lake has a mean depth of 180 feet and a normal storage capacity of 73,790 cfs-months. Ontario Hydro, under a licence of occupation issued and administered by the Ontario Ministry of Natural Resources, regulates the levels of Lake Nipigon to a maximum elevation of 855 feet (GSC) and within a normal operational range of



Ogoki Diversion

Figure 4-2

850-854 feet (GSC). The lake has one drainage outlet, the Nipigon River. Control of Lake Nipigon levels predates the diversion by 18 years when the Virgin Falls Dam was constructed at the Lake Nipigon outlet to control the water supply to the Cameron Falls generating station downstream of the lake and to assist log driving. Flows out of Lake Nipigon are regulated primarily for power generation and are only indirectly influenced by the quantity of the diversion inflow.

Between Lake Nipigon and Lake Superior, the fall in the Nipigon River is about 250 feet, of which 237 feet are utilized at three hydro-power plants - Pine Portage, Cameron Falls and Alexander. The Nipigon River was first used for the production of hydro-electric power in 1920 when the Cameron Falls generating station began operation. The present installed capacity at that station is 72.0 MW. In 1930, 65.2 MW was installed at the Alexander generating station 1.5 miles downstream of the Cameron Falls station. Pine Portage generating station, the latest addition to the system, was built near the outlet of Lake Nipigon in 1950. It has an installed capacity of 128.7 MW, bringing the total installed capacity for the river to 265.9 MW. With the construction of Pine Portage, the use of the Virgin Falls Dam to control Lake Nipigon levels became redundant. Since then the levels have been regulated by the flows through the Pine Portage station.

Environmental Conditions

The Long Lac and Ogoki Diversion project areas are in northwestern Ontario in the physiographic region known as the Canadian Shield, a vast region of eroded igneous, sedimentary and metamorphic rocks. The landscape is mainly one of rolling relief, with a forest-covered terrain of rock knobs and hills containing a myriad of lakes and bogs in the depressions and valleys.

In recent geological time, glaciations have modified the landscape, scraping some rock surfaces bare and leaving extensive deposits of till moraine, and outwash and glacio-lacustrine sands, gravels and clays elsewhere.

Northwestern Ontario is sparsely inhabited. Most economic activity is related to resource extraction industries such as pulp and paper, forestry, mining and hydro-electric production. Tourism and outfitting operations are important to the region's economy. Income is also generated from the trapping of fur-bearing animals and commercial fishing.

Until recently, there had been little detailed investigation of the effects of the diversion projects. Recently, several comprehensive studies have been carried out and reported by Bridger (1978)(20), Peet (1978)(21) and Peet and Day (1980)(22). A review of these studies indicates that the major impacts have resulted from the construction of diversion structures on the main stem rivers, the construction and alteration of diversion channels, the creation of reservoirs, the greatly altered flow regimes and the use of waterways for log transportation. Some details on the environmental conditions and impacts of the Long Lac and Ogoki Diversions are contained in the following paragraphs.

Long Lac Diversion

Downstream of the Kenogami River Control Dam and the Hays Lake Dam on the Aguasabon River, reduced flows occur in bedrock and coarse gravel controlled channels. The flow reduction in these sections has caused changes, including disruptions to fish spawning areas. Increased and reversed flows have changed the ten-mile section of the Kenogami River south of the Kenogami Dam from a riverine to a lacustrine environment. Due to the altered flow regime and levels, there have been changes in species composition and diversity of flora and fauna. The flooding has created a 140-acre marsh which has been designated as ecologically sensitive due to the large area and diversity of flora and fauna. In Long Lake itself, artificially maintained high water levels contribute to shore erosion in fine-grain deposits and have necessitated some shoreline protection.

The diversion channel, which consists of three canal cuts and four small lakes, was largely constructed in coarse gravels which are not easily eroded. The remaining diversion route to the Hays Lake reservoir, which consists of 17 miles of Aguasabon River channel, is in similar material. However, some additional erosion in river meanders has occurred as a result of the flow increases, and this is contributing to sedimentation in the Hays Lake reservoir. The transport of logs down the diversion channel also contributes to erosion. Downstream exchanges of fish and other fauna are possible now between the James Bay watershed and the Aguasabon River; however, upstream migration is prevented by high flow velocities and the regulating dam.

The Hays Lake reservoir area, like the diversion channel, is largely man-made, and was created by raising the former Blue Jay Lake approximately 55 feet and inundating Big Duck Creek and a portion of the Aguasabon River. Most potential environmental problems were foreseen and avoided in the construction of the reservoir. Although the shores, which consist of coarse gravels, moraine and exposed bedrock, do not represent a serious erosion problem, portions have been stabilized. The reservoir has a 15-foot operating range and has little recreational use. Impacts associated with the reservoir include changes in fish species and the reservoir's action as a settling basin, reducing outflows of suspended matter and turbidity.

Ogoki Diversion

The Waboose Dam has created a mixed river and lake impoundment, inundating the river section by up to 40 feet and Mojikit Lake by about 10 feet. Thus the inundation impacts are less pronounced on the lake.

Immediately below Waboose Dam, fast water habitat that was once important for fish shelter and fish food production has been exposed for periods of up to several years. Releases from Waboose Dam, which are usually of one to four months' duration in late spring and early summer of high runoff years, impact on slow moving organisms in stagnant pools, sweep away silt accumulation and aquatic plants and inhibit riparian vegetation locally.

The upper 22 miles of the diversion route down the Little Jackfish River from Mojikit Lake consists of a series of short steep rapids connecting a system of narrow lakes. Because the path of the diversion is over erosion resistant materials such as boulders, moraine or bedrock, the diversion-induced effects are relatively slight. On the other hand, the lower nine-mile section of the route occupies a narrow, eroded meandering valley of unconsolidated sediments. The river has downcut through these thick unconsolidated sand deposits and, two miles above the mouth, has downcut to lake level. The lower Little Jackfish River biotic system has been subjected to extreme and diverse physical disturbances including high suspended silt concentration, channel bed and bank scouring and wide flow fluctuations. It has been estimated that up to 30 million cubic yards of glacio-lacustrine sediment have been removed in the lower river section since the inception of the diversion, much of it during the first few years of operation. This has resulted in the deposition of material, forming deltaic islands at the mouth of the river in Ombabika Bay at the north end of Lake Nipigon, and increases turbidity in the bay.

Amount of Diversion and Limitations

The Long Lac Diversion began in January 1941, and the Ogoki Diversion started about two-and-a-half years later in July 1943. From July 1943 to December 1979, the combined diversion has averaged 5,590 cfs. The maximum and minimum annual combined diversions have been 8,020 cfs and 2,530 cfs, respectively. Since January 1941, the supply to Long Lake has been approximately 1,700 cfs. Of this amount, 1,420 cfs has been diverted southward into Lake Superior and the remainder, 280 cfs, has been spilled northward down the Kenogami and Albany Rivers into James Bay. On a monthly mean basis, this diversion to Lake Superior has varied between a minimum of 65 cfs and a maximum of 3,500 cfs. Physically, the Long Lac diversion system is limited by several factors: the size of the watershed, about 1,690 square miles; the relatively small storage capacity of Long Lake, about 4,190 cfs-months; the normal range of regulation from 1,021.0 to 1,028.4 feet (GSC), or 7.4 feet; and, the minimum required flow of 800 cfs through the sluiceway for log driving.

Normally all of the Ogoki water is diverted southward to Lake Nipigon. However, there are times during excess inflow to Lake Nipigon when the diversion is partially or completely closed. The diversion is reduced to 4,000 cfs when the Lake Nipigon elevation reaches 854.0 feet (GSC) and is shut off completely when it reaches 854.5 feet (GSC). This precaution against flooding is necessary because the outflow from Lake Nipigon cannot exceed 20,000 cfs due to velocity restrictions at the Canadian Pacific Railway bridge. Since 1943, the diversion has been closed or reduced in flow approximately 20 times. The Ogoki reservoir is then permitted to rise to the maximum level of 1,073.67 feet (GSC) and the excess inflow is spilled down the Ogoki River into the Hudson Bay watershed. The average inflow to the Ogoki reservoir since July 1943 has been about 5,000 cfs; 4,150 cfs has been diverted southward to Lake Superior and the remaining 850 cfs spilled northward down the Ogoki River. Monthly diversions from the Ogoki reservoir have varied from 2,000 cfs to 15,000 cfs. However, the quantities diverted from the Ogoki River in any month are not necessarily representative of the amounts of diverted water reaching Lake Superior in that month since water is stored in Lake Nipigon for later release through the power plants during fall and winter months when inflow is low. Since the Summit Control Dam is left wide open as long as the elevation of Lake Nipigon is below 854.0 feet (GSC), the annual diversion is limited only by the storage capacity of the Ogoki reservoir and the discharge capacity of Summit Dam.

During the periods of high water levels on the Great Lakes in 1951, 1952, 1953 and again in the early 1970s, the Ogoki Diversion was closed off entirely or operated at reduced capacity. There is no international control exercised under the Boundary Waters Treaty over these diversions. However, the amounts of water diverted are reported to the International Joint Commission by the International Lake Superior Board of Control.

Hydrologic Effects of Existing Diversions

The diversions through the Long Lac and Ogoki Diversion Projects have increased Lake Superior's natural supply and decreased that of the Albany River basin. Since the meteorological conditions in the diverted watershed are similar to those which exist in the Lake Superior basin, in periods of drought there is little opportunity to bring extra water from this source into the system when low supply conditions would make it advantageous to do so. The ultimate effect of these diversions on the Great Lakes system, as a whole, has been to increase the levels of the lakes as a result of increasing their supplies. However, since the regulation plans on Lakes Superior and Ontario have been designed to take into account these increased water supplies, the maximum criteria levels are unaffected by these diversions.

APPENDIX C

CAPABILITIES OF THE LAKE MICHIGAN DIVERSION SYSTEM LOCATED AT CHICAGO, ILLINOIS

OVERVIEW - GENERAL

1. The divide separating the Great Lakes drainage basin from the Mississippi River drainage basin passes within ten miles of the Lake Michigan shoreline at Chicago. Water has been diverted from Lake Michigan at Chicago into the Mississippi River basin since the completion of the Illinois and Michigan Canal in 1848. At that time the diversion averaged about 500 cfs.

2. The flow of the Chicago River was reversed in the year 1900 by construction of a canal across the divide. The river now flows landward, away from Lake Michigan, into the Sanitary and Ship Canal. Plate 1 shows this area. The Metropolitan Sanitary District of Greater Chicago constructed and operated this canal named the Chicago Sanitary and Ship Canal. This canal begins at the West Fork of the South Branch of the Chicago River, at a point about six miles from Lake Michigan measured along the Chicago River. Flowing southwestward, away from Lake Michigan, the Sanitary and Ship Canal cuts through the divide which separates the Great Lakes drainage basin from the Mississippi River drainage basin, and enters the Des Plaines River Valley. The canal parallels the Des Plaines River and joins the river near Lockport, Illinois, about 31 miles downstream from the junction of the South Branch and the Sanitary and Ship Canal.

3. Upon completion of the Chicago Sanitary and Ship Canal in 1900, the Chicago River was reversed and the diversion was progressively increased to a maximum of approximately 10,000 cfs in the late 1920s. By a U.S. Supreme Court decree, it was gradually reduced to about 3,100 cfs annually by 1938.

PURPOSE AND OVERVIEW OF DIVERSION AREA FEATURES

4. The diversion prevents treated municipal and industrial wastewaters and polluted stormwater runoff from entering Lake Michigan and degrading the Metropolitan Chicago water supply source. Water withdrawn and used for municipal and industrial water supply is conveyed through sewers to treatment plants which discharge to streams and waterways, which carry the flow away from Lake Michigan into the Illinois River watershed (Mississippi River basin). The same diverted flows also help maintain navigable depths on a system of waterways. The waterways provide an important, man-made, navigable link between the deep draft Great Lakes ports and shallow draft waterways of the Mississippi River.

5. The main diversion outlets are the Lockport Lock, hydroelectric powerhouse, and controlling works. Water is discharged to Des Plaines River, a navigable tributary of the Illinois River and part of the Illinois Waterway. Lockport is 36 miles down the Illinois Waterway from Lake Michigan and 290 miles upstream

from the Mississippi River. Most dry weather flow passes through a hydroelectric powerhouse adjacent to the lock. The remainder is discharged from the navigation lock while locking vessels. Floodwaters exceeding the capacity of the powerhouse are discharged through ten controlling works sluice gates, seven of which are located three miles upstream.

6. Direct diversion is admitted into the river-canal system at three locations: Wilmette pumping station; Chicago River Controlling Works; and, O'Brien Controlling Works.

Table 1 - Composition of Diversion in a Typical Year

Public water supply		52%
Stormwater runoff		30%
Direct diversion		18%
Discretionary	10%	
Navigation makeup	4%	
Lakefront lockages	3%	
Lakefront leakage	1%	
	18%	
Total		100%

7. Most of the dry weather flow at Lockport emanates from four large sewage treatment plants: Northside; West-Southwest; Calumet and Clavey Road. The remainder consists of natural low flows of Chicago River; Little Calumet River; Grand Calumet River and water diverted at the 3 lakefront structures.

8. Stormwater runoff from the diverted watersheds of the Calumet and Chicago River (673 sq. mi.), which formerly flowed to Lake Michigan, is discharged to the river-canal system through hundreds of storm sewers and several large pumping stations. In a severe storm event, combined stormwater inflow could greatly exceed the capacity of the Sanitary and Ship Canal. A maximum discharge of about 20,000 cfs to 30,000 cfs can be achieved at Lockport only by lowering the upper pool level seven feet below normal and allowing the river levels at Chicago River and O'Brien Controlling Works to rise about five feet above normal. If the river levels continue to rise, excess flows must be discharged to Lake Michigan to prevent catastrophic flooding in the downtown Chicago of subways, expressways, underpasses, and buildings. Backflow events for the period 1975-1986 are provided on Table 2. It is estimated that the construction of the Chicago Underflow Tunnel and Reservoir System will reduce the incidence of Chicago River backflows at the Chicago River Controlling Works from about once every two years to about once every ten years.

9. Stormwater runoff from the diverted watershed is part of the 3,200 cfs limit of the 1967 decree. Discharges at Lockport are now measured by an acoustic flow velocity meter at Romeo Road, Romeoville, Illinois, three miles above the Lockport controlling works.

Table 2 - Backflow Events to Lake Michigan (1975 -1986)

	Volume (second foot day)		
Date	Wilmette Controlling Works	Chicago River Lock Controlling Works	O'Brien Lock Controlling Works
1975			
Apr 18	12.0	1,747	
Aug 21-22	17.4		
1976			
Apr 24	18.0		
1977			
Jun 11	5.4		
Jun 30	3.9	459	
1978			
Jul 21	13.0		
Sep 13	4.4		
Sep 17	13.2		
1979			
Mar 04	6.0		
Apr 11	1.5		
1980			
Jul 21	21.1	285	
1981			
Apr 28	3.3		
May 29	1.4		583
Jul July	27.0		
Aug 14	13.1		

Date	Wilmette Controlling Works	Chicago River Lock Controlling Works	O'Brien Lock Controlling Works
1982			
Jul 22	0.3		
Aug 07		128	
Dec 03	19.1	383	192
1983			
Aug 17	1.4		
Oct 22	15.0		
1984	None		
1985			
Mar 04	20.5		
Aug 06	7.8		
1986			
Oct 02	7.1		

LEGAL HISTORY

10. In 1922 the State of Wisconsin, concerned about the effect of the Chicago diversion on lowering Lake Michigan levels, successfully sought an injunction to prohibit the State of Illinois from diverting Lake Michigan water.

11. Then in 1925, the United States Supreme Court overturned the injunction and diversion (in addition to domestic pumpage) was allowed at an average of 8,500 cfs, subject to War Department conditions.

12. Again in 1930, the court issued an additional decree requiring the State of Illinois and the Metropolitan Sanitary District of Greater Chicago (MSDGC) to gradually reduce the diversion of water from Lake Michigan, in addition to domestic pumpage, down to an annual average of 1,500 cfs by 30 December 1938. This time frame was intended to allow the State of Illinois sufficient time to construct new sewage treatment facilities to replace the need for large diversions for dilution. The Metropolitan Sanitary District of Greater Chicago designed and constructed the most advanced treatment plants, at that time in the world, in order to satisfy the deadline date set in the decree. After 1938, the total diversion, with domestic pumpage included, was approximately 3,100 cfs.

13. Another Supreme Court Decree in 1967 limited the diversion, including domestic pumpage, of Lake Michigan water into the Illinois Waterway by the State of Illinois and its municipalities, to an average of 3,200 cfs over a five-year period effective 1 March 1970.

14. The 1967 Decree was modified on 1 December 1980, when the court increased the period for determining compliance with the 3,200 cfs limit from a five-year running average to a forty-year running average. In addition, the beginning of the diversion accounting year was changed from 1 March to 1 October. These changes allow the State of Illinois to allocate more water for domestic use without exceeding the average annual rate of 3,200 cfs.

15. The 1 December 1980 modification also directed the Chief of Engineers, Corps of Engineers, to appoint a three-member committee to recommend the method for measuring the diversion using the best current engineering practice and scientific knowledge. The Corps was also directed to reconvene such a committee at least once every five years to report on the method of accounting and operation of the accounting procedures.

16. The Water Resources Bill of 1986 directs the Corps of Engineers to assume the responsibility of computing diversion starting in October 1987.

DESCRIPTION OF THE ILLINOIS WATERWAY AND DIRECT DIVERSION STRUCTURES

17. The Illinois Waterway, the receiving river for diversion, is comprised of a series of eight navigation pools extending 327.2 miles from the mouth of the Mississippi River up to Lake Michigan at Chicago. Plate 2 shows the Waterway. The Waterway includes the following segments: the Illinois River from its mouth at Grafton, Illinois to the confluence of the Kankakee and Des Plaines Rivers; the Des Plaines River to its confluence with the Chicago Sanitary and Ship Canal located one mile downstream from Lockport; the Chicago Sanitary and Ship Canal to the Calumet-Sag Junction. The Metropolitan Sanitary District of Greater Chicago (MSDGC) owns and operates the power generation and sluicing features of the Lockport Dam and Chicago River Lock Controlling Works. Photographs of these features are provided as Figures 1 thru 3. The Corps of Engineers owns and operates all other features associated with the eight navigation Locks and Dams from O'Brien on downstream to the LaGrange Lock.

18. From the Calumet-Sag Junction, the Waterway continues two ways. One route is from the Calumet-Sag Junction up to the Chicago Sanitary and Ship Canal to the Chicago River to Lake Michigan at the Chicago River Lock and Controlling Works. This Canal was completed in 1900. In addition, a northern branch of the Chicago River is linked with Lake Michigan at Wilmette via the North Shore Channel. This segment was completed in 1910. This channel flows southerly about 8.1 miles where it joins with the North Branch of the Chicago River. Diversions from Lake Michigan and its drainage basin through the North Shore Channel flow into the Sanitary and Ship Canal by way of the North and South

branches of the Chicago River. Photographs of this site are shown on Figures 4 thru 5. At the Wilmette intake of the North Shore Channel, there is a sluice gate installed in what was once a lock, and a pumping station designed to permit lake water to be pumped into the channel, but at the same time prevent water in the channel from flowing back into the lake.

19. At the mouth of the Chicago River, there are sluice gates and a lock which control the amount of lake water diverted to enter, and prevent river water from flowing into the lake. MSDGC owns and operates the Controlling Works at the Chicago River Lock. Photographs Figure 6. The Chicago River Lock is owned and operated by the Corps of Engineers.

20. The Little Calumet River and Grand Calumet River rise in the State of Indiana. Part of the flow of the Little Calumet River enters Lake Michigan in Indiana through Burns Ditch as shown on Plate 3 and a part flows in a westerly direction into the State of Illinois. Part of the flow of the Grand Calumet River enters Lake Michigan through the Indiana Harbor Canal at Indiana Harbor, Indiana, and a part flows in a westerly direction into the State of Illinois. After entering the State of Illinois, the Little Calumet River curves to the north and east and unites with the Grand Calumet River to form the Calumet River which connects with Lake Michigan at Calumet Harbor, Illinois.

21. The portions of the flow of the Grand Calumet and the Little Calumet Rivers entering the State of Illinois, and the flow of the Calumet River drain sometimes into the Calumet-Sag Channel and sometimes toward Lake Michigan. The O'Brien Lock was constructed in the Calumet River lakeward of the junction of the Little Calumet River and the Calumet-Sag Channel, downstream of the junction of the Little Calumet River and Grand Calumet River with the Calumet River and just landward of Lake Calumet. The O'Brien Lock was placed in operation on 1 July 1965. The Cal-Sag Channel was completed in 1922. With the O'Brien Lock

Table 3 - Illinois River and Tributary Flows 1/

	Discharge (cfs) 2/		
Station	Min.	Average	Maximum
Sanitary and Ship Canal - Remoeoville	1,930	3,707	16,300
Des Plalines River - Riverside	0.0 3/	483	7,450
DuPage River - Shorewood	0.2 3/	263	12,000
Kankakee River - Wilmington	204	4,299	75,900
Mazon River - Coal City	0.0	338	22,400
Illinois River - Marseilles	1,460	10,760	94,100
Fox River - Dayton	78	1,717	47,100
Vermillion River - Leonore	5.0	825	33,500
Mackinaw River - Congerville	0.2	520	44,800
Illinois River - Kingston Mines	5,150	15,190	88,800
Spoon River - Seville	3.8	1,061	37,300
Sangamon River - Oakford	45	3,362	123,000
LaMoine River - Ripley	3.9	814	28,000
Illinois River - Meredosia	1,220	22,157	123,000
Macoupin River - Kan	0.0	549	40,000

1/ Source: Water Resource Data Illinois Water Year 1985, USGS Report IL-85-2
2/ Discharges are based on entire record period for each particular station
3/ Low flows due to ice jams

in operation some of the runoff from the watershed of the Calumet River system eastward of the O'Brien Lock is diverted to the Calumet-Sag Channel. The O'Brien Lock and Dam is owned and operated by the Corps of Engineers. Photographs on Figures 7 and 8.

22. The width of the Illinois Waterway varies from 160 feet in the upper reaches to 1,400 feet near the mouth at Grafton, Illinois (mile 0.0), except at Peoria Lake (mile 162.3 to mile 182.0) where it expands to one mile wide. The natural elevation drop of the Illinois Waterway is about 75 feet in the 54 mile reach from the Chicago River Lock and Controlling Works at Lake Michigan (mile 327.2) to the beginning of the Illinois River at the Kankakee and Des Plaines Rivers junction (mile 273.0). The elevation drop in the 49 miles from the beginning of the Illinois River to the head of the valley at LaSalle (mile 224.0) is about 53 feet, from LaSalle to Peoria, Illinois(mile 162.0). a distance of 62 miles, the fall is 4 feet; and from Peoria to the mouth at Grafton, a distance of 162 miles, the fall is 28 feet. Profile of the Illinois Waterway is shown on Plate 2. The project depth for the Illinois Waterway project is 9 foot; however, above Lockport up to the O'Brian Lock and Dam and the Chicago River Lock and Dam the depth below normal pool is generally 20 feet. Flow characteristics for selected streams along the Illinois Waterway are provided in Table 3. Drainage areas at the locks and dams along the Illinois waterway are provided on Plate 2a.

COMPONENTS OF DIVERSION

23. Water diverted from Lake Michigan enters the canals from three separate sources. Water is diverted directly from Lake Michigan into the canals through the locks and control works at the mouth of the Chicago River and at the Wilmette Controlling Works, and through the Calumet River and the Little Calumet River to its junction with the Calumet-Sag Channel. Part of the runoff from the drainage basins of the Chicago River and Calumet River systems, which before the canals were constructed flowed into Lake Michigan, now flows directly into the canals or their tributaries or is diverted into the canals or their tributaries through the sewers, interceptors and treatment plant systems in the Sanitary District. Water withdrawn from Lake Michigan through the intake cribs of the Bureau of Water of the City of Chicago, for domestic, industrial and other purposes, is discharged into the Sanitary District's canals after use in the form of sewage effluent and spillage from the interceptors. Water from cities in the Sanitary District not served with water by the City of Chicago, some of which is taken from Lake Michigan and its drainage basin, is similarly discharged after use into the Sanitary District's canals.

24. The Chicago River Lock permits marine traffic to enter and leave the canal system, and prevents canal water from discharging into the lake. The amount of water diverted into the Sanitary and Ship Canal by operation of this lock depends on the number of lockages which varies substantially with the season. The amount of lockage water required also depends on the relative water levels of Lake Michigan and the Chicago River and Sanitary and Ship Canal at the time of each lockage. The maximum annual requirement of the lock at the mouth of the

Chicago River was equivalent to a continuous flow of 45 cfs and the minimum annual requirement was equivalent to the continuous flow of 14 cfs. The water requirements of the O'Brien Lock, is about 60 cfs.

25. Combining the lockage requirements for the Chicago River Lock and the O'Brien Lock and allowing 20 cfs for leakage gives a total estimated lockage requirement in the upper locks of 125 cfs. Lockage requirements at Lockport are in the order of 300 to 450 cfs throughout the year. The average lockage requirement at Lockport for the year is about 370 cfs. Water from all sources in the canal, including effluent, water diverted direct from the lake, lockage water from the upper locks, and a portion of the runoff, is available for lockages and the generation of power at Lockport.

26. In summary, the water diverted from Lake Michigan in the Chicago area consists of the following components:

- Water Supply - water pumped directly from Lake Michigan for domestic and Industrial uses.

- Stormwater Runoff - runoff which originally drained to Lake Michigan from a 673 square mile area, but is now diverted into the Illinois Waterway. The diversion area is outlined on Plate 1.. There are some 526 storm sewer outfalls that drain to the Illinois Waterway.

- Lockages - Water diverted directly from Lake Michigan during filling of the navigation locks at the Chicago and Calumet Harbors (O'Brien Lock) and subsequently emptying into the river and canal system.

- Leakages - water diverted directly from Lake Michigan due to leakage at the three lakefront controlling structures.

- Navigation Make-up - water diverted directly from Lake Michigan at the three lakefront controlling structures to maintain sufficient navigation depths. See the Metropolitan Sanitary District operation report, attachment 1, for a description of this procedure.

- Controlled Diversion - water diverted directly from Lake Michigan at the three lakefront controlling structures for the purpose of improving water quality by dilution. Controlled diversion is the only component of the total Diversion which can be regulated during normal operations.

27. A chart of actual diversion components for 1983 water year is provided as Plate 4. Total flow out of the canal system is measured by an Acoustical Velocity meter gaging station located at Romeoville, Illinois.

ACCOUNTING FOR THE DIVERSION *

28. The State of Illinois, under general supervision and direction of the District Engineer, Chicago District, Corps of Engineers, United States Army,

determines the total of the amount of water diverted from the drainage area which under natural conditions would flow into Lake Michigan. Monthly reports are prepared which are then finalized into an annual report. This determination, partly a measurement and partly an estimate, is determined by taking the total flow at Lockport, adding those diversion flows that bypass Lockport, and deducting all non-diversion flows entering the canal system. Flows not chargeable to diversion include the following:

(1) domestic pumpage from groundwater sources within the Lake Michigan watershed, but not recharged by Lake Michigan;

(2) domestic pumpage from outside the Lake Michigan watershed;

(3) domestic pumpage for federal facilities (Ft. Sheridan, Great Lakes Naval Training Center, Glenview Naval Air Station and Hines Veterans Hospital;

(4) domestic pumpage from Indiana; and,

(5) infiltration and runoff from the Des Plaines River Watershed.

* The Water Resources Act of 1986 changes the responsibility to accomplish the accounting to the Corps of Engineers starting 1 October 1987.

POTENTIAL FOR INCREASING THE LAKE MICHIGAN DIVERSION AT CHICAGO

29. Of the diversion components listed in paragraph 26, the last component would be the component which would be varied in order to obtain a controlled short term increase in any diversion flow at Chicago. The magnitude of any increase in the diversion at Chicago will be limited based on a number of operational and physical constraints. These constraints are as follows:

- Total inflow constraints at the lake front structures are based on Lake Michigan levels, canal levels needed for navigation,and the hydraulic capacity of these structures. Discharge capacities for various lake elevations are provided on Table 4. Descriptions of the diversion structures are provided in Table 5.

Table 4 - Total Lake Michigan Diversion Capability at Chicago Based on Lake Michigan Levels and Normal Chicago River and Calumet River Levels

Lake stage, feet (IGLD)	Portion from(3) Wilmette cfs (1)	Portion from Chicago C.W. cfs (1)	Portion from O'Brien C.W. cfs (1)
581.5	3,500	9,040	5,712
581.0	3,250	8,600	5,448
580.5	3,050	8,000	5,160
580.0	2,850	7,520	4,832
579.5	2,678	7,000	4,500
579.0	2,469	6,456	4,148
578.5	2,234	5,840	3,768
578.0	1,980	5,176	3,332
577.5	1,683	4,400	2,836
577.0	1,316	3,440	2,236
576.5	808	2,112	1,396
576.0	(2)	(2)	(2)
575.5	(2)	(2)	(2)
575.0	(2)	(2)	(2)

Notes:

(1) - Assuming no operational constraints, with canal pools regulated at 576.18 feet IGLD.
(2) - Regulated canal pool elevation of lakefront points is greater than 576.0 feet IGLD.
(3) - Sluice gate only.
(4) - Actual flow will be less due to backwater in channel created by diversion flow.

Table 5 - Description of Diversion Structures

Location	Diversion Structures
Wilmette Controlling Works	4 Pumps - 250 cubic feet per second at 3 foot head Sluice gate 1 - 15 feet high by 32 feet wide
Chicago River Lock Controlling Works	8 Sluice gates - 10 foot square
O'Brien Controlling Works	4 Sluice gates - 10 foot square

. Operation of the canal system has demonstrated that canal velocities become hazardous to navigation when flows as measured at Lockport rise above 10,000 cfs. The greatest hazard is in the narrow reaches of the canal generally from Lockport up to the confluence of the Sanitary Ship Canal and Cal Sag Channel.

Information obtained through recent inquiries on the impacts to navigation of an increased Lake Michigan Diversion at Chicago are described below.

The Corps Lockmaster at Lockport, Illinois, provided the following information - Most tow boats in upper pools (upstream of Lockport) are underpowered and cannot navigate with high flows. The suggested safe flow in the canals is between 6,000 and 7,000 cubic feet per second (cfs). At 10,000 cfs flows, all traffic stops because of high velocities and unsafe conditions.

Towboat companies - Two towboat company owners who handle most of the traffic in the Brandon and Lockport pools were interviewed. One company owner is president of the Illinois River Carriers Association (IRCA). The following is information, which is consistent between two owners, was obtained from them:

1. Maximum allowable flow (safe travel) in Chicago Sanitary Canal is 10,000 cfs. At times of heavy runoff when the flow exceeds 10,000 cfs, most tows tie off until flow falls below 10,000 cfs.

2. These two companies stated that they push about 48 barges of the 50 to 100 barges that pass through this area each day.

3. Most commodities are coal, oil, chemicals, and steel.

4. About 15 commercial carriers operate in this area.

5. Tows are in the following classifications: 900-1,000 hp., 1,000-1,100 hp., 2,200 hp., and 3,200 hp. and above.

6. The critical canal area has a 160-foot width. The usable width is reduced to 125 feet when barges are moored along the canal. Towboats pushing tows that are 70 feet wide by 400 feet long have difficulty navigating through the area, when flows are high and other barges are moored.

7. The area which is most dangerous is upstream of Brandon Lock and downstream of Lockport Lock at the Ruby Street Bridge, Illinois River Mile 288.8. The following has been observed by the towboat owners at Ruby Street.

i. 8,000 cfs at Ruby Street Bridge:

a. Eight-barge tow stopped with 1,100 hp. tow.

b. Eight-barge tow with 2,200 hp. tow can maneuver, but with difficulty.

ii. 10,000 cfs at Ruby Street Bridge.

c. An eight-barge tow with 3,200 hp. boat could not make it through because of high velocities and water coming over barges and deck of tow boat.

In the above three cases, the tow boats usually stall and then control is lost. Most towboat pilots know they can't navigate through the Ruby Street reach and tie off to await lower flows. All have experienced stalling and losing control of tows. Several fuel barges are normally moored in Joliet Harbor and present a dangerous situation.

Based on the above, it is concluded that an Increase Diversion Operating Plan would have to be limited to a maximum of 8,000 cfs measured near Brandon Road Lock not at Lockport. The Des Plaines River flow joins the Chicago Sanitary and Ship Canal flow upstream of Brandon Road Lock.

In addition, flows of 8,000 cfs at Lockport are not as much problem as 6,000 cfs from Lockport and 2,000 cfs from Des Plaines River at Illinois River Mile 288.8. The cross current pushes tows into the left decending bank.

. During minor to severe rainfall events over the Chicago region, the canal system above Lockport is operated to provide flood control relief to the surrounding area. These operations are conducted by MSDGC and would have priority over any direct diversion taking place at the time (any direct diversion would be discontinued until after the event). The MSDGC operating plan is provided as attachment 1.

. Lower system constraints, below Lockport, Illinois, generally relate to the limiting of any increase in diversion flow so that downstream flooded is not aggravated. Because any increase in direct diversion will remain in the Illinois River for days or even weeks (Table 6), a control plan to monitor and limit increases in diversion as related to downstream flood potential would have to be an intergal part of any plan to increase diversion flows at Chicago. Such a preliminary operational plan was developed for the report entitled "Increased Lake Michigan Diversion at Chicago Demonstration and Study Program Information Report to the Congress, dated April 1981," reference a. This plan was revised based on additional evaluations since 1981. The outline of such a plan is provided below:

The operating plan proposed will be refined as time passes, depending on funds available for any actual diversion operation.

a. Initial Plan - The initial plan will utilize data from existing stream gages for the daily operation. General guidelines are as follows:

. Any station or activities reaching its own limiting conditions will limit the diversion increases that are controlled by the lake front structures.

. Diversion flows will be regulated at the lake front structures so as to limit total flow at Brandon Road (Ruby Street Bridge at River Mile 288.8) to a maximum of 8,000 cfs. Flows at Ruby Street Bridge will be estimated by the direct addition of flows at Romeoville as measured by the AVM gage and the Des Plaines River flows measured at the Riverside, Illinois, Gage. Based on these criteria, maximum diversion increases will be 5,000 - 6,000 cfs.

. During periods of expected rainfall on the Chicago region, the canal system above Lockport is operated to provide flood control relief to the surrounding area. These operations are conducted by the Metropolitan Sanitary District of Greater Chicago (MSDGC) and would have priority over any direct diversion taking place at the time. Any direct diversion would be discontinued until after the event. The MSDGC operating plan is provided as attachment 1.

. System constraints below Lockport, Illnois, generally relate to the limiting of any increase in diversion flow so that downstream flooding is not aggravated. Because any increase in direct diversion from Lake Michigan will remain in the Illinois River for days or even weeks (Table 6), a water control plan to monitor and limit increases in diversion as related to downstream flood potential would have to be an integral part of any plan to increase diversion flows at Chicago. Such a preliminary operational plan was developed for the report entitled "Increased Lake Michigan ~iversion at Chicago Demonstration and Study Program Information."

Report to the Congress, dated April 1981, "reference a." This plan was revised based on additional evaluation since 1981. The outline of such a plan is provided in Table 7.

Table 6 - Illinois River Travel Time in Days (1)

	High Flow (40,000 cfs)	Medium Flow (13,300 cfs)	Low Flow (5,800 cfs)
Lake Front to Dresden (60 miles)	0.9	1.4	1.9
Dresden to Peoria (110 miles)	2.3	3.7	4.9
Peoria to Meredosia (88 miles)	2.0	3.5	4.8
Meredosia to Mouth (72 miles)	1.3	2.1	2.9
Grand Total	6.5	10.7	14.5

Note: (1) Flows as determined from the Meredosia, Illinois gage.

* For operation of the plan, the Meredosia gage would be monitored and the increased diversion regulated according to Table 7.

* To prevent flooding of the downstream areas, the Illinois River gages shown on Table 8 would be monitored. The increased diversion would be reduced or curtailed if bankfull conditions are likely to be exceeded. Criteria similar to those developed in Table 6 will be developed for the other stations along the Illinois Waterway.

* National Weather Service forecasts would be closely monitored and the increased diversion would be limited based on the forecasts.

* Seasonal constraints on diversion amounts due to agricultural and fish and wildlife needs will be evaluated during the summer of 1987. Results of these evaluations will be included in the initial operating plan.

Table 7 - Suggested Operating Plan for an Increased Lake Michigan Diversion at Chicago

Estimated base flow at Meredosia without increased diversion cfs	Increased Diversion rate at Chicago cfs (1)	Total flow at Meredosia cfs
9,000	6,000	15,000
14,000	6,000	20,000 (3)
16,000	5,000	21,000 (4)
22,000	3,000	25,000
28,000	1,000	29,000
30,000	0	30,000 (2)

Notes:

(1) May be less when other system constraints are considered.
(2) Approximately 3 feet below bankfull. Bankfull at Meredosia is approximately 40,000 cfs.
(3) Approximately 6 feet below bankfull.
(4) A 1-year storm on the Illinois watershed would increase this to about 41,000 cfs.

b. Improved Plan - As funds become available and as experience is gained during actual operation, improvements in the operating plan will be made. Some of these potential improvements are:

. A direct tie-in to NWS radar at Marseilles, Illinois, will be used to estimate near real-time rainfall-runoff to make initial estimates of flow in systems.

. Self-timed and random reporting Data Collection Platforms at river stage and precipitation stations will be used to send data to the Data Storage System for immediate use in real-time program for determining flows in the Illinois River and tributaries.

. Computer software will be programmed to examine all data when it enters the storage system to determine if threshold values on any streams are exceeded. If values are exceeded, initiate program to begin data analysis, determine runoff, route flows, establish whether levels would be exceeded which would require flow reduction, and provide information to management.

. Attached is a listing of new gages required and/or conversion of existing gages to real-time mode.

New Gage Proposal

1. Des Plaines River at Jackson Street, Lockport, Illinois.
2. Illinois River at Spring Valley, Illinois.
3. Ilinois River at Morris, Illinois.
4. Kickapoo Creek at Peoria, Illinois.
5. Mackinaw River at Green Valley, Illinois

Conversion to Data Collection Platforms

1. Des Plaines River at Jackson Street, Lockport, Illinois.
2. Illinois River at Spring Valley, Illinois.
3. Ilinois River at Morris, Illinois.
4. Kickapoo Creek at Peoria, Illinois.
5. Mackinaw River at Green Valley, Illinois
6. Big Bureau Creek at Bureau, Illinois.
7. Illinois River at LaSalle, Illinois.

. Monitor automatic telemetered Illinois River basin rain gages or convert those which are not automated to automated, on the following streams.

a. Thorn Creek - Chicago Heights
b. Deer Creek - Chicago Heights
c. North Fork Chicago River - Deerfield
d. Weller Creek - Des Plaines
e. Salt Creek - Elmhurst
f. Butterfield Creek - Flossmoor
g. Thorn Creek - Glenwood
h. Hickory Creek - Joliet
i. Skokie River - Lake Forest
j. North Creek - Lansing
k. West Fork, North Fork Chicago River - North Brook
l. Midlothian Creek - Oak Forest
m. Salt Creek - Rolling Meadows
n. Little Calumet River - South Holland
o. Thorn Creek - Thorton
p. Buffalo Creek - Wheeling
q. Flag Creek - Willow Springs

Use the existing National Weather Services Flash Flood network for rainfall-runoff warnings for early decision-making. Weather Service-River Forecasting Center (NWS-RFC) developed relationships for the above 17 stations which will aid in the decision-making process.

Table 8 - Suggested Flood Warning Stations to be Monitored on the Illinois Waterway

Station	River mile	Bankfull elevation (1)	Approximate Bankfull Discharge cfs
Morris	263.1	493.5	32,500
La Salle	224.7	450.0	26,552
Spring Valley	218.4	447.0	21,429
Henry	195.6	447.0	26,290
Peoria Boatyard	164.2	446.0	27,500
Kingston Mines	145.5	442.0	27,972
Havana	119.6	438.0	28,000
Beardstown	88.6	435.0	35,667

Notes:

(1) - Elevation are in feet above National Geodetic Vertical Datum of 1929 and are considered to be those levels above which water would flow out of its river banks.

30. Any actual diversion plan would need to be modified and improved upon as field experience is gained through actual operation of such a program. The Corps of Engineers (Chicago District) received funding in FY 1987 to complete the study cited as reference a. The simulation of river stages with various amounts of increased diversion will be based on the use of a more sophisticated hydraulic model for analyzing impacts of any proposed diversion plan on the Illinois Waterway. This unsteady flow hydraulic model is better at assessing water level changes on the Illinois Waterway that may be a result of an increase in the diversion. Unsteady flow modelling is generally regarded as superior over prveious hydraulic modelling methods for a waterway like the Illinois Waterway as it is better at reproducing the water level profiles as reltaed to wide rivers with numerous large back bay storage areas like the Illinois Waterway. Any operating plans will examine variations in regulation of any increases in diversion so as to benefit downstream interests or reduce the possibility of adverse impacts on the waterway as related to any increased diversion. Included in these considerations will be the interests of flooding, water quality, agricultural, navigation, fish and wildlife, and hydropower. These evaluations are expected to be completed in early 1988.

IMPACTS

31. Any increase in the Diversion will result in a number of impacts on the Great Lakes and on the Illinois Waterway. The report (reference a) evaluated the impacts of increasing diversion on the Illinois Waterway for three types of hydrologic conditions. These are a wet year, a normal year, and a dry year. Under the general flood operational constraints listed above, it could be expected to achieve the following increases (Table 9) in diversion under the three hydrologic conditions on the Illinois Waterway listed above.

Table 10 - Potential Diversion Increases

Illinois Waterway Hydrologic Condition (for a particular year)	Probable Average Increase in Flow for a given year
Normal	6,400 cfs
Wet	1,900 cfs
Dry	6,500 cfs

32. Any increase in the diversion will impact the Illinois Waterway. During the summer of 1987, the Chicago and Rock Island Districts will develop and evaluate the following:

- Develop a hydraulic model of the main stem of the Illinois Waterway which will be able to predict the effects on stages due to flow entering and leaving river valley storage. Existing models have not been able to adequately predict stages on the lower Illinois River due to storage effects.

- Develop operational data storage software for recording and analyzing any data collected during an actual operation.

- Review navigational constraints due to higher river velocities.

- Through mathematical model simulations of historic water years various increased diversion plans will be evaluated. Key areas for additional evaluation are:

  (1) Sediment and erosion impacts.

  (2) Seasonal impacts and constraints required due to agricultural concerns.

  (3) Fish and wildlife and other environmental issues will be further evaluated.

PROBABLE AVERAGE LAKE REDUCTIONS

33. It is estimated that an increase of 5,000 cfs at Chicago over 120 days would result in a reduction of about 0.04 of a foot (0.48 inches) of the level of Lakes Michigan-Huron.

MSDGC Drawdown Operation

Prestorm Conditions:

1. Water levels in the canal system must be maintained within certain elevations by federal law for navigation needs. Title 33 of the Code of Federal Regulations, (Sections 207.420 and 207.425) states that water levels of the lower pools of the Chicago River Controlling Works CRCW (Note 1) and O'Brien Locks must be maintained at between -0.5 and -2.0 feet CCD (Note 2), except during periods of storm runoff. The canal system is usually operated at -2.0 feet CCD to allow for maximum storage volume to reduce flooding during storm events.

When a Storm is Forecast:

2. The Metropolitan Sanitary District of Greater Chicago (MSDGC) determines the amounts of discharge at Lockport, Illinois. When a storm is forecast, they have an operating procedure whereby greater discharges are released through Lockport prior to the predicted rainfall event. The amount of release depends upon the predicted severity of the event. By pre-dumping before a storm, the storage capacity of the canal is increased and a hydraulic gradient away from Lake Michigan is established. This helps to prevent or lessen flooding in Chicago and the necessity to backflow into Lake Michigan.

MSDGC Hydrometeorologic Stations:

3. The MSDGC maintains a network of 23 telemetered precipitation gages situated in the watershed and surrounding areas. Some of the gages are 30 to 40 miles west of the watershed and provide data for predicting rainfall from approaching storms. Data from these rain gages are received and interpreted at the MSDGC Waterways Control Center located in Chicago, Illinois. In addition to the precipitation gage system, the MSDGC maintains in its control center a fascimile recorder which receives U.S. Weather Service radar printouts.

LockPort Operation:

4. For the purpose of flood control management, predicted rainfall amounts are separated into five forecast groups that provide guidelines for the MSDGC Waterway Control Center personnel to issue instructions for the opening of gates at the Lockport Powerhouse, as shown in the following Table.

Attachment 1

Table 9 - Lock Port Drawdown Guidelines

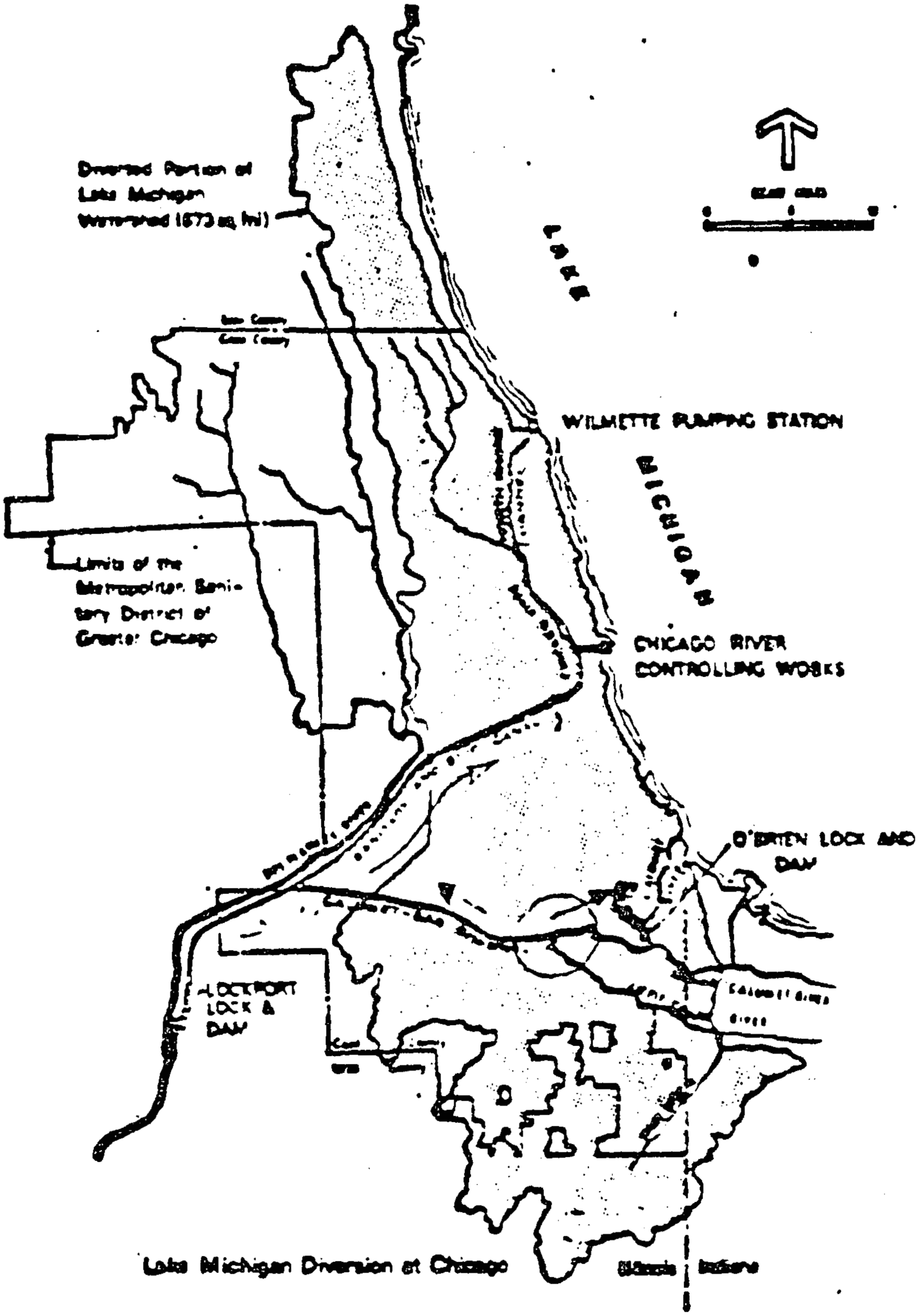
Forecast Precipitation (in.)	Lowest Elevation at Powerhouse (Ft. -CCD)	Lowest Elevation at Sag Junction (Ft. -CCD)
0 - 0.25	-3.0	-2.2
0.26 - 0.50	-4.0	-2.4
0.51 - 0.75	-5.5	-2.7
0.76 - 1.00	-7.5	-3.0
Greater 1.00	-9.0	-4.0

Notes:

(1) - Chicago River Controlling Works

(2) - Chicgo City Datum

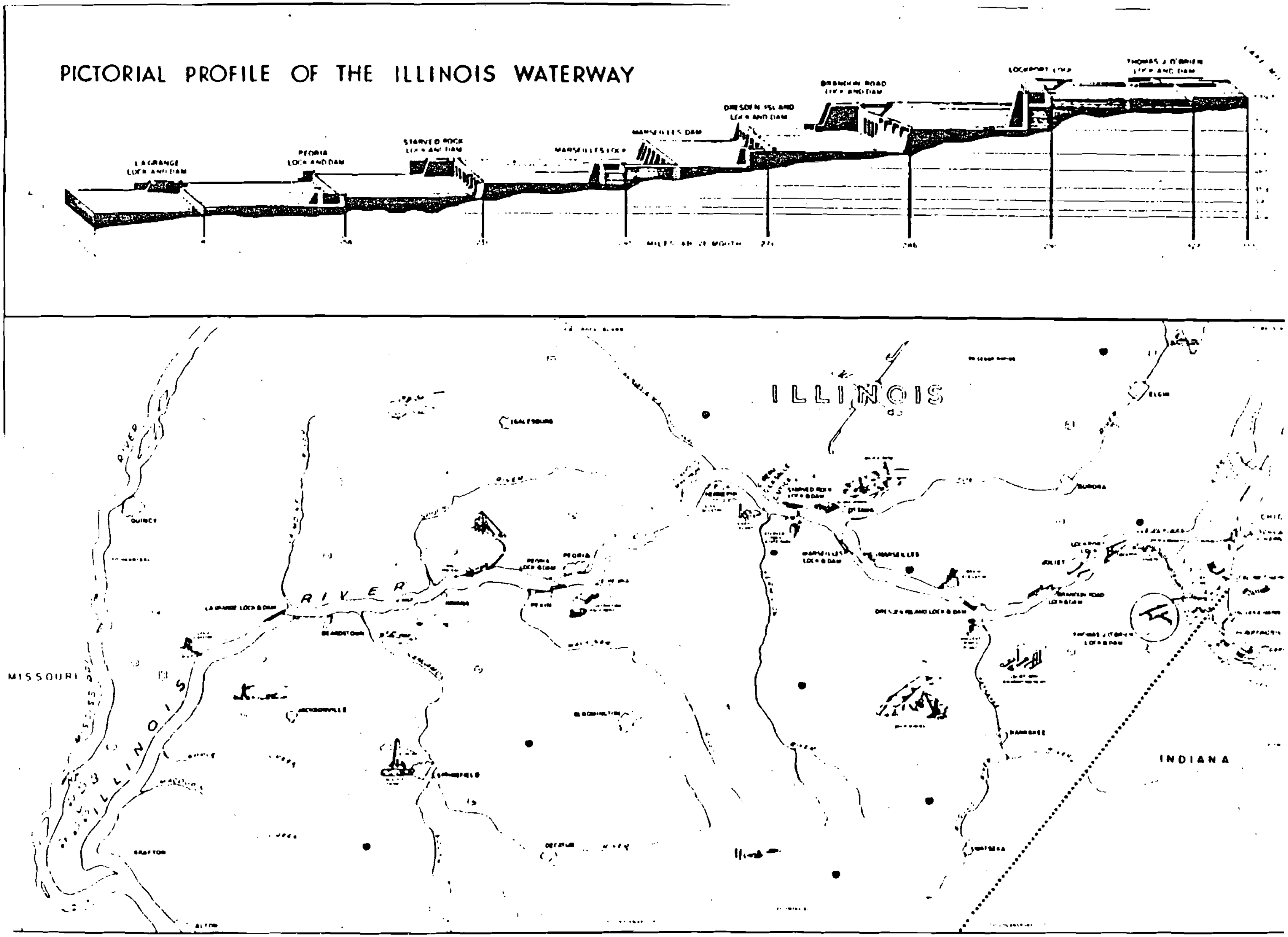
(3) - Normal target levels at Chicago River Locks -2.0 CCD and at Lockport -2.5 CCD



Lake Michigan Diversion at Chicago

PLATE 1

PLATE 2



PICTORIAL PROFILE OF THE ILLINOIS WATERWAY

Table 1 Pertinent data on the locks and dams along the Illinois Waterway

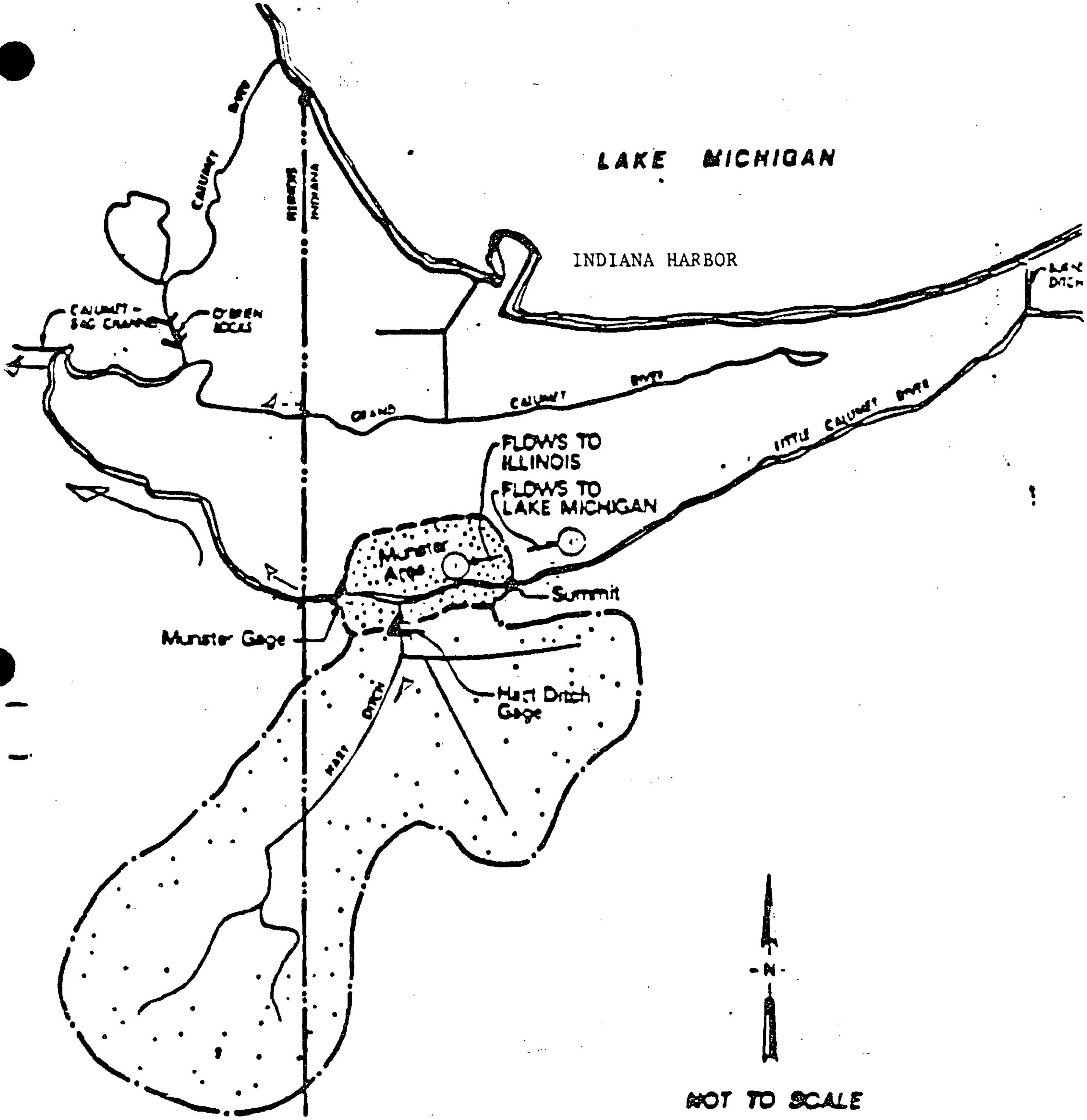
Lock and dam 1/	Miles above mouth	Year completed	Drainage area, square miles	Upper pool elevation 3/
La Grange lock & dam	80.2	1939	25,300	429.0
Peoria lock & dam	157.7	1939	13,900	440.0
Starved Rock lock & dam	231.0	1933	10,300	458.5
Marseilles lock	244.6	1933	7,640	482.8
Marseilles dam	247.0	1933	7,600	
Dresden Island lock & dam	271.5	1933	6,600	504.5
Brandon Road lock & dam	286.0	1933	1,450	538.5
Lockport lock	291.1	1933	740 4/	577.5
Lockport dam	291.1	1905	740 4/	
O'Brien lock & dam 2/	326.3	1905	0	
Chicago River lock 2/ and controlling works	327.2	1938	0	

1/ These locks and dams are Federal structures with the exception of the Lockport dam and the Chicago River lock and controlling works which are owned and operated by Metropolitan Sanitary District of Greater Chicago.

2/ These structures, along with the Wilmette diversion structure, control the direct diversion from Lake Michigan to the Illinois Waterway.

3/ Elevations are in feet above Mean Sea Level (1929 adjustment) and represent the regulated water levels immediately upstream of the indicated structures.

4/ Includes a 673 square mile area which was originally tributary to Lake Michigan.



Location Plan - Little Calumet River

PLATE 3

LAKE MICHIGAN DIVERSION
ACCOUNTING YEAR 1982
AVERAGE ANNUAL DIVERSION = 3087 CFS

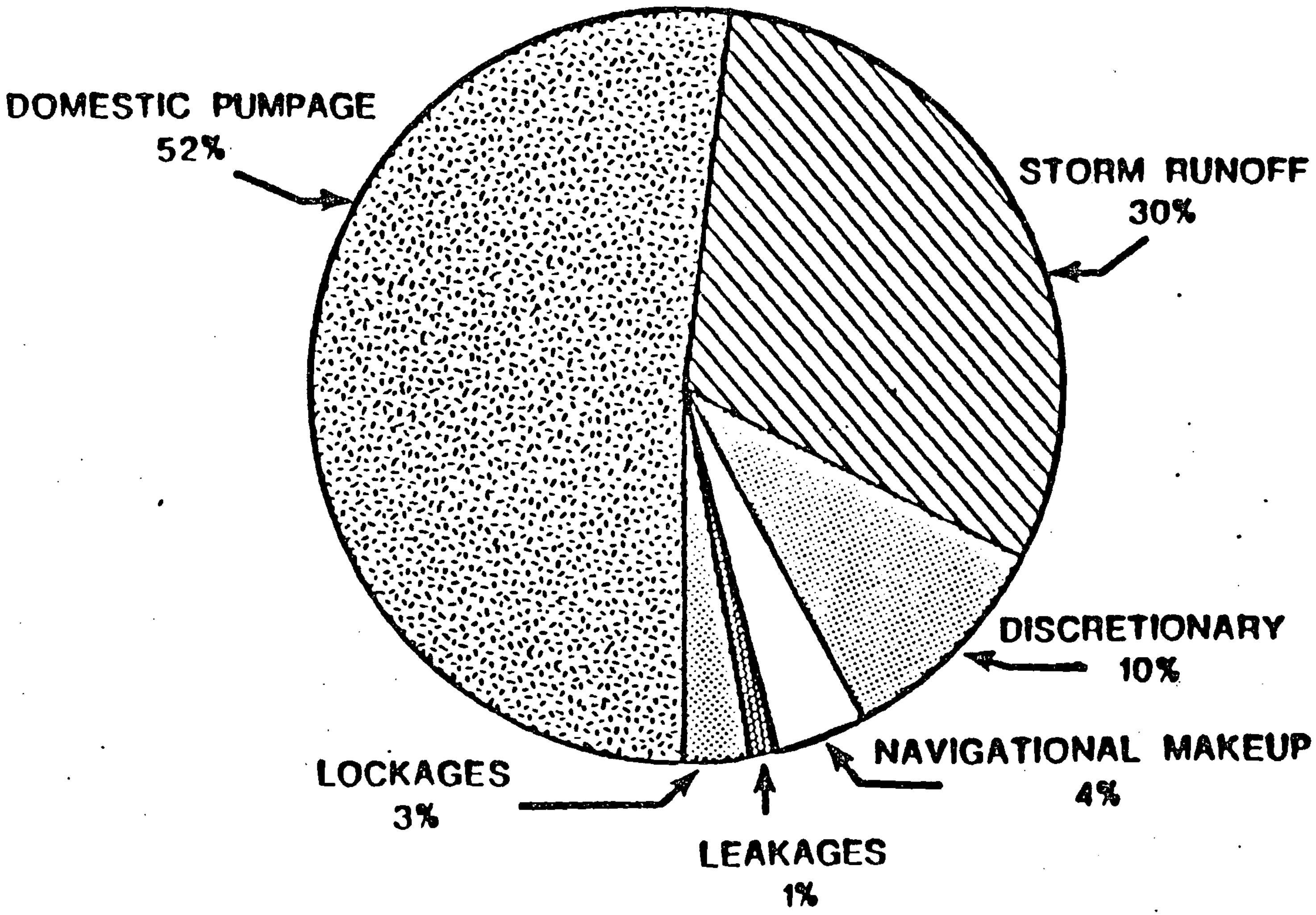


PLATE 4

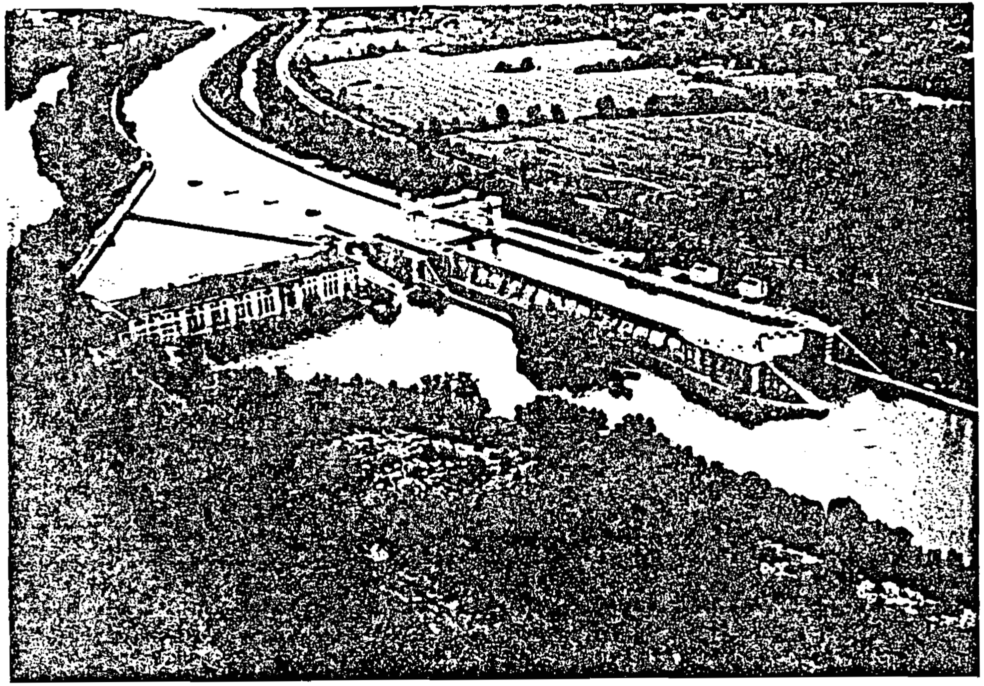


PHOTO -1 AERIAL VIEW OF LOCKPORT LOCK & POWERHOUSE

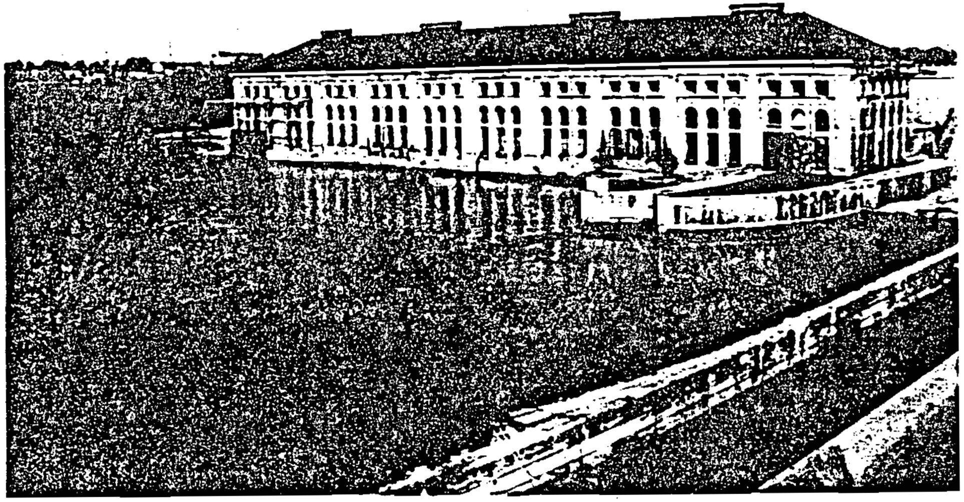


PHOTO -2 DOWNSTREAM VIEW OF LOCKPORT POWERHOUSE

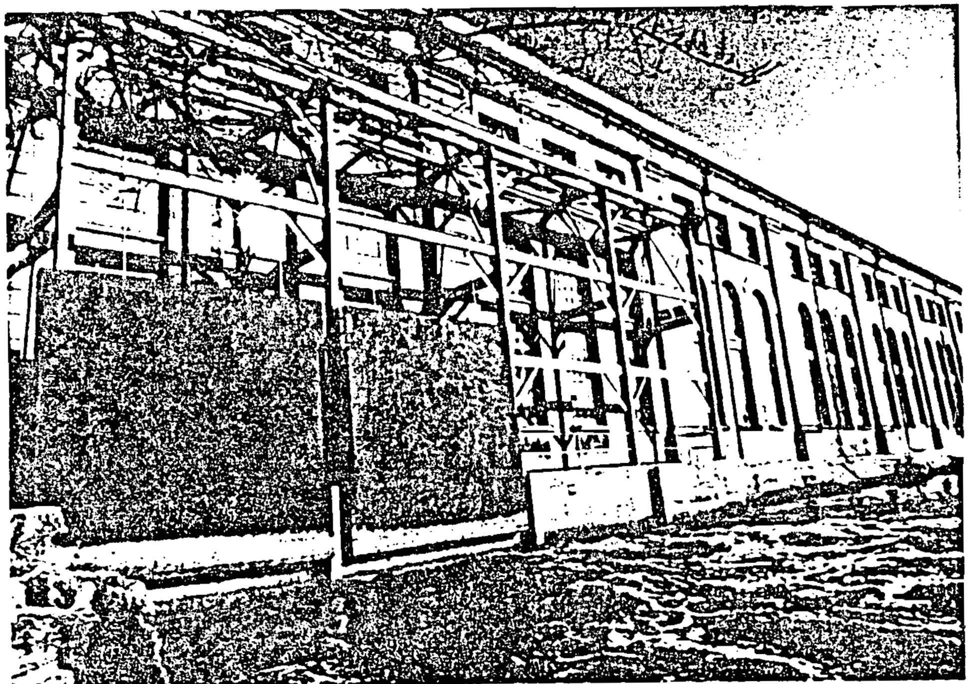


PHOTO -3 DOWNSTREAM VIEW OF TURBINE GATES AT LOCKPORT POWERHOUSE

FIGURE

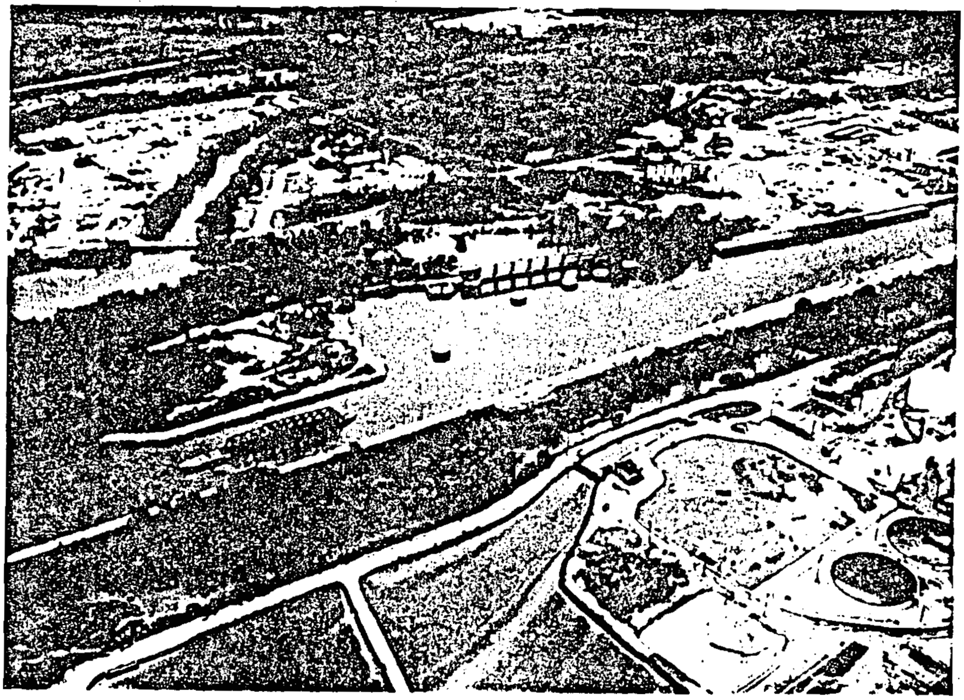


PHOTO -4 AERIAL VIEW OF MSDGC CONTROLLING WORKS

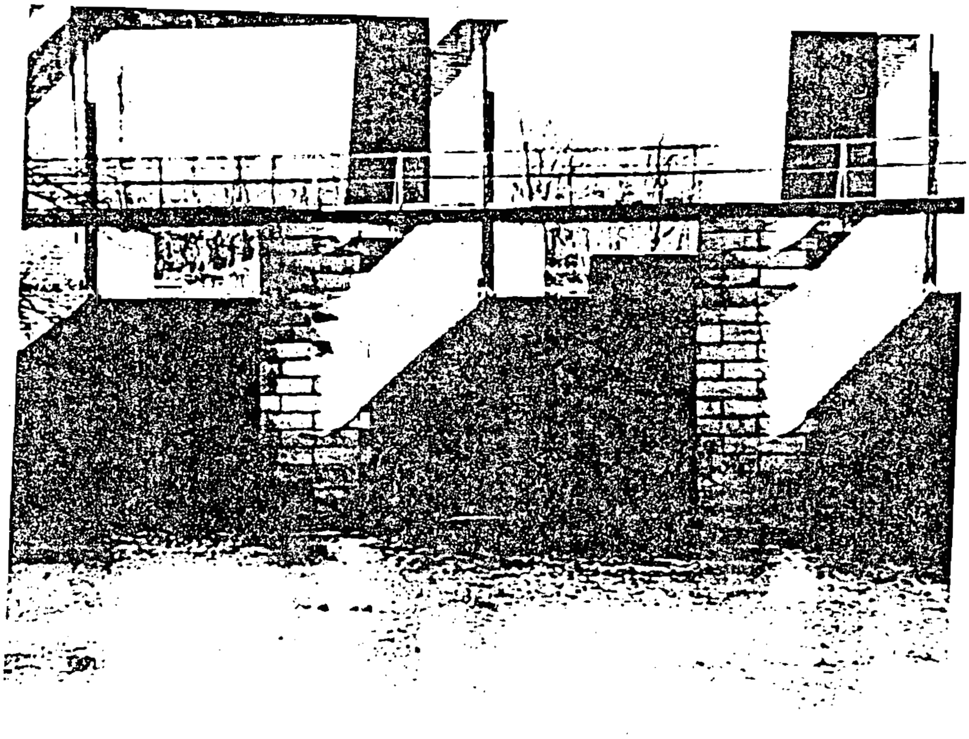


PHOTO -5 DESPLAINES RIVERSIDE VIEW OF MSDGC CONTROLLING WORKS

FIGURE 2

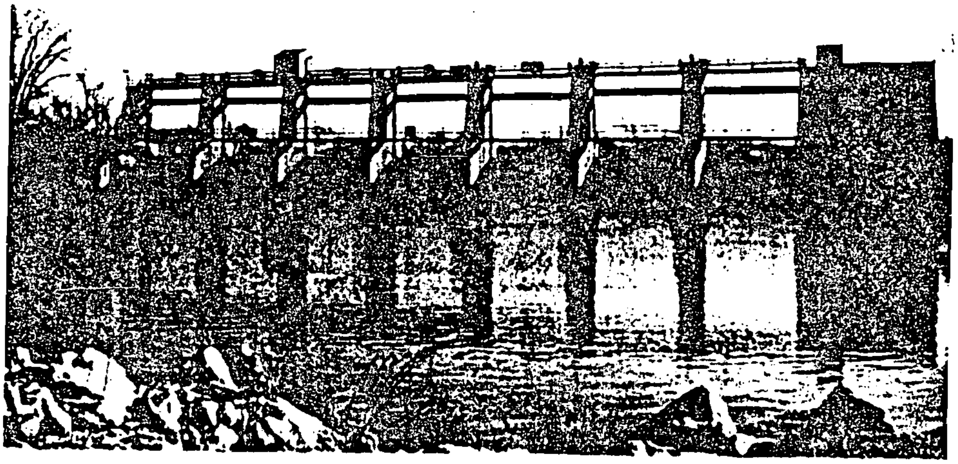


PHOTO -6 DESPLAINES RIVER SIDE VIEW OF MSDGC CONTROLLING WORKS

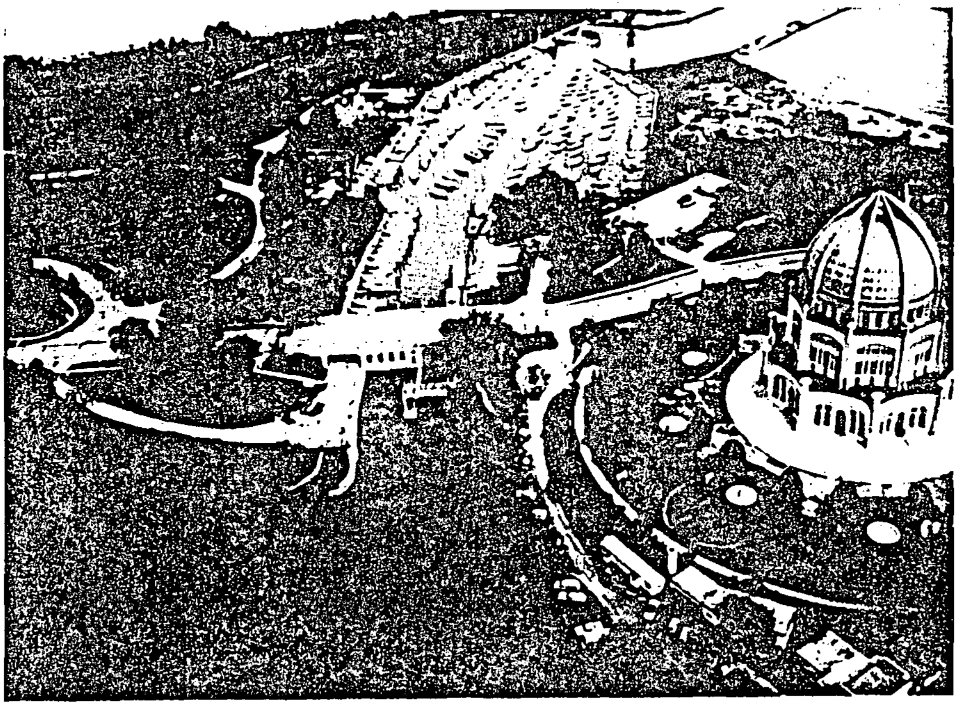


PHOTO -7 AERIAL VIEW OF WILMETTE CONTROLLING WORKS

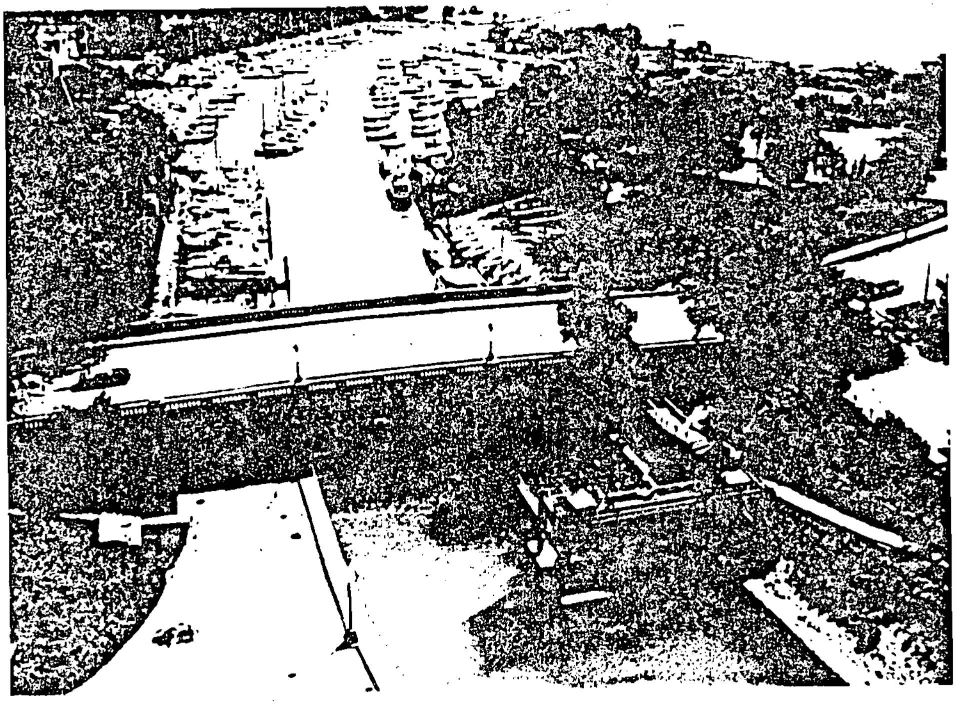


PHOTO -8 AERIAL VIEW OF WILMETTE CONTROLLING WORKS

FIGURE 4

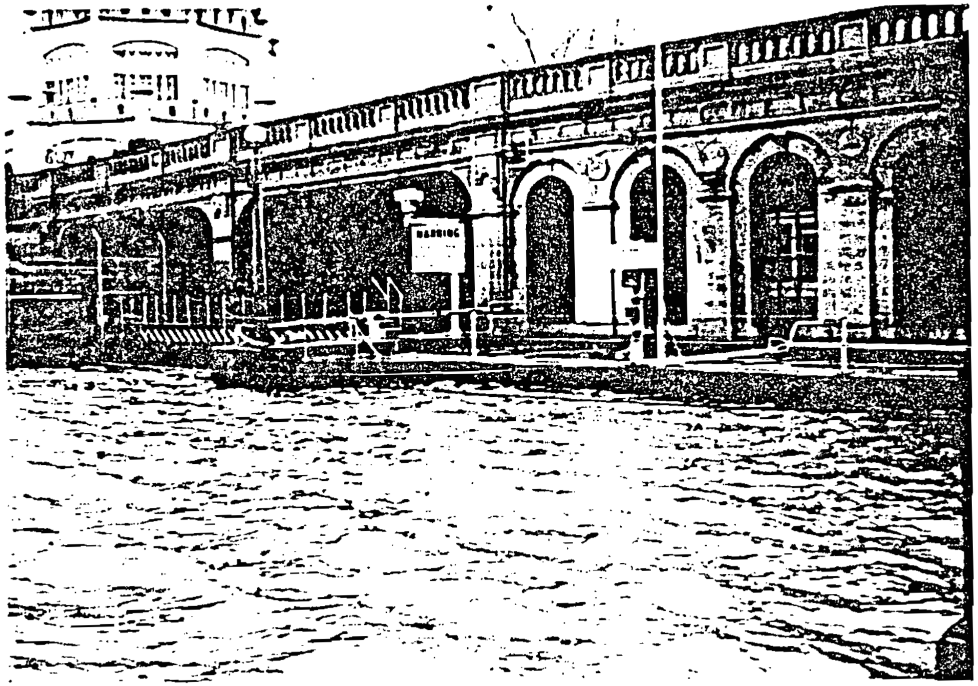


PHOTO -9 LAKESIDE VIEW OF WILMETTE PUMP BUILDING AND SLUICE GATE ON LEFT

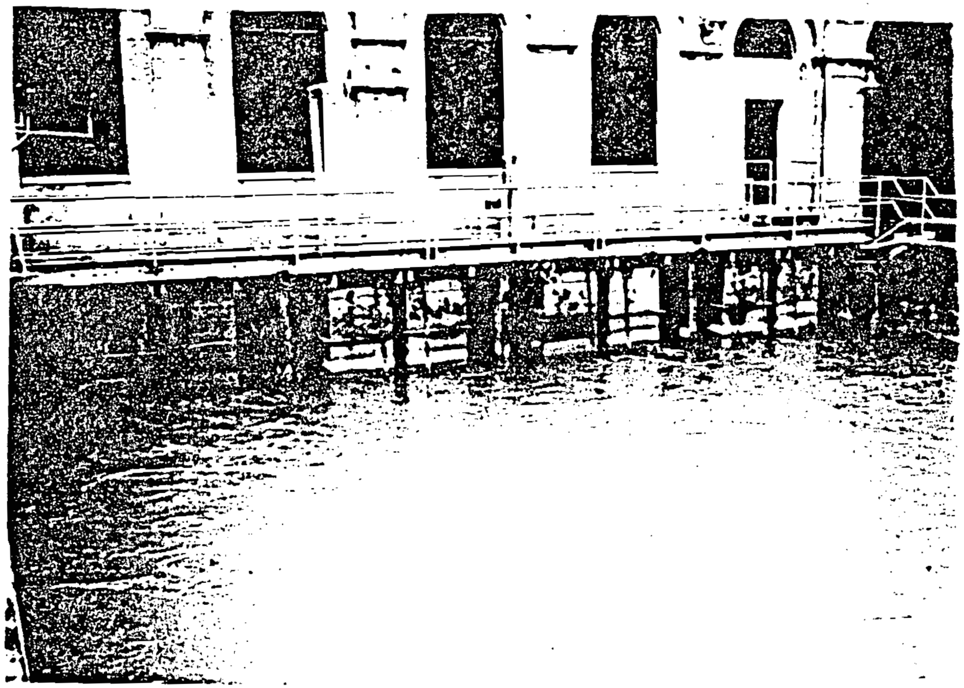


PHOTO -10 CANAL SIDE VIEW OF PUMP OUTLINE - WILMETTE CONTROLLING WORKS

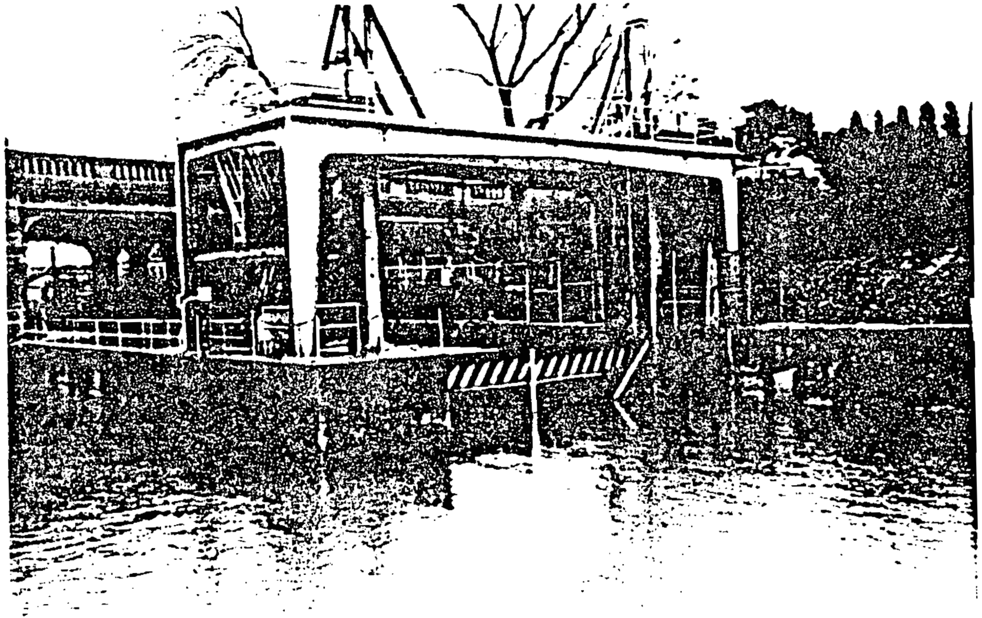


PHOTO -11 CANAL SIDE VIEW OF OLD LOCK SLUICE GATE WILMETTE CONTROLLING

FIGURE 5

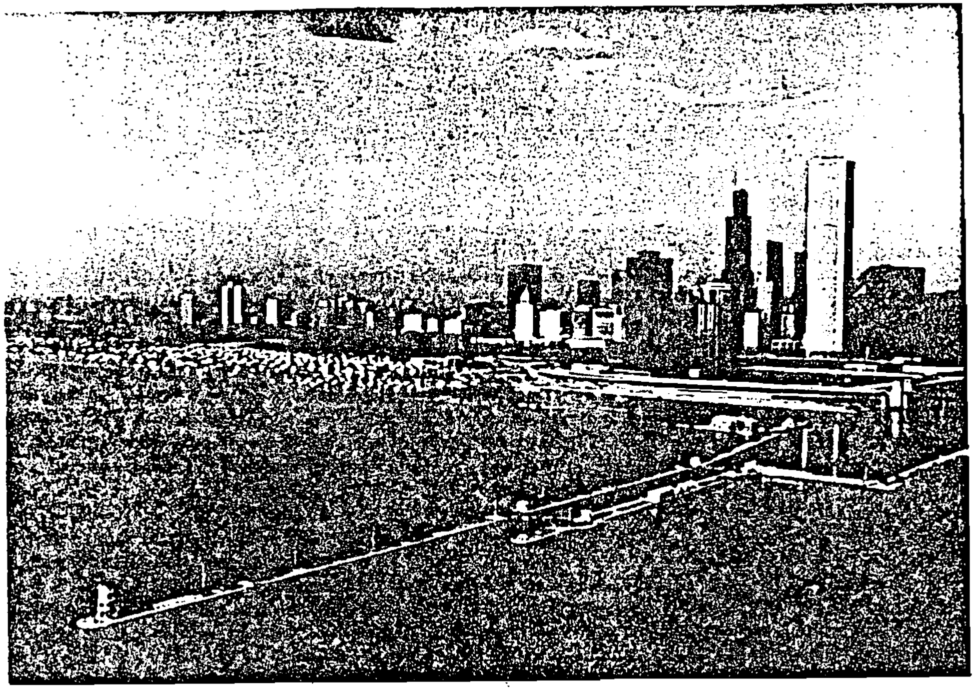


PHOTO -12 AERIAL VIEW OF CHICAGO CONTROLLING WORKS AND LOCK

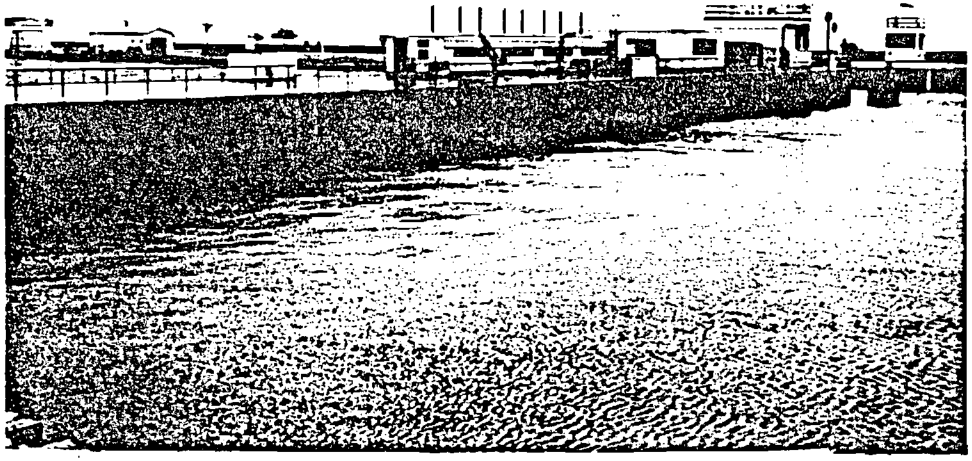


PHOTO -13 CANAL SIDE VIEW OF SLUICE GATE SUPERSTRUCTURE (CENTER) NORTH OF LOCK

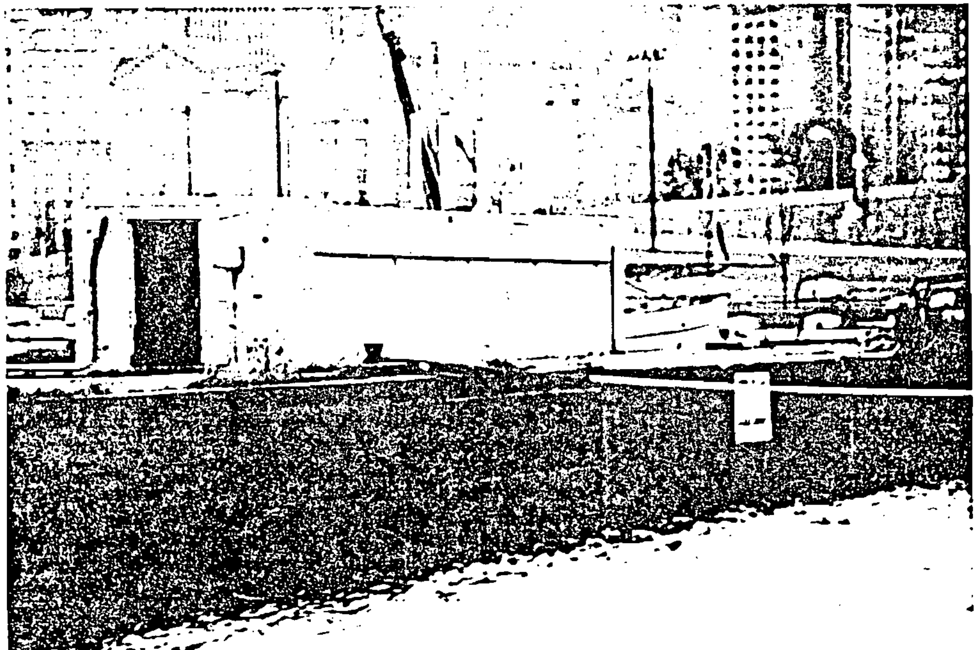


PHOTO -14 CANAL SIDE VIEW OF SLUCE GATE SUPERSTRUCTURE SOUTH OF LOCK

FIGURE 6

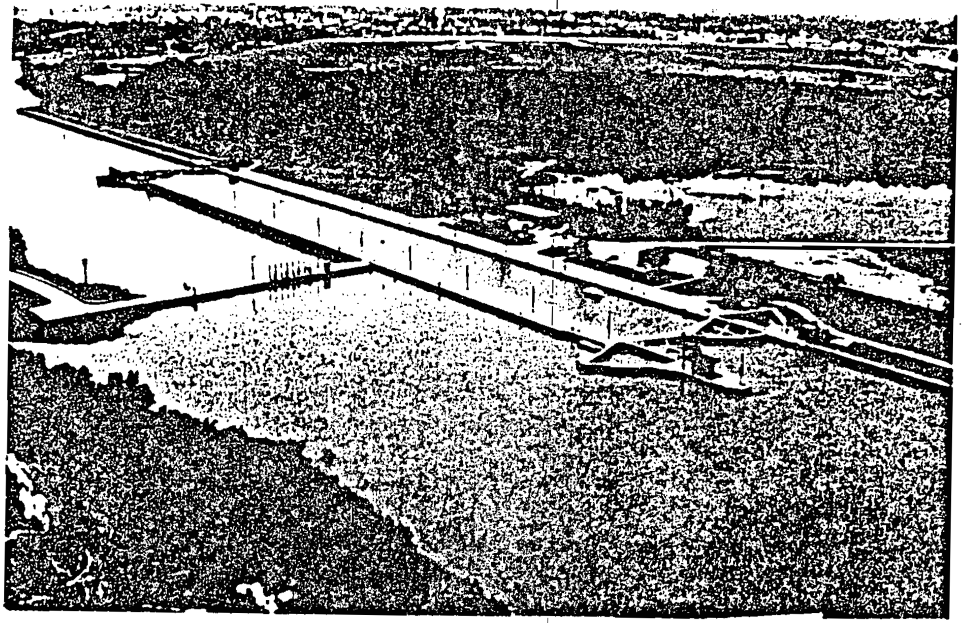


PHOTO -15 AERIAL VIEW OF O'BRIEN LOCK AND DAM

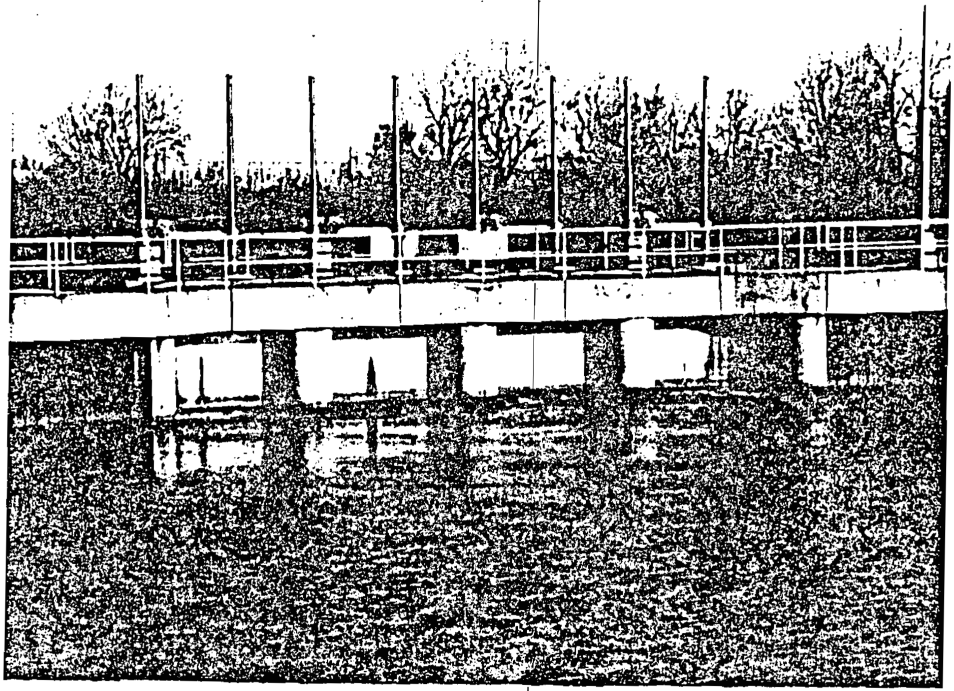


PHOTO -16 CANAL SIDE VIEW OF O'BRIEN CONTROLLING WORKS

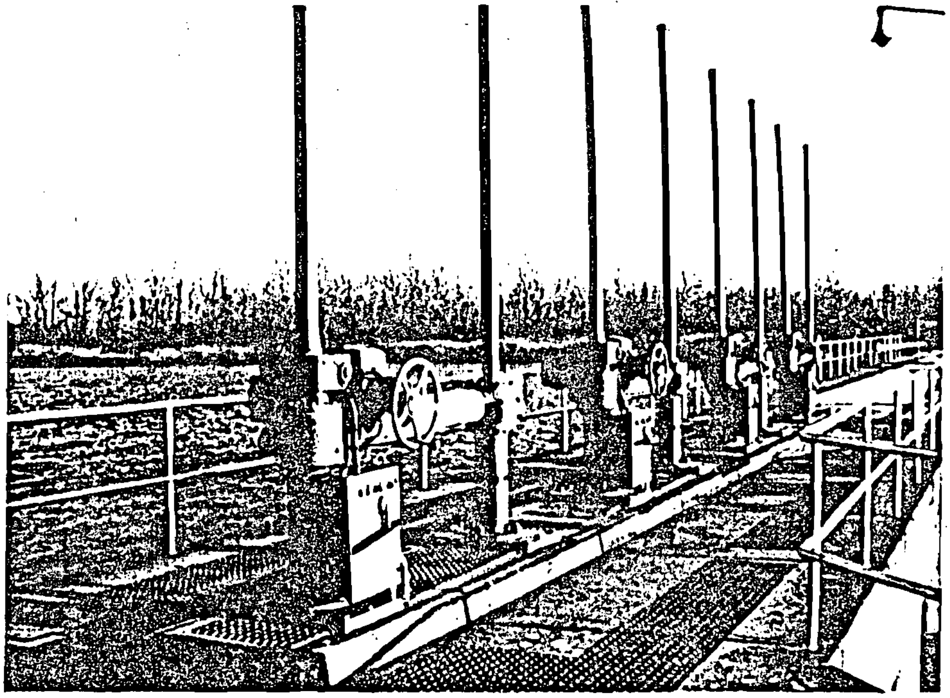


PHOTO -17 TOPSIDE VIEW OF O'BRIEN SLUICE GATES CONTROLLING WORKS

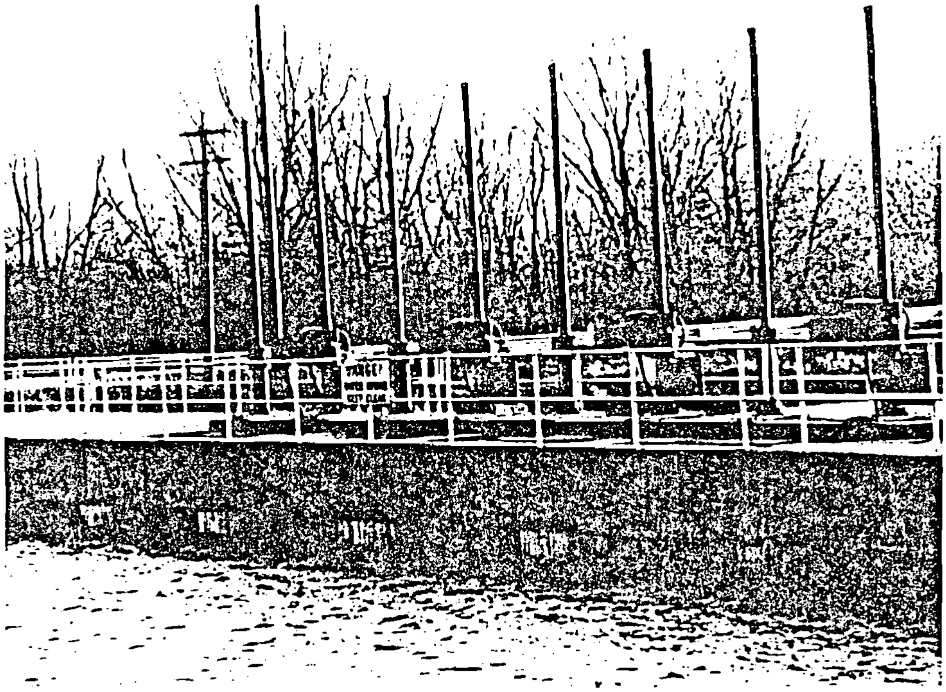


PHOTO -18 LAKESIDE VIEW OF O'BRIEN CONTROLLING WORKS

APPENDIX D

THE NEW YORK STATE BARGE CANAL

SECTION 1

INTRODUCTION

The purpose of this report is to discuss the New York State Barge Canal with respect to its diversion of Niagara River waters, and to examine the legal documents which may limit the amount of water diverted from this source.

The New York State Barge Canal System, see Enclosure 1, consists of four subsystems:

a. The Erie Canal - stretches from the Niagara River at Tonawanda, New York, to the Hudson River at Waterford, New York.

b. The Oswego Canal - connects the Erie Canal with Lake Ontario at Oswego, New York.

c. The Champlain Canal - connects Lake Champlain with the Erie Canal.

d. The Cayuga and Seneca Canals - connect Cayuga and Seneca Lakes with the Erie Canal.

The scope of this report is confined to that portion of the Erie Canal extending from the Niagara River to its juncture with the Oswego Canal, since none of the water diverted from the Niagara River can travel eastward past this point. Eastward from its juncture with the Oswego Canal at Three Rivers Point, water levels in the Erie Canal rise, reaching a summit at Rome, New York. Thereafter, the canal continually descends until it reaches the Hudson River.

1.3 History of Early Canals in New York State.

The first work of interior waterway improvement in New York State was done in the latter part of the eighteenth century between the Hudson River and Lake Ontario, and between the Hudson River and Lake Champlain, by two private companies chartered in 1792. Agitation for state-built canals began about 1808 and resulted in the construction of the Erie and Champlain Canals in the years 1817 to 1825. The original Erie Canal was 4 feet deep, 28 feet wide at bottom and 40 feet wide at the water surface. It was 363 miles long, had 84 lift locks and 13 guard locks, each 90 by 15 feet, and was constructed of stone. In the next decade, several lateral canals were built. The first enlargement of the Erie, Champlain, and Oswego Canals was made between 1836 and 1862. The waterway was made 7 feet deep, 52-1/2 to 56 feet wide on the bottom, and 70 feet wide at the water line. There were 72 lift locks and 3 guard locks, each 110 by 18 feet, inside horizontal dimensions. The total length of the canal was reduced to 350-1/2 miles. The second enlargement, known as the "nine million dollar improvement," was begun in 1896, when a depth of 9 feet was attempted. Because of cost overruns, this work was completed at disconnected localities only, and the canal remained for the most part as left at the end of the first enlargement. Ultimately, practically all the locks of the old canal were doubled to handle the enormous amount of traffic and to provide lockage when one lock was out of commission. Practically all canal boats were towed by mules or horses on a towpath along one side of the canal. Tolls were charged on the old canals. The old Erie Canal provided the first practicable commercial route between the Great Lakes and the United States seaboard. The early traffic on the canal was enormous for the times, and tolls collected brought a wonderful revenue to the State. For many years, there was no competition to this route, and little by little as stretches of railway began to parallel the canal, legislative measures provided against competition. The canals were so popular and lucrative to the State that their finances were not at all times properly handled, and many lateral lines were constructed which proved unprofitable and had to be abandoned.

The old Erie Canal did not terminate at the Niagara River at Tonawanda, as it does at present, but at Buffalo. From Buffalo Harbor, the canal followed a land line just east of the Niagara River to Tonawanda Creek at Tonawanda. The water surface of Tonawanda Creek was held several feet higher than at present by a dam across the creek at Tonawanda. This dam, which was located just downstream from the confluence of Ellicott Creek, prevented normal flow from the Tonawanda Creek Basin (drainage area 658 sq mi) from entering the Niagara River as had naturally occurred in the pre-canal era (see Enclosure 2). Therefore, water from the Tonawanda Creek Basin became available to augment flows in the canal. However, the preponderance of water supply for the western end of the old Erie Canal came from Lake Erie at Buffalo, the flow being regulated by a guard lock located near the northern boundary of the city of Buffalo. When measured near the guard lock in October 1907 by the U.S. Lake Survey, the flow in the Erie Canal averaged 768 cubic feet per second (cfs). A very rough gaging of the flow at Tonawanda in the fall of 1912 showed a discharge of over 1,000 cubic feet per second.

In a letter dated 10 February 1911, the State Engineer and Surveyor of New York reported to the Lake Survey that the average water requirement for the western end of the old Erie Canal was 700 cfs, which was necessary to maintain the slope, and hence navigable depth, in the reach from Lockport to Rochester. This flow included necessary amounts to cover evaporation, seepage, and spillway losses. East of Rochester, the required flow for lockage, seepage, and evaporation was 210 cfs. The requirement for lockage at Lockport was stated as 100 cfs, leaving 600 cfs to be by-passed around the locks. Of the 700 cfs passing eastward from Lockport to maintain the long level, 200 cfs was assumed to be lost by leakage, seepage, and evaporation. Since the flow requirement eastward from Rochester was only 210 cfs, as mentioned above, this left a residual of 290 cfs to be spilled at various wasteways along the level, notably at Gasport, Medina, Albion, and Adams Basin. Under conditions of maximum lockage, seepage, and evaporation, the average total diversion of 700 cfs was considerably exceeded. It was further stated that an additional quantity averaging 233 cfs was diverted from Lake Erie solely for power purposes, being diverted around the locks at Lockport and into Eighteenmile Creek.

SECTION 2

EXISTING CONDITIONS

2.1 Description of the New York State Barge Canal.

Following a public referendum in November 1903, an act providing for the issuance of bonds for an amount not to exceed 101 million dollars for the improvement of the Erie, the Oswego, and the Champlain Canals, became law. Improvement to the Cayuga and Seneca Canals was added shortly thereafter by subsequent legislation. This marked the genesis of the present New York State Barge Canal System.

Enlargement of the Erie Canal segment commenced in 1905. The project was not completed until 1918. In addition to channel and lock enlargements, the route of the new canal deviated substantially from the route of the old Erie Canal. This divergence was simply the result of the difference between two types of canal building: the canalized river and the independent canal. Up to the commencement of the Barge Canal, New York had little experience in river canalization and preferred, for the most part, to dig an independent canal for commercial navigation. However, by 1903, engineers had gained the necessary expertise to make rivers sufficiently quiet and manageable for navigation purposes and the State canals reverted to the channels used for centuries by the Indians and early explorers.

The entire New York State Barge Canal System is 527 miles long. There are 151 miles of artificial land-cut channels and 376 miles of canalized rivers. The designers of the canal used as much as possible, natural waterways such as the Mohawk, Hudson, Oswego and Seneca Rivers, and Oneida Lake.

The controlling depth of the system is 12 feet. All channels, natural and artificial, are dredged to that depth. These channels are also cut to a width of 200 feet in river sections; 94 feet in rock sections; and in earth sections 123 feet at the surface and 75 feet at the bottom. There are 57 locks on the canal. The length between lock gates is 323 feet, allowing vessels of 300-foot length; the width of the lock chambers is 45 feet. Depth of water over the sills is 12 and 13 feet. In many cases, the locks are operated by electric power generated at a powerhouse located at an adjacent lock dam. The locks vary in lift from 6 feet at Locks 25 and 26 on the Erie Canal at May's Point and Clyde, to 40.5 feet at Lock 17 at Little Falls, also on the Erie Canal.

2.1.1 Water Supply Diversions -

One of the major departures from the old Erie Canal created by the new alignment of the New York State Barge Canal concerned the supply of water for the western end. The old Erie Canal diverted water directly from Lake Erie at Buffalo. The New York State Barge Canal diverts water from the Niagara River at Tonawanda. This was initiated in the spring of 1918 with the removal of the dam across Tonawanda Creek at Tonawanda, previously mentioned in Section 1.3. Since that time, water has been known to flow both into and from the Niagara River, depending on the level of the river and the discharge from the Tonawanda Creek Watershed. Enclosure 3 shows the Tonawanda Creek Watershed and its relationship to the Barge Canal and the Niagara River.

The original estimate of the average water supply which the Barge Canal would require from the Niagara River was made by Mr. Emil Kuichling and reported to the State Engineer and Surveyor in 1901. It is as follows, not including the quantity assumed to be necessary for refilling the canal prism each spring:

	cfs
Evaporation, percolation, and absorption by vegetation	376
Leakage at aqueducts, culverts, and waste gates	29
Leakage at lock gates and valves	14
Loss over waste weirs	58
Water for power to operate locks	12
Water for power for electric lights at locks	8
Water for lockages at average rate of 59 lockages per day	208
Water diverted for industrial uses and agriculture	532
Total during navigation season	1,237

The last item in the table, namely 532 cfs, was to include spillage at wasteways for power uses as had been customary at Lockport, Medina, and elsewhere.

Subsequent to the above calculations, it was decided to increase the width of the locks from 28 to 45 feet and the depth from 11 to 12 feet. The quantity of water required for the same number of lockages was thereby substantially increased. However, for maximum conditions of seepage, evaporation, and lockage, it was considered that no greater supply would be necessary, provided none of the 532 cfs was spilled for industrial or agricultural uses at such times. Therefore, the value of 1,237 cfs was retained in all subsequent computations.

The Barge Canal accordingly was designed with such slopes as to be able to extract 1,237 cfs from the Niagara River at a stage of 565.5 feet at Tonawanda, Barge Canal Datum. This flow creates a velocity approximately 2/3 of a mile per hour. It should be pointed out that the reach between Lockport and Rochester, popularly known as "the 60-mile level," might have been constructed with the tops of the banks and the waste weirs as at present, but with a depth 2.27 feet greater at Lockport, and a level bottom all the way to the Genesee River. This would have required an average 1.14 feet deeper excavation and would have involved considerable expense, but would have produced a canal having a 12-foot depth at all times without requiring a flow of water to maintain a slope on the water surface. The result would very likely have been a much smaller consumption of water from the Niagara River. However, this was not done. Consequently, even at times when the requirements for seepage, leakage, lockage, etc. are minimal, it is not possible to reduce the flow very much because of the necessity to maintain the proper slope and assure a depth of 12 feet at all points in the "60-mile level."

There are numerous spillways and waste gates along the Barge Canal to facilitate regulating the water level at the desired elevation and to aid in preventing washouts of the banks. On the "60-mile level" there are 13 such spillways where water may be wasted into small natural water courses flowing northward into Lake Ontario. These small streams all pass under the canal in culverts, except at Medina where an aqueduct carries the canal over Oak Orchard Creek. Each spillway consists of a waste weir 25 to 170 feet long, having its crest along one side of the canal, 12 feet above canal bed, and having two or more sluice gates.

The discharge capacity of the portion of the Barge Canal from the Niagara River to Lockport is dependent upon two factors: first, the depth of water being maintained in the canal at Lockport; and second, the stage of Lake Erie on which the stages of the Niagara River at Tonawanda depend. Computations by the Corps of Engineers prior to 1921 indicated that Lake Erie cannot fall below a stage of 570.46 feet, United States Standard Datum, 1903*, without the depth in the canal at Tonawanda becomming less than 12 feet. At this stage and higher stages, and with 12 feet of water on the upper sill of the locks at Lockport, the discharge of the canal at Lockport was indicated by these computations to be approximately as follows:

Lake Erie Stage United States Datum, 1903*	cfs
570.46	1,280
571	1,500
572	1,900
573	2,300
574	2,700

---

* It is believed that the conversions to present data are: U.S. Datum (1903) - 1.85 feet = International Great Lakes Datum (1955) = New York State Barge Canal Datum - 2.98 feet.

If a depth of only 11 feet is maintained on the sills at Lockport, the discharge conditions were calculated to be approximately as follows:

Lake Erie Stage United States Datum, 1903	cfs
569.69	1,300
570	1,420
571	1,700
572	2,100
573	2,410
574	2,730

As mentioned above, the engineers who designed the canal in 1900 estimated that a flow of 1,237 cfs would have to be extracted from the Niagara River to maintain a 12-foot depth from Lockport to Rochester. Estimates were made for evaporation, percolation, leakage, water power for locks, lockages, and diversions for industrial uses and agriculture. The estimated non-navigation use amounted to slightly over 500 cfs. According to recent information from the New York State Department of Transportation, these estimates have never been accurately measured in the field.

2.1.2 Diversions for Hydropower Generation:

a. Diversions at Lockport - On 25 January 1826, a lease was made to Richard Kennedy and Julius H. Hatch, in consideration of an annual payment of $200.00 for "all the surplus waters which without injury to navigation, or security of the canal, may be spared from the canal, at the head of the locks, in the village of Lockport, to be taken and drawn from the canal at such place and in such manner, and to be discharged into the lower level, at such places and in such manner as the said canal commissioners shall from time to time deem most advisable for the security of the canal, and for the convenience of the navigation thereof."

In 1856, the Lockport Hydraulic Company was incorporated for a 50-year period, and became the assignee of part of the rights of this lease. On 16 August 1907, the Secretary of War granted to the Lockport Hydraulic Company a revocable permit, "To divert water of the Niagara River and its tributaries from the Erie Canal at Lockport, New York, above the locks, for power purposes, not exceeding 500 cubic feet per second." It was to be distinctly understood that the water so diverted should be returned to the canal below the locks, and that this permit should inure to the benefit of all persons and corporations then using said water for power purposes, whether lessees of the applicant or having the right to be furnished by it with water, and including the persons or corporations then diverting water from the Erie Canal at Eighteenmile Creek, Middleport, Medina, Eagle Harbor, Albion, Holley, and other places. In November 1907, the permit was assigned to the Hydraulic Race Company, the successor of the Lockport Hydraulic Company. A plan showing the relationship of Eighteenmile Creek to the Erie Canal is given on Enclosure 4.

The State of New York granted to the Lockport and Newfane Mill Owners Association (of which the Hydraulic Race Company was a member), on 25 November 1913, a revocable permit to divert from the Niagara River through the Barge Canal to Lockport and into Eighteenmile Creek the 500 cfs of water covered by the Federal permit, the association to pay $7,500 per year to the State for the privilege of using the canal as a raceway.

On 13 December 1926, the Federal Power Commission modified the permit, ". . . for a period conterminous with the State permit, or of any renewal thereof, not, however, to exceed fifty (50) years from the date hereof, authorizing the diversion, for the purpose of operating powerhouses for the development and utilization of power, from navigable waters of the United States, to wit, the Niagara River, of an amount not exceeding in the aggregate a daily diversion at the rate of 275 cubic feet per second, the maximum diversion in any calendar day not to exceed said rate by more than 20 percent thereof; said waters to be carried through said New York Barge Canal, to be diverted from above said locks at Lockport . . . to discharge the same, directly into said Eighteenmile Creek for use in the several powerhouses . . ."

According to the New York State Department of Transportation, this permit is presently valid and held by the Niagara Mohawk Power Corporation. However, the nature of Eighteenmile Creek has changed substantially since the early nineteenth century when powerhouses along the creek were common. With the abandonment of the powerhouses, the capacity of the creek has been reduced by the natural encroachment of vegetation. Recent tests performed by New York State Department of Transportation (NYSDOT) have indicated that the safe diversion from the Barge Canal into Eighteenmile Creek cannot exceed about 50 cfs without inundating residential property and farmland.

b. Diversions at Medina and Rochester - The engineers who designed the Barge Canal in 1900 estimated that 1,237 cfs would be required to maintain a 12-foot depth from Lockport to Savanah, New York. The above was based on a straight gradient from Lockport to Rochester. It became evident after the opening of the canal that the canal had been built on a steeper gradient from Lockport to Medina than from Medina to Rochester. Consequently, less water was needed between Medina and Rochester than was needed between Lockport and Medina. A surplus of water amounting to 225 cfs thus developed at Medina. In 1925, the water was certified to be surplus by the New York State Waterpower Commission and was leased to a private utility.

A flatter gradient exists east of Rochester than from Medina to Rochester. This results in a surplus of 600 cfs at the Genesee River. This surplus was certified by the Waterpower Commission in 1925 and licensed to the Rochester Gas and Electric Company.

In 1948, the State was faced with lawsuits by riparian owners in the Oswego and Seneca watershed areas on the grounds that construction of the Barge Canal had adversely altered the previous flow regime. At that time, 150 cfs flowed easterly from Rochester in the canal. In 1949, an agreement was reached whereby an additional 225 cfs would be sent easterly from

Rochester for a total of 375 cfs. Studies were made to determine if that much additional Lake Erie water could be carried in the canal between Lockport and Rochester. It was determined that, for a number of reasons, both physical and legal, it would not be advisable to increase the flow in this section of the canal by 225 cfs. Instead, the amount of water released to Rochester Gas and Electric was reduced by 225 cfs to 375 cfs.

Enclosure 5 lists the seven known hydro plants presently using this surplus canal water. During the navigation season, these plants can extract enough water to generate 10,832 KW.

2.1.3 Diversions for Other Purposes -

Both the New York State Legislative Document No. 27, 13 March 1957 and Genesee River Basin Planning Memo No. 10, New York Division Water Resources, 1968, listed New York State Barge Canal diversions in effect at the time. The amounts tabulated in each report are shown on Enclosure 6. In addition to the diversions for power, it can be seen that there are diversions for domestic purposes, industry, and irrigation.

SECTION 3/ENCLOSURES 7, 8

OMITTED
NOT APPLICABLE

SECTION 4.1/Enclosures 9, 10

OMITTED
NOT APPLICABLE

4.2 Physical Limitations on the Flow Carried in the Barge Canal from the Niagara River to Lockport.

The maximum flow is limited hydraulically by the elevation of the Niagara River at Tonawanda and the regulated elevation of the canal at Lockport. However, there is no evidence to indicate the maximum flow that can be safely carried in this reach.

4.3 Physical Limitations on the Flow Carried in the Barge Canal from Lockport to Rochester.

In 1957, the New York State Department of Transportation carried out a field investigation to determine the possibility of passing additional water for farm irrigation purposes in this reach. Just prior to the tests, the amount of water reaching Lockport was determined by current metering to be 1,120 cfs. It was further determined during the field tests that the amount of flow in the "60-mile level" could not be increased more than 100 to 150 cfs unless all spillways between Lockport and Rochester were permanently raised to prevent local flooding. According to NYSDOT, no further work on this subject has been pursued.

4.4 Allowable Diversions from the Barge Canal into Eighteenmile Creek from a Legal Standpoint.

In 1926, the Federal Power Commission issued to the Hydraulic Race Company et al. a license for the diversion of 275 cfs from the Barge Canal into Eighteenmile Creek. Recent correspondence from NYSDOT indicates that this diversion was subsequently transferred to Niagara Mohawk and used at its Schoellkopf Station at Niagara Falls. The Schoellkopf plant was destroyed by a rock slide in 1956. It has been suggested that, following that event, the license for this diversion was transferred to the New York Power Authority Project at Niagara Falls. However, at present, this possibility is still being investigated.

4.5 Physical Limitations on the Flow Diverted from the Barge Canal into Eighteenmile Creek.

Recent field investigations were undertaken by NYSDOT to determine the possibility of flow augmentation to improve water quality downstream from the Lockport sewage plant. It was found that flood plain development and channel encroachment by vegetation limited the safe diversion from the Barge Canal into Eighteenmile Creek to little more than 50 cfs.

4.6 Accounting and Reporting Diverted Flows.

In the report to the Governments entitled "The Preservation and Enhancement of Niagara Falls" by the International Joint Commission in 1953, the following excerpt is of interest:

> "The New York State Canals. --The New York State Barge Canal forms a shallow draft connection between Lake Erie, Lake Ontario, and the Hudson River. Water is diverted from the Niagara River at Tonawanda and returned to Lake Ontario. While no record of diversions is kept, it is estimated that the amount of diversion during the navigation and winter season is 1,100 and 750 cubic feet per second, respectively. These rates are used for the purpose of this report."

In the absence of better information, this practice continues to this day with one notable exception. Beginning in 1956 the canal has been dewatered annually during the non-navigation season (generally from mid-December to late April or early May). Consequently, there has been no flow in the canal during the winter season for the past 29 years.

With respect to the individual diversions from the Barge Canal for various purposes, it is doubtful that anyone knows the true amounts of these diversions.

SECTION 5

OMITTED

NOT APPLICABLE

REFERENCES

1. Letter from the Secretary of War to the House of Representatives, December 7, 1920, Congressional Documents. 66th Congress, 3rd Session, 1920-1921, "Diversion of Water from the Great Lakes and Niagara River," p. 123-138; 198-207.

2. Noble E. Whitford, "History of the Barge Canal of New York State," Supplement to the Annual Report of the State Engineer and Surveyor for the Year Ended June 30, 1921.

3. Joseph R. Stellato, "Amount and Use of Waters Diverted from the Niagara River by Barge Canal," New York State Department of Transportation Report, Albany, NY, September 1981.

4. Joint Legislative Committee on the Barge Canal to the Legislature of the State of New York, Legislative Document No. 36, Constitutional Provisions, Article XV, 1961.

5. New York State Legislative Document No. 27, March 13, 1957.

6. Genesee River Basin Planning Memo No. 10, New York Division of Water Resources, 1968.

7. Treaty Between the United States and Great Britain Relating to Boundary Waters, and Questions Arising Between the United States and Canada (The Treaty of 1909), January 11, 1909.

8. Treaty Between the United States of America and Canada Concerning Uses of the Waters of the Niagara River (The Treaty of 1950), February 27, 1950.

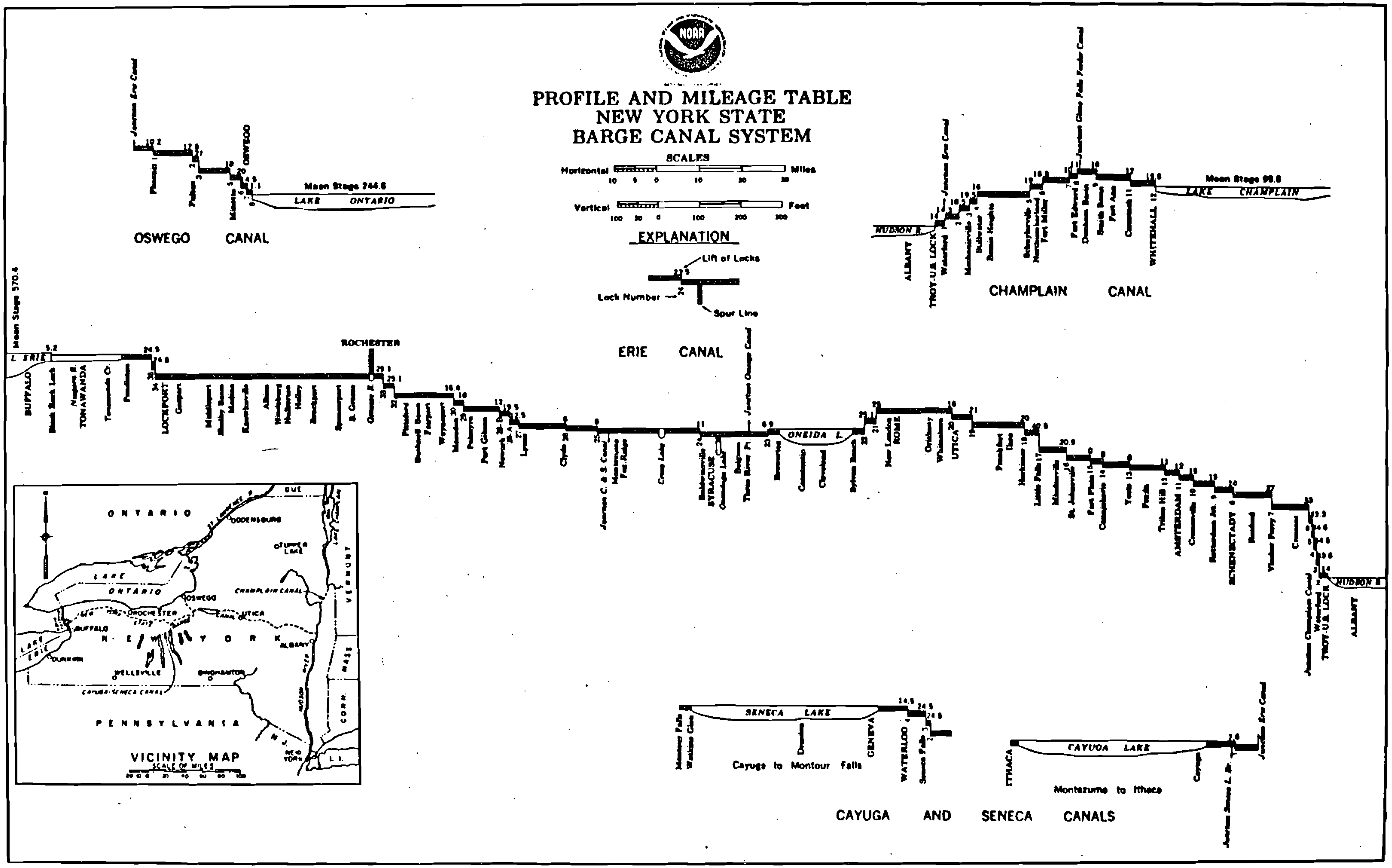
9. Letter from the Assistant Superintendent of Operation and Maintenance, New York State Department of Transportation to the Secretary, U.S. Section International Joint Commission, July 15, 1953.

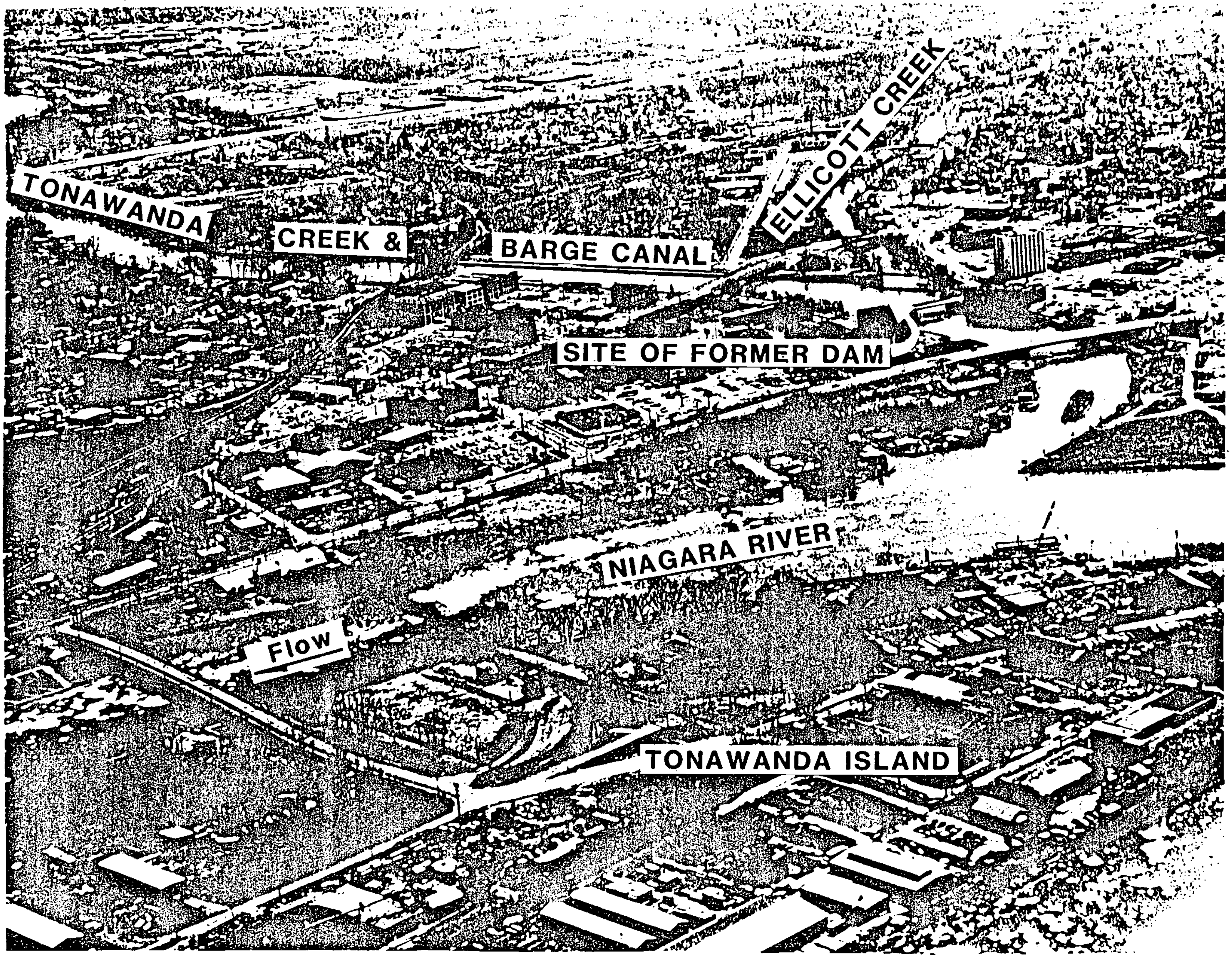
10. Letter from Secretary, U.S. Section, International Joint Commission to Assistant Superintendent of Operation and Maintenance, New York Department of Transportation, July 21, 1953.

11. Order Issuing License, United States of America Federal Power Commission to Niagara Mohawk Power Corporation (Project No. 2424), December 9, 1964.

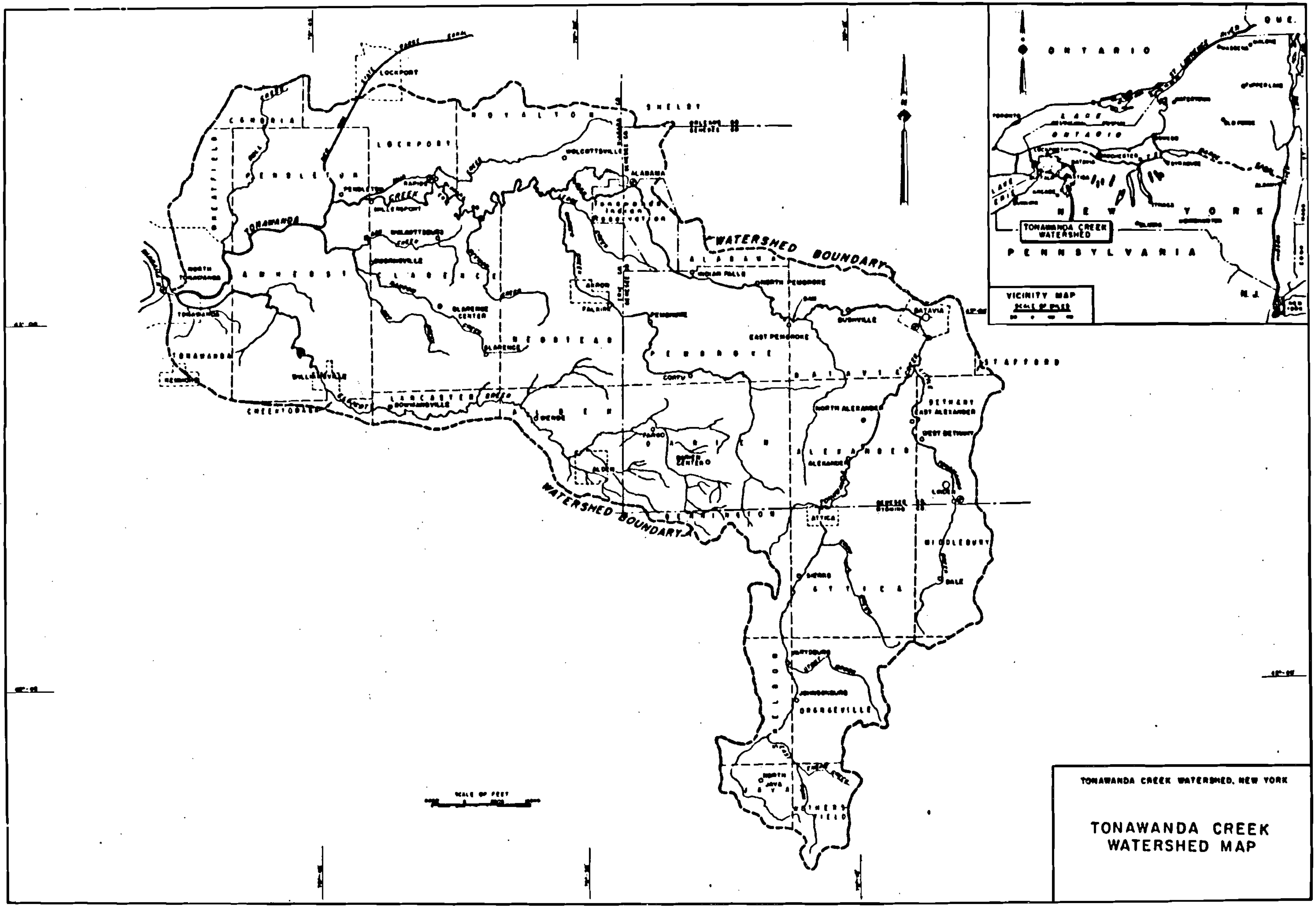
12. Report of the International Joint Commission, United States and Canada on the Preservation and Enhancement of Niagara Falls, May 12, 1953.

PROFILE AND MILEAGE TABLE NEW YORK STATE BARGE CANAL SYSTEM




TONAWANDA
CREEK &
BARGE CANAL
ELLICOTT CREEK
SITE OF FORMER DAM
NIAGARA RIVER
Flow
TONAWANDA ISLAND

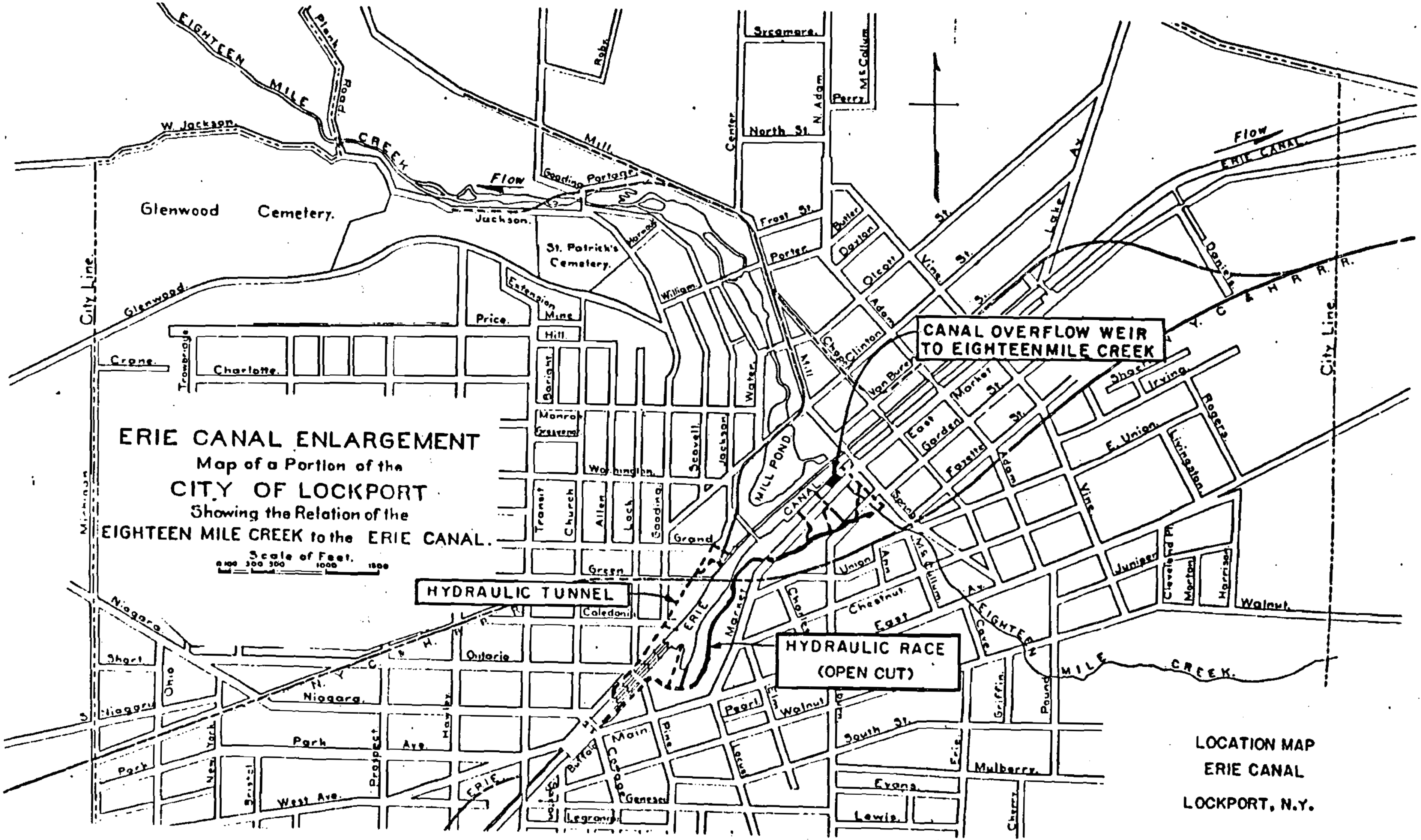
Enclosure 2



TONAWANDA CREEK WATERSHED, NEW YORK

TONAWANDA CREEK WATERSHED MAP

Enclosure 3



LOCATION MAP
ERIE CANAL
LOCKPORT, N.Y.

Summary of Hydro Plants Using N. Y. State Barge Canal Water

Plant Location & Name	Owner	Rated KW	Rated CFS	Head Ft.	E.F., KW/CFS	Canal Q. Used CFS		Capacity from Canal Q. KW	
						Normal	Present	Normal	Present
LOCKPORT (1)									
Race Street	NM	2700	800	50	3.38	800	800	2700	2700
MEDINA (2)									
Oak Orchard	NM	350	225	25	1.56	225	180	351	281
Glenwood	NM	1500	445	62	3.37	225	180	758	607
Waterport	NM	4650	780	80	5.36	225	180	1206	965
[illegible]OCHESTER									
#26	RG&E	3000	1862	25	1.61	375	600	604	966
#2	RG&E	6500	1300	91	5.00	375	600	1875	3000
#5	RG&E	38250	4300	137	8.90	375	600	3338	5340
								10832	11159

(1) This flow is extracted from Tonawanda Creek and discharged into the canal, so that it is not lost from the canal system.

(2) Assumes that the three Medina plants use the diverted water in series.

New York State Barge Canal Diversions

	(1)	(2)
Water diverted from Niagara River	1120	1333
Lockport & Newfane Mill Owners Assoc.		10*
Domestic Use (Lockport)		125*
Industry (Hartland)		16
Domestic Use (Middleport)	4	12
Niagara Mohawk (Medina)	225	225
Domestic Use (Medina)	3	
Domestic Use (Lyndonville)		4
Hunt Foods (Albion)		44.6*
Domestic Use (Albion)	7	4
Domestic Use (Holley)	10	10
Domestic Use (Brockport)	10	10
Domestic Use (Spencerport)		5.2
Irrigation	22	83.9
Domestic Use (Brighton)		9.4
Rochester Gas & Electric	375	375
Flow to east of Rochester	375	375
Other Industry		12.4
Other Domestic Use		11.5
Losses	90	

Sources:
(1) New York State Legislative Document #27 March 13, 1957
(2) Genesee River Basin Planning Memo #10, N.Y. Div. Water Resources, 1968

*Indicates diversion no longer active.

Enclosure 6

APPENDIX E

SIGNIFICANT PHYSICAL EFFECTS OF STOPPING THE OGOKI AND LONG LAC DIVERSIONS - ALBANY RIVER AREA

Introduction

The Long Lake and Ogoki Diversions together divert a long term average annual flow of about 5,600 cubic feet per second (cfs) from the Albany River (James Bay) drainage basin to Lake Superior. The older of these diversions, Long Lake was completed in 1939. It was constructed jointly by Ontario and Ontario Hydro to permit log driving from the Long Lake area to Lake Superior and to provide additional flow at Niagara Falls for the generation of electricity. Both of these original uses continue today. In addition, since 1948, electricity has been generated locally at the Aguasabon Generating Station of Ontario Hydro. Average annual diverted flow from Long Lake is 1,400 cfs. The Ogoki Diversion, completed in 1943, was constructed by Ontario Hydro to supply additional water for generating stations on the Nipigon, St. Mary's and Niagara Rivers. Average annual diverted flow is 4,200 cfs.

The long term effects of these diversions on the levels of the Great Lakes was quantified as a part of the work carried out under the Great Lakes Diversions and Consumptive Uses Study and is given in Table 1.

Figure 1 shows the area of the diversions and control structures.

Scenarios examined:

1. Ogoki Diversion

   (a) Ogoki Diversion flow closed completely from the Great Lakes basin by closing the Summit Dam and opening the Waboose Dam to the extent required to ensure that no further dam operation would be needed to prevent water levels on the Ogoki Reservoir higher than have existed in the past;

   (b) As in (a) above but the Waboose Dam operated to maintain water levels in the Ogoki Reservoir at suitable elevations for recreation and other current usage of the reservoir area;

2. Long Lake Diversion

(a) Long Lake flow closed completely from the Great Lakes Basin by closing the Diversion Control Dam and opening the Kenogami River Dam to the extent required to ensure that no further dam operation would be necessary to prevent water levels on Long Lake higher than have existed in the past;

(b) As in (a) above but the Kenogami River Dam operated to maintain water levels on Long Lake at suitable elevations for recreation and other current usage of the reservoir area;

(c) As in (b) above but Diversion Control Dam operated to permit a flow of 1,200 cubic feet per second from Long Lake to Lake Superior as required for log driving each year.

Physical Effects

1. Ogoki Diversion

.1 Impact on Energy:

Impacts are the same for Scenarios 1(a) and (b).

Locally, at the Nipigon River generating stations, there would be an average annual loss of 606,000 MWH of electrical energy; additional average annual loss to other Ontario Hydro plants would be 344,000 MWH. Losses to U.S. plants at Sault Ste. Marie and Cornwall and to Quebec plants at Beauharnois and des Cedres have not been estimated.

Replacement energy would come from from thermal generation. Additional generation of acid gas to replace local loss would total 9,600 tons and to replace system loss, 5,500 tons.

While there would be no short term problem with transmission line capacity, a loss of this diversion for a longer term (beyond 1990) would require an upgrading of the East-West tie-line and probable cancellation of the proposed new development on the Little Jackfish River. This additional capacity, 600,000 average annual MWH, will be required early in the next decade. Alternate energy sources would be more expensive and could cause far greater environmental damage.

.2 Environmental Impacts

.1 Levels and Flows

.1 Lake Nipigon and Nipigon River.

With loss of the diverted flow, to attempt to meet energy demands, Ontario Hydro might be expected to make maximum usage of available local Lake Nipigon inflow and storage capacity. This would result in lower levels in Lake Nipigon throughout the year and especially so in late winter, early spring. It is probable too, that thermal generating stations at Thunder Bay and Atikokan would be base-loaded and that the Nipigon River generation would be used for peaking. This would result in large changes in river flow each morning and evening. See figure 2.

.2 Ogoki and Albany Rivers

Except for a period of about three months in 1974 and of about 8 months in 1984-85, outflow from the Waboose Dam northward to the Albany River has been essentially zero except during periods of much above average precipitation when spill northward was permitted for brief periods. If the Diversion were turned northward average annual weekly peak flow in the Ogoki River below the Waboose Dam would increase from near zero to about 9,000 cfs and from 5,000 to more than 14,000 cfs at its confluence with the Albany River. Albany River flows at this confluence would also increase by about 9,000 cfs or about 35%. See figure 3.

.3 Ogoki Reservoir and Mojikit Lake

The level of these waterbodies is controlled by the Summit and Waboose Dams. Under Scenario 1(b), there would be essentially no change from existing conditions. Under Scenario 1(a), with the Summit Dam closed and the Waboose Dam opened to permit free flow to the north, the whole would behave as an unregulated lake rising to a level dictated by the volume of the spring freshet, then falling to a minimum level in the late winter or early spring. In most years, there would be a temporary increase in level because of the fall rains. Since sufficient stop logs must be removed to ensure against flooding in the spring and because under

Scenario 1(a) no dam operation is planned to regulate summer or early spring levels, it is possible that levels would rise to higher and fall to lower elevations than those experienced since the Diversion has been in operation. See figure 4.

The area, between the Summit and Waboose Dams, under license for flooding to Ontario Hydro, is 53,121 acres. Much of this land would be dewatered under Scenario 1(a).

.4 Little Jackfish River and Chain of Lakes

In a state of nature, the height of land lay between North and South Summit Lakes, the present location of the Summit Dam. With this dam closed, the flow to Lake Nipigon from this system would be reduced to local natural inflow. Pre-diversion flows averaged 140 cfs with peak discharges of about 750 cfs. Post-diversion flows have averaged 4,200 cfs with a median freshet peak discharge of more than 9,000 cfs and a maximum freshet flow of more than 15,000 cfs.

The area downstream of the Summit Dam under license to Ontario Hydro for flooding is 24,769 acres. If the diversion were closed to the south, all of this land would be dewatered.

.2 Fish and Wildlife

.1 Lake Nipigon and Nipigon River

In Lake Nipigon, the major concerns would be the effect of the low fall and winter water levels on the survival of brook trout and whitefish spawn and of the low spring levels on the spawning success of walleye. All could be severely damaged. In the Nipigon River, the quality of the salmonid habitat would be lowered.

No impact on wildlife is anticipated on these waterbodies.

.2 Ogoki and Albany Rivers

There has been a shift in the aquatic population in the Ogoki River to adjust to the reduced flow since the diversion was constructed. Releases to the north have been mainly in late spring or summer so that impact on spring spawning fish was mitigated to some extent. If, however, the diversion were turned north throughout the year, there would probably be a major disruption of sturgeon and walleye spawning runs.

Major impact on wildlife would be the flooding of aquatic feeding areas of moose and the drowning of beaver houses.

.3 Ogoki Reservoir and Mojikit Lake

Under Scenario 1(b) there would be essentially no impact on the fish and wildlife in these waterbodies.

Under Scenario 1(a), there would be major impacts.

Both the Ogoki Reservoir and Mojikit Lake, and particularly the former, have extensive shallows which would be lost if Waboose Dam were opened up more than necessary. Exposure of the shallows would:

- destroy moose aquatic feeding habitat;
- significantly reduce waterfowl and wading bird habitat;
- severely impair Osprey fishing opportunity and possibly disrupt Osprey nesting;
- significantly reduce production of pike, walleye, whitefish and sturgeon; and
- render commercial outpost camps almost unusable;

The shallows make excellent habitat for pike, the major species sought by sport fishermen on the two waterbodies. They are vital to the productivity of other fish species as well.

Walleye come a close second in importance to pike in the sport fishery. Loss of lake area, particularly the present littoral zone would cost walleye production, especially in very young fish. Mojikit is a candidate source for the Ministry of Natural Resources' adult walleye transfer program.

There is a commercial license on Mojikit which allows 9,000 kg of whitefish and 900 kg of northern pike. Because of fish prices and other factors, this fishery is not presently very active. The only significant impact of loss of whitefish production of the short term would be on the whitefish population as a component of the fish community/food web of Mojikit/Ogoki.

Lake Sturgeon occupy both waterbodies and depend heavily on shallows for foraging habitat. The Ogoki Reservoir supports a small (250 kg/year) active commercial sturgeon fishery.

Standing timber was not removed from most of the flood area when the Diversion was established in the early 1940's. Some trees have since been cut at the waterline by rot, ice, and winds, but a large percentage are still standing.

The impact of water level drop on the local Osprey population beyond loss of forage area is not very predictable. Osprey nest in the tops of standing trees in the flooded area. Long term loss of water around these sites would probably make the nests more vulnerable to predation and could cause Osprey to abandon them.

.4 Little Jackfish River and Chain of Lakes

Impacts are the same for both Scenarios 1(a) and 1(b).

Loss of the diverted flow from this system would cause extensive impact on the aquatic community. There would be:

- reduction of riverine habitat, loss of more than 70% of flowing water habitat;
- a reduction of littoral zone size in each lake, and exposure of much of the present littoral zone in each lake;
- a decrease in flushing rate of the main stem lakes from a period of months to a period of possibly years dependent on the duration of the water diversion to the Ogoki River; and

- changes to water quality; most significant would be the localized depletion of dissolved oxygen in some isolated basins and river sections.

Changes in these physical factors would manifest themselves in shifts in aquatic species composition and a decrease in species diversity along the river system. Shifts in production would occur at each trophic level. Shifts would be lake and river section dependent and might be positive or negative.

The long term effects of diverting water from the little Jackfish River would also be dependent on the duration and extent of diversion. The longer the period of diversion the more likely the possibility of long lasting negative impacts.

The lower portion of the Little Jackfish is a major area of recruitment for the walleye fishery of northern Lake Nipigon. The loss of spawning and rearing habitat would impact not only the fishing in the chain of lakes and Little Jackfish River but also in Ombabika Bay and Lake Nipigon.

A decrease in water levels along the Little Jackfish River would not significantly affect terrestrial communities. Aquatic fur bearers on the lakes and river would recolonize to lower water levels or move to more favourable habitat. A shift in populations would be transitory and would be dependent on the duration and timing of the diversion.

.3 Socioeconomic Impacts

.1 Lake Nipigon and Nipigon River

Effects are the same for Scenarios 1(a) and 1(b)

There are 13 commercial fishing licenses on Lake Nipigon, five cruise boat operators, a number of boat rental businesses, municipal and private docks. All of these would be affected by lower water levels. At low water levels, commercial fishermen with high docks and some outfitters have trouble getting their cruisers out. There would be increased hazard to navigation and complaints from all about docks.

On the Nipigon River, there could be water supply problems for Chalet Lodge and the Lake Helen Indian Reserve. Cottagers would be inconvenienced and quality of the recreational fishery would be lowered.

.2 Ogoki and Albany Rivers

Impacts would be the same for Scenarios 1(a) and 1(b).

There are Indian communities at the confluence of the Ogoki and Albany Rivers - Indian Reserve No. 65; and at the mouth of the Albany River - Indian Reserve No. 67; Fort Albany and Kashechewan. In addition, the Indians use the rivers for travel to hunting, trapping and fishing grounds.

An increase in debris, such as logs, windfall and aquatic vegetation in the river is anticipated during the initial stages of release. As water levels increase debris that has accumulated at low water levels will be mobilized into the river. Debris in the river creates an increased boating hazard for clients using the outfitter camps and decreases float plane landing opportunities. A significant increase in debris in the river and lakes may result in a temporary cancellation of outpost camp operations.

An increase in water velocities along the river (in excess of 1.5m/s) may cause outfitter camp client dissatisfaction because of increased boating hazard, a decrease in river access and a decrease in fishing opportunities and success.

Rising water levels will affect existing camp structures, docks, and boats if these have not been located above the anticipated high water level.

The effects of a release on outfitters may also be extended to trappers, and include reduced access to shoreline trap areas, reduced services from fly-in operations, an increase in boating hazard and possible damage to equipment and structures. Increased risk to the trappers is not expected to be as significant as to outfitter clients because of trapper experience in wilderness situations.

A decrease in commercial fishing success and an increase in effort may be anticipated following the release from the Waboose Dam. The likelihood of significant impacts would be lessened by an increase in the time frame from first release to the onset of fishing activities in the fall. Sources of impact originate from an increase in debris which would foul nets, and an increase in water velocities which may limit access to traditional fishing locations and redistribute fish within the river system.

While flood flows in the Albany River at Ogoki might be expected to increase by from about 35 to more than 50% of those experienced during the period of diversion, percentage increase at Fort Albany and Kashechewan would be much less. It is not anticipated that the increase in peak flows on the lower river would cause significant added flood damage. However, if the diversion were turned to the north and if flooding were to occur, in the same way that the diversions are perceived to be the cause of flooding on the Great Lakes, they would also be perceived to be the cause of flooding on the Albany.

.3 Ogoki Reservoir and Mojikit Lake

There would be essentially no socioeconomic impact on these waterbodies under Scenario 1(b).

Under Scenario 1(a), it could be anticipated that the ten outpost camps and the commercial fish camp located on the shores of these waters would be rendered almost unusable. Depending on the length of time the diversion might be turned north, loss of business and of fish stocks could affect the profitability of the outpost camps and enterprises dependent on them for a much longer period. More than 10% of the fly-in fishing outposts in the Nipigon District would be affected by the lower water levels and poorer fishing opportunity.

Strong objections to this Scenario could be expected from Armstrong area outfitters, the Armstrong Chamber of Commerce and the local Ministry of Natural Resources offices.

.4 Little Jackfish River and Chain of Lakes

Effects of Scenarios 1.a and 1.b would be identical.

With the very high impact on the fishery of this area, it is not improbable that the fly-in tourist outfitter located on one (Zigzag) of the lakes in this system would be forced to relocate his operation. Loss of the spawning grounds in the lower river would affect the fishery (recreational and commercial) in Ombabika Bay and the northern parts of Lake Nipigon.

2. Long Lake Diversion

.1 Impact on Energy

Impacts are the same for Scenarios 1(a) & 1(b)

Locally, at the Aguasabon Generating Station, there would be an average annual loss of 265,000 MWH of electrical energy; additional average annual loss to other Ontario Hydro plants would amount to 117,000 MWH. Losses to U.S. plants at Sault Ste. Marie and Cornwall, to the Quebec plants at Beauharnois and des Cedres and to the privately owned Canadian plant at Sault Ste. Marie, have not been estimated.

Replacement energy would come from thermal generation. Additional generation of acid gas to replace local loss would total 4,200 tons and to replace system loss would be an additional 1,850 tons.

Under Scenarios 1.a and 1.b, the Aguasabon Generating Station would be taken out of operation for the duration of the closure of the Diversion. Under Scenario 1(c), the station could be operated for about six months each year. Whether or not this would be done would be a decision for Ontario Hydro to make.

It is noted that the six month period of operation would be during late spring, summer and early fall when demand for electricity in Northwestern Ontario is in the low half of the cycle. If the station were operated, energy losses would be something less than half of those estimated for Scenarios 1(a) and 1(b). Acid gas generation would be something more than half of that estimated above.

.2 Environmental Impacts

It is noted that there is very limited use of the diversion route, Aguasabon River and Hayes Lake for recreation or commercial exploitation other than for conveyancing of water and of logs. The Ministry of Natural Resources Air Base on Hayes Lake could only remain operational if Hayes Lake were maintained at an elevation near those that have existed over recent years. See figure 5.

.1 Levels and Flows

.1 Long Lake and Kenogami River Upstream of Dam

This lake, about 52 miles long and only 2 and 1/2 miles in breadth at its widest, is divided into two physiographic sections. The southern less used section is very deep, up to 610 feet, has rugged shores with little beach and cliffs rising up to 300 feet above the water. The northern section is relatively shallow, depths little more than 50 feet, has gentle shorelines with beaches and shallow, marshy bays. The only communities , bordering the lake are near its extreme northern end.

In a state of nature, lake levels were controlled by the natural outlet and normally rose to a peak elevation in the spring, then fell gradually to a minimum level in late winter or early spring of the following year. Lake level is now controlled by the Kenogami River Dam, located about 10 miles north of the original lake outlet and the Diversion Control Dam, located on the Diversion Canal about 5 miles south of the south end of Long Lake. Under regulation, the lake is filled by the spring freshet and is held near its upper limit until late fall, then drawn down during the winter months.

Prior to the construction of the diversion, average annual flow in the Kenogami River at the dam site was about 1,600 cfs. Since the diversion was constructed, water is spilled northward only as required to control the level of Long Lake. This occurs in most springs and from time to time in the fall. May to June flows northward of 2,500 to 3,000 cfs are typical. The daily maximum northward flow, since the diversion was built, is nearly 15,000 cfs. At other times of the year, northward flow is limited to leakage from the dam, about 25 cfs.

The water level of the Kenogami River at the dam site was raised by about 25 feet.

Under Scenario 2(a), the level of Long lake would return to near its natural state with late spring and early summer level near those that have existed over the past 45 years, but with mid and late summer and fall levels lower than those experienced since construction of the Diversion. See figure 6.

The level in the Kenogami River upstream from the dam would, throughout most of the year, be much lower than those that have existed since its construction.

Under Scenarios 2(b) and 2(c), impacts on water levels of these waterbodies would be minimal.

.2 Kenogami River downstream of the Dam and Albany River

As stated above, pre-diversion average annual flow in the Kenogami River at the dam site was about 1,600 cfs. This has been reduced to about 200 cfs with releases concentrated mainly in the freshet period. Because the portion of drainage basin diverted is a relatively small part of the total basin, the effect on peak levels and flows is limited and impacts of the diversion are largely restricted to the 11 miles of river between the Dam and Chipman Lake.

Under Scenarios 2(a) and 2(b), flows would return to nearly "state of nature". Under Scenario 2(c), flows during the May to November period would be similar to those of the past 45 years and "state of nature" during the remainder of the year. See figure 7.

.2 Fish and Wildlife

.1 Long Lake and Kenogami River upstream of Dam

Damage to the fishery in Long Lake itself is not seen as a great problem under any of the scenarios. Under Scenario 1.a there would be a significant loss of habitat between the natural lake outlet and the Kenogami River Dam. The most significant impact of Scenario 2(a) would be the probable dewatering of a large cattail marsh that has formed around the Kenogami River outlet from Long Lake. Now designated as an "area of national scientific interest" (A.N.S.I.) because of its large area and the diversity of its flora and fauna. Draining of this area would result in the destruction of waterfowl and furbearer habitat. Under Scenario 2(c), there would be limited loss of fishery habitat.

.2 Kenogami River downstream of Dam and Albany River

Under Scenario 2(a) and 2(b), if the Diversion were opened northward in the spring, prior to the spawning period or in the summer after spawning is completed, damage to the fishery would be minimal. Under Scenario 2(c), the flow reduction in May could dewater spawning areas before eggs have hatched or fry have moved off; flow increases in late fall could cause a high mortality among furbearers.

.3 Socioeconomic Effects

Under Scenarios 2(a) and 2(b), the most significant socioeconomic effect would be the impact of the loss of log driving from Long Lake to Lake Superior. Kimberly-Clark of Canada Limited derives an annual benefit by using water transport instead of rail or road. The economic viability of the pulp mill at Terrace Bay, a one-industry town, is marginal and a loss of this benefit, unless compensation were provided to the company, could result in its closing. Closing of the mill could result in the direct loss of up to 2,500 jobs in the Terrace Bay, Longlac and Nakina areas and have an indirect effect on a population of about 7,500 people.

1. Long Lake and Kenogami River upstream of Dam

Under Scenario 2(a) there would be a negative impact on the tourist industry and recreation in the Longlac area. Private and public docks have been built to accommodate water levels maintained by

Ontario Hydro; during the second half of the summer, most of these would be too high for convenient use. There would be navigation problems in Long Lake and in the river. Extensive mud flats would create aesthetic problems; loss of waterfowl and furbearers would have a direct impact on hunters and trappers.

There are two Indian Reserve, No.s 58 and 77 on Long Lake that would be directly affected.

Under Scenario 2(b), socioeconomic impacts, except to the forest industry, would be minimal.

Under Scenario 2(c), impacts on the forest industry would be mitigated but trappers would be directly affected by the loss of furbearers.

.2 Kenogami River downstream of Dam and and Albany Rivers

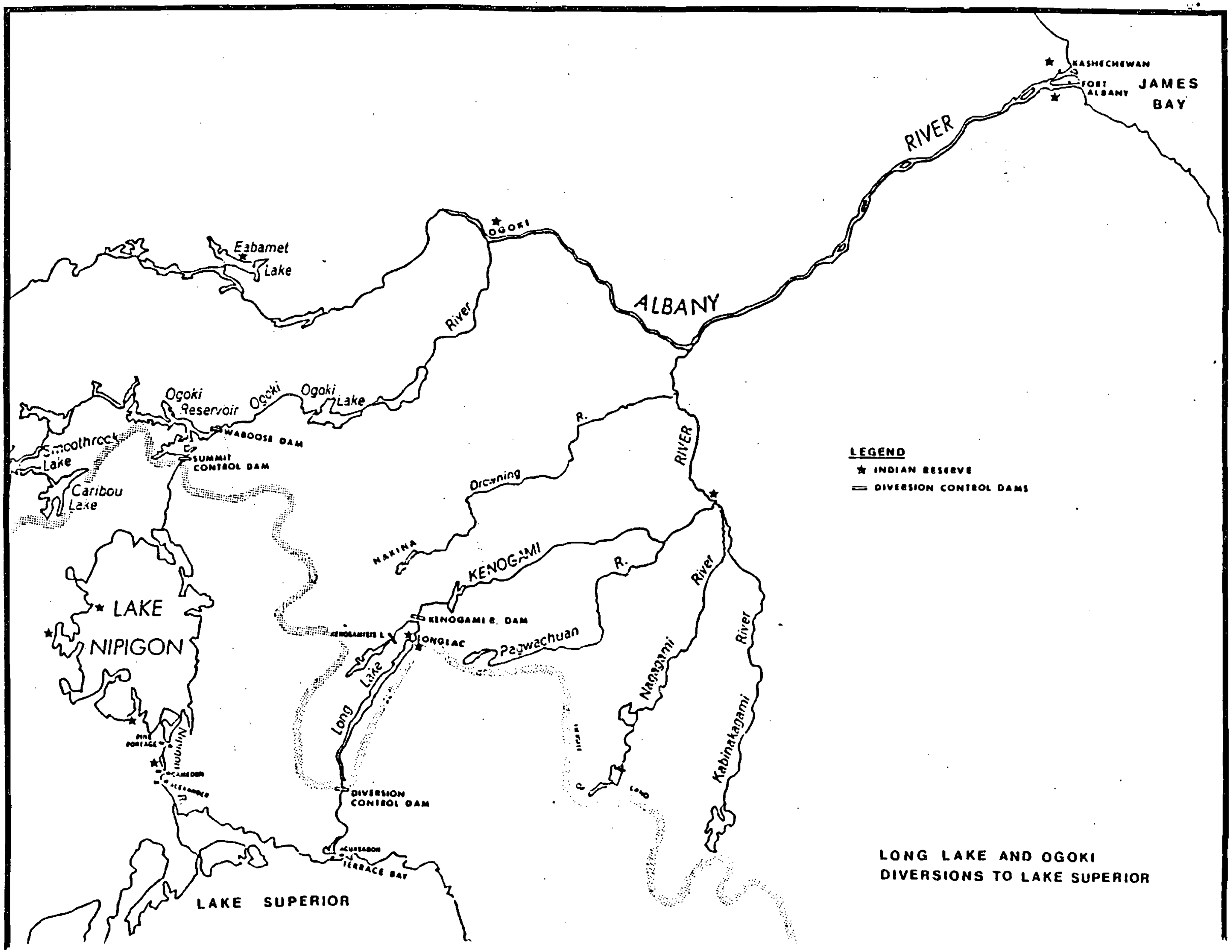
There are two bridges, owned by Kimberly-Clark Canada Limited, over the Kenogami River downstream from the Dam. These are endangered by any flows in excess of 9,000 cfs. Flows of this order are more probable during any freshet period during which the whole of the Kenogami River flow is turned to the north.

Other socioeconomic impacts are limited under Scenarios 2(a) and 2(b) provided the timing of the increased flow avoids the spawning period of fish in the rivers and does not occur in late fall. Under Scenario 2(c), there would be an economic impact on trappers.

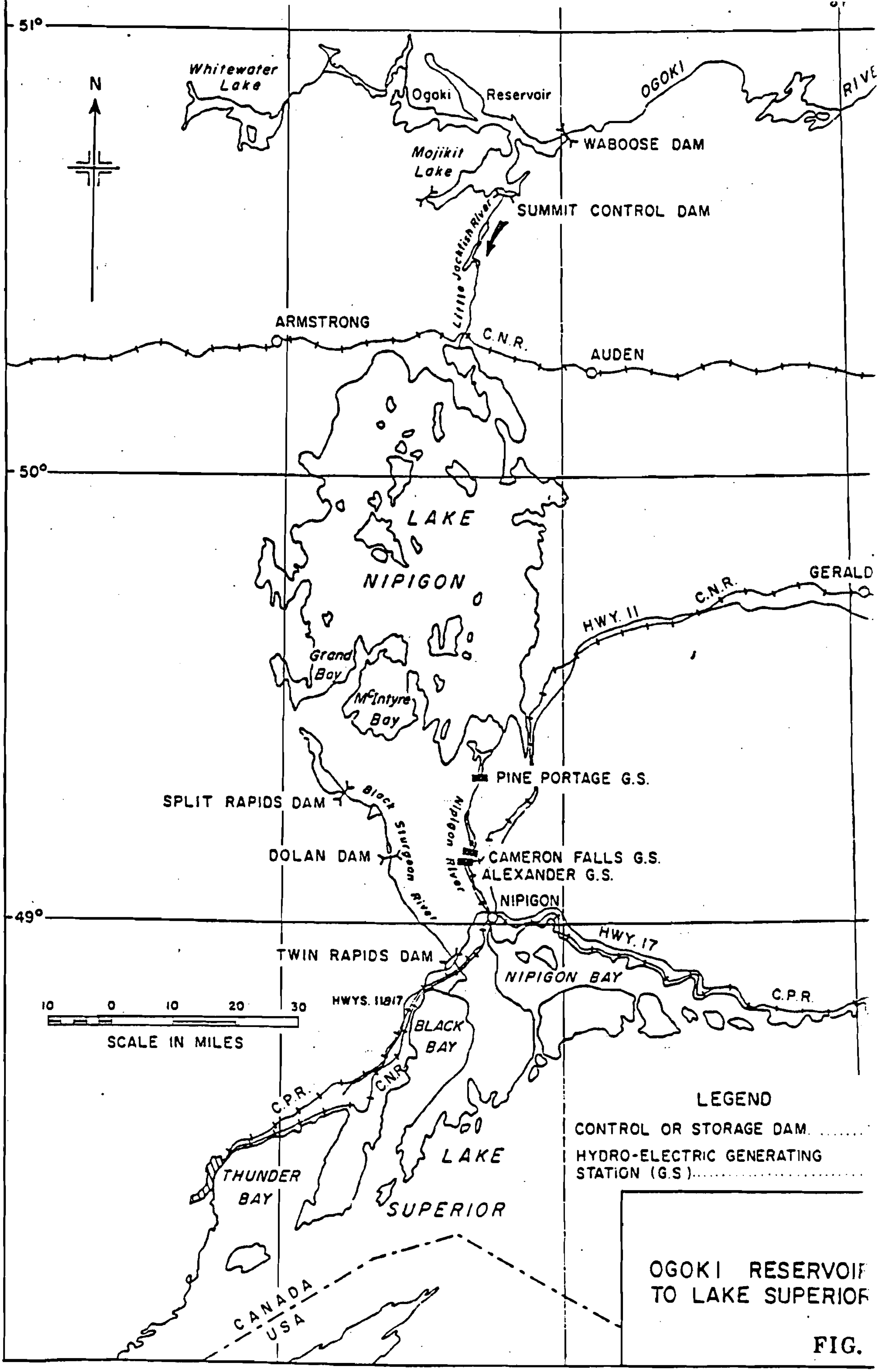
As with the Ogoki Diversion, although its volume may add only a small percentage to flood peaks on the Albany River at Fort Albany and Kashechewan, the opening of the Long Lake Diversion to the north would be perceived in downstream areas as the cause of any flooding that might occur.

IMPLEMENTATION COSTS

		Initial	Annual
Scenario	1(a)	$ 3,700	---
	1(b)	$ 3,700	$15,000
	2(a)	$ 50,000	$ 25,000
	2(b)	$ 50,000	$ 31,000
	2(c)	$ 50,000	$ 31,000



LONG LAKE AND OGOKI DIVERSIONS TO LAKE SUPERIOR



OGOKI RESERVOI
TO LAKE SUPERIO

FIG.

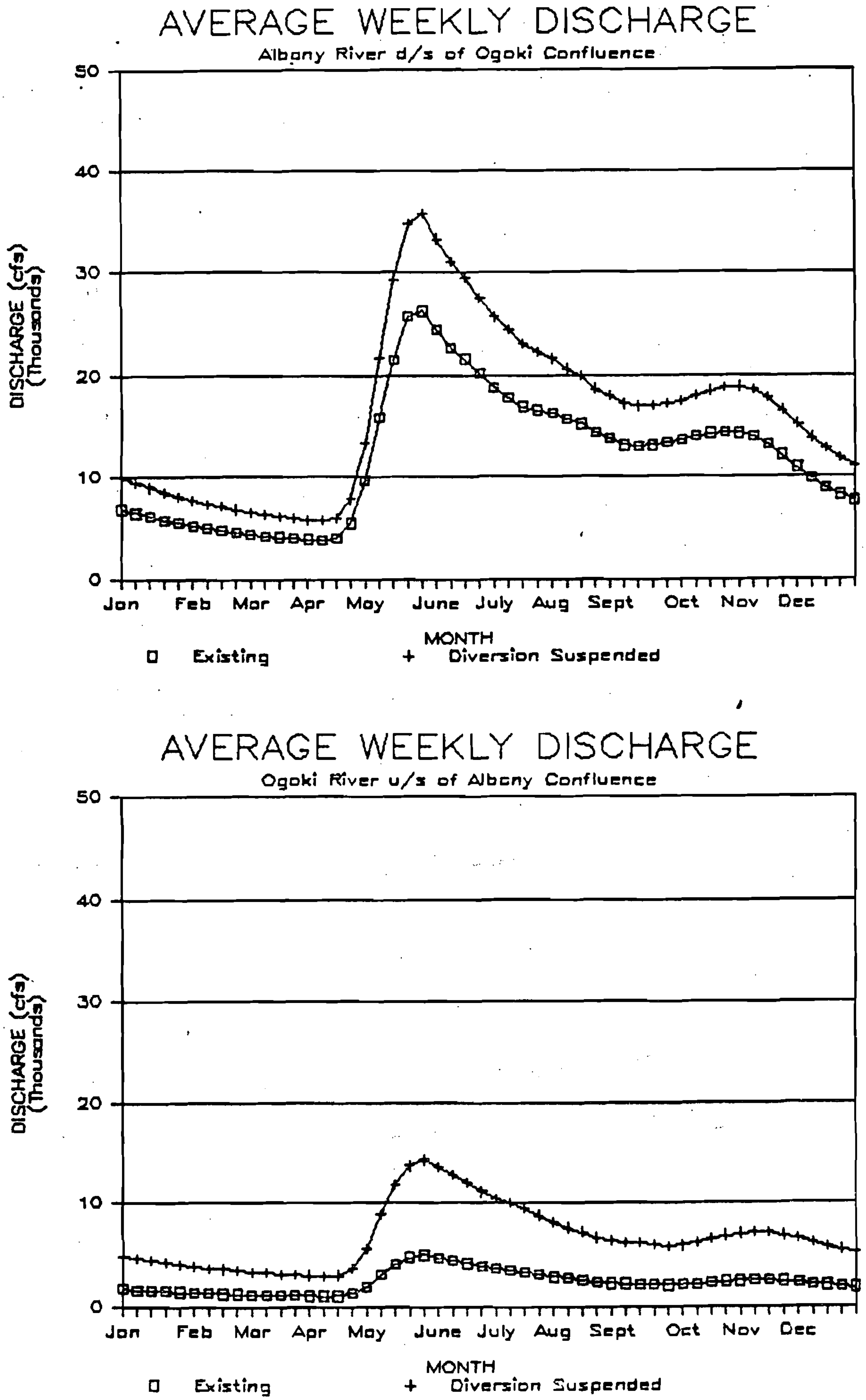

AVERAGE WEEKLY DISCHARGE
Albany River d/s of Ogoki Confluence
DISCHARGE (cfs) (Thousands)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
MONTH
□ Existing
+ Diversion Suspended
AVERAGE WEEKLY DISCHARGE
Ogoki River u/s of Albany Confluence
DISCHARGE (cfs) (Thousands)
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
MONTH
□ Existing
+ Diversion Suspended

FIGURE 3

MOJIKIT LAKE MONTHLY MEAN LEVELS

AT MOJIKIT LAKE – STATION NO. 04GB003

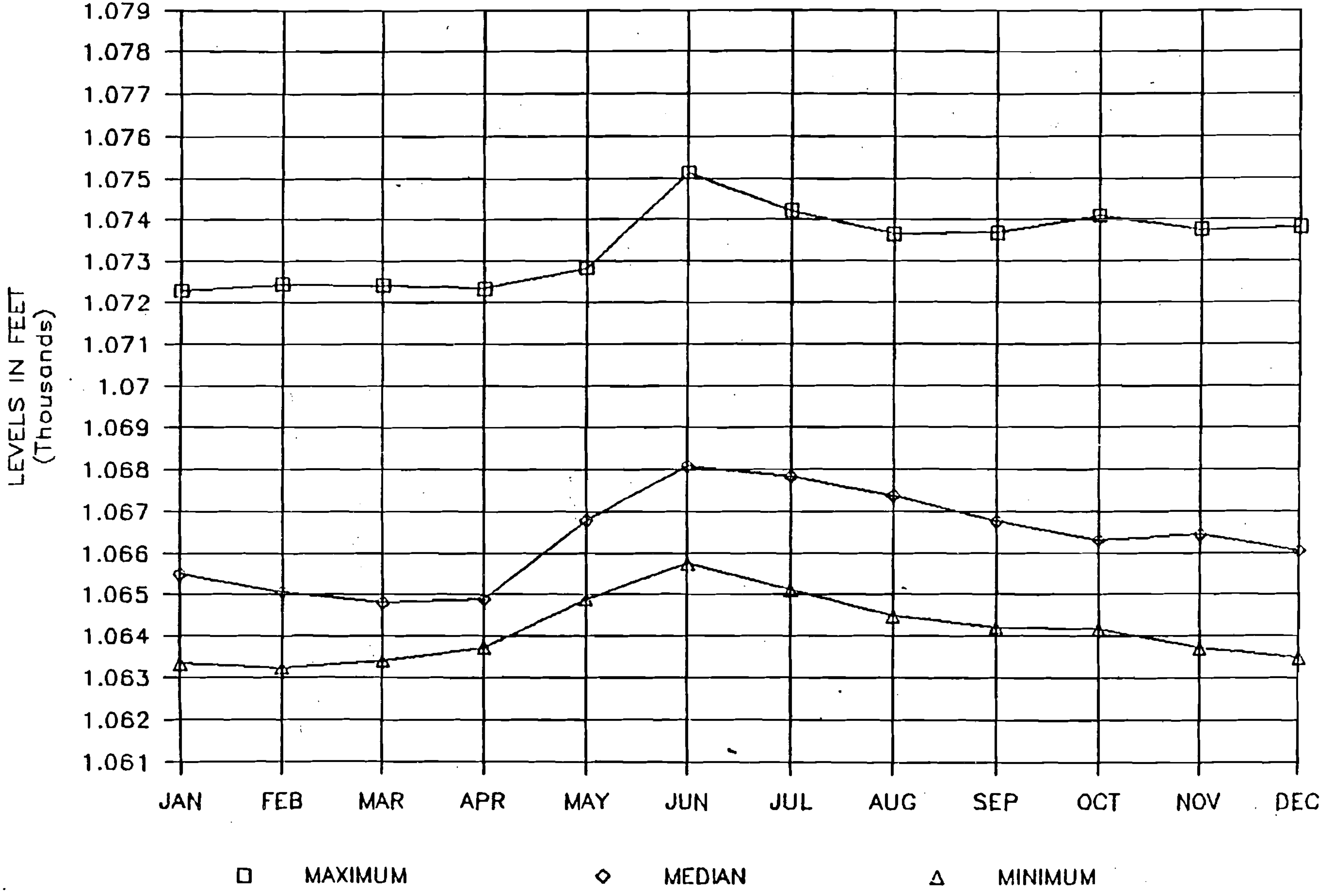
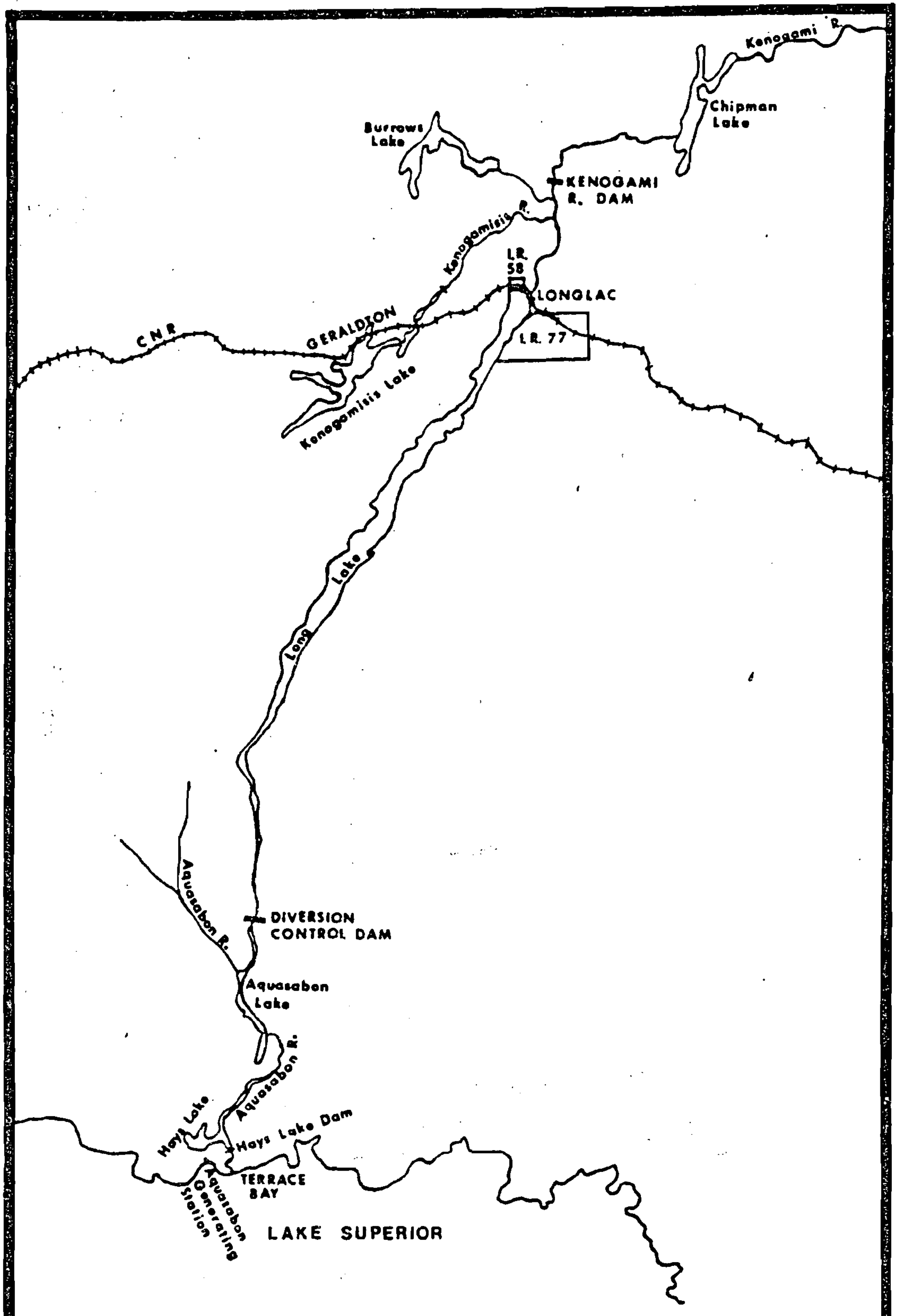


FIGURE 4

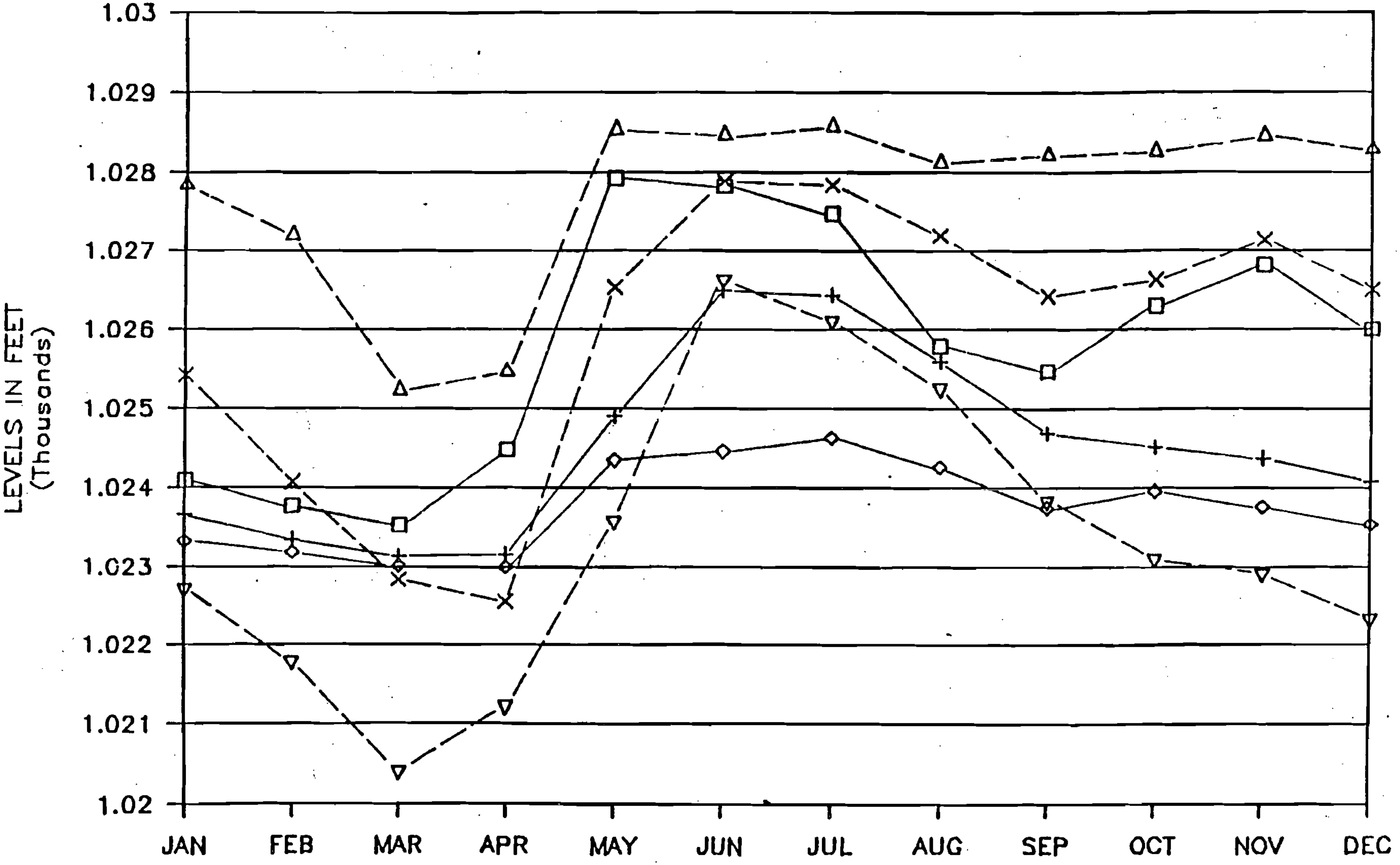


LONG LAKE RESERVOIR TO LAKE SUPERIOR

FIG. 5

MONTHLY MEAN LEVELS OF LONG LAKE

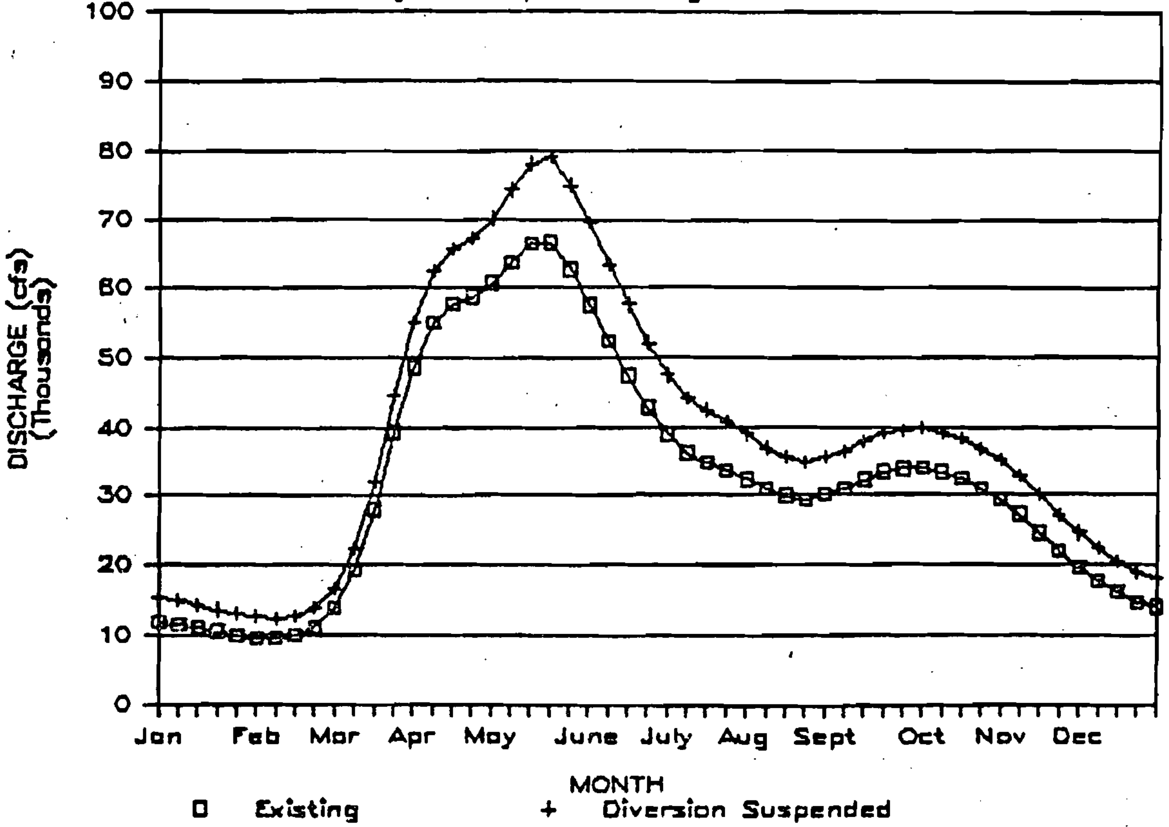
AT LONGLAC — STATION NO. 04JD001



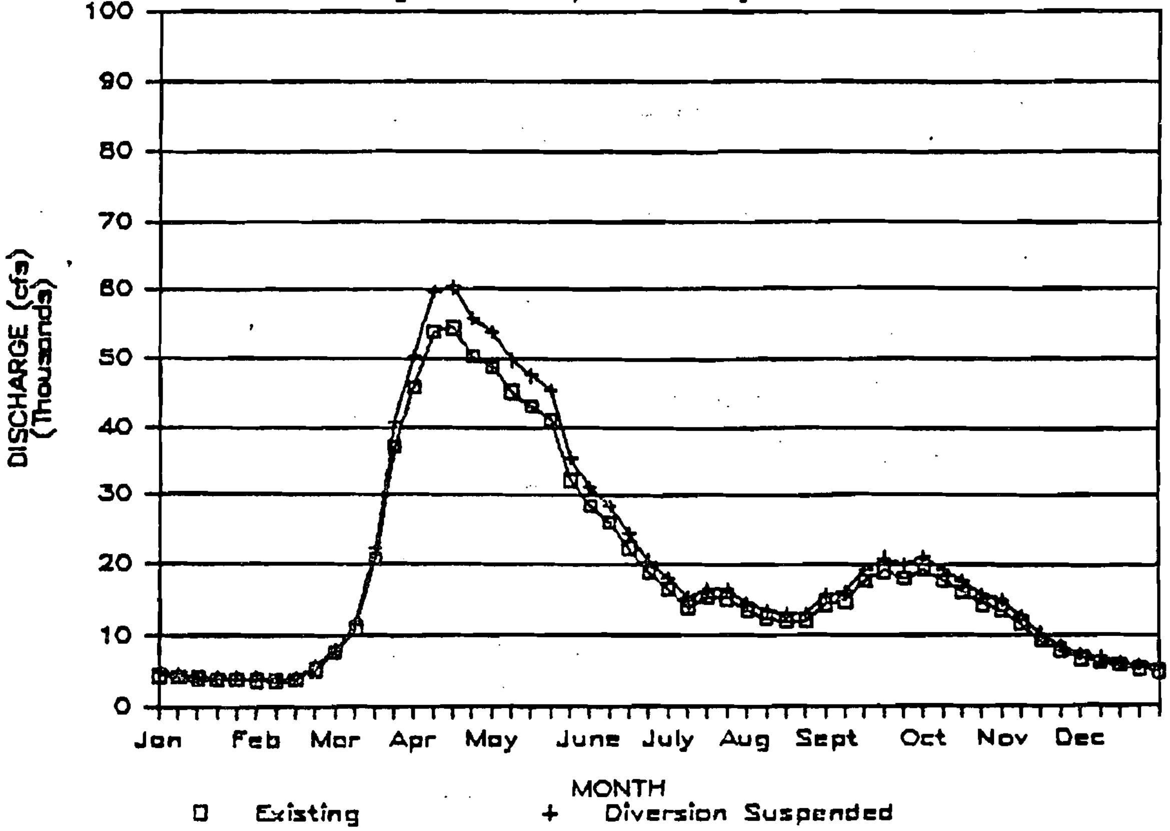
LEGEND

MAXIMUM, MEDIAN & MINIMUM LEVELS 1924 TO 1930 ————
(PARTIAL RECORDS ONLY)

Figure 6


AVERAGE WEEKLY DISCHARGE

Albany River d/s of Kenogami Confluence


AVERAGE WEEKLY DISCHARGE

Kenogami River u/s of Albany Confluence

FIGURE 7