IN THE

Supreme Court of the United States

October Term, 1966

STATES OF WISCONSIN, MINNESOTA, OHIO AND PENNSYLVANIA, Complainants, vs. **STATE OF ILLINOIS and the METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO,** Defendants, **UNITED STATES OF AMERICA,** Intervenor.	No. 1 Original
STATE OF MICHIGAN, Complainant, vs. **STATE OF ILLINOIS and the METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO,** Defendants, **UNITED STATES OF AMERICA,** Intervenor.	No. 2 Original
STATE OF NEW YORK, Complainant, vs. **STATE OF ILLINOIS and the METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO,** Defendants, **UNITED STATES OF AMERICA,** Intervenor.	No. 3 Original

TECHNICAL APPENDIX TO PETITION FOR MODIFICATION OF DECREE

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SUMMARY

Even minor fluctuations in the levels of the Great Lakes have important consequences to many of the 35,000,000 people in the drainage basin. The uses that are most affected are shoreline property, fish, wildlife and recreation, commercial navigation, and hydroelectric power production. At several locations along the lakes man has through his actions slightly affected the Great Lakes' levels.

At Chicago the opportunity was exploited for opening a channel between Lake Michigan and a tributary of the Mississippi River for transportation and as a means of disposing of effluents without polluting the city's water supply.

In 1930 the U.S. Supreme Court limited the direct diversion of Lake Michigan water at Chicago to 1500 cfs, not including unlimited domestic diversion which at the time was about 1700 cfs. In 1967 the Court issued a new decree limiting the total diversion to 3200 cfs.

The water diverted at Chicago presently has many uses, including slightly over half as domestic demand (including industrial uses), and about a quarter as lockages, leakages, discretionary dilution, and navigational makeup. About one fourth of the diversion limit must be held in reserve, however, to provide for the maximum five-year moving average runoff of stormwater within the 673-square-mile diverted drainage area.

The people of northeastern Illinois have made major commitments in waste-water treatment facilities in the past to control water pollution from domestic sewage. Continuing pollution control programs, especially the Tunnel and Reservoir Plan which will control combined sewer overflows, have as a goal the realization of maximum beneficial use of Lake Michigan diversion flows.

Continually growing demands for water supply, especially Lake Michigan waters, prompted the State of Illinois to enact legislation and develop procedures to be used for the allocation of Lake Michigan waters. A series of public hearings was held. Policies to govern the allocation decision making were developed relating to Lake Michigan allocation and water conservation. The cost-effective sources of water supply for each entity were analyzed by computer. Finally, allocations were made for the year 1977 through 1980.

The Supreme Court decree specified that a 5-year moving average of water use, including stormwater runoff, be used in accounting for diversion. The amount of runoff within the diversion area is therefore an important factor, since it controls the amount of water that can be allocated for other uses. Determination of its quantity is difficult due to the complexity of the watershed. Several parties have calculated the runoff, however, and have arrived at values in the vicinity of 550 cfs as an average.

A computer study for this report concluded that average annual runoff varied from 360 cfs to 795 cfs during a 100-year period with a maximum 5-year moving average of 706 cfs and a 100-year average of 562 cfs.

If the 5-year moving average of 706 cfs must be reserved for runoff from the 3200 cfs diversion limit, deficiencies in water are projected for most of a 35-year planning period because of increasing demand. If only the average of about 550 cfs is reserved, future demands can be met after about 1980, when in-stream aeration is installed to meet water quality standards.

It is recommended that the accounting procedure specified for use in determining Lake Michigan diversion at Chicago be modified to allow stormwater to be counted as a fixed value. Reserving 550 cfs for stormwater runoff is suggested as being reasonable.

The Supreme Court decree specifies that the Lake diversion flows be calculated by determining the flow past Lockport in the Illinois waterway and subtracting out quantities that are not diversion. Determination of the flows at Lockport requires summation of flows through several structures, each measurement being subject to error. Deductions from the flows at Lockport are also subject to substantial errors. Analysis of the data resulting from the existing accounting procedure reveals significant discrepancies in runoff quantities.

Construction of facilities which are planned or underway will further complicate the measurements at Lockport.

Therefore it is felt that the inadequacies of the system at the present time, plus future modifications that would be required, make the present accounting method for Lake diversions virtually unworkable. A new accounting method is required.

The 1967 Supreme Court Decree contains provision for modifications. It is proposed that the accounting method be modified to fix the stormwater runoff, for accounting purposes, at 550 cfs. Fixing the runoff would allow measurement of all other diversion flows to be made at the points of withdrawal from Lake Michigan. Measurement of domestic flows would be made at 22 intake points on the Lake. Direct diversion would be measured at the three inlets from the Lake to the waterway system. Calibration of pumps, gates, locks and leakage at the three control points would provide a reasonably accurate accounting of diversion. Unmeasured diversion from Indiana would have to be prevented. A highly automated accounting system is suggested to measure and record flows.

The proposed accounting system would allow better water quality maintenance in the Illinois waterway, would allow increased domestic water use without an increase in diversion, and would allow a more accurate accounting of diversion flows.

It is essential that the impact of any changes in the Great Lakes basin be closely examined to insure that none of the rights of other lake users are abrogated. To this end, the natural fluctuations of Lake Michigan-Huron, Lake Erie, and Lake Ontario were plotted for a 100-year recording period. A computer analysis was used to determine the induced incremental changes that would have occurred in lake levels if the proposed modifications to the Lake Michigan accounting method had been in effect for the same 100-year period.

The results of the analysis indicate that fluctuations in lake levels resulting from the proposed change in accounting method would be, at most, a tenth of an inch. Changes in flow through the connecting rivers would be, at most, 0.08 percent of mean flows.

Analysis of the effects of these changes on hydroelectric power generation at Niagara and in the St. Lawrence River revealed that no net change would occur and short term effects would be negligible.

Analysis of the effects of the proposed changes on shore erosion reveals that a very small but positive benefit to shoreline owners would occur. This results from a tendency of the proposed changes to slightly decrease the natural fluctuations in lake levels.

No measurable effects were identified on commercial navigation or on fish, wildlife, or recreation interests due to the proposed changes in the Chicago diversion accounting method.

CHAPTER I

THE WATERS OF LAKE MICHIGAN ARE CRITICALLY IMPORTANT TO THE HEALTH AND WELFARE OF THE PEOPLE OF THE STATE OF ILLINOIS.

Regulation of the Great Lakes

Since the time 10,000 years ago when the Wisconsinian glacier receded from North America, the Great Lakes have acted as huge stabilizers of the hydrologic cycle in their 300,000 square-mile drainage basin. Figure 1 shows the extent of the drainage basin. The 95,000 square miles of water surface in the lakes is a massive series of reservoirs that absorb seasonal and even annual variations in precipitation. Within recorded history the level of the lakes and connecting waterways has not varied more than seven feet, with a maximum variation of about two feet in any one year.*[1]

The remarkable stability of the lake levels, and the resultant unusually low variations in flow in their interconnecting channels and the outlet at the St. Lawrence River, does not mean, however, that the changes in lake levels are insignificant. On the contrary, the 35,000,000 people in the drainage basin are affected by even minor changes in lake

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*Note: The lake levels referred to throughout this report are those which are dependent only on the volume of water in the lake. Short-term changes in lake level at a specific point, such as would be caused by winds and changes in barometric pressure, and are often dramatic, are specifically excluded from consideration because they are not related to the volume of water entering or leaving the lakes.

1. International Joint Commission, Canada and United States, *Further Regulation of the Great Lakes,* 1976.

Figure 1. Great Lakes Basin

levels in several ways. Shoreline property owners are dramatically affected when water levels and storm conditions combine to erode beaches, dunes and manmade structures. The long cycle between maximum high water levels, up to 15 years, result in a tendency for intensive development along the lake shores by people and agencies that do not take into account the historical fluctuations. Fish, wildlife and recreation interests are affected by lake levels, particularly extended low levels. Boating and navigation are also inhibited by low levels. Hydro-electric power production varies with both upstream and downstream lake levels and the resulting variations in discharge.

Man has influenced the lake levels in several ways. The subject of this report, diversion of water out of the drainage basin at Chicago, was first accomplished in 1848. Diversions into Lake Superior from the Ogoki River and Long Lac beginning in 1939 add an average of 5,400 cubic feet per second (cfs) to the Great Lake system. A diversion between Lake Erie and Lake Ontario at the Welland Canal averages 7,000 cfs and has since 1829 lowered the level of Lake Erie. A smaller diversion between the same two lakes through the Erie Canal has virtually no influence on Lake levels.

Dredging of the St. Clair and Detroit Rivers between Lakes Huron and Erie dates back to 1856. These navigational improvements permanently lowered the levels of Lakes Michigan and Huron.

The level of Lake Superior has been affected by man since 1822, with a measure of control established in 1921 by increasing the channel outlet into Lake Huron and controlling the flow with gates. Similar controls have been installed on the St. Lawrence River since 1960.

Consumptive use of water from the Great Lakes consists of manufacturing products containing water (beverages being a good example) and exporting them out of the basin, irrigating crops and lawns (thus increasing evaporation losses to the air), and losing water through industrial processes or thermal power generation. The total consumptive use of water in the Great Lakes Basin was estimated to be 2770 cfs in 1976, with 6000 cfs expected in the year 2000 and 13,000 by the year 2030. This will lower levels in all of the Great Lakes.[2]

History of Lake Diversion at Chicago

Chicago's initial growth was largely due to its location near the point where a portage of less than two miles separated a tributary to the Great Lakes from a tributary to the Mississippi River. In 1816 a strip of land was purchased from the Indians at the portage, and in 1848 the Illinois and Michigan Canal was completed.[3] Water was diverted through the canal from Lake Michigan at a maximum rate of 1000 cfs.[4] Improvements were made in the canal during 1865 to 1871, and the years before 1884, although water flowed in both directions during storms. A

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2. *Ibid.*

3. Metropolitan Sanitary District of Greater Chicago (MSDGC), *How to Bottle Rainstorms,* a brochure prepared by Keifer & Associates, Inc. (then Bauer Engineering, Inc.), Chicago, Illinois, February 1974 (hereinafter "Rainstorms").

4. Ad Hoc Committee of the Illinois Water Resources Commission, *Technical Report: Investigation of Options for Increasing Use Efficiency of Lake Michigan Diversion Water,* Chicago, Illinois, October 1976.

major storm in 1885, causing a disastrous toll of dead from water-borne disease, led to an 1889 plan to permanently reverse the flows of the Chicago and Calumet Rivers, into which the City's sewer system was directed. In 1889, the Sanitary District of Chicago was formed and 1900 saw the opening of the Sanitary and Ship Canal.[5] The North Shore Channel, the Cal-Sag Channel, the locks downstream at Lockport, and the locks and controlling structures at the mouth of the Chicago River, at Wilmette and at O'Brien Lock were constructed in subsequent years. Each of these structures is shown on Figure 2. Diversions up to 8500 cfs have been authorized in the past.[6]

U.S. Supreme Court Decree Limiting Diversion to 3,200 cfs

During low water periods in the lakes, other states and Canada were concerned about the effect of the Chicago diversion on lake levels. Finally, in 1925, a suit, *Wisconsin et al.* v. *Illinois et al.,* was brought before the U.S. Supreme Court to limit the diversion. The decree resulting from this suit, dated April 21, 1930, limited the allocation of direct diversion of Lake Michigan water by the Metropolitan Sanitary District of Greater Chicago (the former Sanitary District of Chicago) to 1500 cfs after December 31, 1938. This amount was in addition to the unlimited domestic pumpage that was used by local municipalities and industries. The decree also established a formula to account for direct diversion by measuring flows at the Lockport control

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5. MSDGC, *Rainstorms.*

6. Illinois Department of Transportation, Division of Water Resources. *Program and Rules and Regulations for the Allocation of Water from Lake Michigan,* Springfield, Illinois, August 1976.

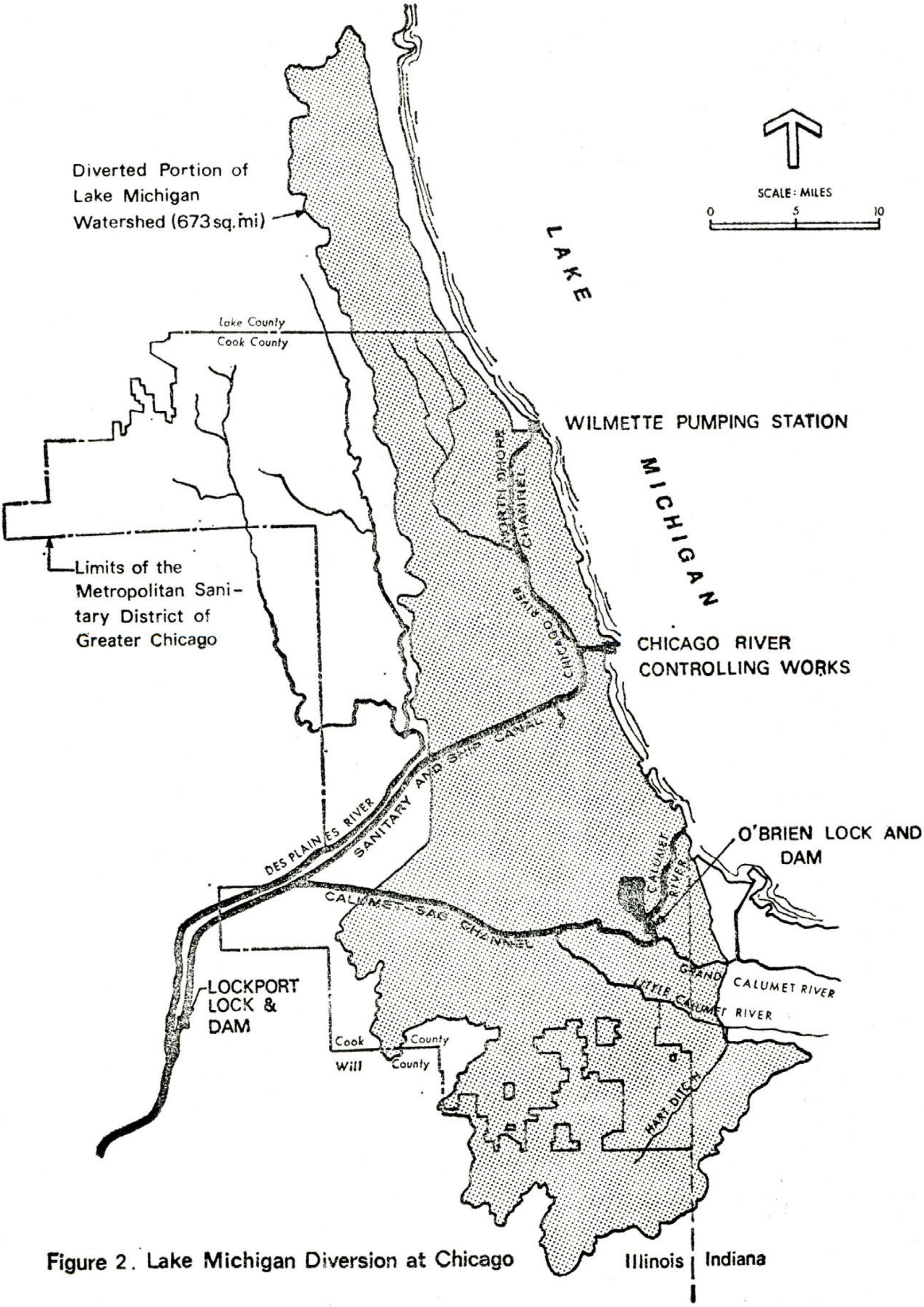

Figure 2. Lake Michigan Diversion at Chicago

works. Lockport was a logical location for the measurement, since the controlling works at the Chicago River were not completed until 1938.

The case was later reopened, and after extensive testimony before Special Master Maris, an enlarged decree was issued on June 13, 1967. In the decree, the Supreme Court stated that effective March 1, 1970, . . . "the State of Illinois and its municipalities, political subdivisions, agencies, and instrumentalities . . . are hereby enjoined from diverting any of the water of Lake Michigan or its watershed into the Illinois waterway, whether by way of domestic pumpage from the lake the sewage effluent derived from which reaches the Illinois waterway, or by way of storm runoff from the Lake Michigan watershed which is diverted into the Sanitary and Ship Canal, or by way of direct diversion from thel ake into the canal, in excess of an average for all of them combined of 3,2000 cubic feet per second."[7]

The decree authorizes the State of Illinois to apportion diversion waters "among its municipalities, political subdivisions, agencies, and instrumentalities for domestic use or for direct diversion into the Sanitary and Ship Canal to maintain it in a reasonably satisfactory sanitary condition, in such manner . . . as the State may deem proper, subject to any regulations imposed by Congress in the interests of navigation or pollution control."[8]

The Demand For Diversion Water In Illinois

The water diverted from Lake Michigan in the Chicago area is used for several purposes and by a number of agencies. The uses are described briefly below. Also discussed is

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7. *Wisconsin et al.* v. *Illinois et al.,* 388 U.S. 426 (1967).
8. 388 U.S. 427-8 (1967).

stormwater runoff, which is included in the diversion as an inevitable result of the change in drainage pattern caused by reversing the flow of the Chicago and Calumet River systems. The amount of stormwater runoff diverted from the lake is included in the 3,200 cfs allowable diversion. Figure 3 shows the relative magnitude of each of the present uses.

Domestic Demand (Including Industrial Use)

There are 110 entities using Lake Michigan water for residential, commercial, municipal or industrial processes. These entities include the City of Chicago and 74 adjacent municipalities supplied from its system. The total present demand (1977) of these entities is approximately 1,739 cfs, or 54.5 percent of the total allowable diversion.[9]

Lockages

Lockages are those volumes of water diverted when the navigation locks are filled with Lake Michigan water and emptied into the river system, which is normally maintained two to five feet lower than the Lake. It is estimated that an average of 155 cfs is presently used for lockages, representing 4.8 percent of the allotment.[10]

Leakages

It is currently estimated that 74 cfs is lost from Lake Michigan by leakage at the three controlling structures. This is 2.3% of the allotment.[11]

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9. Illinois Department of Transportation, Division of Water Resources, *Opinion and Order in the Matter of Lake Michigan Water Allocation,* LMO 77-1.

10. *Ibid.*

11. *Ibid.*

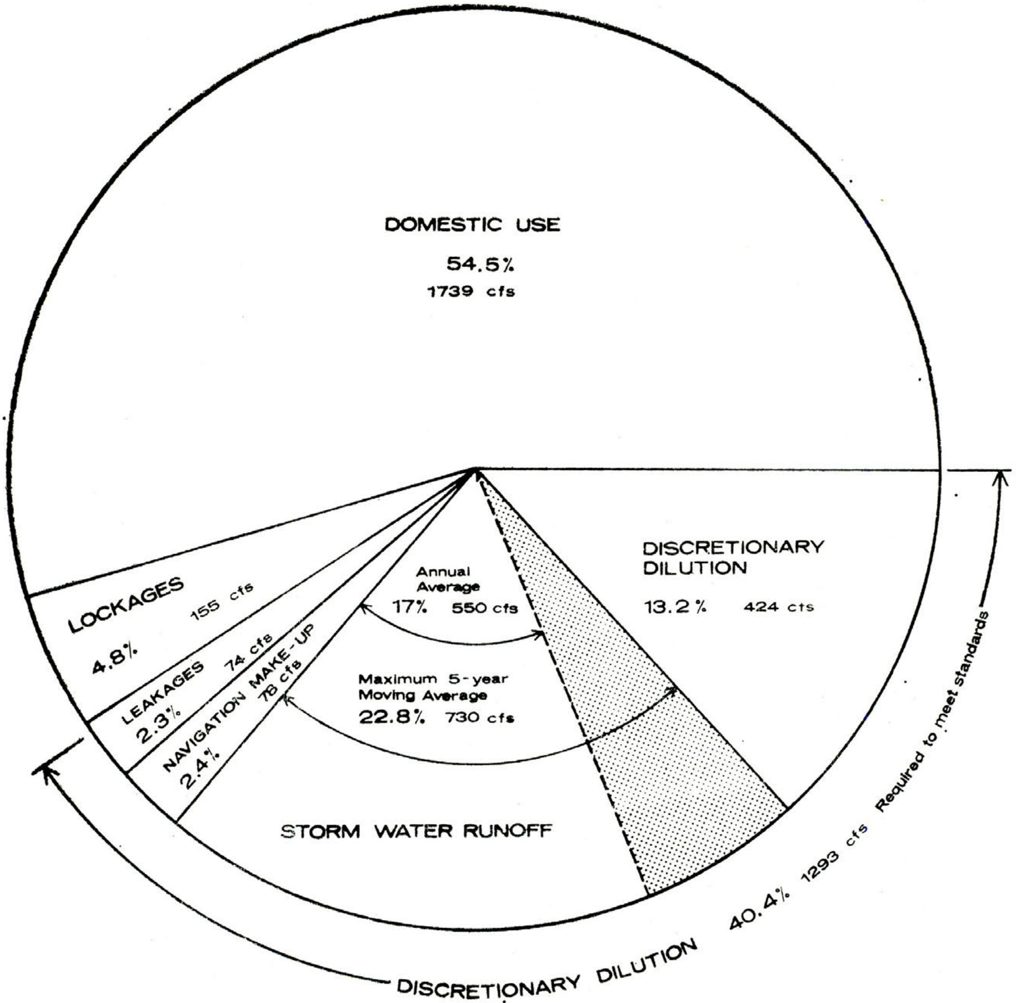

Figure 3. 1977 Uses of Lake Michigan Water in Northeastern Illinois
(Total Diversion Limited to 3200 cfs)

Navigation Make-Up

When a storm is predicted in the Chicago metropolitan area, water is released from Lockport to make room in the river system for the anticipated runoff so as to mitigate flood damages. If the runoff does not materialize to the extent anticipated, water from Lake Michigan must be diverted to raise the river system back to levels required for navigation. An average of 78 cfs, or 2.4 percent of the allotment, is required for this purpose.[12]

Runoff

The stormwater runoff which previously entered Lake Michigan, but which now is tributary to the Illinois River system, must be estimated and included as diversion. Figure 2 shows the 673 square-mile area of this diversion. The amounts of runoff and the accounting system used to estimate it are discussed at length in Chapter III. For purposes of illustrating its significance, however, Figure 3 shows the historical average of approximately 550 cfs (17 percent of the allotment) and the 730 cfs (22.3 percent of the allotment) that is currently anticipated as a maximum five-year moving average flow.[13]

Discretionary Dilution

Unlike the previously described uses the remaining 424 cfs (13.2 percent) of the 3,200 cfs diversion limitation is not necessary for an on-going human or economic enterprise. This volume of water is presently used, in addition to lockages, leakages and navigational makeup, as direct diversion into the waterways to improve water quality. It is referred to as discretionary dilution since it is the only part of the diversion water that can be varied under day-to-day operation.

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12. *Ibid.*
13. *Ibid.*

As future demands for water result in increased allocations for domestic use the amount of water available for dilution will decrease, unless the volume reserved for stormwater runoff can be reduced. If the average annual runoff is used rather than the maximum 5-year moving average, the amount available for new domestic use and discretionary dilution becomes 604 cfs (18.9 percent of the total).

The amount of discretionary dilution that would presently be necessary to meet water quality standards in the Illinois River system is 1,293 cfs (40.4 percent of the total diversion). Therefore the Federal and State standards for water quality in the several canals and rivers in the Chicago area cannot be met at the present time.

Water System Improvements in the Chicago Area

The diversion of water from Lake Michigan at Chicago at the turn of the Century is only one of a number of major public works undertaken by the Metropolitan Sanitary District of Greater Chicago (MSDGC) to protect the health and well-being of its residents through maintenance of water quality. Even prior to the limitation of diversion by the Supreme Court in 1930, major sewage treatment plants had been put into operation. The impetus for construction of the treatment plants was the development of the activated sludge treatment process in England in 1912.[14] The Calumet Treatment Plant opened on the south side in 1922 and the Northside Plant opened in 1927. Following the decree, the West-Southwest Plant, then and still the world's largest,

14. MSDGC, In-House Memo: "Diversion Accounting at Chicago by the Metropolitan Sanitary District," Jonathan Stimson.

was completed in 1939. The plants have been periodically expanded and improved to allow compliance with the decree without recurrence of nuisance conditions caused by excessive oxygen-demanding wastes in the waterways.

The MSDGC has embarked on the massive Tunnel and Reservoir Plan (TARP) that will, by 1995 at a cost of nearly $2 billion, largely eliminate combined sewer overflows to the waterways. This first-of-a-kind project uses large tunnels in the bedrock to convey overflows from 640 overflow points in the combined sewer system to storage basins, from which they will be pumped to three sewage treatment plants at a manageable rate. Figure 4 shows the 375-square-mile combined sewer area served by TARP and the locations of the 120 miles of conveyance tunnels, three storage reservoirs and treatment plants.

TARP will be constructed in two phases. Phase I is already under construction and is scheduled for completion in 1986. It consists of most tunnel segments so that the first flush of stormwater, containing most pollutants from the urban area, can be intercepted and treated. This will have major water quality benefits and reduce the need for discretionary dilutions. Phase II, scheduled for completion in 1995, contains the remaining tunnels and major storage reservoirs. It will have additional water quality benefits, but will be primarily a flood control project since it will enable storage of nearly all combined sewer overflow. It will also eliminate the need for navigational makeup water.

In the meantime, during 1978 and 1979, construction will be completed by MSDGC on a system of in-stream aerators. Air diffusers at nine locations in the river system will result in dissolved oxygen concentrations of up to 90 percent saturation at the diffuser sites. This will dramatically reduce the need for dilution with discretionary flows.

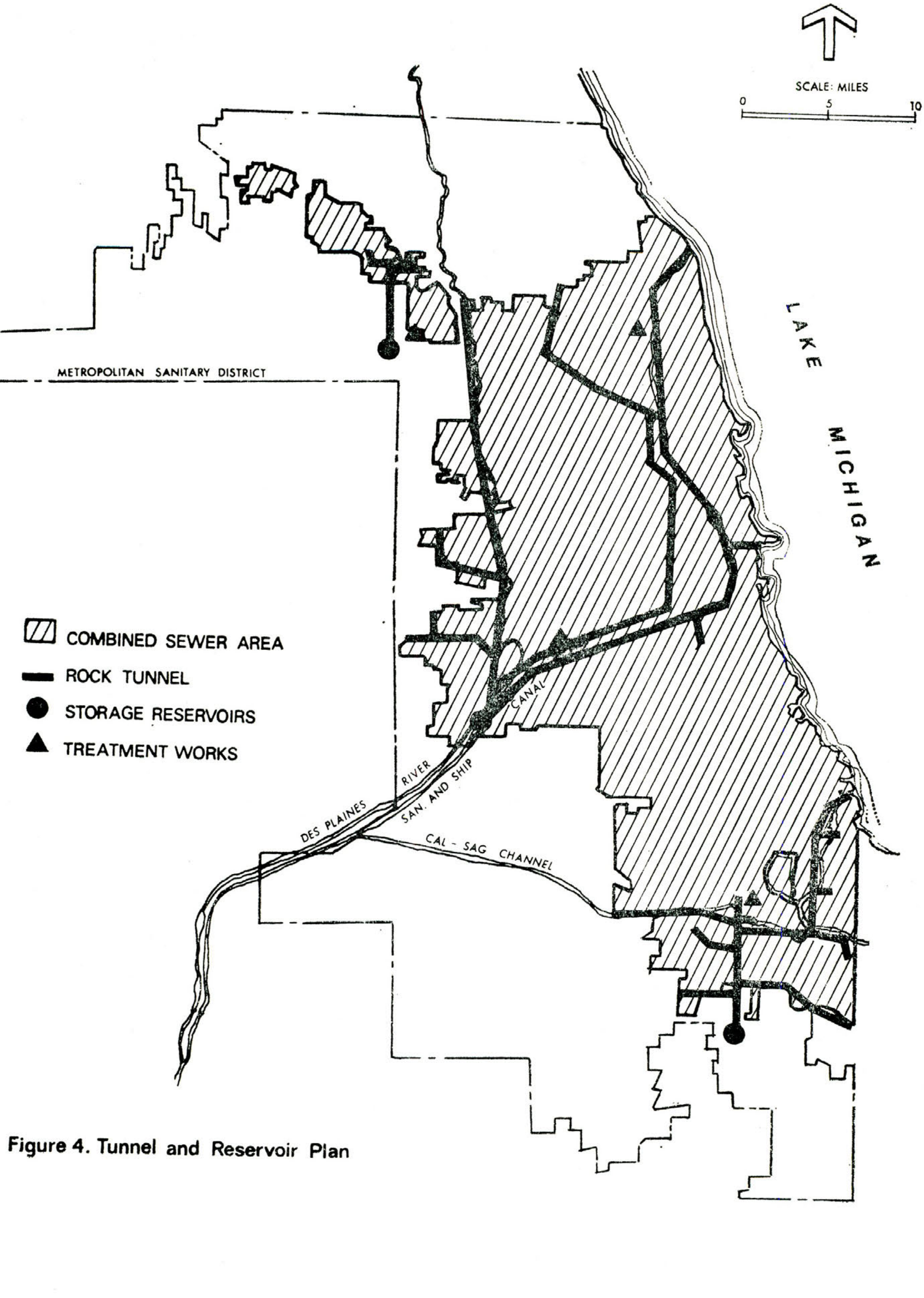

Figure 4. Tunnel and Reservoir Plan

The City of Chicago has during the last several decades undertaken a massive effort to diminish the leakage from its water system. The success this program has achived is evidenced by the present domestic flow, which has remained approximately the same as that in 1928, while the population served by the system has increased by about a million people.

These programs, far in excess of those undertaken in other metropolitan areas, have as a goal the realization of maximum beneficial use of the Lake Michigan diversion flows.

Future Demands for Diversion Water

Despite the efforts that have been made to use the Lake Michigan diversion waters wisely, there is a large demand for Lake water that is unfilled. This demand is presently in the form of dilution water to enable the river system in the Chicago area to meet State and Federal water quality requirements. In-stream aeration and the TARP plan will eventually eliminate much of this demand, but it will be replaced by a more persistent demand.

During the next decades, overpumping of the groundwater sources that presently supply water for many of the over 200 municipalities in northeastern Illinois will cause depletion due to mining that has occurred since rapid suburban growth began. Unless another sources of water is made available, these areas will be unable to support their present populations, let alone the predicted future growth.

Because of this impending critical shortage of groundwater and the anticipation that Lake Michigan was the only realistic source for its replacement, a comprehensive study of the Chicago diversion and its allocation was undertaken by the State of Illinois. This study and its results are the subject of Chapter II.

CHAPTER II

THE STATE OF ILLINOIS' PRESENT ALLOCATION AND REGULATION WILL CONSERVE AND PROTECT THE WATER RESOURCES OF NORTHEASTERN ILLINOIS, WITHIN THE LIMITATIONS IMPOSED BY THIS COURT'S DECREE.

Allocation to Domestic Users

The 1967 United States Supreme Court Decree authorized the State of Illinois to divert 3,200 cfs of water from Lake Michigan. In the following year, the State General Assembly designated the Department of Transportation as the agency responsible for the apportionment.[1] The Department is required to develop a "continuing program for apportionment of Lake Michigan water among political jurisdictions for domestic use or direct diversion in accordance with the terms and conditions of the Supreme Court Decree."

The first allocation of Lake Michigan water was made in 1972 following a series of public hearings. Several affected parties filed complaints for administrative review, and in 1973 the circuit court set aside the allocation, holding that the Department of Transportation had failed to observe procedural due process safeguards.

Beginning with a prehearing conference in December 1974, the allocation process began anew. Applications for an allocation were received by the Department of Transpor-

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1. Illinois P.A. 76-1844, effective October 10, 1969, amended by P.A. 77-163, effective Janary 1, 1972, revised the "Level of Lake Michigan Act" of 1929 (Ill. Rev. Stat., Ch. 19, Sec. 119, *et seq.* (1977).

tation from all interested parties; hearings were held from February 1975 until November 29, 1976, when the record was closed. The complete record included over 10,000 pages of transcript in addition to applicants' exhibits and submittals.

The Illinois Department of Transportation established two goals in discharging its responsibility to implement the "Level of Lake Michigan Act" of 1929, as amended:

> To assure adequate water supplies to the citizens of northeastern Illinois
>
> and
>
> To distribute fairly and equitably Lake Michigan water among entities requiring such water.[2]

The long term water supply portion of the program consists of four components: a water supply task force, a program of technical studies and analyses, a technical assistance program to insure effective use of existing water supplies, and efforts to obtain increased water supplies, if necessary.

The policies which governed the allocation decision-making were developed after a series of meetings in which public participation was encouraged. The policies governing use of Lake Michigan water at the Chicago diversion were as follows:[3]

A. Policies Relating to Water Supply and Lake Michigan Allocation

1. Pursuant to the requirements of State law and the Supreme Court Decree, the Department shall require, as

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2. Illinois Department of Transportation, Division of Water Resources, *Program and Rules and Regulations for the Allocation of Water from Lake Michigan,* 1976.

3. *Ibid.*

a condition of any allocation order, that all "feasible means reasonably available" to the State and its municipalities, political subdivisions, agencies and instrumentalities are employed to conserve and manage the water resources of the region and the use of water therein in accordance with the best modern scientific knowledge and engineering practice.

2. The competing needs of all water users in the region will be considered and the allocations will reflect the Department's best efforts to facilitate the most efficient and economical use of water in the region in light of long range needs and objectives.

3. Water needs of the six-county northeast region will be determined through analyses of population, economic growth and water use. Such analyses will be performed in consultation with recognized regional and area-wide planning authorities as well as with the affected communities.

4. Commingling of ground and surface waters will be required unless it can be shown not to be a practical and economically feasible means of meeting water demands.

5. Unless substantially less costly processes of desalinization become available, utilization of groundwater from the Mt. Simon aquifer for water supply will not be considered.

6. Every effort shall be made to coordinate water supply with wastewater planning. As the streams in northeastern Illinois become cleaner and bottom loads are removed, the connections between surface and groundwater will be improved and the potential for both artificial and natural recharge expanded. Wastewater reuse for human consumption will be deferred until it has been demonstrated that such reuse does not present a health hazard.

7. The expanded and continued use of the shallow aquifer system will be encouraged where economically feasible.

8. Consideration will be given to the development of groundwater sources in areas of surplus for exportation to areas of shortage.

9. The Department will assess utilization of navigation and lockage and leakage flows and may condition permits for such uses upon implementation of procedures and practices to decrease waste and to increase use efficiencies.

10. The Department will support the existing policy against returning untreated stormwater runoff from combined-sewered areas within Cook County to Lake Michigan in order to prevent degradation of Lake Michigan water quality.

11. The Department will provide technical assistance to promote the efficient use of ground and surface water by northeastern Illinois water users.

12. The Department will assess and monitor current water accounting practices and procedures and may condition permits upon implementation of adequate procedures approved by the Department.

B. Policies Concerning Water Conservation in Northeastern Illinois

1. Surface waters will be preserved and protected for use as future sources of public and industrial water to the extent practical.

2. The mining of the deep aquifer will not be allowed beyond the point at which the lowest groundwater table in any section simulated by the "Illinois State Water Survey Model" reaches a point 100 feet above the top of the Ironton-Galesville formation. The Department may require that an applicant stop using water, other than for emergency or standby purposes, from the deep aquifer as a condition to receiving an allocation of Lake Michigan water. This will allow the deep aquifer to be maintained to meet

the needs of the remaining users. To ensure that steps necessary for a shift to a Lake supply can be taken before the critical level is reached, the Department will follow the policy of making allocations to communities reasonably in advance of the time at which the critical level can be expected to be reached.

3. Expansion of Lake Michigan water service areas will be planned and programmed on a coordinated basis to secure area-wide benefits and economies of scale. Existing systems will be utilized to the maximum extent feasible.

4. The Department requires, as a condition for receipt of Lake Michigan water, that applicants adhere to the following conservation practices:

a. That all new water services shall be metered.

b. That leakage detection and control programs shall be conducted on all public water systems on an anunal basis, with annual auditing procedures instituted to reconcile water production records with billing quantities.

c. That water rate structures shall be at flat or increasing rates so as to discourage excessive water use.

d. That (where applicable to permittee) permittee will modify local plumbing codes to require that:

(i) In all new construction and in all repair and/or replacement of fixtures or trim, only fixtures and trim not exceeding the following flow rates and/or water usage shall be installed. These ratings are based on a pressure at the fixture of 40 to 50 psi.

Water Closets, tank type:	3.5 gal. er flush
Water Closets, flushometer type:	3.0 gal. per flush
Urinals, tank type:	3.0 gal. per flush
Urinals, flushometer type:	3.0 gal. per flush
Shower heads:	3.0 GPM
Lavatory, sink faucets:	3.0 GPM

(ii) Lavatories for Public Use—Faucets of lavatories located in restrooms intended for public use shall be of the metering, or self closing type.

(iii) Car Wash Installation—Car wash installations shall be equipped with an approved water re-cycling system.

e. That all sewer flushing with potable water will be banned.

f. That permittee will adhere to specific levels of groundwater and specific aquifer usage determined by the Department.

5. It shall be the general policy of the Department to cooperate with the United States Environmental Protection Agency and the Illinois Environmental Protection Agency.

An extensive program of analysis, using computer modeling, was performed to determine the most cost-effective sources of water for each municipal or other entity in the six-county northeastern Illinois area. The alternative water supplies investigated included the shallow (sand, gravel and dolomite) aquifer, groundwater transfer from water-rich to water-poor townships, shallow aquifer recharge, the deep sandstone aquifer, Lake Michigan, commingling of groundwater with Lake Michigan water, and the use of other surface waters, including the Kankakee and Fox Rivers. The results of this study, which encompassed the six counties of Cook, DuPage, Kane, Will, McHenry, and Lake, are shown in Figure 5.

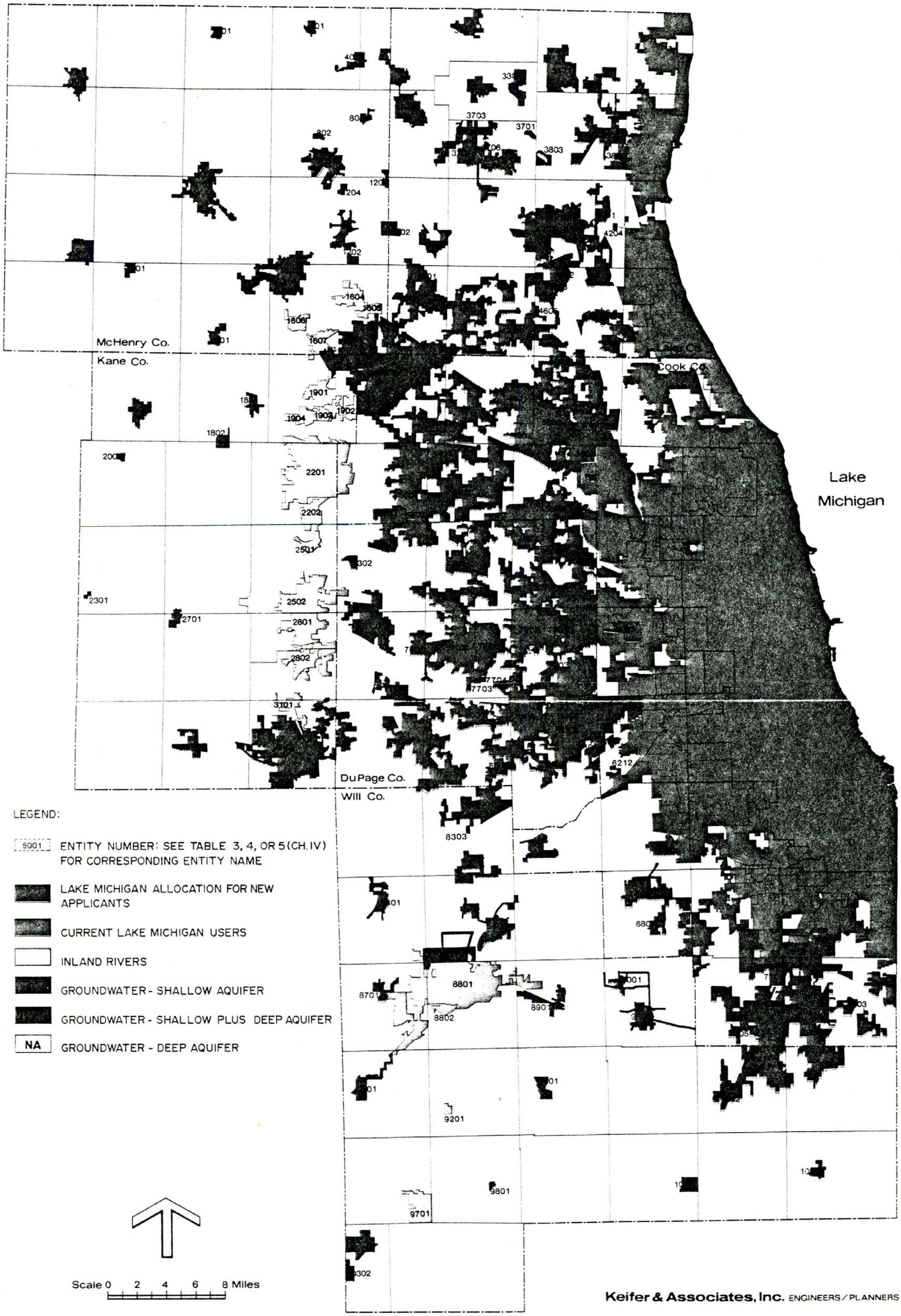

Figure 5. Apparent Cost Effective Sources of Water Supply for all Entities in the Study Area

Upon completion of the evidentiary hearings, the technical studies and the policy development, allocations were made for the years 1977 to 1980 only. For 1977, 111 allocations were made totaling 1,739 cfs; unallocable runoff was established at 730 cfs; and the amount of lockages, leakages, navigational maintenance and discretionary dilution was the remaining 731 cfs of the 3,200 cfs limit. For 1980, the number of allocations is increased to 130 totaling 1,826 cfs; unallocable runoff remains at 730 cfs; and the quantity for lockages, leakages, navigational maintenance and discretionary diversion decreases to 627 cfs. A reserve of 17 cfs makes up the remainder of the 3,200 cfs limit.[4]

The allocations made by the Illinois Department of Transportation were, with one minor modification, upheld on review by the Circuit Court of Lake County, Illinois. *Village of Riverwoods* v. *Ill. Dept. of Transportation,* No. 77 MR 62 (July 18, 1978).

Stormwater Runoff

The determination of the amount of runoff leaving the Great Lakes basin from the 673 square-mile diversion area is very complex and is not amenable to precise computation. Its measurement is not directly possible because runoff from the DesPlaines River basin mixes with runoff from the diverted area prior to flowing through Lockport. The runoff is, however, a very important factor in the diversion since it varies widely from year to year and, in effect, controls the amount of diverted water that is available for discretionary uses.

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4. "In the matter of Lake Michigan Water Allocation," LMO 77-1, Opinion and Order of the Ill. Dept. of Transportation.

The quantity of runoff is a function of a multitude of interrelated factors, such as the volume of precipitation falling on the area, the aerial distribution of precipitation, the soil moisture preceding rainfalls, snow melting rates, the capability of different soils to absorb water and transmit it to groundwater tables, the discharge of water from groundwater sources to streams, temperature, cloud cover, wind, vegetation and other factors affecting loss of water to the air, urban development affecting imperviousness and the absorption of water by the soil, and the infiltration of water into groundwater tables from stream channels and floodplains. It includes both surface runoff and water entering the surface streams because of infiltration and inflow in sewer systems.

Calculation of runoff by simulation of these variables on a computer is possible, but accuracy requires the establishment of many factors for the heterogeneous drainage basin and some known runoff events to aid in calibration of the computer model.

The large diversion area is made up of a number of subdrainage basins and interconnected sewer systems which add to the complexity of determining runoff in such a way that the calculations are always subject to some degree of error. Therefore no exact determinatoin of runoff can be made. However, various parties have suggested values for the average annual runoff from the 673 square-mile total diversion area shown in Figure 2. Table 1 summarizes these various values and their sources.

Table 1

MEAN ANNUAL RUNOFF FROM DIVERSION AREA

Mean Runoff cfs from Chicago area, formerly tributary to Great Lakes	*Data Sources and Description*	*Reference*
408	Hydrocomp & NIPC's report to IDOT: for 1900 condition	Northeastern Illinois Planning Commission Staff Paper, "Water Yield, Urbanization and the North Branch of the Chicago River" Oct. 14, 1976 (Table 3.0)
553	for present condition	
555	International Great Lakes Levels Board: for 1935-1964 average of 11.2″ (see Table A-8 of the reference)	"Regulation of Great Lakes Water Levels—Appendix A: Hydrology and Hydraulics" Report to the International Joint Commission, Dec. 7, 1973.
404	for 1935-1964 Mean Runoff of 0.6 cfs/sq. mi. (see Figure A-10 of the reference)	
552	MSDGC's data for 1966-1974 calendar year average	"Lake Diversion Testimony Technical Reports," the Metropolitan Sanitary District of Greater Chicago, p. 11, Chapter B.
572.5	for 1966-1974 accounting year average	

446	Keifer & Associates, Inc. for less developed watershed area	"Lake Michigan Water Allocation Study," K&A, August 1976, Table 7, p. IV-151.
521	Keifer & Associates, Inc. for 1900 condition	"Storm Runoff Simulation for the Lake Diversion Area," K&A, Feb. 1977, Table 2, p. V-2.
562	Keifer & Associates, Inc. for 1970 condition	Runoff Analysis for repeat of 100 years of historical rainfall data as presented in this report.
533.7	Hazen, Sawyer and Hudson representing New York State	Maris Hearing (Mr. Hazen's Testimony) Transcript, Vol. 49
550	Greeley and Hansen, representing the State of Illinois	Maris Hearing (Mr. Langdon's Testimony) Transcript, Vol. 65.

The two values (533.7 and 550 cfs) of runoff testified to by opposing sides during the hearings before Special Master Maris, which culminated in the 1967 Supreme Court Decree, are in quite close agreement, and would seem a sound basis upon which to set an average that could be agreed upon by the Great Lakes users. A strong argument could be made that the runoff used in accounting for the Chicago diversion should not be greater than that which occurred at the time of the diversion (about 1900). Any increase in runoff caused by urbanization should not be assessed against the people within that area. However, for this report, the value of 550 cfs is proposed.

A storm water runoff simulation for the lake diversion area was prepared for the Illinois Department of Transportation in 1977.[5] In the simulation, daily rainfall records from ten gauges in the diversion area were inputted for the 25 year period 1951 to 1975. The model was calibrated by comparison of predicted runoff and actual runoff as measured by the USGS at its permanent stream gauging stations in Niles and South Holland.* The watershed was subdivided into previous (vegetated and opend land) and impervious (streets, parking lots, roofs, etc.) areas, since each responds differently to the same hydrometeorological input.

In order to extend their runoff data file for the present report, Keifer & Associates, Inc., utilized the results of that 25-year analysis to develop a relationship between precipitation at the official U.S. Weather Bureau Gauge in Chicago and runoff from the drainage area formerly tributary to Lake Michigan. Figure 6 shows the average annual run-

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5. Illinois Department of Transportation, *Storm Runoff Simulation for the Lake Diversion Area,* by Keifer & Associates, Inc., Chicago, 1977.

*Note: The United States Geological Survey maintains permanent stream gauging stations (part of a nationwide network) at Niles and South Holland, Illinois. At each station a water-stage recorder continuously records water depth or stage. A stage-discharge relationship is used to calculate stream flow. Each year a report is published showing the mean flows every day of the preceding year for each gauge. The Niles gauge measures flows on the North Branch of the Chicago River. Its drainage area is the northern 100 square miles of the 673-square mile diversion area. The South Holland gauge is on the Little Calumet River. Its drainage area is the southern 205 square miles of the diversion area.

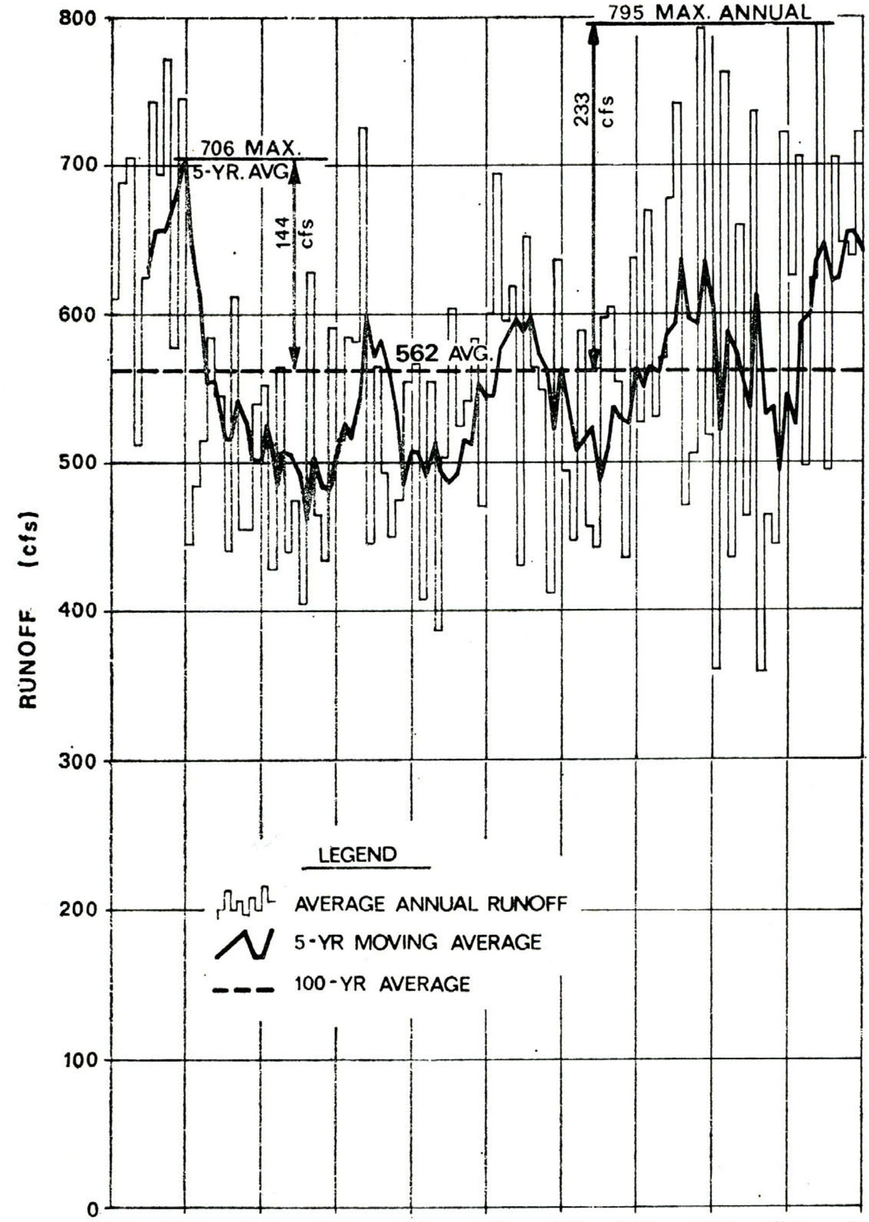


Figure 6. Increased Availability of Water for Allocation by Using Annual 5-Year Moving Average and 100-Year Average Values of Runoff

off as determined from this relationship for a repeat of the 100 years of recorded precipitation from 1876 to 1975, assuming land use conditions as they existed in 1970. The wide variations in average runoff, from a low of 360 cfs to a high of 795 cfs, is evident from the figure. The inability to predict such variation for any future period is obvious.

The 1967 Supreme Court decree established a 5-year moving average period for meeting the 3,200 cfs diversion limit, with the maximum single year not to exceed 3,520 cfs. The 5-year moving average of runoff is also shown in Figure 6. It has varied between a high of 706 cfs and a low of 462 cfs. Thus, in order to assure meeting the diversion limits, based upon historical records, diversion waters totaling 706 cfs or greater have to be reserved for stormwater runoff, thus not being available for other uses.

The actual way in which discretionary use of the water is controlled also illustrates the problem of having a major unpredictable, uncontrollable element in the diversion accounting formula. Since the accounting period ends in February, discretionary diversion of Lake water into the river system must be withheld until late in the fall or winter, when it is reasonably apparent that heavy precipitation will not cause the 5-year average diversion to exceed the limitation. The summer months, when discretionary diversion is most effectively used to improve water quality, are the time when such water must be withheld.

Once again on Figure 6, the average of 100 years of runoff is shown, having a value of 562 cfs. If this quantity were used instead of the 5-year moving average to account for storm runoff flows, an additional 144 cfs of discretionary diversion would be available for use where and when it is most needed.

The benefit of this change is best observed when all of the uses of Lake Michigan water are compared under the existing proposed accounting procedures. Figure 7 shows the projected uses of Lake Michigan water when the maximum historic 5-year moving average stormwater runoff must be reserved. As can be seen, the current users of Lake Michigan water will require slightly more water as time passes. Beginning in 1979, allocations are made to new applicants who have no realistic alternative source. This causes a substantial change in domestic water use, which is the highest priority use.

If the water quality standards which were set in 1973 by the Federal government and the State of Illinois are to be met, discretionary dilution must be diverted from the Lake, in addition to lockages, leakages and navigational makeup water that already is diverted directly. The sum of all of these direct diversions is shown in Figure 7, which illustrates the dramatic reductions in the need for diluted water as major pollution abatement facilities are completed. Chapter I briefly discusses these facilities.

Also shown on Figure 7 is the 706 cfs that must be reserved from the allocation for a 5-year moving average stormwater runoff. This flow cannot be included in the dilution flows because it occurs in large surges of short duration and in uncontrollable times and places.

As becomes apparent in Figure 7, from the present to 1986, the water quality standards cannot be met with the present diversion limitation of 3,200 cfs. Also, beginning in about 1998, domestic demand has increased to the point where water quality standards may be contravened. Furthermore, under the present accounting procedures, once an entity is granted an allocation it cannot be withdrawn at a later date. Reserving the maximum 5-year moving average storm runoff of 706 cfs would preclude the allocation of

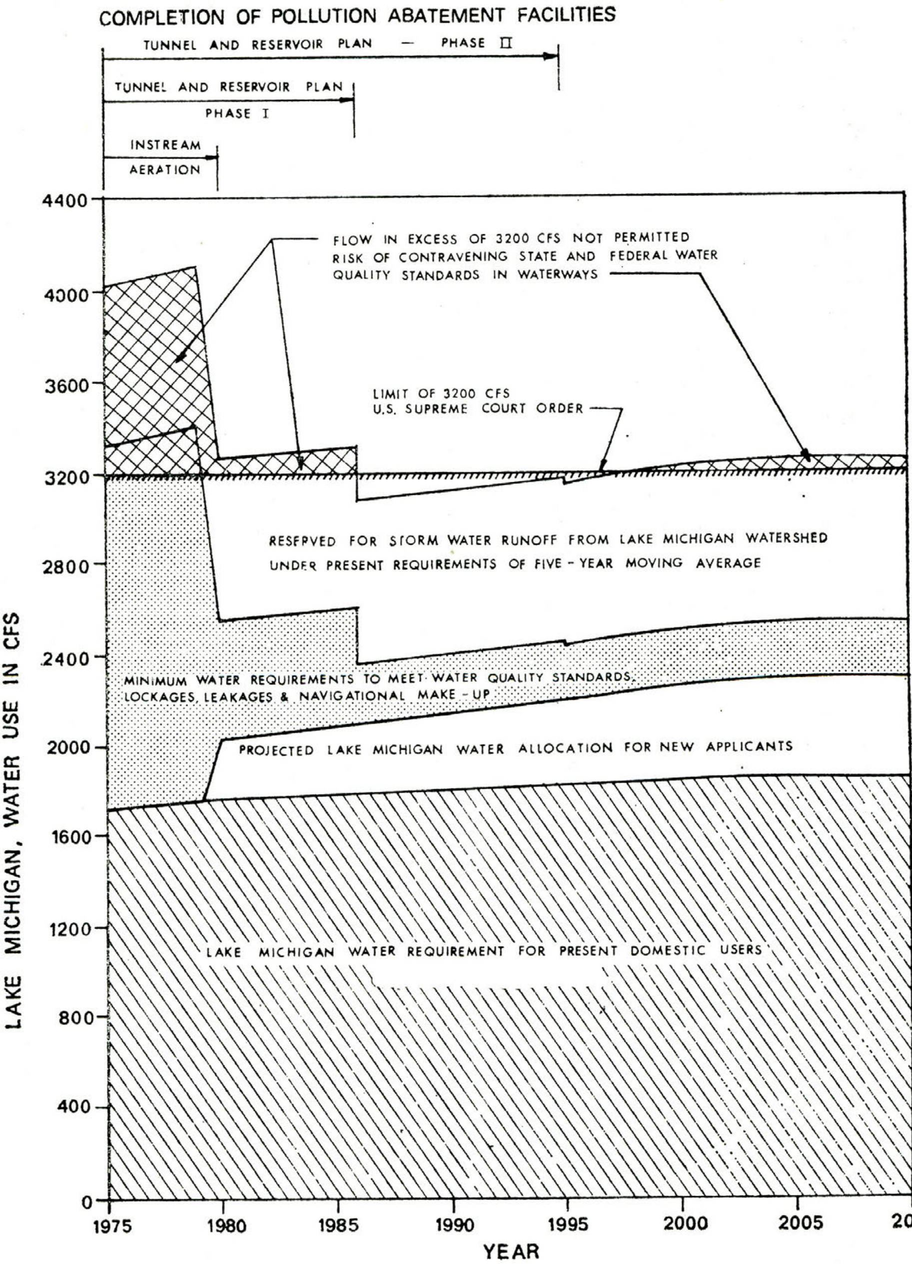


Figure 7. Projected Lake Michigan Water Using Five-Year Moving Average For Storm Water Runoff

water to all of the domestic users needing it and/or for use in maintaining water quality standards. Thus, an important shortage of diversion water is indicated.

Figure 8 is similar to Figure 7, except that the reserve for stormwater runoff has been fixed at 550 cfs, a reasonable figure based upon the analyses performed by various parties and discussed previously. As is shown, beginning in 1980, when the in-stream aeration is completed, water quality standards can be met, and additional water would be available within the 3,200 cfs limit to satisfy unforeseen needs.

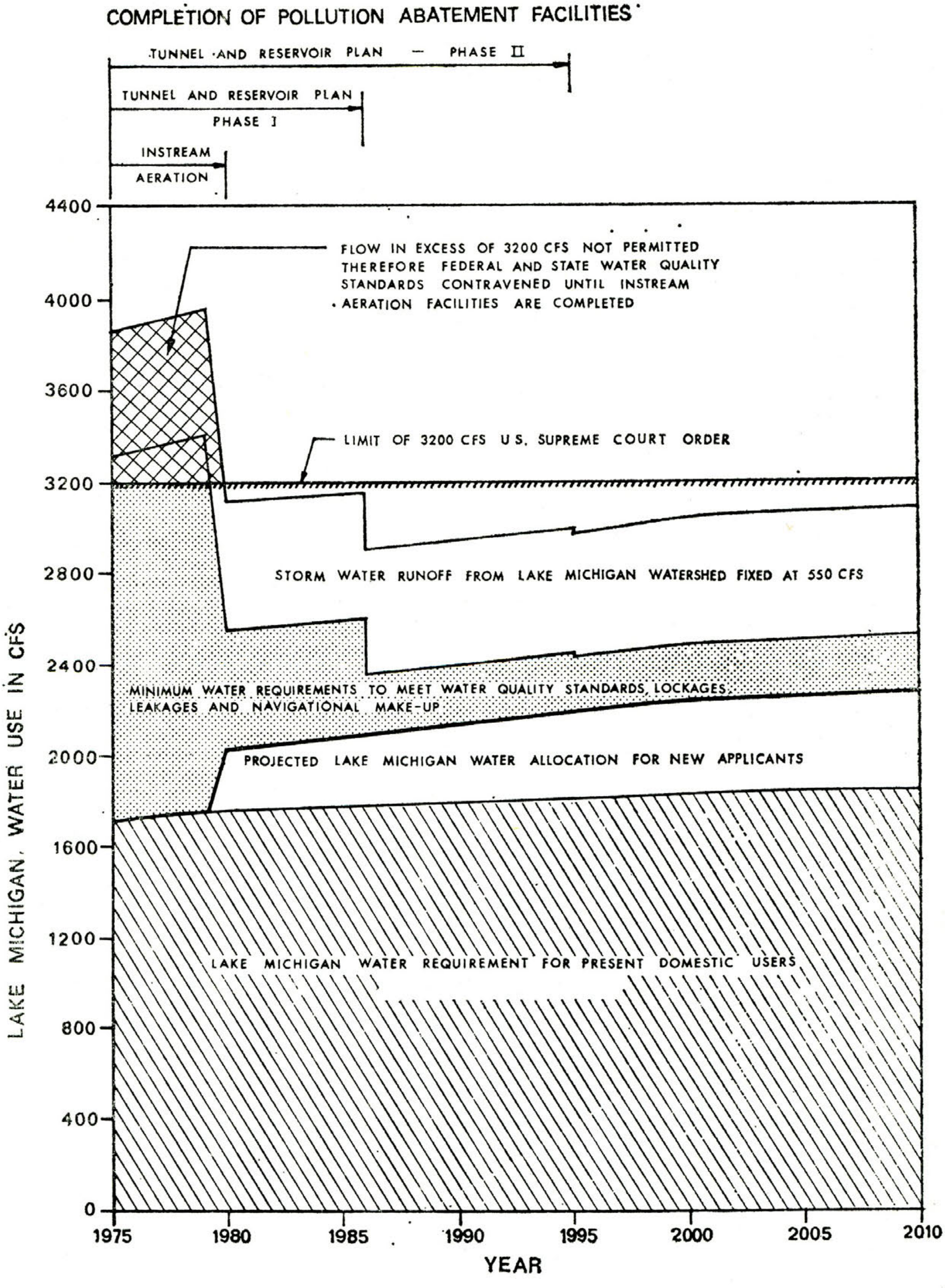


Figure 8. Projected Lake Michigan Water Use With Fixed Storm Water Runoff

CHAPTER III

THE ACCOUNTING SYSTEM THAT ILLINOIS IS REQUIRED TO USE IN MEASURING THE LAKE MICHIGAN DIVERSION PREVENTS THE STATE FROM MAKING THE BEST, MOST EFFICIENT USE OF LAKE MICHIGAN WATER.

The 1967 Supreme Court decree specifies the method of accounting that is to be used to determine the quantity of diverted Lake Michigan water. The steps that are required can be summarized as follows:

1. Determine the total flow which passes through the Sanitary and Ship Canal at Lockport.
2. Deduct from the Lockport flow the total amount of domestic pumpage from Lake Michigan that is diverted through the canal.
3. Deduct the total domestic pumpage from ground sources inside the Lake Michigan watershed that is diverted through the canal.
4. Deduct the total domestic pumpage from outside the Lake Michigan watershed that reaches the canal above Lockport.
5. Deduct the total estimated stormwater runoff from the Illinois River Watershed reaching the canal.
6. Deduct the total domestic pumpage from Indiana or Wisconsin that is diverted through the canal.
7. Deduct the water diverted by Illinois into Lake Michigan from outside the Lake Michigan watershed.
8. Add the total amount of domestic pumpage from Lake Michigan that is diverted through the canal.

The reason that domestic pumpage from Lake Michigan is first deducted, then added back into the diversion flows (Steps 2 and 8) is that the 1930 Supreme Court decree placed no limit on domestic pumpage; thus it was subtracted from Lockport flows. The 1967 decree simply added these flows back into the diversion to be limited.

Flow Measurement At Lockport

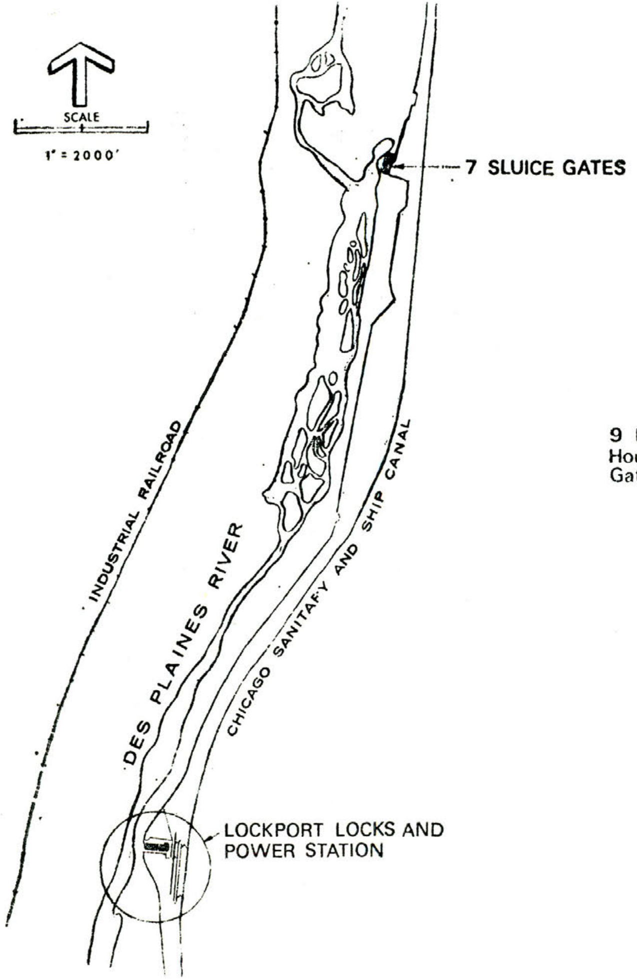
The measurement of "the total flow of the canal at Lockport," which is the most important of the steps in accounting, bears some discussion. Figure 9 shows the locations of the measuring points in the Sanitary and Ship Canal at Lockport. There are a total of eight locations at Lockport where flows must be measured on a daily basis to determine the total flow. The "total flow at Lockport" contains the following elements:[1, 2]

Turbines 1 and 2, Turbine 5, Exciters—These components of the power generation facilities in the power house are used more or less continuously. Turbines 1 and 2 are 127 inches in diameter, can generate 7,500 KVA each and were installed in 1935. Turbine 5 is the only remaining of the original seven 4000 KVA units that were installed in 1907.

The flows for the turbines are determined from the metered power outlet using rating curves supplied by manufacturers. The curves were developed based upon model studies. The flow through the two water driven exciters is determined from a table, based upon the head and the

1. Adhoc Committee of the Illinois Water Resources Commission, *Investigation of Options for Increasing Use Efficiency of Lake Michigan Diversion Water,* 1976.

2. Metropolitan Sanitary District of Greater Chicago (MSDGC), *Hydraulic Report Manual,* December, 1975.



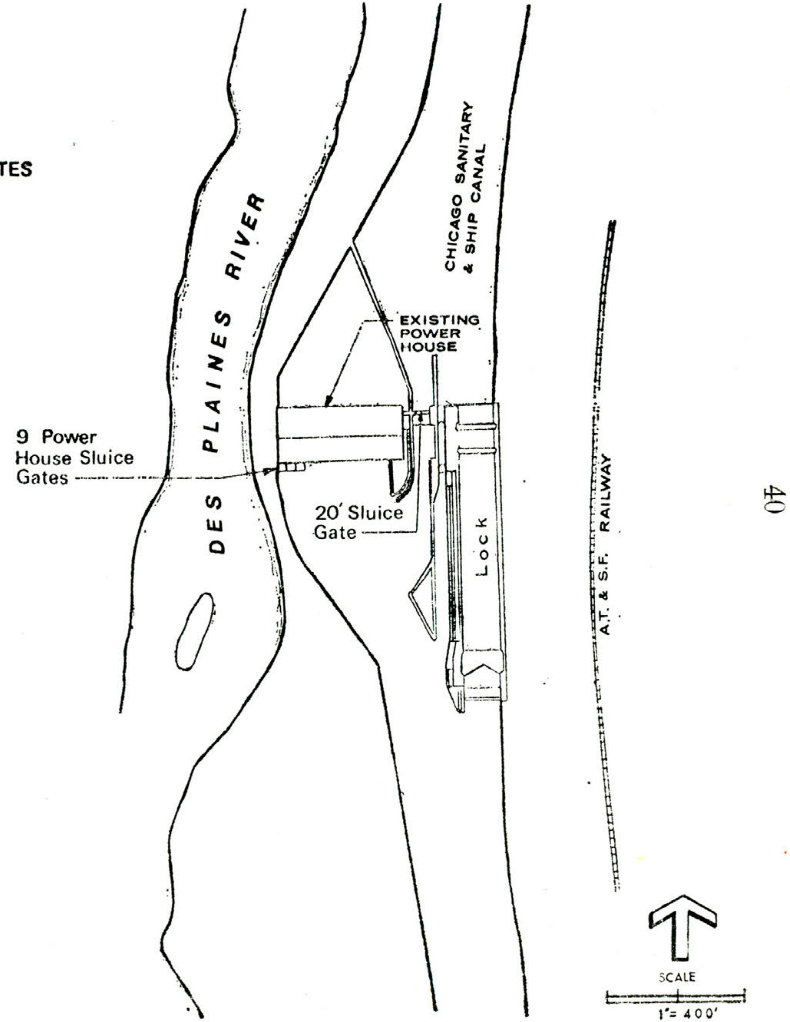


Figure 9. Lockport Controlling Works

amount of power being supplied. The head at the power house varies between 30 and 40 feet. Accuracy of these measurements is purported to be ±5%.

Powerhouse Sluice Gates—These nine gates were installed in draft tubes for three of the original turbines. They are used intermittently to pass excess flows.

The flow is calculated from head-discharge rating curves developed from model tests run at the University of Illinois. The accuracy of the curves is purported to be ±5%.

Leakages—Leakage through the gates of the U.S. Government locks occurs because of the water level differential at the gates, which are not completely water tight. A record is kept by the U.S. Army lockmaster to determine leakage from the upstream and downstream gates. Leakage through the locks is calibrated twice each year by determining the change in water volume in the lock when it is full and when it is empty. These measurements are purported to be quite accurate.

Lockages—Lockage is determined from records of the number of times the lock is filled each day, each filling requiring a specific volume of water. The volume is calculated from the upstream and downstream water levels and the area of the lock, 74,725 sq. ft. Lockage is purported to be accurate to ±1%.

Controlling Works Sluice Gates—Seven sluice gates are located about 2 miles upstream from the Lockport locks to allow passage of large flows caused by heavy runoff in the drainage basin from the canal to the Des Plaines River. Each gate is 30 feet wide and approximately 16 feet high and is capable of discharging 1500 to 4500 cfs, depending on the level of the canal. A head-discharge relationship for each gate is used to measure flows. The accuracy of the measurement is purported to be within ±10%.

Industrial—Flows used at two oil refineries and for cooling water at Argonne National Laboratory are withdrawn from the canal and metered. These flows are either lost to evaporation or are discharged to the Des Plaines River or its tributaries, and thus do not pass through the canal at Lockport.

The relative magnitudes of these various flows during the accounting year from March 1975 through February 1976 is shown in Figure 10. The major fluctuations in total flow are apparent from the figure, as is the variability of most elements that make it up. The accuracy of each of the elements has been estimated, and the accuracy of the total flow measurement is purported to be ±4%.

The wide fluctuations in flow, shown in Figure 10, to a very large extent are due to stormwater runoff.

Deductions from Measured Flow for NonDiversion Water

Figure 11 shows the same total measured flow at Lockport as developed on Figure 10. The deductions shown in the figure are comprised of several elements as described in the following paragraphs.

Domestic pumpage from ground sources inside and outside the Lake Michigan watershed is deducted. This deduction is probably measured at the sources quite accurately.

Stormwater runoff from the Illinois River watershed is measured in several ways. Flows from a pump station that transfers water from the Des Plaines River watershed into the diversion area and pumpage from a small completed portion of the Tunnel and Reservoir Plan are measured. Flows from drainage areas tributary to the Sanitary and Ship Canal, but which drained to the Des Plaines River in the past, are estimated by comparison with the flow in Hart Ditch, which is judged to have a drainage area simi-

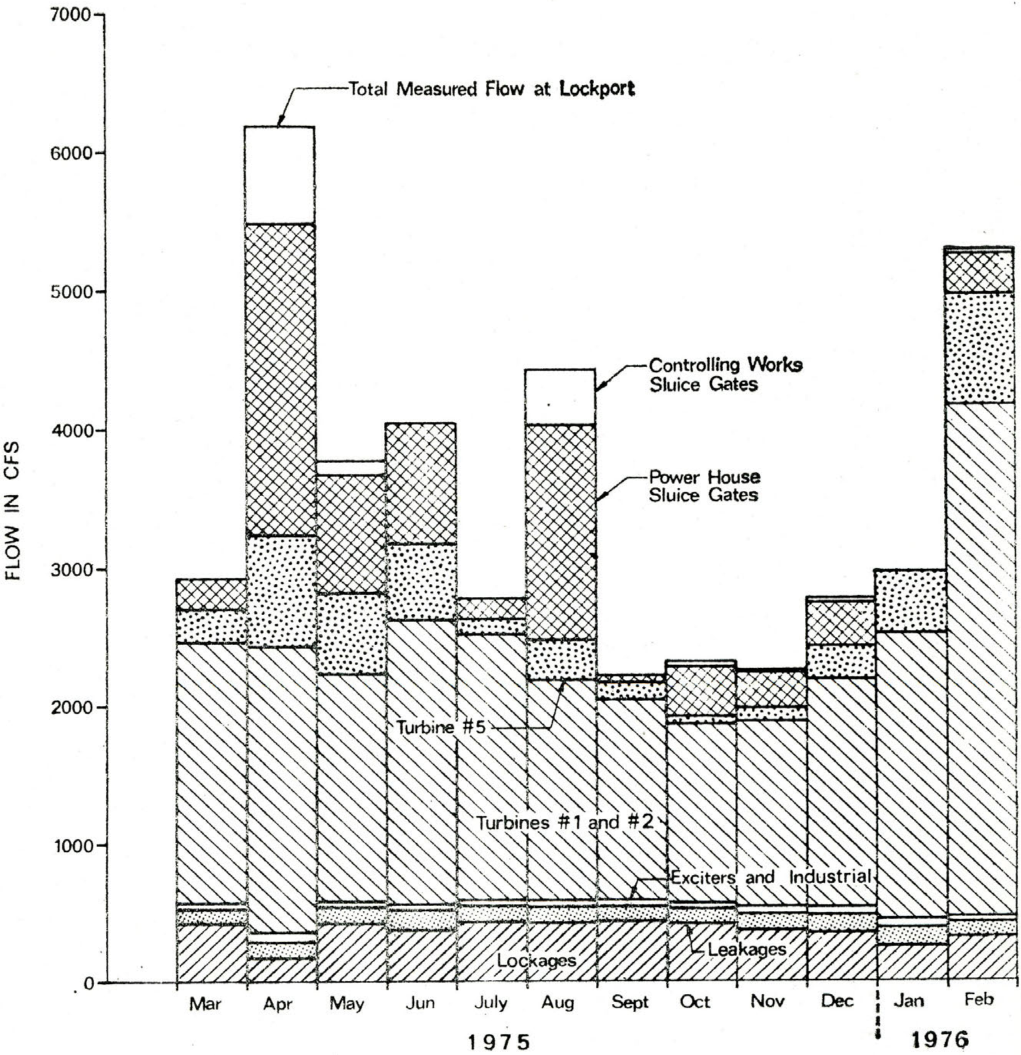


Figure 10. Breakdown Showing Relative Magnitude of Lockport Measurements

lar to part of the watershed. Some inaccuracies are inherent in this assumption because Hart Ditch is in an urbanizing watershed, whereas the area it is used to simulate is largely permanent open space and because the two areas are far enough apart to have significantly different precipitation.

A relatively small quantity of domestic pumpage from six communities in Indiana enters the Grand Calumet River and at times is transported westward with river flows and thus passes through Lockport.[3] This is not considered diversion subject to the decree, and thus it is measured and deducted from Lockport flows.

Subtracting the deductions discussed above from the total measured flow at Lockport gives the monthly variation of diversion flows shown in Figure 11. In order to arrive at a 5-year moving average diversion of 3200 cfs, the flow for the water year 1975 amounted to 3110 cfs.

Inadequacies of the Present Accounting Method

The problems associated with the present method of accounting for diversion at Chicago are demonstrated by the results of attempts to determine runoff quantities using measurements at Lockport.

To determine the monthly values of stormwater runoff, the Lake Michigan pumpage entering the canal is first subtracted from the monthly diversion flows. This gives the combined direct diversion and stormwater runoff. If the total direct diversion of Lake Michigan water entering the canal system through Wilmette, the Chicago River Controlling Works and the O'Brien Locks is then subtracted, the value remaining would be the stormwater runoff. (This latter subtraction is not shown on Figure 11.)

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3. *Ibid.*

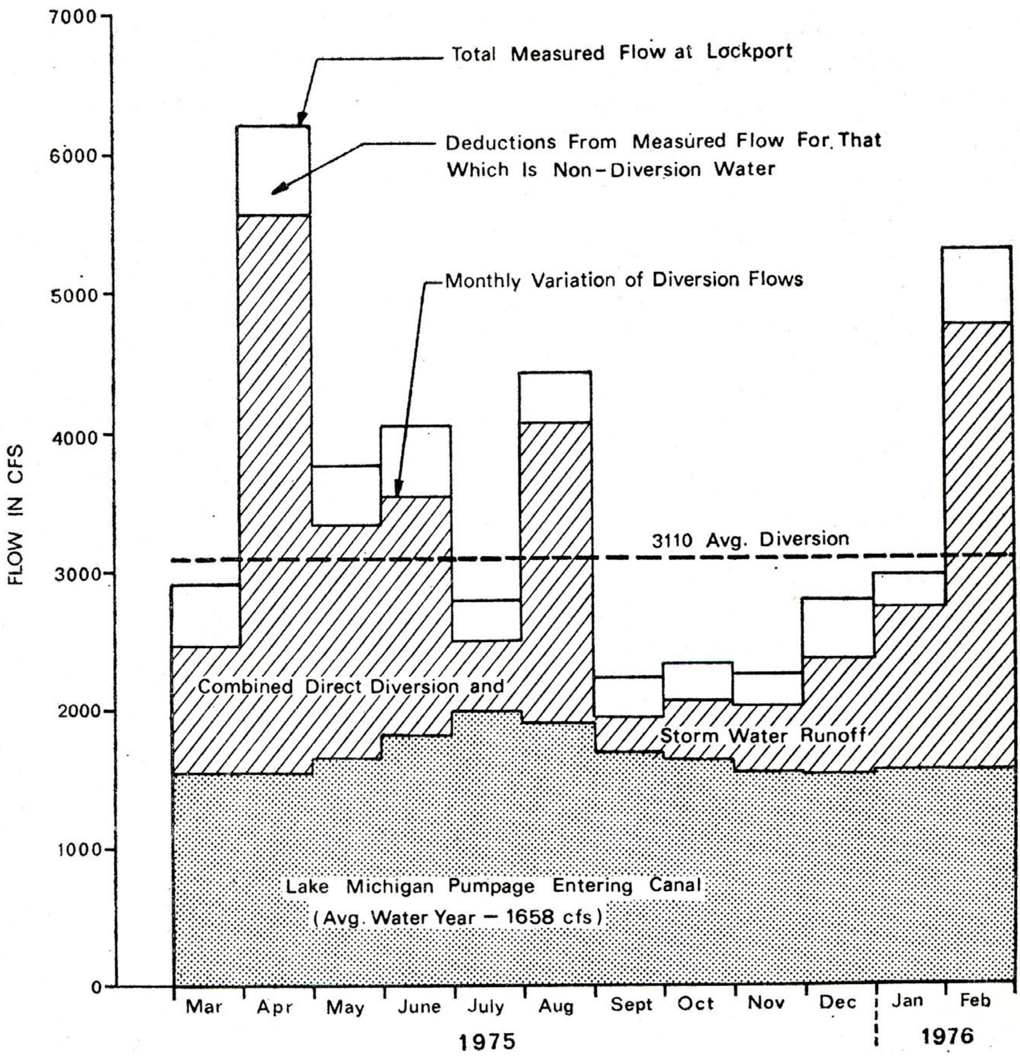

Figure 11. Monthly Variations of Diversion After Subtraction of Non-Diversion Water

This method was used to estimate stormwater runoff for each month in the period 1966 through 1974.[4] Of the 108 months in this period, runoff values were calculated as negative in nine months and zero in five months. Runoff was calculated as less than the sum of that recorded at the Niles and South Holland gauging stations of the USGS, which measure flow from only about half the watershed,* a total of 29 months, or 27 percent of the time. In order for the calculated runoff to be correct, the contribution from the heavily impervious central portion of the diversion area (including most of the City of Chicago) would have had to be negative.

During these same nine years the calendar year average flow is 552 cfs, which agrees closely with the other estimates shown in Table 1, page 29. The high incidence of obvious errors in the monthly figures, however, is indicative of deficiencies in the accounting method.

It is known that high Lake Michigan levels cause reversal of the flow in the Grand Calumet River, resulting in Lake Michigan water passing through Lockport.[5] This flow is not measured and thus would be included in the stormwater runoff as determined in the method just described. This flow would result in even larger errors in this method.

Construction of new facilities that are planned or underway will vastly further complicate the determination of diversion using measurement at Lockport.

Beginning in 1979 it is planned that newly allocated diversion water will be entering 18 communities in the Des

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4. MSDGC, *Lake Diversion Testimony Technical Reports*, R1075LD2, Table 6, 1975.

5. IDOT, *Opinion and Order*, at 38.

*See note, p. 22

Plaines River basin (see Figure 2) or further west in the DuPage River basin. This water will not flow past Lockport, and thus would have to be added to the Lockport flows if the present accounting method is used in the future.

The Tunnel and Reservoir Plan, previously described in Chapter I and Figure 4, will result in water from the Des Plaines River basin mixing with water from the diversion area at a large number of points along the tunnel system. The area outside the diversion area which will become tributary to the Sanitary and Ship Canal, and flows from which will pass through Lockport, is shown in Figure 12. The determination of runoff from this new tributary area will be extremely difficult, but would be required for deduction from Lockport flows if the present accounting method is used in the future.

Conclusions Regarding Present Accounting Method

The present method of accounting for Chicago diversion requires a number of measurements and estimates of unmeasurable quantities. It is known to be subject to significant error, all of which cannot be assessed.

Construction of future facilities will cause bypass of diversion flows through other streams around Lockport and draining of non-diverted flows through Lockport.

The inadequacies of the system at the present time, plus the future modifications that would be required, make the present accounting method virtually unworkable. A new accounting method is required.

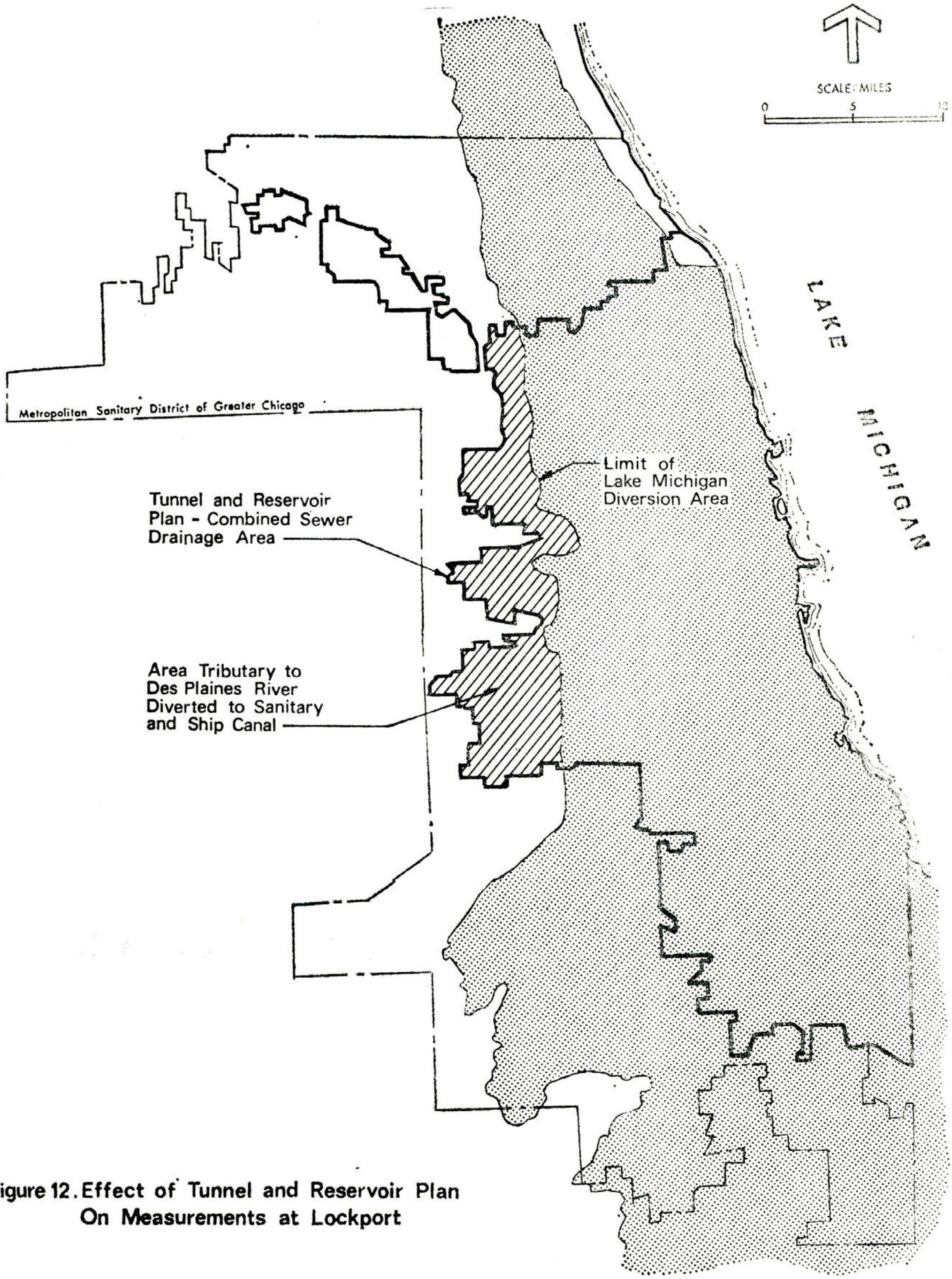

Figure 12. Effect of Tunnel and Reservoir Plan On Measurements at Lockport

CHAPTER IV

THE MODIFICATIONS THAT ILLINOIS PROPOSES TO THE ACCOUNTING SYSTEM WILL PERMIT ILLINOIS TO BETTER CONSERVE AND MAINTAIN ITS LAKE MICHIGAN WATER.

The 1967 Supreme Court decree contains provision for requesting a modification of the diversion limit. It is not the intention of Illinois at this time to request an increase in the diversion amount beyond the present limit of 3200 cfs.

It is proposed, however, that the stormwater runoff be fixed at an average rate of 550 cfs for accounting purposes. The 550 cfs would include surface runoff, storm sewer flows, and infiltration and inflow to sanitary sewers from the 673 square-mile diversion area, as well as some minor flows which are difficult to measure.

Fixing the stormwater runoff would also allow other important changes to be made in the accounting system. Measurements of all of the diverted quantities could be made at the points where they leave the lake. Figure 13 shows a reporting system that will be suitable for the proposed accounting method but will not change the institutional procedures now in effect.

Measurement Of Diverted Flows

Figure 14 locates each of the entities withdrawing water from Lake Michigan for domestic water supply. Each of these entities would be responsible for measuring flows at their intake or treatment facilities, a practice that is followed in any case, and reporting the flows to a central agency, the MSDGC. Such measurement of flows can be done very accurately.

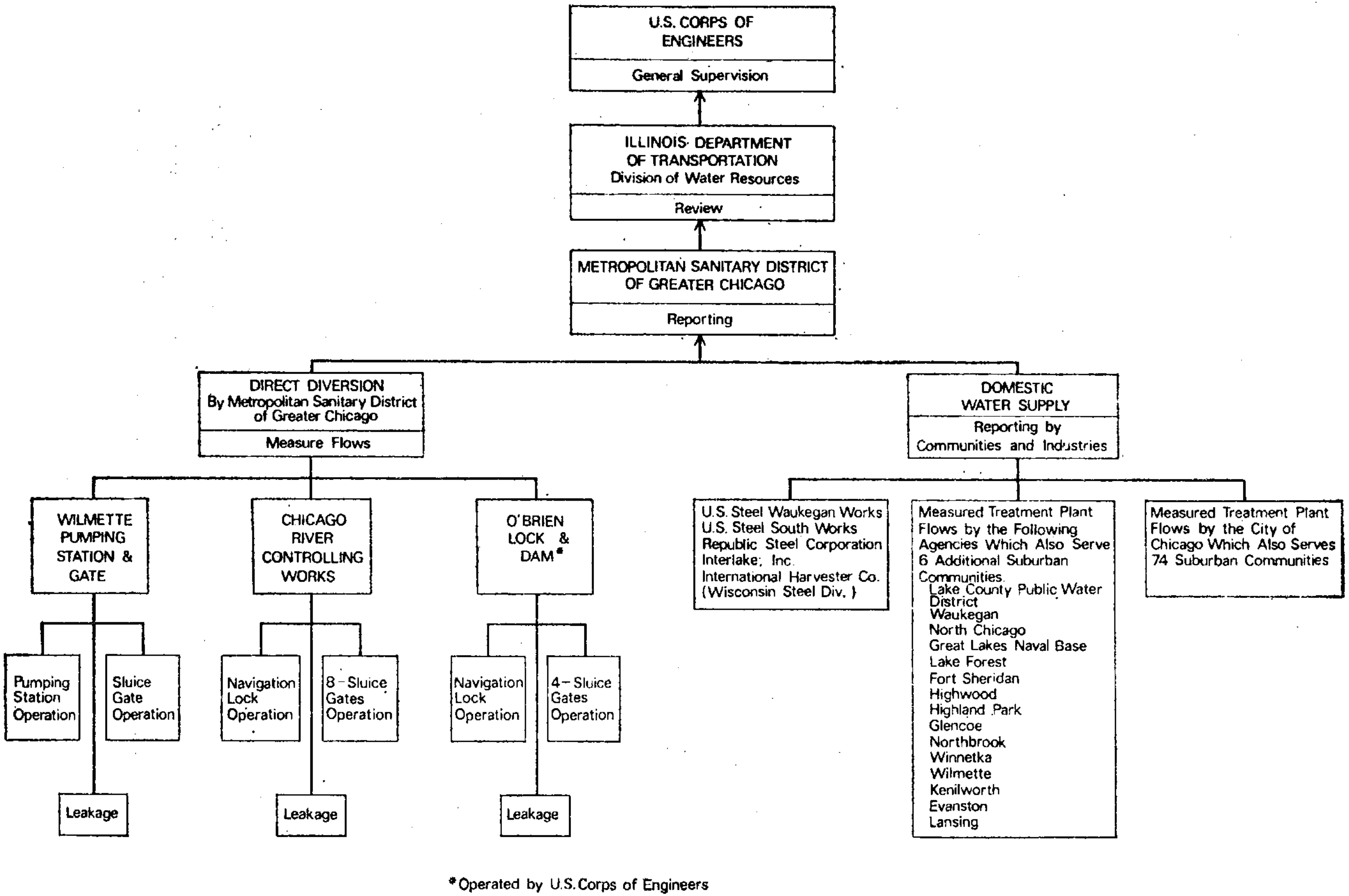

Figure 13. Reporting Method of Lake Diversion Accounting System

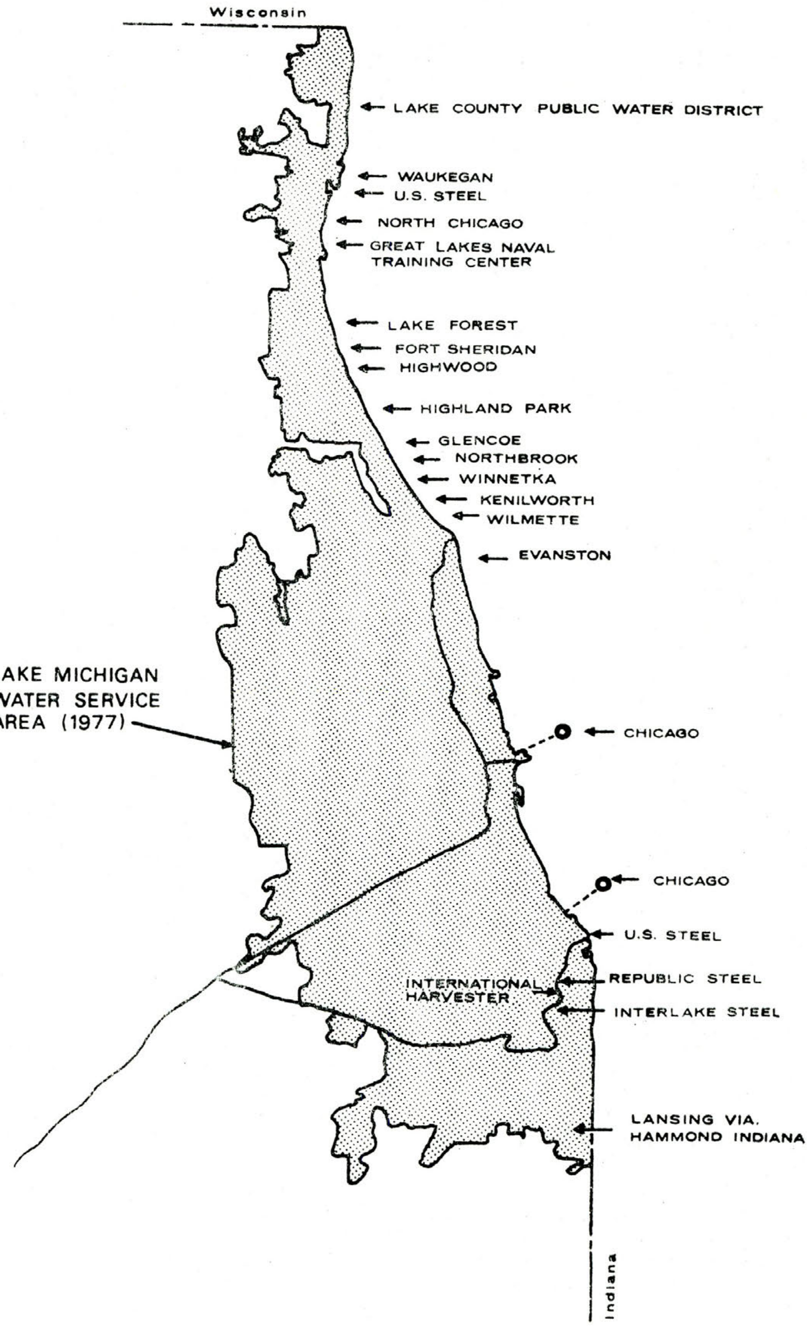

Figure 14. Lake Michigan Water Intakes

Flows should also be measured at the three points where water is diverted directly into the waterways: the Wilmette Pumping Station, the Chicago River Controlling Works, and the O'Brien Lock and Dam. Figures 15, 16 and 17 illustrate the configuration of these three diversion points.

The Wilmette Pumping Station originally included a pumping station in parallel with a lock. The lock has been replaced by a 32-foot wide sluice gate that can be raised high enough for small boats to travel between Lake Michigan and the North Shore Channel. Four turbine pumps are available during periods of low lake level to pump water into the channel. During high lake levels there is excessive leakage through the pumps, which is somewhat rectified by inserting metal plates in screen chambers upstream of the pumps.

It is suggested that a low dam be placed as shown in Figure 15 to prevent high Lake Michigan waters from leaking through the pump tubes. The pumps should easily handle the increased head required to pump water over the dam and the dam will not interfere with boat access through the sluice gate.

Accounting of flows would be accomplished by recording Lake Michigan and North Shore Channel levels, the operation of each pump, and operation of the sluice gate.

At the mouth of the Chicago River, shown in Figure 16, is a single lock that is used for both commerical and recreational boats. There are two sets of four 10-foot by 10-foot sluice gates to regulate flows into or, in the event of very high river levels, out of the river system. A long wall, through which some minor leakage may occur, separates the Lake Michigan harbor from the Chicago River.

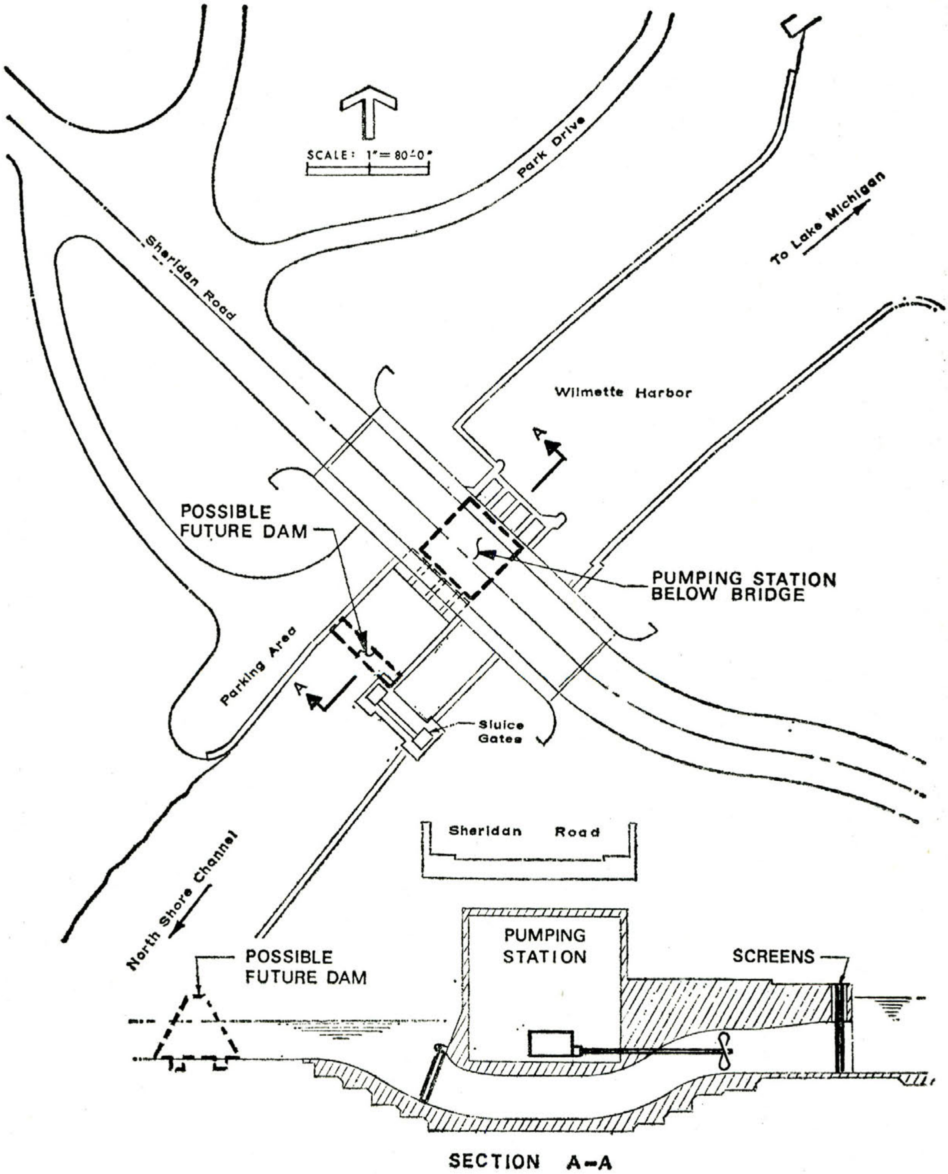

Figure 15. Wilmette Pumping Station

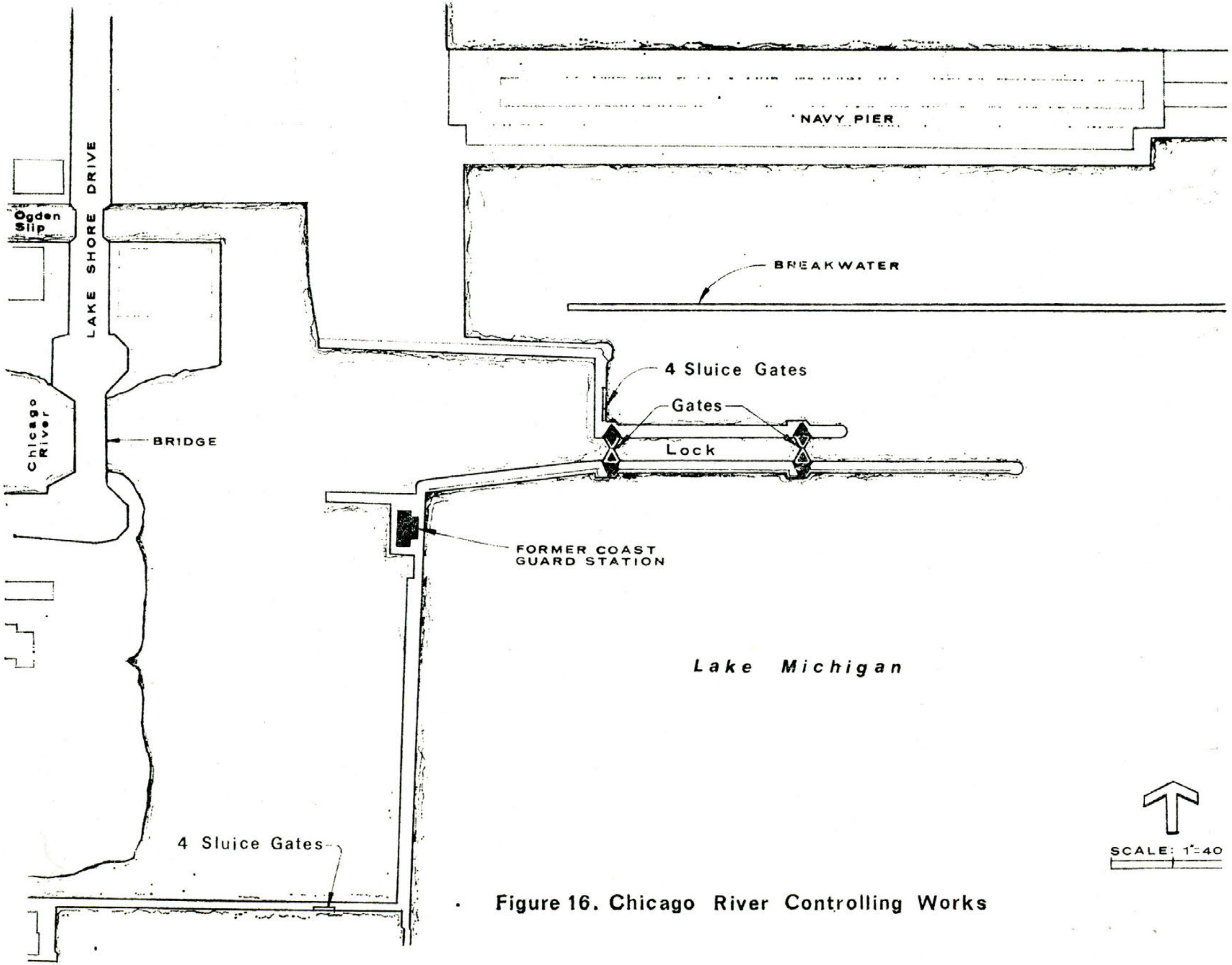

Figure 16. Chicago River Controlling Works

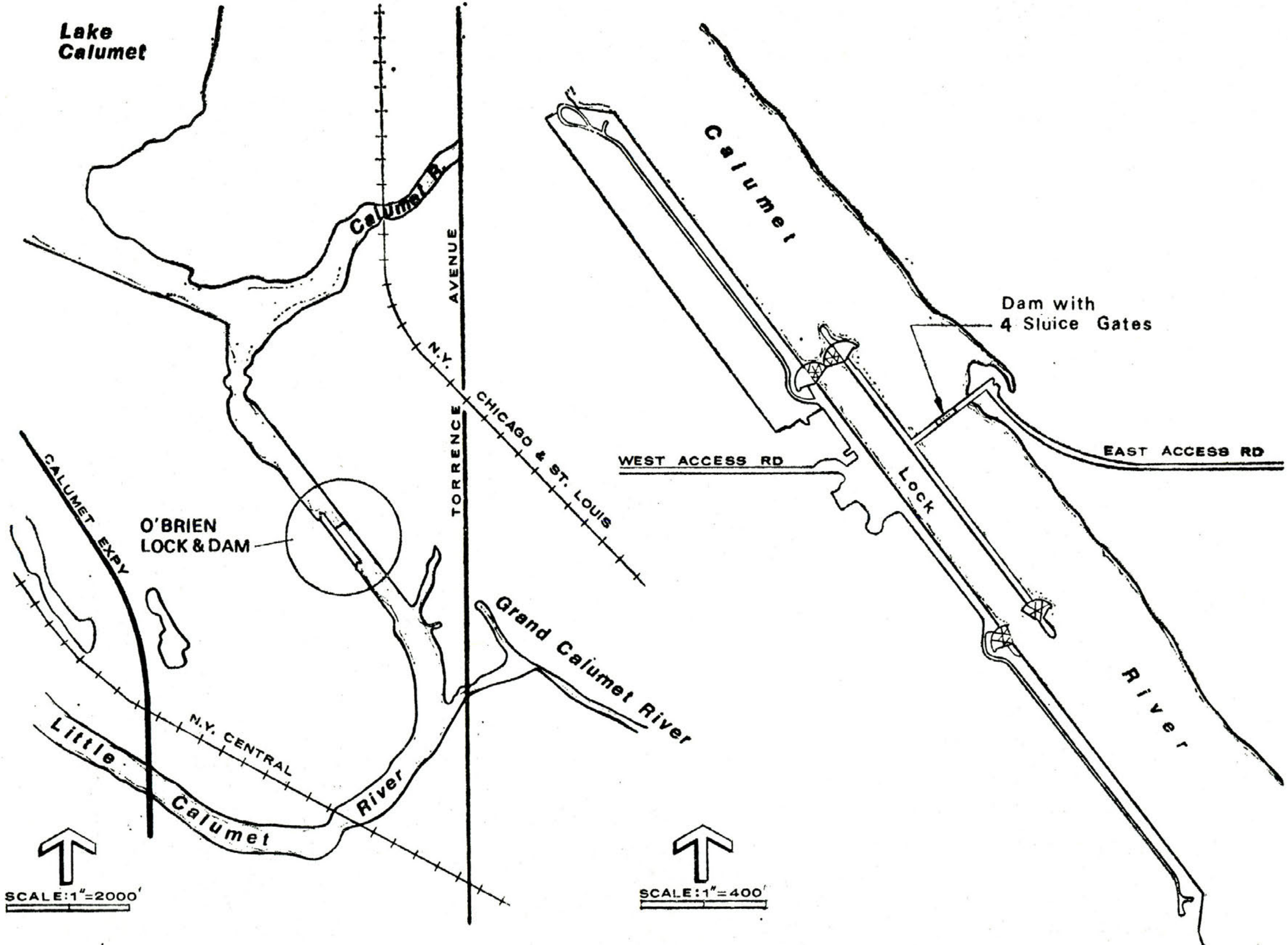

Figure 17. O'Brien Lock And Dam

Flows could be accounted for by calibrating the locks and sluice gates, measuring leakages through them periodically, and testing a representative section of the wall to determine leakage, if any. Recording the Lake and river levels, the number of lockages and the operation of the eight sluice gates would provide the data necessary to determine the flow. These records are being kept at the present time.

The O'Brien Lock and Dam is illustrated in Figure 17. Four 10-foot by 10-foot sluice gates allow waters to flow through the dam. Accounting of flows would require recording the Calumet River levels on either side of the dam and lock and monitoring lock and sluice gate operation. Leakage through the lock and sluice gates would have to be calibrated. Again, much of this data is presently being recorded.

Automation can replace many of the time-consuming hand measuring and reporting procedures now employed. The Illinois Department of Transportation, Division of Water Resources, could certify the calibration of each of the measurements periodically.

Minor Accounting Factors

Four relatively minor items should be addressed to provide for a straightforward and accurate system of accounting for Chicago diversion flows.

Grand Calumet River

The only modification of the waterways required to utilize the proposed accounting method is construction of a dam in the Grand Calumet River to eliminate diversion of Lake Michigan water into Illinois from Indiana. This dam has previously been found feasible and was once scheduled for construction, but was not built.

Three of the items involve some flows which are very difficult to account for. It is proposed that the State of Illinois initially quantify these flows or otherwise account for them to the satisfaction of the U.S. Army Corps of Engineers at the time of the change in diversion accounting procedures, and that they be considered a part of the fixed average runoff (550 cfs) or the domestic flows for Chicago diversion accounting.

Little Calumet River

The Little Calumet River has a summit just east of the Indiana-Illinois state line. Water entering the river east of the summit flows eastward and through Burns Ditch into Lake Michigan. Flow entering west of the summit is tributary to the Illinois Waterway and is presently measured at Lockport. Hart Ditch, a tributary stream to the Little Calumet River, enters west of the summit, and therefore is part of the 673 square-mile diversion area.

In times of storms, however, Hart Ditch flows split, part flowing east to Lake Michigan. The U.S. Army Corps of Engineers[1] has estimated that of the total annual flow, 90 percent flows westward into Illinois. Thus, 10 percent, or approximately six cfs, on an annual basis, flows to Lake Michigan.

Since construction of the Burns Ditch in 1926, the flow has been dividing in the above manner. Therefore, because of the difficulty in accurately measuring such flow, we suggest that this small discharge be considered as a part of the fixed runoff of 550 cfs for accounting purposes.

North Shore Sanitary District

Infiltration and inflow into sanitary sewers in the area tributary to the North Shore Sanitary District treatment

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1. U.S. Army Corps Engineers, ***Interim Review Report, Little Calumet River Indiana,*** December 1973, page F24.

facilities on the Des Plaines River results in the diversion of a small amount of runoff which does not flow through Lockport. This flow is now estimated to be approximately 14 cfs. Planned improvements will reduce its quantity. This flow should be considered part of the 550 cfs runoff from the 673 square-mile diversion area.

Consumptive Use of Water

The water pumped directly from Lake Michigan has numerous domestic and industrial uses. Some of these can be classified as consumptive uses. They include water used for the making of exported beverages, lawn sprinkling, etc. This quantity of water is estimated to be in the neighborhood of three percent of the total domestic demand (3% of 1700 cfs is 51 cfs). Since water that is consumptively used is not returned to the Great Lakes by any other municipality in their watershed, it therefore should not be assessed as part of the diversion at Chicago.

By measuring diversion water at the input points, the measured diversion water will include the quantity of water which is consumed. Since when flows are measured at Lockport the consumptively used flows are never accounted for, the actual diversion would be decreased by approximately 51 cfs if the new accounting procedure is adopted.

Inclusion of the consumptive water use in the diversion amount is a necessary result of the recommended modifications to the diversion accounting procedure. It would be accounted for as an unmeasured portion of the domestic and industrial flows from each of the reporting entities.

Summary Of Benefits

The benefits realized by the new accounting system can be summarized very succinctly:

1. Fixing the stormwater runoff at 550 cfs allows use of discretionary dilution water to more effectively maintain water quality in the Illinois waterway.
2. Fixing the stormwater runoff at 550 cfs allows increased domestic use of the diverted waters without increasing the total diversion.
3. Fixing the stormwater runoff at 550 cfs allows the diversion to be measured at the points where water leaves the Lake, resulting in the ability to measure the flow elements, and thus the total flow, more accurately.

CHAPTER V

ILLINOIS' MODIFICATIONS WILL HAVE NO ADVERSE EFFECT ON THE GREAT LAKES OR ON ANY PARTY TO THIS CASE.

Effect On Lake Water Levels

It is essential that the impact of any changes in the Great Lakes basin be closely examined to insure that none of the rights of other lake users are abrogated. The areas of potential impact of changes in water level are hydroelectric power generation, shore erosion damages, commercial navigation and fish, wildlife and recreation. Each of these areas has been studied in detail, and the data presented in previous studies are very useful for projecting the effects of the proposed changes in the Lake Michigan diversion accounting method[1].

To provide a perspective from which to analyze impacts, it is instructive to examine the fluctuations in lake levels which have taken place in the past. Figure 18 shows the levels of Lake Michigan-Huron (which are considered a single lake since their levels are the same), Erie, and Ontario, as they have been recorded over a 100-year period. (Lake Superior is not included since it is not affected directly by levels in the other lakes.) Plotted for comparison is the annual precipitation at the official U.S. Weather Bureau gauge in Chicago.

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1. International Great Lakes Levels Board, *Regulation of Great Lakes Water Levels Series Appendices A-G,* A Report to the International Joint Commission, December 7, 1973.

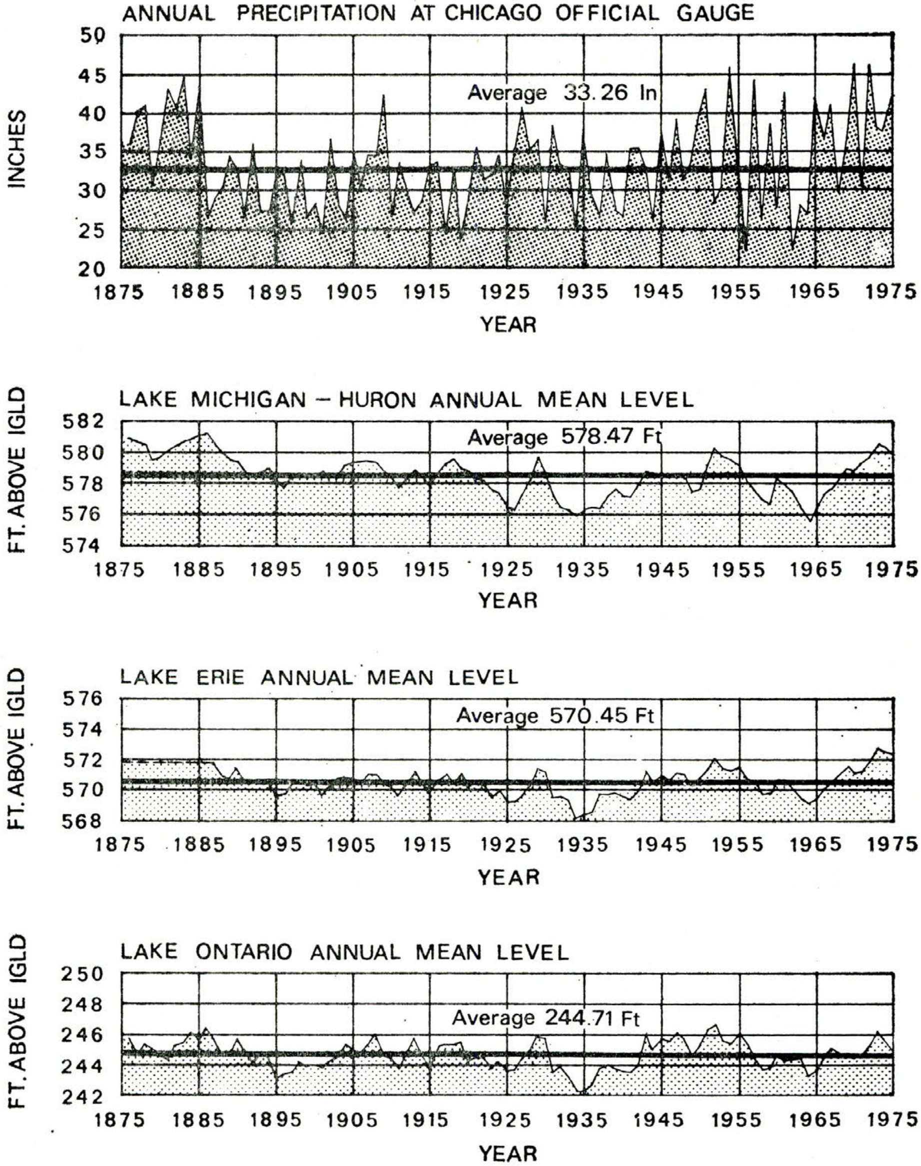

Figure 18. Annual Rainfall at Chicago
Annual Mean Level of the Downstream Lakes

There are many factors affecting lake levels besides precipitation, such as temperature, cloud cover, evaporation, and runoff, all of which must be integrated over the entire drainage basin. Thus it is not surprising that precipitation from a single gauge does not closely correlate, year by year, with lake levels. It can be observed, however, that during prolonged periods of above average precipitation there is a tendency for lake levels to rise, and vice versa. The recent decades indicate this trend. The periods 1945 to 1955 and 1965 to 1975 were generally wetter than average. During each of these decades lake levels tended to be high. On the other hand, during the comparatively dry decade 1955 to 1965, the lake levels were below average.

In order to determine the impact of an action such as manipulating the lake diversion at Chicago, it is necessary to project superimposed variations of lake level on the natural fluctuations.

Computer simulation of the lakes and connecting river systems was used to determine the impacts resulting from the proposed lake diversion accounting method. Lakes Michigan and Huron, Lake Erie and Lake Ontario were considered as large reservoirs through which variations in flow were routed. Conservation of mass dictates that the inflow to any lake minus the outflow equals the change in volume stored. For small changes the change in volume stored is simply the surface area times the change in lake elevation. For purposes of the routing, Michigan and Huron are considered as a single reservoir since there is no perceptible flow restriction between them.

Data on discharge from each lake as a function of the stage in the lake were used, along with the change in lake volume for incremental changes in depth to perform a storage routing through the lakes.[2] For example, Lake Michigan-Huron has had an outlet discharge through the St. Claire River varying from 107,000 cfs to 233,000 cfs as the recorded lake levels varied up to 5.76 feet. Lake Erie's outlet discharge, as determined at a rock ridge in the Niagara River upstream of Niagara Falls and the power station intakes, has ranged from 149,000 cfs to 258,000 cfs with a maximum variation in lake level of 5.06 feet. The discharge of Lake Ontario has varied between 176,000 cfs and 310,000 cfs as the stage varied a maximum of 5.64 ft.

Changing the accounting method used at Chicago to measure diversion will have very minor effects on the Great Lakes over the short term period. This is because by fixing the average annual runoff for accounting purposes, other diversions, primarily discretionary diversion, can be controlled independently of the runoff in any given year or 5-year period. For a wet year, the actual diversion would likely be higher than 3,200 cfs, while for a dry year the actual diversion would likely be less than 3,200 cfs. This appears to be beneficial since it would work in the direction of decreasing lake fluctuations.

Figure 19 illustrates the changes in lake levels due to deviations in computed runoff from the Chicago diversion area from its 100-year average value (562 cfs). These deviations in annual runoff are plotted at the top of the figure and were routed by computer through the lake system to obtain the changes in lake water levels. A less than average annual runoff would normally tend to lower lake water levels but under the proposed accounting method would not; thus a positive incremental change in water level. A higher than average annual runoff would normally

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2. International Great Lakes Levels Board, *Regulations*, Appendix B, Vol. 1, pg. B-76.

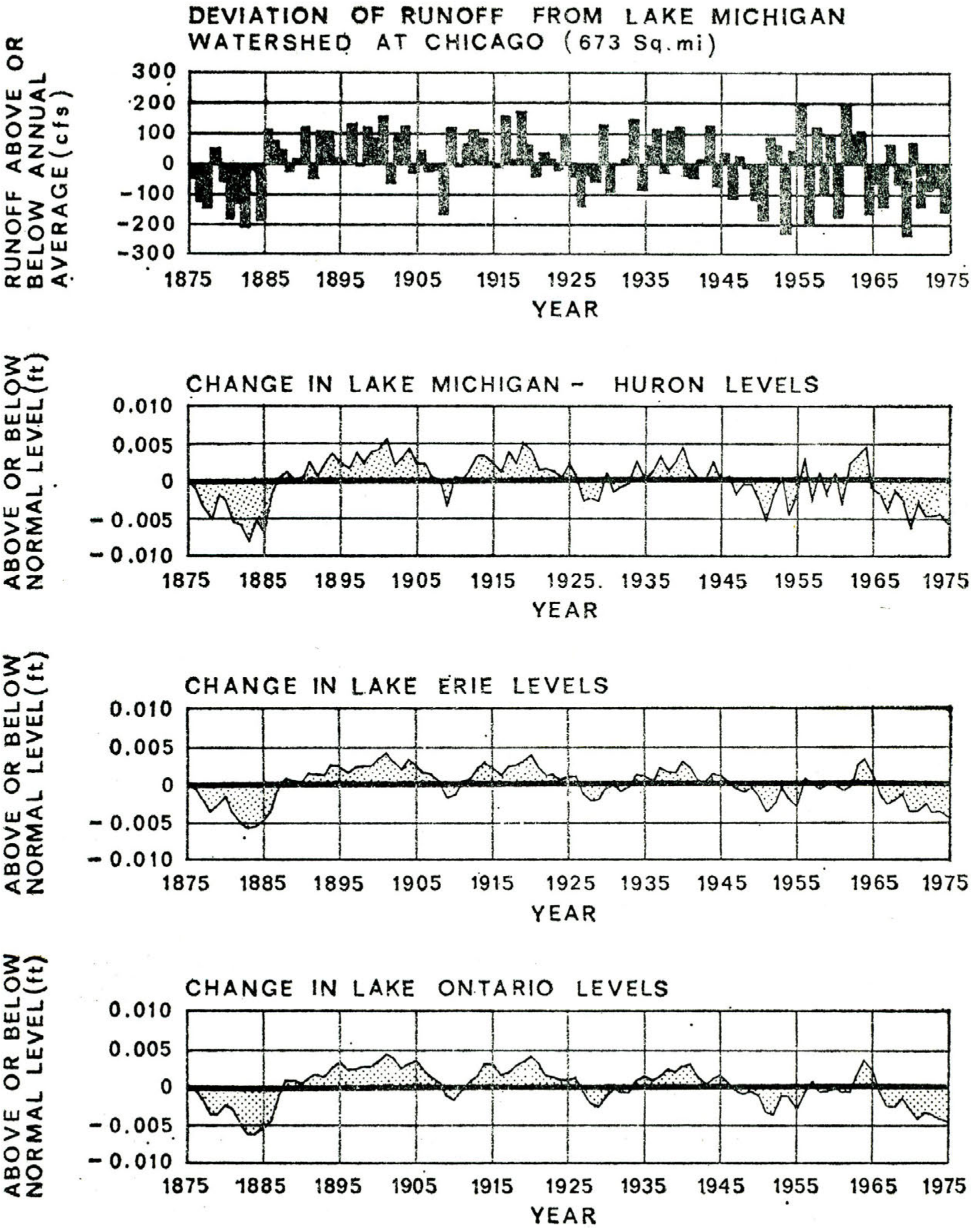

Figure 19. Change in Lake Levels due to Deviation of Runoff from Its 100-Year Average Value

tend to increase water levels, but under the proposed accounting method would not, resulting in a negative incremental change in water level.

The most important result of this analysis is the order of magnitude of the changes caused by deviations in runoff. The greatest induced increase and decrease in the levels of Lake Michigan-Huron are -0.0080 feet and +0.0058 feet, or less than a tenth of an inch variation in actual levels. Similarly, the outflow from the lakes is only affected by values from -151 cfs to +110 cfs, compared with normal flows varying from 107,000 to 233,000 cfs in the Detroit River. This represents a maximum fluctuation of only 0.08 percent of the mean river flow. The other lakes and their outlets will experience similarly insignificant fluctuations due to changes in the Lake Michigan diversion accounting method.

Effect On Hydroelectric Power Generation

The major water use upon which slight changes in water flows in the Great Lakes may impact is for the generation of hydroelectric power. The subject was extensively studied by the International Great Lakes Levels Board and the data generated during these studies were used for this assessment.[3]

As was previously discussed, modification of the Lake Michigan diversion accounting method would result in very small fluctuations in lake levels, with resultant minor fluctuations in lake outlet flows, but would not result in changes in the long-time average lake levels or outlet flows. The impact of these fluctuations can be determined when data are available on the change in power as a function of

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3. International Great Lakes Levels Board, *Regulations,* Appendix F, Power.

water level and flow. Analysis of the data points out that very small changes in lake levels, such as the maximum fluctuations of about .01 feet induced in Lake Erie, have unmeasurably small effects on power generation when each facility has a static head between 80 to 300 feet. Data have been developed, however, on total energy output at the various hydro-electric facilities as a function of flow.[4]

Table 2 shows the impact that changes in flow have on power generation at all of the Great Lakes hydroelectric facilities. Changes in Lake Ontario outlet flows will effect the Robert H. Saunders Generating Station of Ontario Hydro and the Robert Moses Power Dam of the Power Authority of the State of New York. It is assumed that any change in flow will be equally divided between these two facilities. Farther down the St. Lawrence River, in Quebec, are the Cedars Generating Station and the Beauharnois Powerhouse, which also share the total flow of the river in parallel channels. Since the Beauharnois facility is larger and is more significantly effected by changes in flow, it was assumed for this analysis that any fluctuations in flow occur in the Beauharnois input and not in that of the Cedars Station.

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4. *Ibid.*

Table 2

POWER OUTPUT AS A FUNCTION OF FLOW FOR GREAT LAKES HYDROELECTRIC FACILITIES

System and Location	Input Lake	Power vs. Flow (kw/cfs)	Ref.[a]
Ontario Hydro			
St. Lawrence	Ontario[b]	6	Fig. F-34
Niagara	Erie[b]	22	Fig. F-10
Quebec			
Beauharnois	Ontario[c]	7	Fig. F-40
Cedars	Ontario[c]	3	Fig. F-41
Power Authority of the State of New York			
St. Lawrence	Ontario[b]	6	Fig. F-34
Niagara	Erie[b]	26	Fig. F-17, F-28
Four Plants on the St. Mary's River	Superior	—no effect—	

[a]Referred figures are those from Appendix F of *Regulation of Great Lakes Water Levels,* published by International Great Lakes Levels Board, December 7, 1973.

[b]Effects are equally divided on Ontario System and New York State system.

[c]Assume effects on Beauharnois Plant but not on Cedars Plant.

At the outlet of Lake Erie, there are eight hydoelectric power plants on the Canadian side operated by Ontario Hydro, including six on the Niagara River (including a pumping-generating station) and two on the Welland Canal. This total power output versus flow had been previously determined with two curves, one for tourist days when a minimum of 100,000 cfs must be maintained over the Niagara Falls, and another for times when the minimum flow over the falls is reduced to 50,000 cfs. The change in power as a function of flow is, however, the same for either curve.

On the American side at Niagara are the Robert Moses Niagara Power Plant and the Lewiston Pumping Generating Plant, both operated by the Power Authority of the State of New York. Curves were developed for the combined American plants for several different operating modes, depending on the month of the year, and whether it is a weekday or weekend. A weighted average of each time period was developed for this analysis. Table 2 shows the power versus flow values for the combined facilities in each state or province. The hydroelectric facilities at the outlet of Lake Superior were not considered in this analysis since they are separated from any direct effects of Chicago diversion.

A computer analysis was made of the changes in hydroelectric power generation at each system due to changes in flows brought about by changes in lake levels. The changes in lake levels used are those shown in Figure 19. The results of the analysis are shown in Figure 20. The relative magnitude of the induced changes is shown by including the installed capacity of each system for comparison. No change will be induced in the average power generation at any facility.

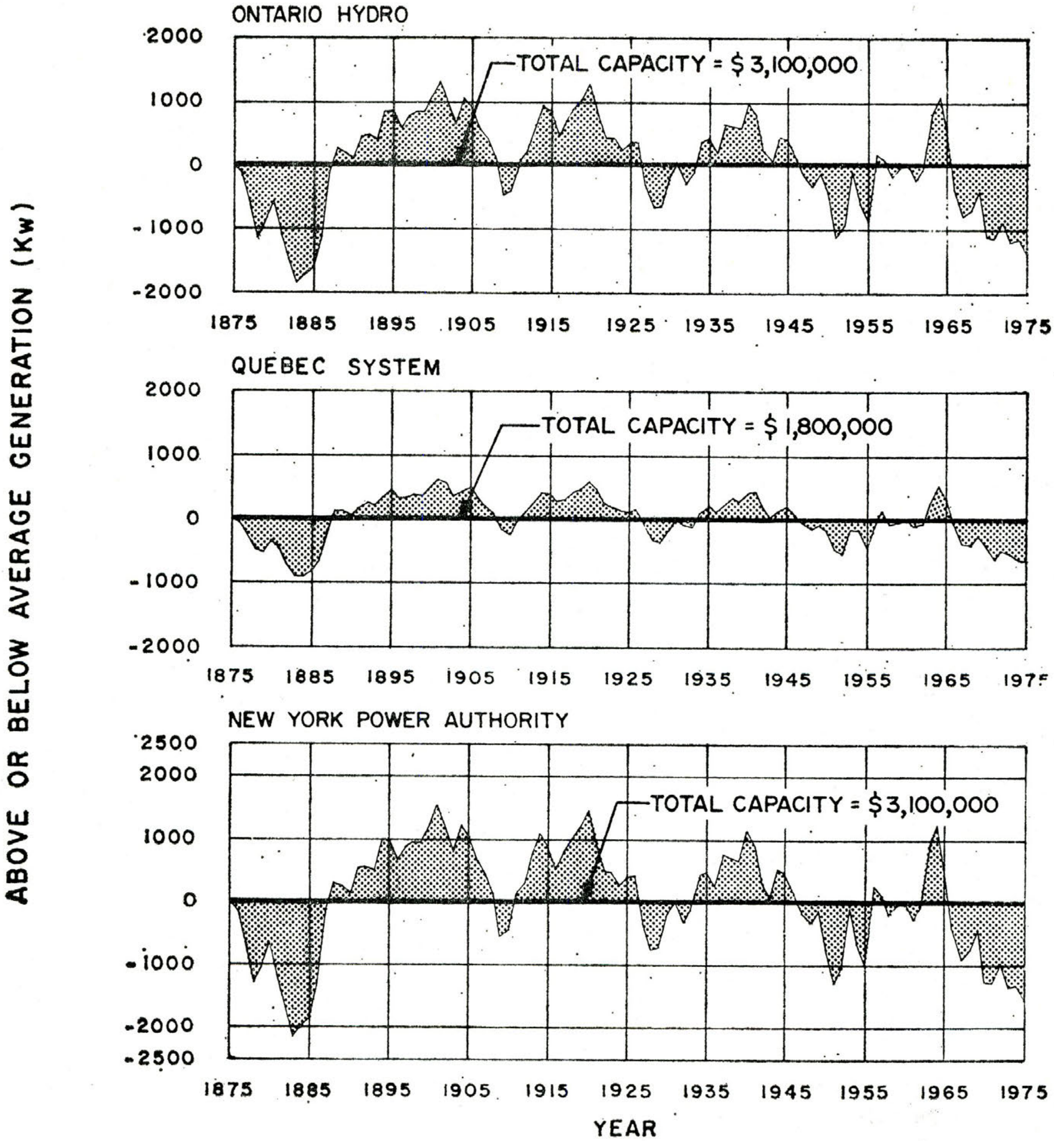

Figure 20. Effect of Using 100 - Year Average Runoff at Chicago on Hydroelectric Power Generation

The top curve of Figure 21 shows the effect of the flow variations resulting from the proposed change in the accounting method for Chicago diversion on all of the generating facilities. The induced changes fluctuate between +3507 kilowatts and —4895 kilowatts. The maximum deviation is less than ±0.06 percent of the total installed capacity of 8,000,000 kilowatts.

Effect On Shore Erosion Damages

The effect of Great Lakes water levels on shoreline damages due to erosion has been extensively studied.[5] These studies were used to determine effects on damages that would occur due to changes in lake levels brought about by modification of the Chicago diversion accounting method.

Curves were developed by the International Great Lakes Levels Board for both the Canadian and American side of Lake Huron-Michigan, Lake Erie and Lake Ontario showing damages as a function of the month of the year and lake level. At each location there is, as may be expected, a dramatic increase in damages as the lake level rises. The rapid rise in damages as lake levels increase results in a much higher impact due to induced fluctuations during periods of high lake levels than would be the case during periods of low lake levels.

The damage versus lake level curves for each lake-nation location, using annual average damages instead of monthly average damages, were used in a computer program to arrive at total annual changes. Two inputs previously generated in this study were used in the program: the levels

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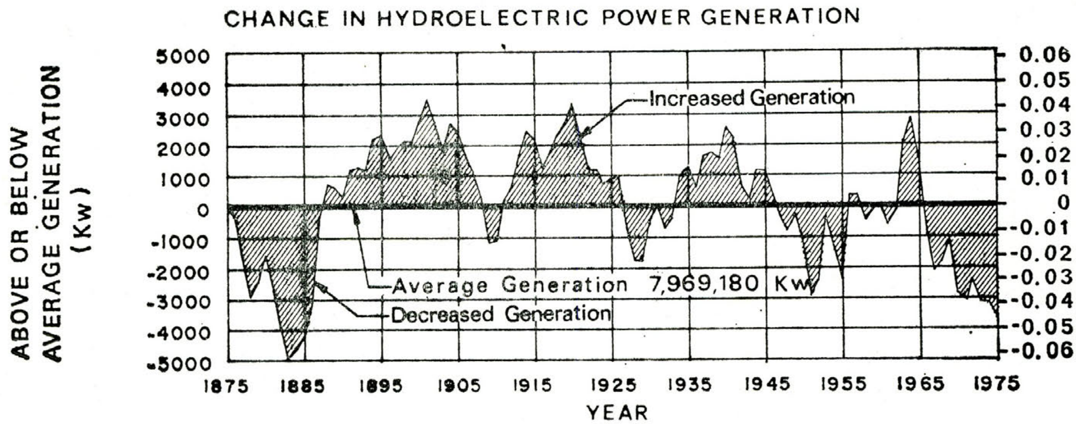
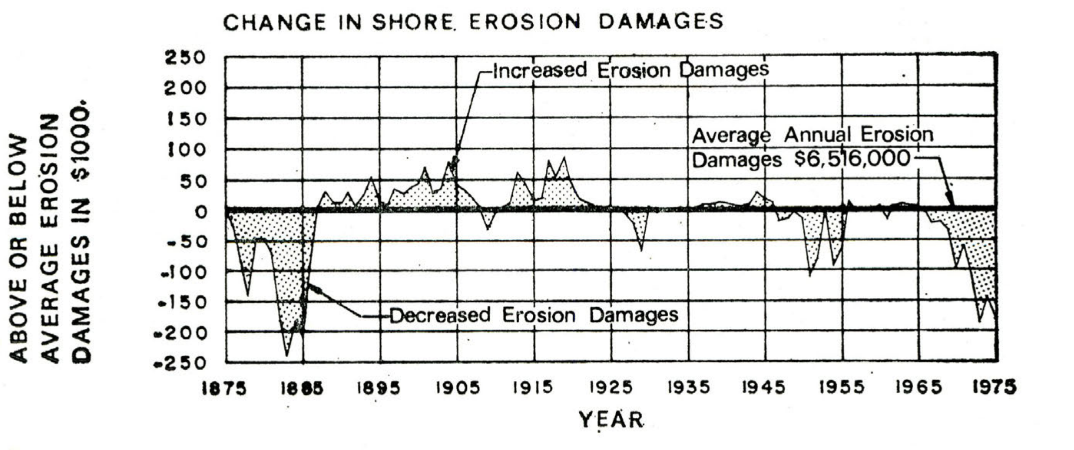
5. International Great Lakes Levels Board, *Regulations*, Appendix C, Shore Property.





EFFECTS ON COMMERCIAL NAVIGATION

Non-measurable Effects due to insignificant changes in Lake Levels (See Figure 20)

EFFECTS ON FISH, WILDLIFE AND RECREATION

Non-measurable Effects due to insignificant changes in Lake Levels (See Figure 20)

Figure 21. Effect of Using 100-Year Average Runoff at Chicago, on Downstream Interests within the Great Lakes – St. Lawrence Basin.

of each lake over the period 1875 to 1975 (shown in Figure 18), and the induced changes in lake levels that would have occurred in the same years due to the proposed change in the Lake Michigan diversion accounting method (shown in Figure 19).

The results of this analysis for each of the three lakes and two nations are shown in Figure 22. The induced changes are small compared to the total damages.

The total induced changes in damages for three lakes and two nations are shown in the second graph of Figure 21. The changes in shoreline damages are relatively small, ranging from +$86,000 to —$241,000, compared with a total average annual damages of $6,500,000, in 1971 dollars. When the fluctuations in induced damages are integrated over the 100-year time period, however, a net benefit is realized of $1,500,000. This results from a general tendency for the changes to slightly decrease the lake levels when lake levels are high from natural causes and to increase the lake levels when they are low from natural causes.

Effects On Commercial Navigation And Fish, Wildlife And Recreation

The International Great Lakes Levels Board studied the effects of regulating lake levels on commercial navigation and on fish, wildlife and recreation.[6,7] Study of these re-

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6. International Great Lakes Levels Board, *Regulations,* Appendix E, Commercial Navigation.

7. International Great Lakes Levels Board, *Regulations,* Appendix D, Fish, Wildlife and Recreation.

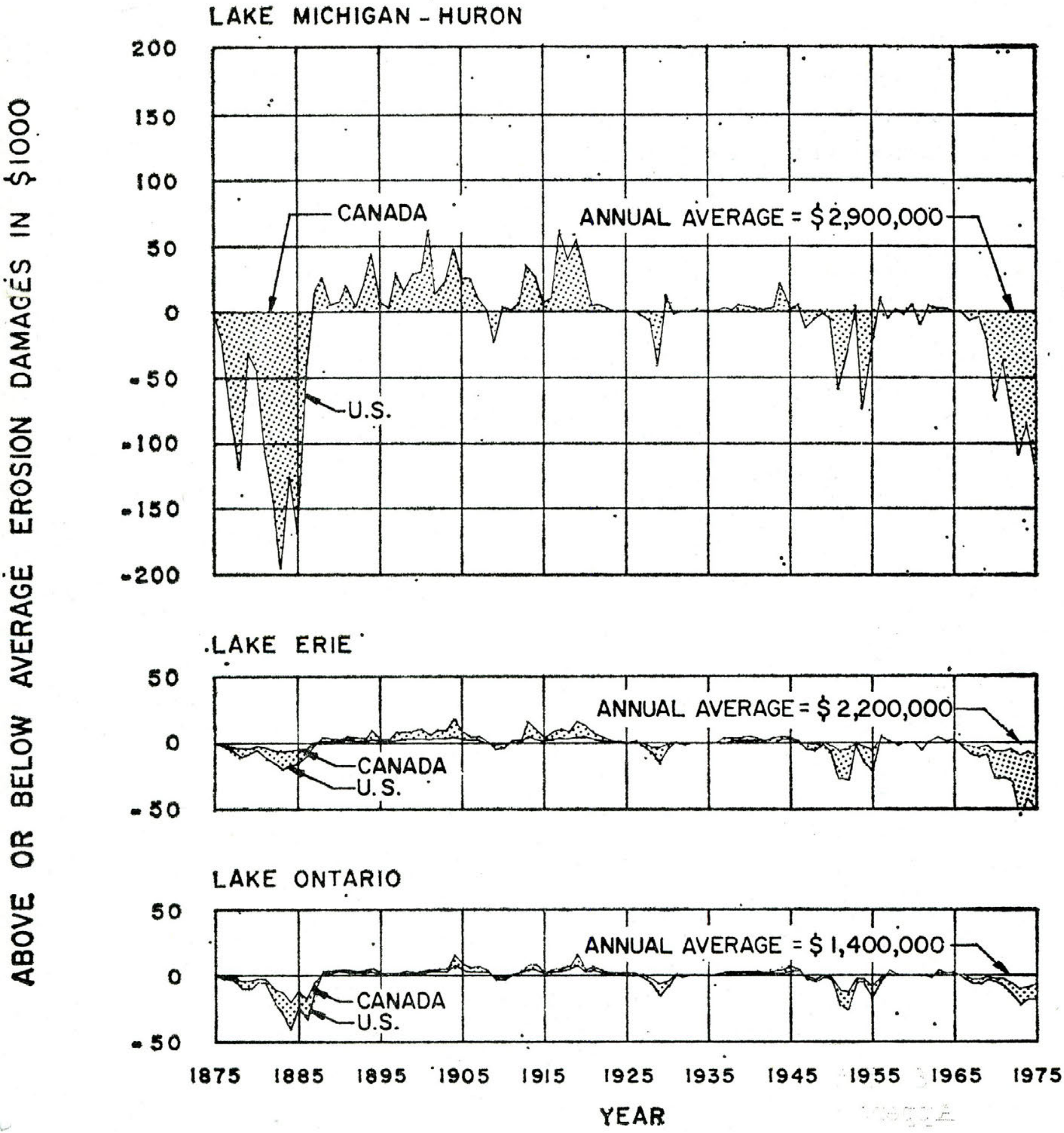

Figure 22. Effect of Using 100-Year Average Runoff at Chicago on Shore Erosion Damages.

ports indicates no measurable effects on these interests will be generated by fluctuations in lake water level or flow of the very small magnitudes caused by revision of the Chicago diversion accounting method.

Summary Of Effects

The effects on other users of the Great Lakes of changing the Chicago diversion accounting procedure can be summarized as follows:

1. The maximum change in any lake level caused by implementation of the new accounting procedure would be less than a tenth of an inch. Maximum induced fluctuations in flow would be only 0.08 percent of mean river flow. Both average lake levels and average flows would be entirely unchanged.

2. There would be no effect on average hydroelectric power generation. Short-term effects would be negligible, no more than ±0.06 percent of installed capacity.

3. A very small, but positive, decrease in erosion damages would accrue to shoreline property owners due to a tendency for the new accounting system to result in slightly lower fluctuations in the levels of Lakes Michigan, Huron, Erie and Ontario.

4. There will be no measurable effects on commercial navigation or on fish, wildlife, or recreation.