INDIANA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER
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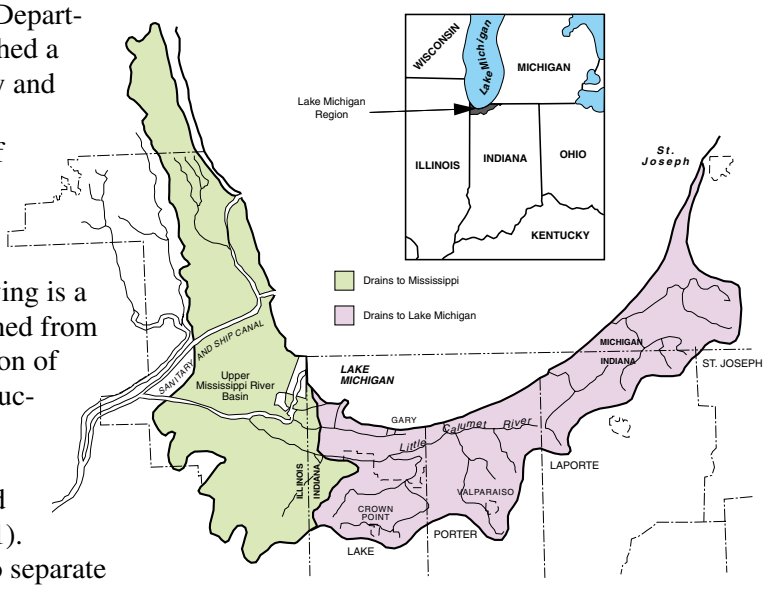
WATER RESOURCE AVAILABILITY IN THE LAKE MICHIGAN REGION, INDIANA - EXECUTIVE SUMMARY

Figure 1. Location of the Lake Michigan Region



In response to legislative directives contained in the 1983 Water Resource Management Act, the Indiana Department of Natural Resources, Division of Water published a report describing the availability, distribution, quality and use of surface water and ground water in the Lake Michigan Region, Indiana.* The fourth in a series of 12 regional watershed assessments, the report provides hydrologic data and related information for planners, government officials and others interested in the Region's water resource. The following is a summary of that report. The full report can be obtained from the Indiana Department of Natural Resources, Division of Water. For ordering information, please see the instructions printed at the end of this summary.

The Lake Michigan Region encompasses a total of 604 square miles (sq.mi.) in northwest Indiana and approximately 241 sq.mi. of Lake Michigan (figure 1). The Region, as it exists today, forms a portion of two separate major drainage basins. Of the total area in the Region, about 81 percent (489 sq. mi.) is drained by streams that flow directly into the Indiana portion of Lake Michigan. The remaining 115 sq. mi. or 19 percent is drained by streams that flow into the states of Illinois or Michigan.

Most of the streamflow from the Region that enters the state of Michigan eventually enters Lake Michigan. However, little if any, of the streamflow entering the state of Illinois from the Region enters Lake Michigan. Instead, the water travels through the Mississippi River Basin and into the Gulf of Mexico.

Four Indiana counties lie partially within the Lake Michigan Region, but the three counties of Lake, Porter, and LaPorte constitute more than 99.5 percent of the Region's land area in Indiana.

SOCIOECONOMIC SETTING

The Lake Michigan Region is predominantly urban and is one of the state's most heavily populated and industrialized areas. In 1990, approximately 86 percent of the Region's total population of 607,424 resided in urban areas. Fifteen of the 21 urban areas in the Region had population totals of 10,000 persons or greater. Gary and Hammond, the Region's largest cities, had populations of 116,646 and 84,236, respectively.

The total population in the Lake Michigan Region has been declining since the 1970s and is expected to continue to decline for the next two decades. There has been a southward shift of population from highly urbanized areas near Lake Michigan to urban and suburban areas lying near the southern boundary of the Region.

Per capita income in the Region has been variable, and recent unemployment trends have been higher than the state average. Employment and earnings by industy are based to a large extent on manufacturing, trade, services and government. These four economic sectors make up approximetely 81 percent of the total workforce and total earnings in the Region. The service sector has the largest workforce among the economic sectors; and although manufac-

*Indiana Department of Natural Resources (Beaty, J.E., Gosine, R., and Smith, M.A., eds.), 1994, Water resource availability in the Lake Michigan Region, Indiana: Division of Water, Water Resources, Assessment 94-4

turing engages only about 22 percent of the workforce, it accounts for the largest payroll (approximately 36 percent). The regional economy is shifting from a manufacturing base to a service and trade base.

Although the Region is highly urbanized in the north, agricultural land constitutes almost one-half of the land. Urban or built-up land accounts for about 29 percent of the Region's land area; forest land for about 17 percent; and water, wetlands and barren land for the remaining 5 percent.

PHYSICAL ENVIRONMENT

The climate of the Lake Michigan Region is classified as temperate continental, which describes areas with warm summers, cool winters, and the absence of a pronounced dry season. Precipitation and temperature throughout the Region vary considerably on a daily, seasonal and yearly basis. Superimposed upon the regional variability are localized weather modifications attributable to the presence of Lake Michigan and the Gary-South Chicago metropolis. Lake-effect processes in northern areas of the Region help to moderate extremes in temperature. The lake effect also causes more cloudiness, on average, and can produce frequent snows. In snow-belt areas of Lake, Porter, LaPorte and St. Joseph County, annual snowfall averages as much as 70 inches, or about twice the normal amount received elsewhere in northern Indiana (figure 2).

Annual evapotranspiration in the Lake Michigan Region accounts for approximately 25 inches (70 percent) of the 36 inches of normal annual precipitation. The theoretical average annual water surplus of 11 inches is considered adequate for the Region as a whole; however, the variability of rainfall and its uneven geographic distribution can occasionally limit crops and water supplies.

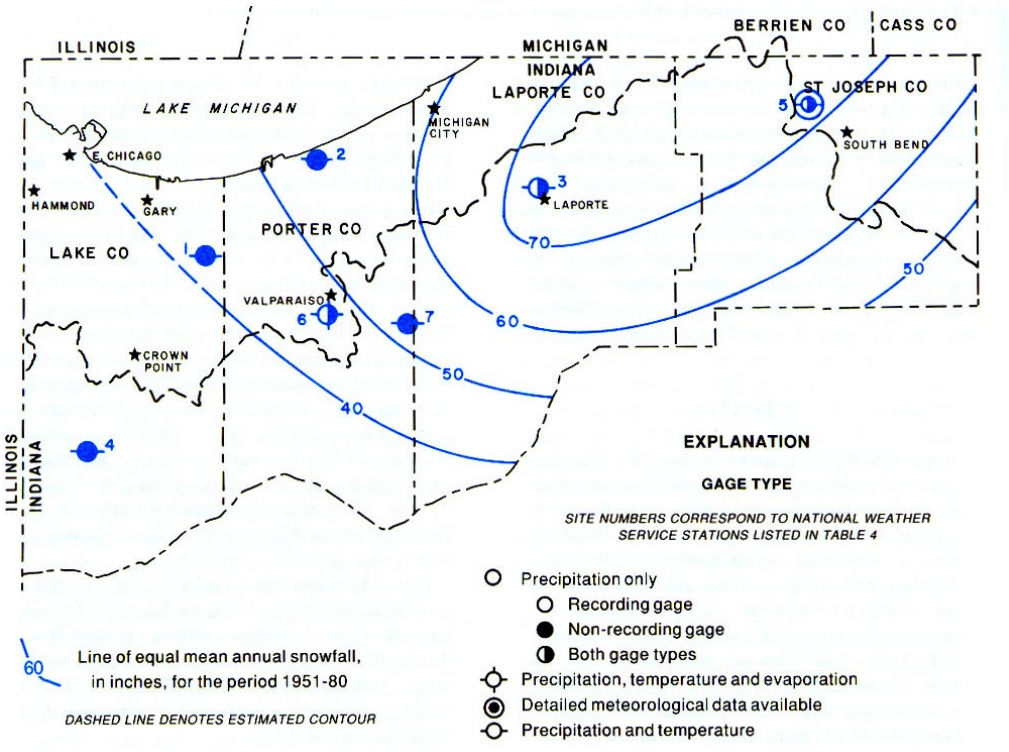


Figure 2. Location of National Weather Service stations and mean annual snowfall in and near the Lake Michigan Region

The landscape of the southern part of the Lake Michigan Region is primarily a product of latest Wisconsinan glacial events of the Lake Michigan lobe. Subsequent retreat of the Lake Michigan lobe from the morainal area and development of the ancestral Lake Michigan were responsible for most of the landscape in the northern part of the Region. Major landscape elements include: 1) the Valparaiso Morainal Area which is comprised of the Valparaiso, Tinley, and Lake Border end moraines; and 2) the Calumet Lacustrine Plain. Local relief ranges from a nearly featureless lake plain to more than 100 feet along the crest and northern flank of the Valparaiso Moraine.

The surficial deposits in the southern part of the Region are primarily the result of glacial processes, but the deposits in the northern part of the Region are the result of glacial, lacustrine, coastal, and eolian (deposited after transport by wind) sedimentation (figure 3). Tills overlie most outwash sands in the Lake Michigan Region and

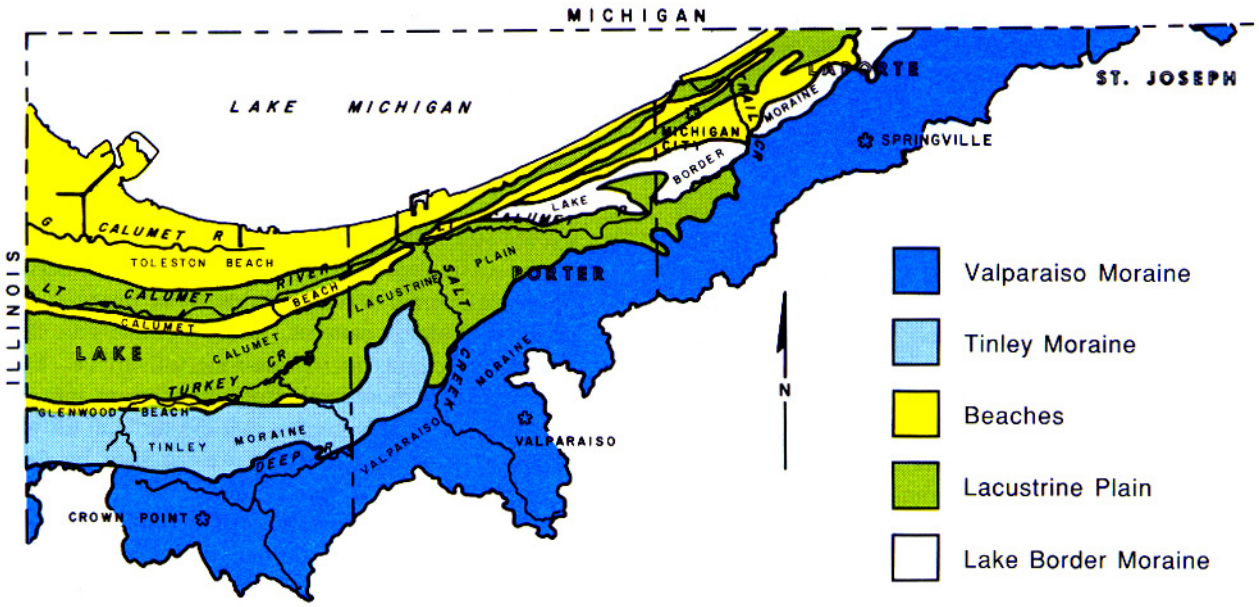


Figure 3. Major physiographic features

extend to the surface. However, the thickness and texture of the surficial tills are not uniform across the morainal complex. Thick basal tills cover the surface of the western segment of the Valparaiso morainal complex and a veneer of debris-flow tills is present along the northern slopes and crest of the eastern part of the Valparaiso morainal complex. A relatively impermeable till overlies the sandy core of the Lake Border Moraine and extends to the surface. Fine-grained lacustrine and dunal sands, and medium-grained coastal sands form most of the surficial deposits of the Calumet Lacustrine Plain.

The thickness of unconsolidated deposits generally ranges from 100 to more than 350 feet. Unconsolidated deposits are thinnest in the western portion of the Region and thickest where the Valparaiso Moraine forms a topographic high over a bedrock valley west of LaPorte.

Regional bedrock structure in the Lake Michigan Region is controlled by two principal features: the Kankakee Arch in the southwest and the Michigan Basin in the northeast. Bedrock is not exposed at the surface, but rocks occurring at the bedrock surface range from Silurian to Mississippian age.

Soils associated with the Valparaiso Morainal Area are generally clayey or loamy soils; and sandy soils are found in the Calumet Lacustrine Plain. Soils on the end moraines of the Valparaiso Morainal Area have been developed primarily in clay-rich glacial till. Loamy soils are more common in the eastern part of the morainal area. The soils that are formed on morainal swells and slopes are well-drained, but the soils in plains, ice-block depressions and relict glacial drainageways are poorly-drained. In the Calumet Lacustrine Plain, sandy soils occur on dune and beach complexes and on lacustrine and coastal deposits.

COASTAL ENVIRONMENT

Fluctuations of water levels have occurred on Lake Michigan and the other Great Lakes since they were formed. Changes in lake levels affect extent of flooding, shoreline erosion and shoreline property damage, wetland acreage, depths of navigation channels, and hydroelectric power output. Unusually high lake levels in the 50s, 70s and mid-80s led to numerous investigations concerning causes of lake level fluctuations and potential modifications to the lake system to solve problems related to extreme lake levels.

The amount of erosion or deposition that occurs in any given year at any given location along the shoreline is affected by such natural factors as: physical configuration of the shoreline, direction of sand movement, availability of sand, and seasonal differences in storm intensity. In general, seasonal differences in storm intensity result in a yearly cycle of narrow winter beaches and wide summer beaches. High lake levels and severe storms usually result in

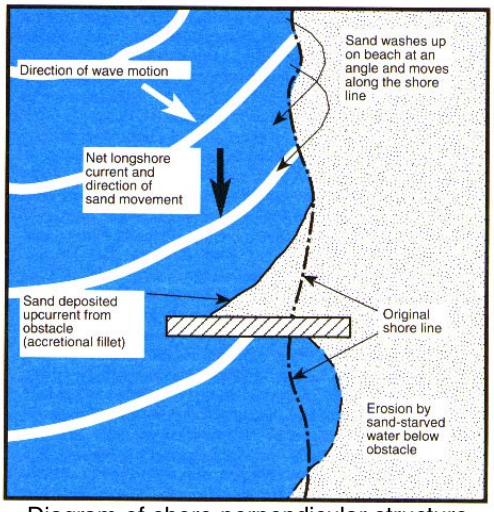


Diagram of shore-perpendicular structure impact on shoreline

Diagram of shore-parallel bulkhhead/seawalls impact on shoreline

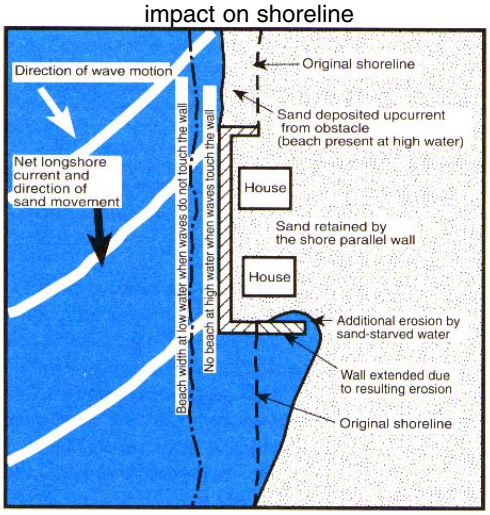


Figure 4.

the highest erosion rates along the unprotected portions of the Indiana shoreline.

Changes occurring to Indiana's shoreline during historic times are the result of both natural processes and human influence. One of the greatest changes to the shoreline is the existence of peninsulas of man-made land projecting out into Lake Michigan, created primarily for industrial expansion. A total of approximately 4,053 acres of man-made land was created, surveyed and is now patented.

Man-made structures affect sand movement along the shoreline, resulting in erosion of sand in some locations and accumulation of sand in other locations (figure 4). Numerous examples of both situations exist along the Lake Michigan shoreline.

Although a very limited resource, Indiana's 45-mile shoreline has much to offer to many diverse users; hence, competition and conflicts are inevitable. The shoreline now accomodates a diversity of uses, ranging from heavy industry to environmental preservation.

Management of Indiana's shoreline is now subject to an array of federal, state and local jurisdictions. An inititative is, however, currently underway to build a comprehensive coastal zone management program for Indiana. The state has acquired federal funds to develop a coastal zone management (CZM) program acceptable for inclusion in the federal CZM program. If Indiana is accepted into the federal program, the state will be eligible for approximately $500,000 a year to administer its program.

SURFACE-WATER HYDROLOGY

The surface-water resources of the Lake Michigan Region include Lake Michigan; the Little Calumet, Grand Calumet, and Galena Rivers; Trail Creek; an extensive network of smaller tributary streams and ditches; several natural and man-made lakes; ponds and man-made excavations; and scattered remnants of marshes, swamps, and other wetlands.

The present surface-water hydrology of the Lake Michigan Region is markedly different from the natural drainage conditions that existed prior to permanent settlement of the area. The most extensive changes include modifications of the Lake Michigan nearshore and lakeshore areas and channelization of the Grand Calumet and Little Calumet Rivers.

Of the Region's streams, the Grand Calumet River supports the largest number of high-capacity withdrawals, primarily for industrial purposes. The Grand Calumet River has considerable flow but was not analyzed for supply potential because natural-flow analysis is almost impossible because most of the flow in the river is industrial cooling and processing water and waste treatment plant effluents.

The water-supply potential of the Little Calumet River and its tributaries varies considerably across the Lake Michigan Region because of the geographic variation in flows. The water-supply potential of the Little Calumet River and its major tributaries is greater along the reaches in Porter County than in Lake County. In Lake County, the high variability in flow is mainly due to the low permeability of the soils and the considerable degree of urbanization and development in the northern part of the county. Conversely, greater sustained (low) flows occur in the drainage networks of the Little Calumet River in Porter County because of higher ground-water contributions.

In both the Little Calumet River at Porter and Salt Creek at McCool, base flow comprises about 68 and 64 percent of the respective stream flow during a year of average precipitation. In Hart Ditch at Munster, base flow

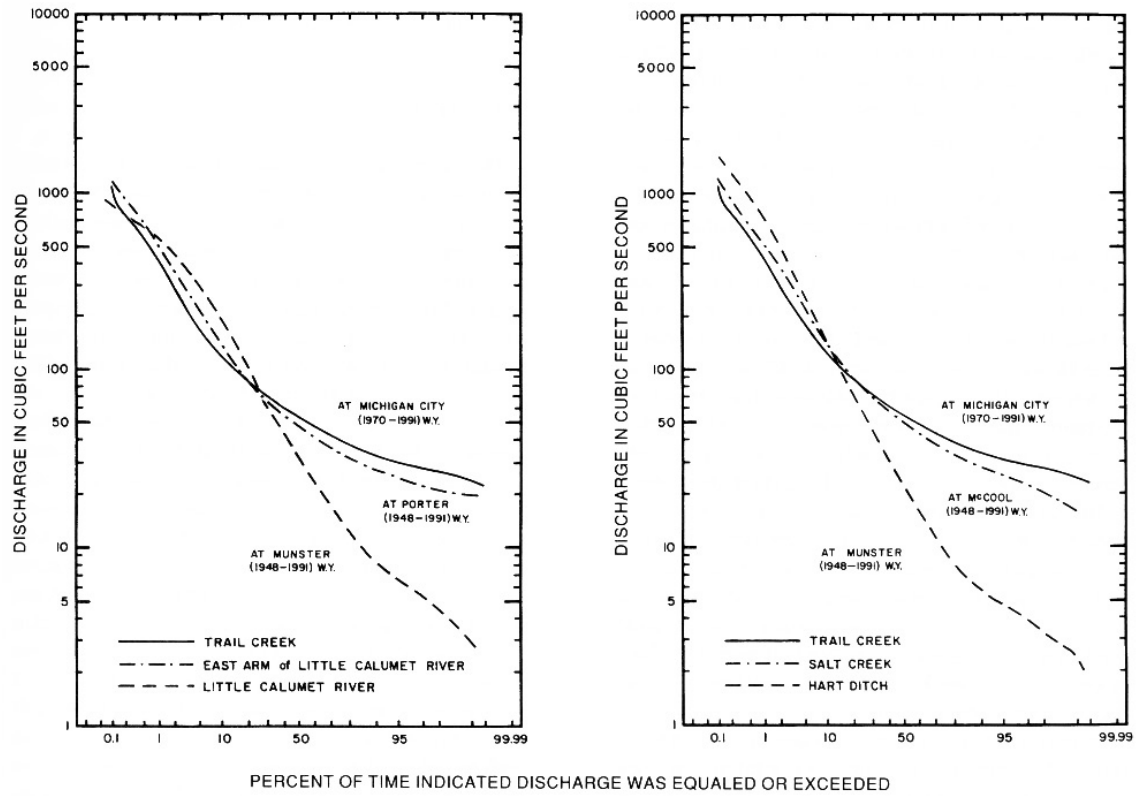


Figure 5. Duration curves of daily mean stream flow for gaging stations on Trail Creek, Salt Creek, Hart Ditch and Little Calumet River

comprises, on average, only about 43 percent of the total stream flow.

The water-supply potential of Trail Creek is the most favorable of all the streams in the Lake Michigan Region. The surficial sediments in the watershed of Trail Creek are highly permeable compared to other watersheds in the Region. On average, base flow comprises about 76 percent of total stream flow in Trail Creek. At present, registered water withdrawals from Trail Creek are used for irrigation of golf courses. Flow duration curves for Trail Creek, Salt Creek, Hart Ditch, and segments of the Little Calumet River are shown in figure 5.

Flooding in the Lake Michigan Region is primarily due to overbank flow and inadequate storm drainage. Most of the critical flooding occurs along the mainstem and tributaries of the Little Calumet River in Lake County. Extensive development of the area, poor drainage characteristics of the soil, inadequate channel capacity to handle flood flows, and high water table all contribute to prolonged floods. The most disastrous flooding in the watershed is in northern Lake County because of the high concentration of development.

Flooding problems along the mainstem of the Little Calumet River in Lake County are expected to be alleviated to a considerable degree after completion of the Little Calumet River Flood Control and Recreation Project. Work on the project began in 1990 and is scheduled for completion by 1998.

SURFACE-WATER QUALITY

The extensive urban and industrial development that characterizes much of the Lake Michigan Region has had detrimental effects on surface-water resources of the area. Within the Region, only three of 17 selected stream sections evaluated by IDEM were found to fully support designated uses (table 1). Consequently, various federal and state agencies have produced strategies to protect and restore the surface-water resources of the area.

Because Lake Michigan is hydrologically connected with other Great Lakes, and because much of the Region's drainage ultimately discharges into Lake Michigan, pollution in the Calumet Area and other areas around the Great Lakes has also been a source of concern for other states and Canadian provinces which surround the Great Lakes.

Table 1. Designated uses and use-support status of selected streams

{Adapted from Indiana Department of Environmental Management 1992-1993 305(b) [1994?]}

Designated surface-water uses in Indiana: Aquatic life; Recreation; Agriculture; Industrial; Public-water supply

Use support status: FS, stream is currently supporting designated use; PS, stream is partially supporting designated use; NS, stream is not supporting designated use at present.

Watercourse	Nearest town(s)	Designated use support status	Miles affected	Probable cause of impairment
Coffee Creek	Chesterton	NS (aquatic life)	2	Urban Runoff
Upper Salt Creek	Valparaiso	NS (aquatic life) NS (recreation)	4	Low D.O. Bacteria
Lower Salt Creek	Portage	NS (aquatic life) NS (recreation)	4	Low D.O. Bacteria
Upper Trail Creek and tributaries	Michigan City	NS (aquatic life) NS (recreational)	42	Bacteria, Pesticides Agricultural Runoff, PCBs
Lower Trail Creek	Michigan City	NS (aquatic life) NS (recreational)	3	Pesticides Bacteria, PCBs
Galena River and tibutaries	Heston, Lalimere	FS (aquatic life)	13	
Burns Ditch	Lake Station, Portage	NS (aquatic life) NS (recreational)	8	PCBs, Pesticides Bacteria
Little Calumet River	Porter, Chesterton	NS (aquatic life) NS (recreational)	6	Bacteria, PCBs Cyanide, Pesticides
Little Calumet River	Hammond	NS (aquatic life) NS (recreational)	10	Bacteria, PCBs Cyanide, Pesticides
Indiana Harbor Canal	Whiting, E. Chicago	NS (aquatic life) NS (recreational)	4	Bacteria PCBs, Pesticides Mercury Low D.O.
E. Branch, Grand Calumet River	Gary, E. Chicago	NS (aquatic life) NS (recreational)	10	Bacteria Oil and grease PCBs, Pesticides Cyanide Lead
W. Branch, Grand Calumet River	Hammond, E. Chicago	NS (aquatic life) NS (recreation)	3	Bacteria Low D.O. PCBs, Pesticides Lead Ammonia CSO, cyanide
Plum Creek	Dyer	FS (aquatic life)	4	
Hart Ditch	Munster, Highland	FS (aquatic life)	2	
Beaver Dam Ditch	Crown Point	NS (aquatic life)	7	Poor Habitat Low D.O.
Deep River	Hobart	NS (aquatic life)	4	Runoff, POTW Poor Habitat
Deep River	Lake Station	NS (aquatic life)	4	Sewage

As a result of such concerns, the first Great Lakes Quality Agreement was signed in 1972 between the United States and Canada. The primary goal of the agreement was to reduce pollutant loads to the Great Lakes and to control cultural eutrophication. Emphasis was placed on municipal and industrial point-source discharge problems.

Early in the 1980s, the Great Lakes Water-Quality Board, a scientific subcommittee of the International Joint Commission (IJC), placed parts of northwest Lake County on a list of areas around the Great Lakes, called Areas of Concern (AOC), where remedial actions were necessary to restore all beneficial uses.

A number of plans and strategies have thus, been developed to improve water-quality conditions in streams in the AOC of Northwest Indiana. Current strategies include: the Northwest Indiana Action Plan, the Remedial Action Plan for the Grand Calumet River/Indiana Harbor Canal-Nearshore Lake Michigan Area Of Concern, the Lakewide Management Plan, and the Great Lakes Initiative. There have also been efforts to improve water-quality in the Trail Creek watershed. The most recent effort is development of a Watershed Management Plan for Trail Creek.

Data from nine of the 22 active IDEM monitoring stations in the Lake Michigan Region are used in this study to analyze selected constituents of streams in the Lake Michigan Region. Data used in the analysis was collected for a 10-year period, primarily spanning the time from the early 1980s to early 1990s. Results are compared to state and federal water-quality standards.

Apparent seasonal trends are noted in median levels of dissolved oxygen within streams in the Lake Michigan Region. The variations in seasonal median DO levels may be inversely related to seasonal changes in median water temperature. Seasonal variations in specific conductance may not be significant for most stations.

Variations in water-quality are observed among samples from different streams and from different locations within the same stream. Lower median concentrations of dissolved oxygen and higher median levels for chloride and specific conductance are observed in samples from the West Branch of the Grand Calumet River than in samples from the East Branch of the Grand Calumet River. Differences in median specific conductance and median DO levels are also observed between the East Branch and West Branch of the Little Calumet River, and between different segments of the Indiana Harbor Canal.

Over the 10-year period from 1982 to 1992, violations of the dissolved-oxygen criteria are observed in a greater percentage of samples from the West Branch of the Grand Calumet River, than in samples from the East Branch. Of the stations in the Indiana Harbor Canal, the highest percentage of DO criteria violations are observed in the Lake George Branch for the same period. DO violations are recorded in fewer samples from the East Branch of the Little Calumet River than in samples from the West Branch. Violations of DO standards are also recorded in samples from Trail Creek, which is a designated salmonid stream.

The levels of certain parameters in some Lake Michigan Region streams have, at times, exceeded applicable water-quality standards. Many samples from the IDEM stream-monitoring stations contain iron levels that exceed the 0.3 mg/L secondary maximum contaminant level (SMCL). Coliform bacteria levels in many of the major streams of the Lake Michigan Region frequently exceed standards established for body-contact recreation. Furthermore, concentrations of cyanide in waters of the Grand Calumet River, the Little Calumet River, and Indiana Harbor Canal have sometimes exceeded the maximum permissible levels for protecting aquatic life.

Various trace metals were detected in both effluent and ambient water samples collected during a 1988 IDEM study to quantify the presence and distribution of toxic substances in the Grand Calumet River and Indiana Harbor Canal. No violations of minimum water-quality criteria for antimony, nickel or zinc were detected in any of the 1988 IDEM samples. Violations of minimum water-quality standards for copper, lead, and arsenic were only detected in samples from the West Branch of the Grand Calumet River. However, minimum-standards may vary within the Grand Calumet River and Indiana Harbor Canal waterway due to variations in hardness. It is therefore, possible that levels of copper, lead or arsenic were present in samples from the East Branch of the Grand Calumet River or the Indiana Harbor Canal at levels above the minimum-standards but below analytical detection limits.

The samples from the 1988 IDEM study of the Grand Calumet River and the Indiana Harbor Canal were also screened for 145 synthetic organic compounds. Thirty-five of the different organic compounds being screened for were detected in ambient stream samples. However, only 11 of the 35 compounds which were found above detectable levels in stream samples were also detected in effluent samples. This difference in number of organic compounds detected was interpreted to indicate that non-point sources may contribute synthetic organic compounds to the Grand Calumet River and Indiana Harbor Canal. Uncontrolled combined sewer overflows and stormwater discharges have

also been identified by IDEM as possible sources of potentially toxic substances in the Grand Calumet River and Indiana Harbor Canal.

The IDEM has conducted biological sampling in the Region, including sampling macroinvertebrate communities. Streams in the Region classified as non-supportive of aquatic life include: the Grand Calumet River, Indiana Harbor Canal, Little Calumet River, Burns Ditch, Trail Creek, Deep River, Salt Creek, and Coffee Creek. Streams classified as supportive of aquatic life include Galena River and its tributaries, an unnamed tributary of Little Calumet River near the town of Pines in Porter County, Plum Creek, and Hart Ditch.

Fish population sampling has been chosen by the USEPA and the IDEM as one biological method for assessing Indiana water quality. IDEM and EPA staff, in 1990, sampled a total of 197 headwater and wading stream sites in the Central Corn Belt Plain ecoregion to develop and calibrate an Index of Biotic Integrity for use in Indiana.

Lake Michigan drainageways in northwest Indiana were among three sub-basins sampled for the ecoregion study. In contrast to other subregions sampled, a trend in declining water quality with increasing drainage area was observed in the Lake Michigan drainageways. The Lake Michigan sub-basin is made up of two divisions: the East Branch Little Calumet River Division and the Lake Michigan Division. The East Branch of the Little Calumet River Division includes the area from Burns Ditch, the East Branch of the Little Calumet River, and all tributaries such as Salt Creek, Reynolds Creek, and the unnamed tributary in LaPorte County. The Lake Michigan Basin division of the Lake Michigan drainage includes the Grand Calumet River basin and the West Branch of the Little Calumet River and its tributaries, such as Deep River, Turkey Creek, and Hart Ditch. The two divisions of the Lake Michigan drainageways sub-basin are based on presence or absence of salmonid species, because keystone species such as salmon and trout determine the characteristics of a fish community. The East Branch of the Little Calumet River Division contains a salmonid component; whereas, the Lake Michigan Division does not have a salmonid component for headwater sites.

A total of 48 individual stations were sampled in the entire Lake Michigan sub-basin. More than half (58.3 percent) of the stations sampled were classified as poor in terms of biotic integrity. Only 10.4 percent were classified as fair. Of the two divisions within the sub-basin, the East Branch of the Little Calumet Division displayed better water quality in headwater streams than the Lake Michigan Division.

The Indiana State Department of Health (ISDH) is responsible for issuing fish consumption advisories for streams and lakes in the state. Fish consumption advisories are issued for specific lakes and streams, and represent suggested restrictions on the size and species of fish that should be eaten. The Indiana portion of Lake Michigan and tributary streams (Burns Ditch, the Little Calumet River, Trail Creek, and Kintzele Ditch) are all included in a joint fish-consumption advisory due to concerns about PCBs. The advisory applies to the following fish species of the given length: brown trout (under 23 inches), chinook salmon (21 to 32 inches), coho salmon (over 26 inches), and lake trout (20 to 23 inches). The ISDH advises that women of child-bearing age and children should completely avoid eating these fish, and that women past child-bearing age and adult men should limit consumption to one-half pound per week. More stringent consumption advisories, however, have been issued by ISDH for larger fish in Lake Michigan. The following fish from the waters under the advisory should not be consumed by anyone: brown trout and lake trout over 23 inches; chinook salmon over 32 inches, and carp and catfish. The IDEM also advises that no fish species of any size should be eaten from the Grand Calumet River and Indiana Harbor Canal.

Within the Lake Michigan Region, the IDEM had identified the Grand Calumet River and the Indiana Harbor Canal as areas where sediment contamination may be contributing to non-support of uses. Known contaminants on sediments in both streams are cyanide, metals, PCBs, PAHs, and other organic compounds. Contaminated sediments in the Indiana Harbor Canal may represent a threat to Lake Michigan. Some sediments from another stream in the Region, Trail Creek, have pesticide and metal concentrations above background levels. Contaminated sediments are thought to present one of the most serious threats to water quality in the Region.

Navigational waterways, such as the Indiana Harbor and Canal and Trail Creek, require periodic dredging to remove and dispose of accumulated bottom sediment. Although the Indiana Harbor and Canal needs to be dredged, the Corps of Engineers has had great difficulty locating a site to dispose of the contaminated sediments which have accumulated on the bottom.

The 240 square miles of Lake Michigan subject to Indiana jurisdiction is one of the most important natural resources in the state. Thus, maintaining and protecting water-quality in Lake Michigan will be necessary for contin-

ued use and development of this valuable resource.

During 1980 and 1981, the Indiana State Board of Health (ISBH)/now the Department of Health (ISDH), examined the relationship between climate and water chemistry in Indiana's Lake Michigan. Water samples were collected from nearshore, offshore, near-surface, and near-bottom of the lake in an attempt to establish spatial and seasonal trends in water chemistry.

Seasonal thermal layering, both vertical and parallel to the shoreline, were identified in the lake during the course of the ISBH study. Differences in concentrations of certain ions were also detected between near-shore and off-shore samples and between shallow and deep samples. Thermal layering was thought to explain the differences in chemistry because it might prohibit mixing. Thermal layering in Lake Michigan does not appear to be permanent or seasonally stable.

In the mid 1970s, two important investigations took place which provided important insights about chemical dispersion and current flow of southern Lake Michigan. One, by IIT Research Institute, examined chemical dispersion of materials from Indiana Harbor Canal into Lake Michigan and as a result, provided evidence that pollution from Indiana Harbor Canal could enter Lake Michigan. The other, by Argonne National Laboratory, examined current movement and pollution transport in southern Lake Michigan. The researchers were able to trace the movement of water from Indiana Harbor Canal to the City of Chicago's South Water Filtration Plant. The Canal water descended as a plume below the surface of Lake Michigan and was carried toward the offshore intake of the Chicago plant by the prevailing current.

Selected data from five water-quality monitoring stations in Lake Michigan are analyzed in this report and compared to legal standards and suggested concentration limits. Analysis indicates that median levels of sulfate, chloride, and specific conductance are similar among the stations. In general, few violations of applicable water-quality standards are observed in the Lake Michigan data set. Graphs of median monthly values at three Lake Michigan monitoring stations may indicate that DO levels in Lake Michigan are inversely proportional to ambient temperatures.

Although the data set examined contains few violations of E. coli bacteria, there are times when beaches along the Lake Michigan coastline in Indiana are closed because E. coli counts have exceeded values for full-body contact recreation.

The only other lake besides Lake Michigan which is part of the IDEM fixed-station water-quality monitoring network is Wolf Lake. Data collected from 1982 to 1992 from this station were used in this report to estimate median levels and variability in concentrations of selected water-quality parameters in the lake. None of the Wolf Lake samples contained DO levels below minimum DO criteria for aquatic-life use. However, slightly more than three percent of samples analyzed exceed the upper limit of pH for aquatic-life use. Approximately 81 percent of monthly measurements from Wolf Lake (1988 to 1992) contain E. coli levels below or equal to 10 organisms per 100 ml. The highest single-sample level in the data does not exceed recreational-use criteria, but is above the permissible 30-day average E. coli level. Concentrations of phosphorous and nitrate+nitrite are observed in some water samples from Wolf Lake at levels which may promote algae growth. Nine samples, collected from December, 1988 to October 1991, were analyzed for metals. Concentrations of lead and copper in excess of the detection limit were found in some samples. Mercury was not detected in eight of the nine samples, but was detected at a level of almost twice the established MCL in the remaining sample.

GROUND-WATER HYDROLOGY

Ground-water availability in much of the Lake Michigan Region is considered poor to moderate. Six unconsolidated aquifer systems are defined according to hydrologic characteristics of the deposits and environments of deposition. Three bedrock aquifer systems are defined on the basis of hydrologic and lithologic characteristics (figure 6).

Only three of the six unconsolidated aquifer systems are laterally extensive in the Lake Michigan Region: the Valparaiso Moraine Aquifer system, the Lacustrine Plain Aquifer system, and the Calumet Aquifer system. The southernmost system, the Valparaiso Moraine Aquifer system is a till-capped deposit cored with fine- to medium-grained sand which contains some gravel lenses. Common thicknesses of this aquifer system generally range from about 10 to more than 100 feet in Lake and Porter Counties, but are greater in LaPorte County. Expected high-

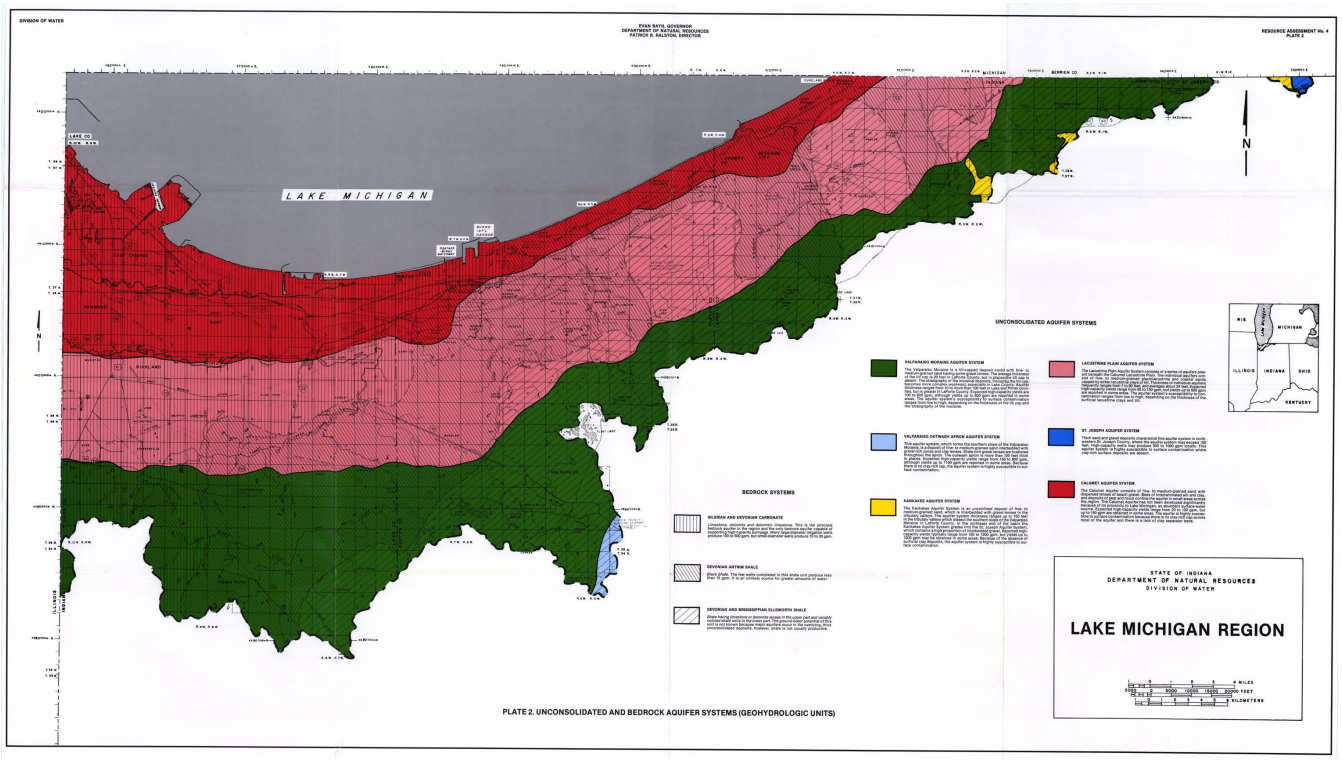


Figure 6. Aquifer systems. (**click here to enlarge**)

capacity yields are 100 to 600 gpm, although yields of up to 800 gpm are reported in some areas.

The Lacustrine Plain Aquifer system consists of a series of aquifers present beneath the Calumet Lacustrine Plain. The individual aquifers consist of fine- to medium-grained glaciolacustrine and coastal sands capped by either lacustrine clays or till. Thickness of individual aquifers frequently ranges from 7 to 90 feet, and averages about 24 feet. Expected high-capacity yields range from 50 to 150 gpm, but yields up to 500 gpm are reported in some areas.

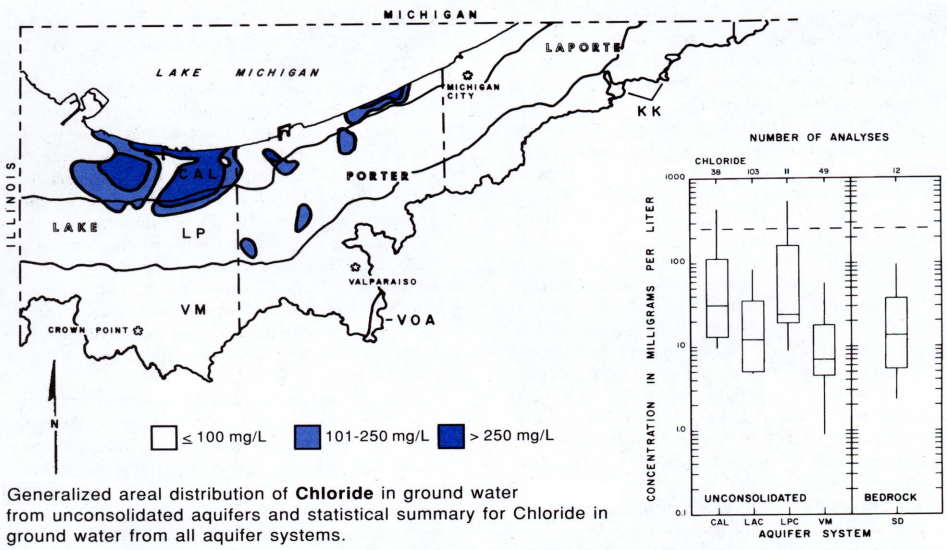
The Calumet Aquifer system consists of fine- to medium-grained sand with dispersed lenses of beach gravel. Beds of interlaminated silt and clay, and deposits of peat and muck confine the aquifer in small areas across the Region. The Calumet Aquifer has not been developed significantly because of its proximity to Lake Michigan, an abundant surface-water source. Expected high-capacity yields for the Calumet Aquifer range from 20 to 100 gpm, but up to 150 gpm are obtained in some areas.

The Valparaiso Outwash Apron, the Kankakee, and the St. Joseph aquifer systems have small areal extent in the Lake Michigan Region but consist of highly-productive glacial outwash sand and gravel with yields ranging from 100 to 1200 gpm.

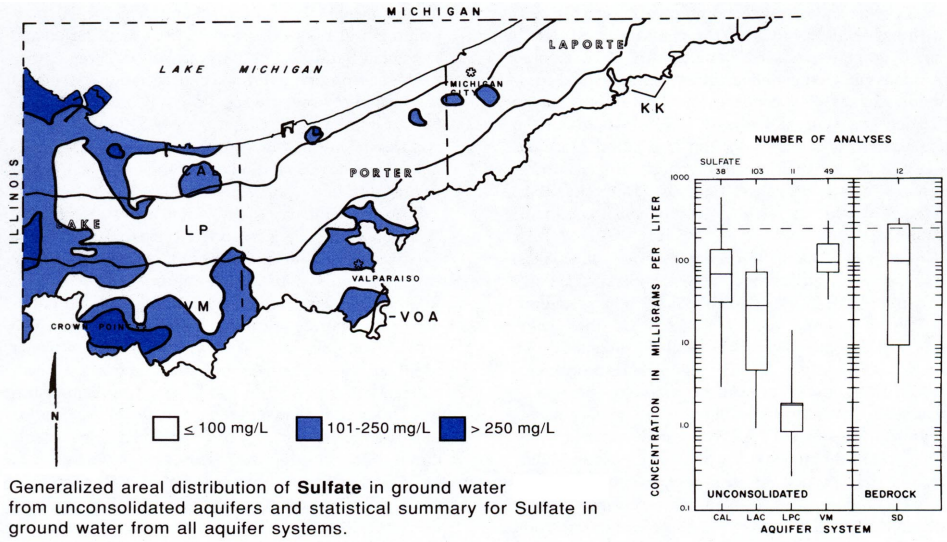
Silurian and Devonian carbonate rocks form the most utilized bedrock aquifer system in the Lake Michigan Region. However, water-yielding capabilities of the aquifer system are not uniform throughout its extent. It is composed of limestone, dolomite, and dolomitic limestone and is the only bedrock aquifer capable of supporting high-capacity pumpage. Many large-diameter irrigation wells produce 100 to 500 gpm, but small-diameter wells produce 10 to 30 gpm.

GROUND-WATER QUALITY

Ground water in the Lake Michigan Region is generally hard to very hard, neutral to slightly alkaline, and generally dominated by calcium, magnesium, and bicarbonate. Although ground water in the Region is predominantly calcium and bicarbonate dominated, numerous samples are chemically dominated by other anions and cations. The domination of ground water by anions and cations other than calcium and bicarbonate indicates that, locally, there can be considerable variation in the nature of water chemistry in the Lake Michigan Region. A large degree of



Generalized areal distribution of **Chloride** in ground water from unconsolidated aquifers and statistical summary for Chloride in ground water from all aquifer systems.



Generalized areal distribution of **Sulfate** in ground water from unconsolidated aquifers and statistical summary for Sulfate in ground water from all aquifer systems.

Figure 7.

variation in ground-water chemistry is exhibited in the Calumet Aquifer system; whereas, little variation is exhibited in the Valparaiso Moraine Aquifer system.

In some areas of the Lake Michigan Region, human-induced aquifer pollution has locally diminished the quality and utility of ground-water resources. In most of the Region, however, ground water meets drinking-water standards, although iron commonly exceeds the Secondary Maximum Contaminant Level (SMCL). Other constituents that commonly exceed SMCLs include manganese and total dissolved solids (TDS). Chloride and sulfate concentrations can be variable and are sometimes high; and nearly all aquifer systems in the Region have some samples that exceed the SMCLs (figure 7). Fluoride also exceeds the SMCL in a few samples in the Calumet Aquifer and in the Silurian and Devonian Bedrock Aquifer systems and even exceeds the MCL in one sample from the Region. Nitrate concentrations are below the MCL for all ground-water samples in the data set.

The Valparaiso Moraine Aquifer system, the most highly mineralized of the Region's unconsolidated systems, has ground water containing the highest median alkalinity and hardness, and the highest median concentrations of calcium, magnesium, iron, sulfate and TDS. Ground water of the Lacustrine Plain Aquifer system underlying the Calumet contains the lowest median concentrations of these constituents except for alkalinity and magnesium.

Alkalinity, TDS, and fluoride concentrations are generally higher in bedrock aquifer water than the unconsolidated aquifers. In addition, hydrogen sulfide gas is most commonly detected in bedrock wells, where reducing conditions are most likely to occur.

Over the past 100 years, the intensive settlement and the industrial and agricultural practices that accompany development have created ample opportunity for ground-water contamination in the Lake Michigan Region. Some cases of actual or potential ground-water contamination have already been identified in the Region. For example, in four of five National Priority List (NPL) sites in the northwest portion of the Region, ground-water contamination was considered severe enough to justify treatment of the contaminated aquifers.

Numerous ground-water sampling studies have been done in the past decade to determine the extent of ground-water contamination in the Region. Since 1981, the USEPA found detectable levels of at least one Volatile Organic

Compounds (VOCs) in raw water of four public supplies within the Region. Numerous cases of ground-water contamination within the Region have also been documented by the Indiana Department of Environmental Management. A registry of case histories is maintained by the IDEM and provides additional details on chemical contamination in the Region.

Unconsolidated aquifer systems that are highly susceptible to contamination from surface sources include the Kankakee, Valparaiso Outwash Apron, St. Joseph, and the Calumet. The Valparaiso Moraine Aquifer System can be susceptible where surficial clay layers are absent or discontinuous.

Numerous ground-water protection initiatives have been undertaken in the state in recent years, including development of a Ground-Water Protection Strategy and Implementation Plan and a Wellhead Protection Plan. Special emphasis is currently being placed on northwest Indiana with numerous studies being performed in the Region by Indiana Department of Environmental Management (IDEM), U.S. Environmental Protection Agency (USEPA), U.S. Geological Survey (USGS), and the Indiana Geological Survey (IGS).

WATER USE AND PROJECTIONS

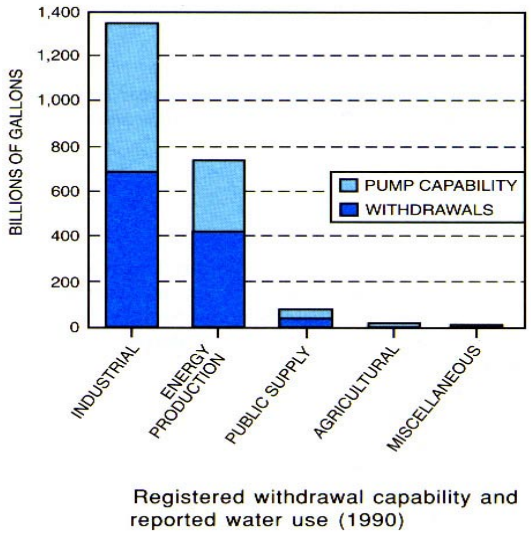


Figure 8.

In northwestern Indiana, abundant fresh water from Lake Michigan has promoted the development of an extensive urban and industrial belt along the southern coast of the lake. Water supplies in the interior of the Lake Michigan Region come primarily from unconsolidated aquifers.

In the Lake Michigan Region, surface-water withdrawals accounted for approximately 99 percent of the registered facilities during 1990. Registered water withdrawals in the Lake Michigan Region averaged 1127.6 billion gallons or approximately 3 billion gallons per day in 1990. About 60 percent of the withdrawals were for industrial purposes, and nearly 37 percent were for energy production purposes. The remaining 3 percent of withdrawals were for public supply, agricultural or miscellaneous facilities (figure 8).

A general declining trend in demand is projected for most water withdrawal uses in the Region, but an increase in demand is projected for instream uses.

WATER RESOURCE DEVELOPMENT

Although there is a general declining trend in demand for water, future water demands in the Lake Michigan Region are expected to remain high, especially for both the large population and the manufacturing-based industry. It is anticipated that most of the demands will be on Lake Michigan because it is by far the major source of water withdrawal use in the Region, accounting for approximately 99 percent of total water withdrawals. There are, however, constraints on development of Lake Michigan and the other Great Lakes. Present political and legal constraints limit diversion and consumptive use of water from the Great Lakes including Lake Michigan. The Great Lakes Charter was signed by the governors and premiers of the Great Lakes states and provinces which requires that any state or province that is considering approval of a new or increased diversion or consumptive use of Great Lakes water exceeding 5 million gallons per day in any 30-day period notify and consult with the governors and premiers of the other Great Lakes states and provinces. In addition, a law passed by the U.S. Congress requires that any new or increased diverions of Great Lakes water be approved by all of the governors of the Great Lakes states.

Lakes and wetlands will continue to provide a wide range of recreational opportunities, fish and wildlife habitat, various hydrologic benefits, and, in a few cases, minor water supply sources. However, these systems are not considered as significant sources of supply because of their limited storage capacity, water-quality considerations, and regulatory, economic and environmental constraints.

The largest withdrawals from streams come from the Grand Calumet and Little Calumet Rivers. The largest

volumes of water withdrawn are used for industrial processing and golf-course irrigation. Despite the constraints discussed above, surface-water supply in the Region generally exceeds demand. Although localized or short-term water-quantity conflicts may have occurred among water users, the greatest conflicts in the Lake Michigan Region have been related to water-quality issues.

Ground-water resources availability of the Lake Michigan Region is considered fair to moderate when compared with the rest of the state. Development of ground water in the coastal region has been somewhat limited, due primarily to the proximity of Lake Michigan's vast water resource. Ground-water withdrawals in the interior portion of the Region are used primarily for public and domestic drinking water supplies. Whereas, ground water withdrawals near the coast are used primarily for industrial purposes.

Ground-water quantity conflicts have not been a primary issue for the Lake Michigan Region. Since the Emergency Regulation statute became effective, the Water Rights Section of the IDNR, Division of Water has conducted ten investigations in the Lake Michigan Region. Two of the ten investigations resulted in documentation that a dewatering operation for mineral extraction and another for construction purposes had impacted domestic wells, and "timely and reasonable compensation" was provided to the homeowners under the provisions of IC 14-25-4.

To order a copy of the publication "Water resource availability in the Lake Michigan Region, Indiana", send $7.50 plus $3.00 for shipping and handling to:

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