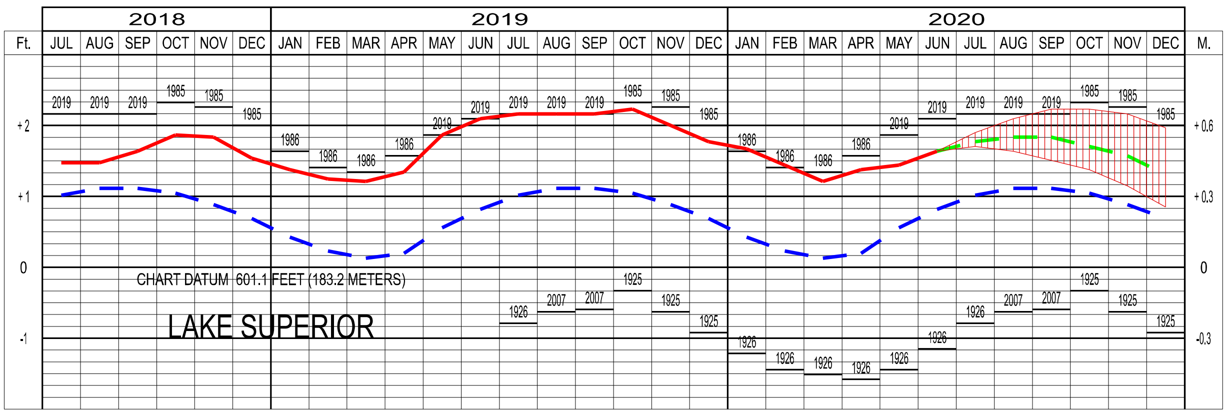
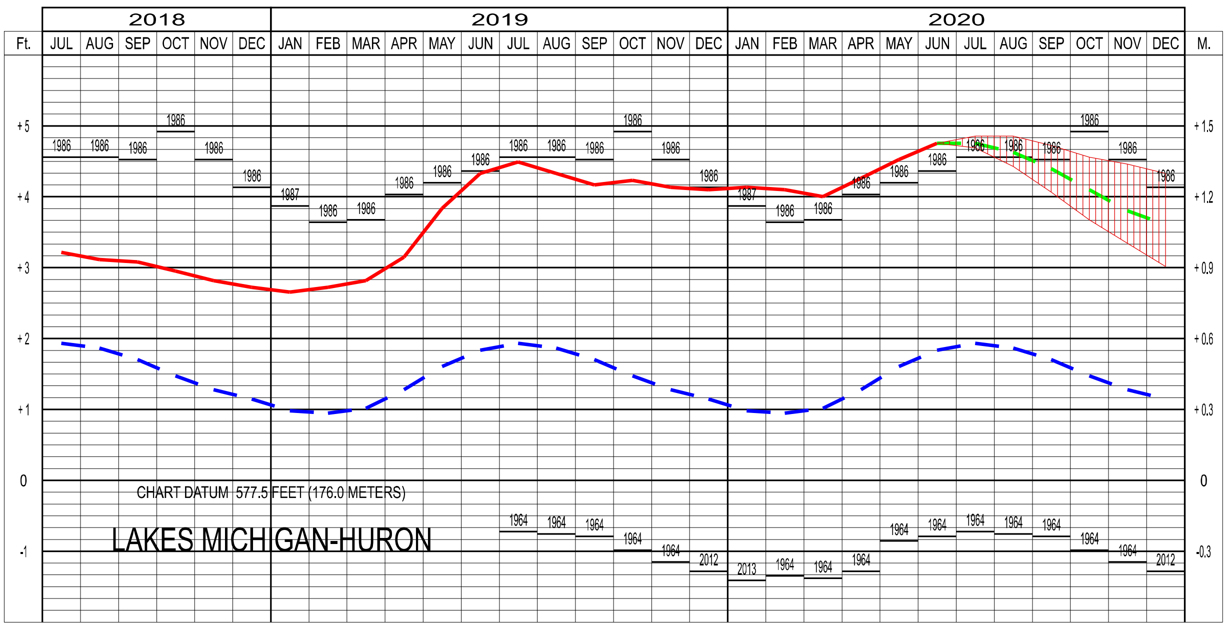
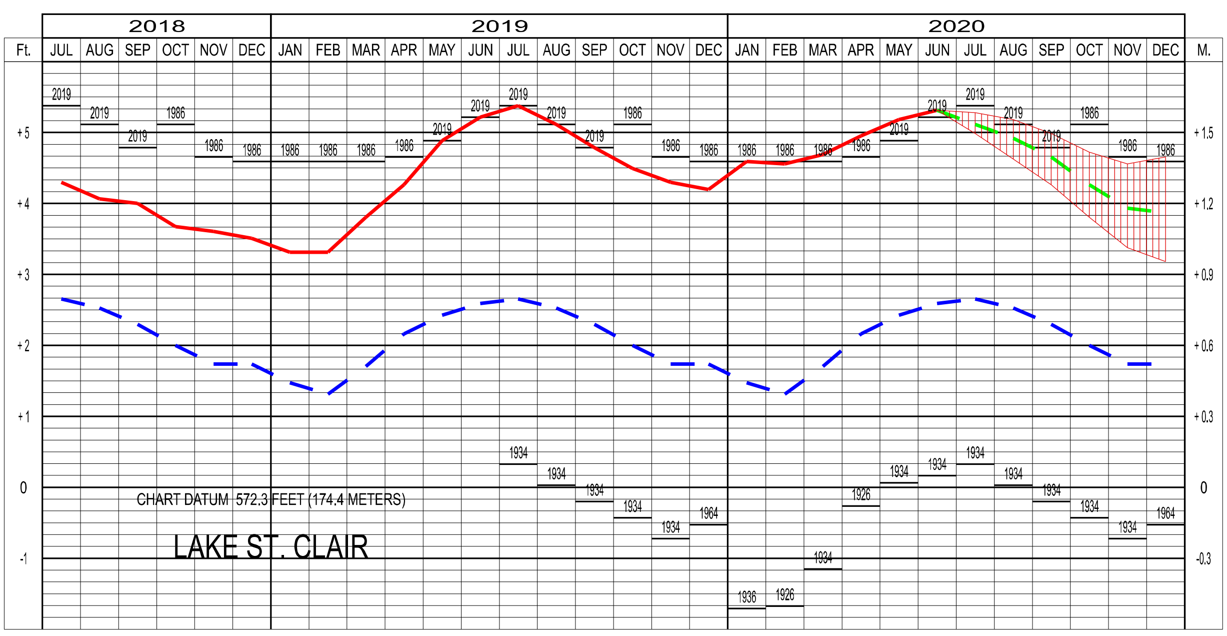
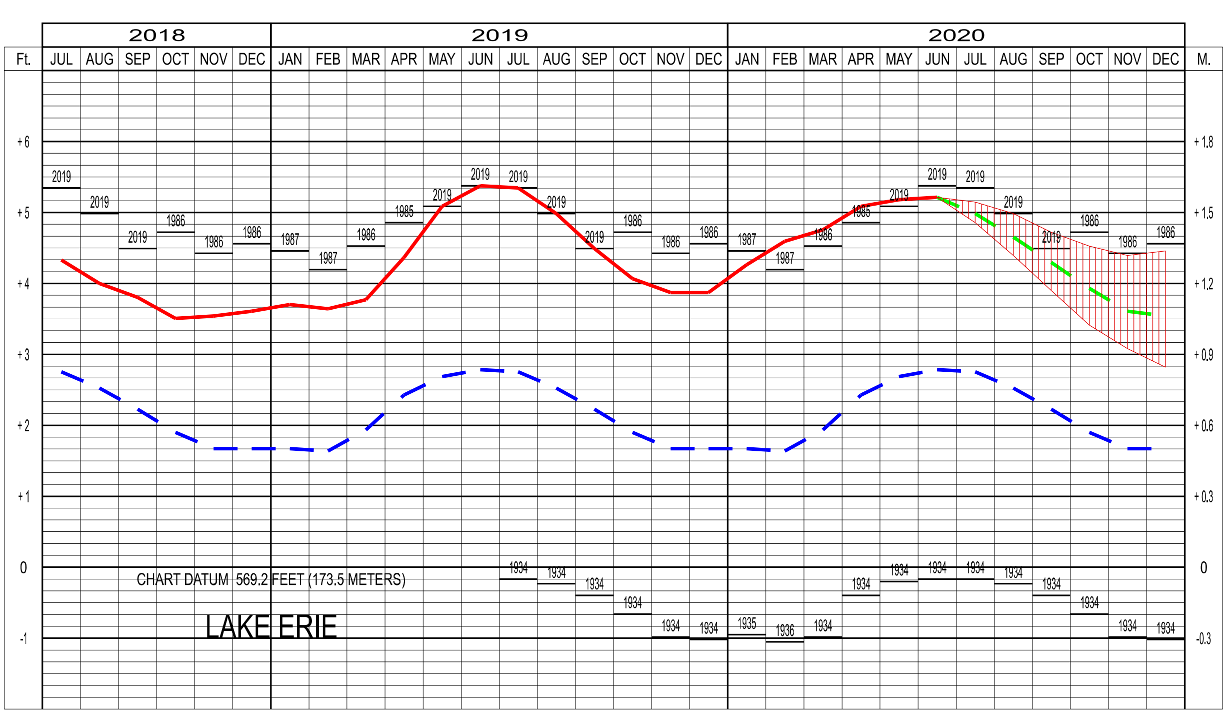
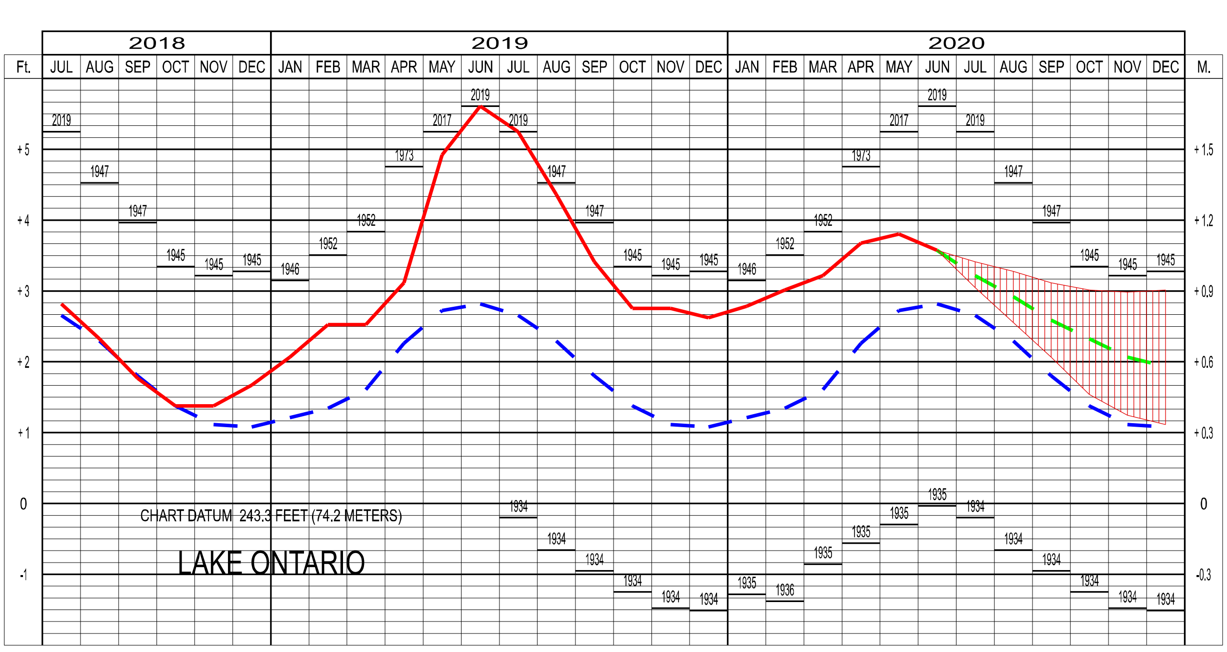










ELEVATIONS REFERENCED TO THE CHART DATUM OF EACH RESPECTIVE LAKE

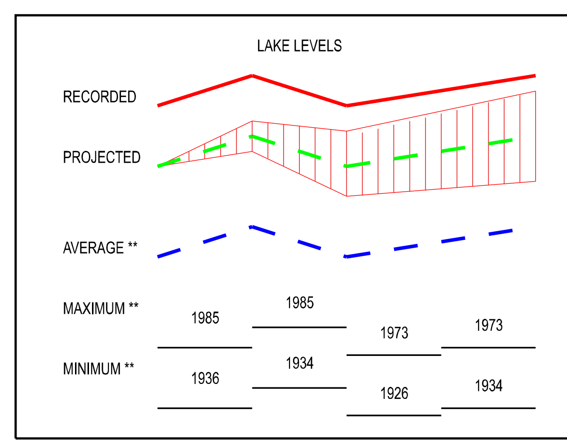
US Army Corps of Engineers
Detroit District

MONTHLY BULLETIN OF LAKE LEVELS FOR THE GREAT LAKES

JULY 2020

Monthly mean water levels for the previous year and the current year to date are shown as a solid line on the hydrographs. A projection for the next six months is given as a dashed line. This projection is based on the present condition of the lake basin and anticipated future weather. The shaded area shows a range of possible levels over the next six months dependent upon weather variations. Current and projected levels (solid and dashed lines) can be compared with the 1918-2019 average levels (dotted line) and extreme levels (shown as bars with their year of occurrence). The legend below further identifies the information on the hydrographs.

LEGEND



The levels on the hydrographs are shown in both feet and meters above (+) or below (-) Chart Datum. Chart Datum, also known as Low Water Datum, is a reference plane on each lake to which water depth and Federal navigation improvement depths on navigation charts are referred.

All elevations and plots shown in this bulletin are referenced to International Great Lakes Datum 1985 (IGLD 1985). IGLD 1985 has its zero base at Rimouski, Quebec near the mouth of the St. Lawrence River (approximate sea level).

JUNE MEAN LAKE LEVELS

(IGLD 1985)

		Superior	Mich-Huron	St. Clair	Erie	Ontario
* 2020	Ft.	602.69	582.19	577.49	574.44	247.01
	M.	183.70	177.45	176.02	175.09	75.29
2019	Ft.	603.15	581.76	577.40	574.61	249.05
	M.	183.84	177.32	175.99	175.14	75.91
** MAX.	Ft.	603.15	581.79	577.40	574.61	249.05
	M.	183.84	177.33	175.99	175.14	75.91
	Yr.	2019	1986	2019	2019	2019
** MIN.	Ft.	599.90	576.64	572.34	569.06	243.41
	M.	182.85	175.76	174.45	173.45	74.19
	Yr.	1926	1964	1934	1934	1935
** AVG.	Ft.	601.87	579.27	574.77	572.01	246.26
	M.	183.45	176.56	175.19	174.35	75.06

* provisional
** Average, Maximum and Minimum for period 1918-2019

Information

Recorded monthly mean water levels in this bulletin are derived from a representative network of water level gages on each lake (see cover map). Providers of these data are the U.S. Department of Commerce, NOAA, National Ocean Service, and Integrated Science Data Management, Department of Fisheries and Oceans, Canada. The Detroit District, Corps of Engineers and Environment and Climate Change Canada derive historic and projected lake levels under the auspices of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data.

This bulletin is produced monthly as a public service. The Corps also, on a weekly basis publishes online the *Great Lakes, Connecting Channels and St. Lawrence River Water Levels and Depths*, which provides a forecast of depths in the connecting rivers between the Great Lakes and the International Section of the St. Lawrence River. This *Monthly Bulletin of the Lake Levels for the Great Lake*s may be obtained free of charge by writing to the address shown on the front cover, by calling (313) 226-6441 or emailing hhpm@usace.army.mil. Notices of change of address should include the name of the publication. This information is available on the internet at http://www.lre.usace.army.mil/Missions/GreatLakesInformation.aspx.

Great Lakes Basin Hydrology
June 2020

According to preliminary estimates, precipitation in the Great Lakes basin was slightly below average in June. Lakes Superior and Michigan-Huron experienced precipitation that was near to slightly above average, while in the Lakes Erie and Ontario basins precipitation was well below average at 67% and 55% of average, respectively. Water supplies to the lakes were below average on all lakes, except Lake Michigan-Huron, which had slightly above average water supplies in June. Outflows in June remained above average as a result of the high water level conditions. Preliminary estimates indicate that outflows through the St. Clair River and Detroit River were above record-highs for the month of June.

Record high monthly mean water levels continued on Lakes Michigan-Huron and St. Clair in June. Lake Michigan-Huron surpassed its previous record from 1986 by 5 inches, while Lake St. Clair surpassed its record high level from last year by 1 inch. From May to June, Lakes Superior and St. Clair each rose about 2 inches, while Lake Michigan-Huron rose about 3 inches. Lake Erie climbed less than an inch from May to June and Lake Ontario began its seasonal decline, falling 3 inches.

PRECIPITATION (INCHES)

BASIN	June				12-Month Comparison			
	2020	Average (1900-2017)	Diff.	% of Average	Last 12 months	Average (1900-2017)	Diff.	% of Average
Superior	3.44	3.31	0.13	104	27.78	30.59	-2.81	91
Michigan-Huron	3.24	3.19	0.05	102	32.62	32.52	0.10	100
Erie	2.36	3.50	-1.14	67	33.10	35.55	-2.45	93
Ontario	1.77	3.19	-1.42	55	31.46	35.83	-4.37	88
Great Lakes	3.01	3.27	-0.26	92	31.19	32.76	-1.57	95

LAKE	June WATER SUPPLIES[1] (cfs)		June OUTFLOW[2] (cfs)	
	2020	Average (1900-2008)	2020	Average[3] (1900-2008)
Superior	127,000	155,000	81,000	77,000
Michigan-Huron	210,000	204,000	256,000	192,000
Erie	-2,000	31,000	276,000	216,000
Ontario	22,000	42,000	331,000	263,000

Notes: Values (excluding averages) are based on preliminary computations; cfs denotes cubic feet per second.

[1] Net basin supply is the net result of precipitation falling on the lake, runoff from precipitation falling on the land which flows to the lake, and evaporation from the lake. Negative net basin supply denotes evaporation exceeded runoff and precipitation. The net total supply can be found by adding the net basin supply and the outflow from the upstream lake.

[2] Does not include diversions.

[3] Lake Ontario average water supplies and average outflows are based on period of record 1900-2005

US Army Corps of Engineers ®
Detroit District

Great Lakes Update

Volume 206: From Record-Lows to Record-Highs in 6 years

Background

In January 2013, Lakes Superior and Michigan-Huron were in the midst of a 14-year streak of below average water levels. Lake Michigan-Huron's monthly mean water level sunk to 576.02 feet (IGLD85) that month. Not only was this level a record-low for the month of January, it was the lake's lowest monthly mean level since 1918, the beginning of its period of record.

By May 2019, just six 6 years later, the Great Lakes were experiencing record-high levels. Lakes Superior, St. Clair, Erie, and Ontario matched or set numerous record high monthly mean levels in 2019. Moreover, in June 2019, Lakes Erie and Ontario climbed to their highest overall monthly mean level in their period of record dating back to 1918, while Lake St. Clair achieved the same milestone a month later. Based on preliminary water level statistics for 2020, Lake Michigan-Huron has set monthly mean record high levels for January, February, March, April, and May this year. (Lakes Michigan and Huron are considered as one lake hydraulically due to the connection at the Straits of Mackinac.)

Figures 1 through 5 show the Great Lakes' monthly mean water levels from the end of the low water level period to 2019, plotted against their respective monthly long-term average (LTA) levels. The solid line represents the 2013 to 2019 monthly water levels and the dashed line represents the LTA levels for each month.

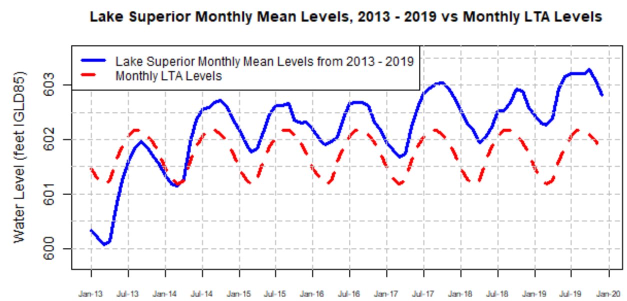


Figure 1: Plot of Lake Superior water levels from 2013 to 2019 versus the lake's LTA levels.

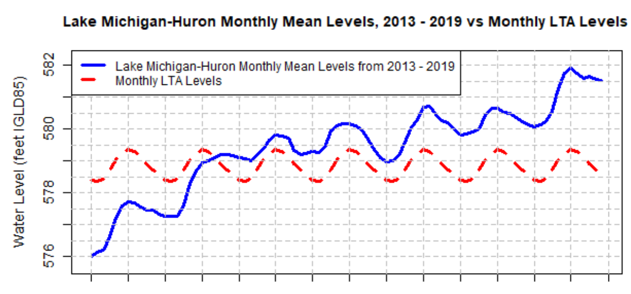


Figure 2: Plot of Lake Michigan-Huron water levels from 2013 to 2019 versus the lake's LTA levels.

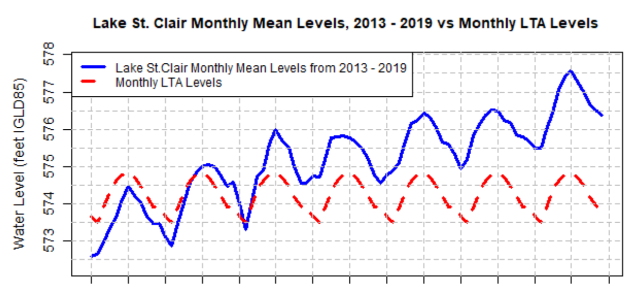


Figure 3: Plot of Lake St. Clair water levels from 2013 to 2019 versus the lake's LTA levels.

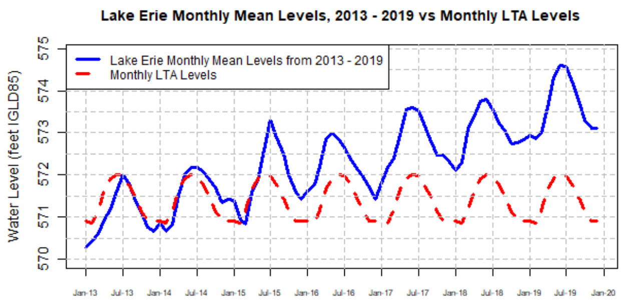


Figure 4: Plot of Lake Erie water levels from 2013 to 2019 versus the lake's LTA levels.

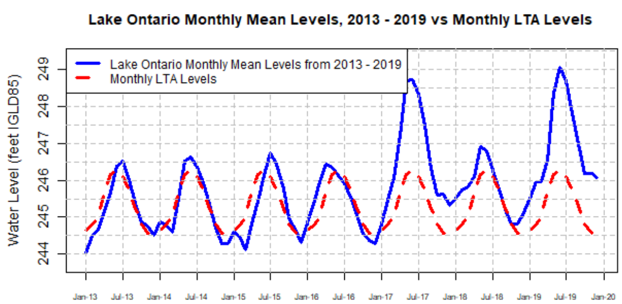


Figure 5: Plot of Lake Ontario water levels from 2013 to 2019 versus the lake's LTA levels.

This update article chronicles the shift from the historic low water levels of the late 90's to the early '10s, to the historic high water levels that are occurring today. No discussion of long-term Great Lakes water level fluctuations is complete without an evaluation of Net Basin Supply (NBS). Net Basin Supply is the combined effects of precipitation falling on the lakes' surface, runoff draining to the lakes, and evaporation from the lakes' surface, and is the primary driver of water level changes on the Great Lakes. NBS data from 2009 to 2019 is preliminary, not final.

Historic El Niño Triggers Water Level Decline

The El Niño of 1997-98 was the most powerful on record up to that point, bringing record-high temperatures and significantly below normal precipitation throughout the region. Lake Superior's winter precipitation was the second lowest since the early 1960s. Moreover, the much warmer conditions substantially reduced total snowfall in the basin and snowpack accumulation that winter.

The 1997-1998 El Niño seemed to usher in a transition to higher lake surface water temperatures and higher evaporation rates in Lakes Superior and Michigan-Huron. The below plots of Lakes Superior and Michigan-Huron's annual average lake surface temperatures and annual evaporation data estimates from the Great Lakes Seasonal Hydrological Forecasting System (GLSHyFS) model, developed by NOAA's Great Lakes Engineering & Research Laboratory (GLERL), show a noticeable trend of generally higher surface temperatures and annual evaporation after 1997.

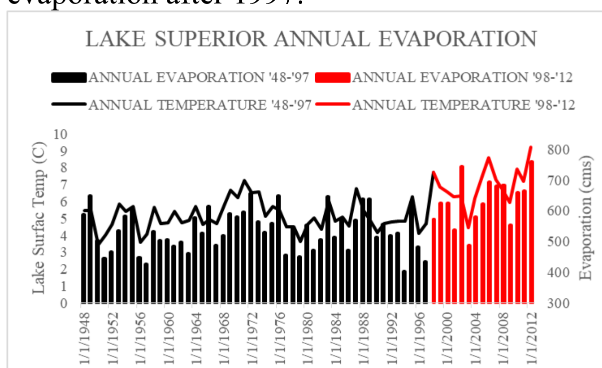


Figure 6: Comparison of annual evaporation and lake surface temperatures from 1948-2012, Lake Superior.

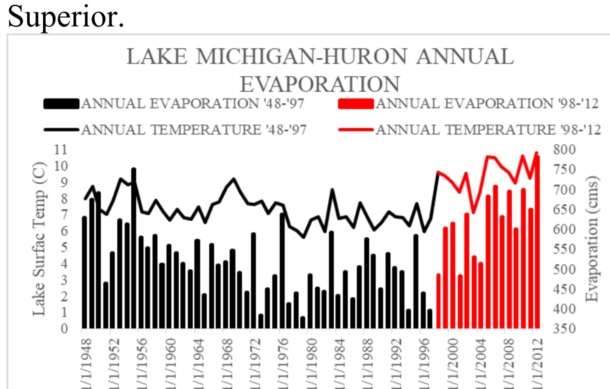


Figure 7: Comparison of annual evaporation and lake surface temperatures from 1948-2012, Lake Michigan-Huron.

Evaporation from the lake surface is directly related to the difference in temperature between the air and lake surface. Evaporation increased over this time period, as did the air and surface temperatures, but their temperature difference did not. What could be the cause of the enhanced evaporation? Evaporation rates generally go higher as water temperatures go higher.

The combination of below normal precipitation/snowfall, reduced snowpack accumulation, and somewhat increased evaporation in the Great Lakes basin from mid-1997 through 1999 resulted in considerable water level decline. Lakes Michigan-Huron, St. Clair, and Erie's levels plummeted 28 to 31 inches between July 1997 and July 1999, while Lake Superior fell 11 inches; Lake Ontario dropped 44 inches in the 8-month period between April and December 1998. By the end of 1999, the lakes ranged from 2 to 14 inches below LTA.

Levels of Lower Lakes not as Extreme

It is important to note that the lower lakes (St. Clair, Erie, and Ontario) did not experience the same continuous trend of below average levels during this decade-and-a-half period as the upper lakes. The monthly levels of Lake St. Clair were below average from early 1999 to the end of 2008, but the lake achieved many months of near average to above average water levels in 2009 and 2011.

Lake Erie was nearly continuously below average from Spring 1999 to Summer 2004, but its level was, in general, near average from mid-year 2004 to early 2012. Figure 8 illustrates Erie's levels.

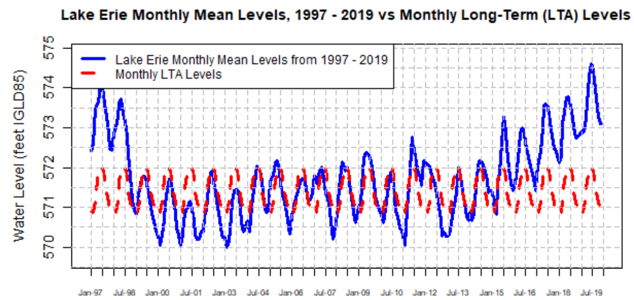


Figure 8: Lake Erie water levels from 1997-2019.

Lake Ontario did not experience any multi-year long stretch of below average water levels during this period. Annual NBS is the sum of monthly NBS in a calendar year. From 1999-2011, the average annual Net Basin Supply for Lakes Erie and Ontario was 27% and 13%, respectively, above normal. 2011 stands out in particular as Lake Erie experienced precipitation that was 49% above average, and for Lake Ontario, 24% above average. The 2011 annual NBS of Lakes Erie and Ontario were their highest and 4th highest, respectively, since 1900 (up to that point in time).

Deeper review of the Upper Lakes

It is also important to note that the annual NBS for Lake Michigan-Huron was 95% of average during the 12 years between the historically low NBS years of 1998 and 2012. In fact, the lake's annual NBS was above average in 6 of the years in the 1999 to 2011 time span. Precipitation was above normal in 9 of those years. It wasn't that the lake's NBS was continually below average year after year after year. Rather, there were no consecutive year streaks of above average NBS to provide an upward push to the water levels.

Another factor that impacts Lake Michigan-Huron water levels is the inflow into the lake from the St. Marys River. In 12 of the 15 years from 1998 and 2012, the St. Marys River monthly outflow into Lake Michigan-Huron was below average in 10 or more months. St. Marys River monthly outflow statistics are preliminary from 2009 onward.

For Lake Superior, the 15-year period of below average water levels was marked by consistently dry conditions. Annual precipitation was below average in 9 of the years between 1997 and 2012. Precipitation during winters was especially lacking. Based on the coordinated Great Lakes precipitation statistics, six of the ten driest winters since 1950 occurred during the 1998-2014 low water level period as shown in below Figure 9.

Winter	November-February Precipitation (inches)	Rank
2002-03	4.6	1
2006-07	5.7	2
1962-63	6.0	3
1986-87	6.0	3
1999-00	6.0	3
2009-10	6.0	3
1954-55	6.0	3
1997-98	6.1	8
2011-12	6.2	9
1993-94	6.2	9

Figure 9: The 10 Lowest November through February Overbasin Precipitation Amounts for Lake Superior from 1950-2017.

An indicator of runoff in a watershed is soil moisture. Soil Moisture is the amount of pore space within soil occupied by water. The lower the soil moisture, the higher the volume of rainfall that can potentially percolate into the pore space of the soil, and less the volume of water that stays on the surface and runs into streams and rivers. Low soil moisture is an indication of low runoff.

The soil moisture map (Figure 10) of the U.S. from January 2003 by NOAA's Climate Prediction Center shows exceptionally below normal soil moisture in the majority of the Great Lakes basin, and is representative of the low soil moisture, and thus low runoff, during this period.

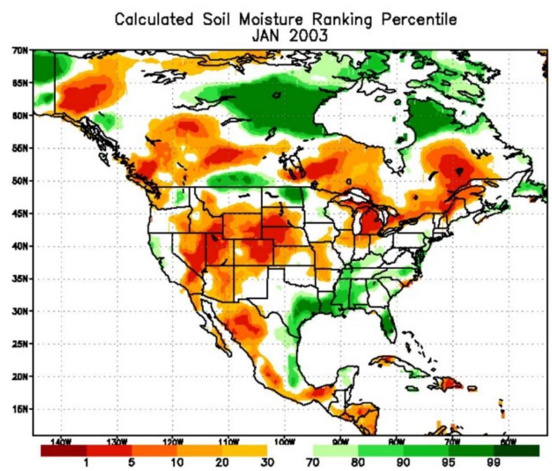


Figure 10: NOAA's Climate Prediction Center map of Soil Moisture Percentile Ranking for North America, January 2003.

From 1999 to 2003, Lake Superior's average monthly departure from LTA levels was 7 inches below monthly LTA. Above average NBS in 2004 brought the lake's level to near average in the cold-season months of 2004-2005. However, annual NBS to Lake Superior was below average every year from 2005 to 2012. Continuous years of below average water supplies led to Lake Superior descending to record-low monthly mean levels in August and September 2007. During 2008 and 2009, the lake's monthly mean levels were an average of 12 inches below monthly LTA.

The "Non-Winter" of 2011-12

In the fall of 2011, the levels of Lakes St. Clair, Erie, and Ontario were near or above their LTAs. However, the unusual winter of 2011-12 plunged the upper lakes into record- and near record-lows. This winter was distinguished by far below normal precipitation and near-record high temperatures in the Great Lakes region and the nation as a whole.

Above average temperatures persisted into the spring and summer. According to the GLSHyFS model, monthly air temperatures over Lakes Superior and Michigan-Huron were 10° F above average in June and July 2012. For all lakes, air temperatures were above average in all months of 2012 except for Lake Ontario in November. In addition, according to the NWS and Environment and Climate Change Canada, the Great Lakes experienced some of their highest lake surface temperatures in a century in the spring and summer of 2012. The GLSHyFS model calculated 2012 annual evaporation from the Great Lakes to range from 22% to 42% above average.

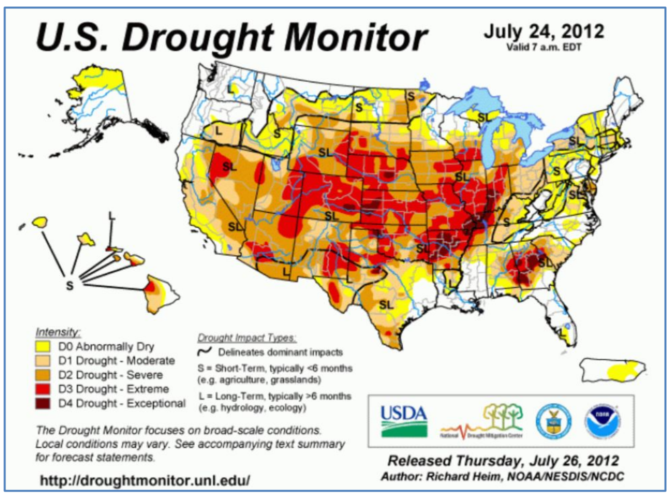


Figure 11: Drought Monitor Map from July 2012 produced by NOAA's Climate Prediction Center.

In 2012, severe drought conditions were felt nationwide (Figure 11 above). Much of the country east of the Rocky Mountains received below normal snowfall in winter 2011-12. Moreover, precipitation in the spring and summer seasons were below average for Lakes Michigan-Huron, Erie, and Ontario. The low snowfall and below average spring rainfall in the Great Lakes basin led to decreased runoff for all of the lakes. The Advanced Hydrologic Prediction System (AHPS) model, also developed by NOAA GLERL, calculated runoff to Lakes Superior, Michigan-Huron, Erie, and Ontario to be 20% to 33% below average in 2012.

The dry conditions culminated in Lake Superior just barely missing its record-low October monthly mean level by 1 inch. Just a month earlier, the lake experienced its lowest NBS on record for the month of September.

Lake Michigan-Huron set new record low water levels during the months of December 2012 and January 2013. The lake's 2012 Annual NBS was its 2nd lowest since 1900 and its April and September monthly NBS were its lowest and 2nd lowest on record for those respective months.

Lakes St. Clair and Erie did not experience a seasonal rise in 2012. Their monthly mean levels fell 20 and 22 inches, respectively, from January 2012 to 2013. In fact, Lake Erie's monthly mean level declined 10 consecutive months from December 2011 to October 2012. Its monthly NBS was at or below average 9 of 12 months in 2012.

Lake Ontario declined 28 inches from February 2012 to December 2012.

Water Levels Rebound in 2013, Receive Boost from Polar Vortex of 2013-2014

2013 proved to be a turning point. For only the 2nd time since the high-water level year of 1996, all of the Great Lakes experienced above average precipitation in the same year. This led to above average rises for all the lakes in the spring and summer (Figure 12). Precipitation was actually above average throughout the basin in 2008, but in contrast to the low-water period, the wet year of 2013 was succeeded by a climatological event that sustained the wet conditions.

The Polar Vortex winter of 2013-2014 brought record-low temperatures and record/near-record snowfall to the basin. Various cities from Petoskey, MI, to Toledo, OH, experienced their highest winter snowfall amounts on record. Moreover, cities like Chicago, IL and Duluth, MN, received the third-highest seasonal snowfall totals in their histories.

The harsh winter produced record-high ice cover over the Great Lakes. The cooling of the lake surface by the bitterly cold temperatures and record-high ice cover lowered lake surface temperatures, moderately depressing evaporation in spring and summer. As a result of the reduced evaporation and the abundant runoff generated from the melting of the above average snow accumulation, all of the Great Lakes experienced above average Net Basin Supplies in April, May, and June 2014.

For Lake Superior, monthly NBS was above average in 13 of 14 months between May 2013 and June 2014. The annual water supplies in 2014 for Lakes Superior and Michigan-Huron were in excess of 50% above average, and were their 2nd and 4th highest Annual NBS, respectively, since 1900. In addition, the annual NBS was over 20% above average for Lakes Erie and Ontario in 2014.

Lake	2013 Seasonal Rise (in)	2014 Seasonal Rise (in)	Historical Average Seasonal Level Rise (in)
Superior	23	19	12
Michigan-Huron	20	23	12
St. Clair	23	26	16
Erie	21	18	14
Ontario	34	25	21

Figure 12: Great Lakes Seasonal Rises in 2013 & 2014 versus Historical Average Seasonal Rises.

Due to those seasonal rises, Lake Superior reached its long-term monthly average in March 2014, ending a 15- consecutive year period in which the lake was below LTA. By September 2014, Lake Michigan-Huron matched its LTA, the first time in 16 years the levels of all of the Great Lakes were at or above average at the same time.

Generally Wet Conditions Persist Through 2019

In 2015 and 2016, NBS was moderate basin-wide, even somewhat below average in the lower lakes. The upper lakes remained above LTA those years. However, in 2017, Lake Ontario commenced the surpassing of record-high levels. The lake experienced above average monthly NBS 9 months that year, and its 2017 Annual NBS was its highest on record. Propelled by above average precipitation in March, April, May, and June, including nearly 6 inches of rainfall in May, the lake rose 53 inches in 2017 and set record-high monthly mean levels for May and June. In addition, in 2019, Lake Ontario experienced above average monthly NBS every month except March and August.

Lake Superior's Annual NBS was above average every year from 2013 to 2019, in contrast to the low water level period when Annual NBS was below average in 14 of the 16 years. In addition to its near-record 2014 Annual NBS, the lake experienced its 6th highest Annual NBS in 2017, and its 11st highest Annual NBS in 2019, since 1900.

Lake Michigan-Huron's Annual NBS has been above average in 5 of the past 7 years. The lake received its highest Annual NBS on record in 2019, its 4th highest Annual NBS in 2014 and its 8th highest Annual NBS in 2017, during this period. Below Figures 13 and 14 illustrate the flip from generally below average to generally above average NBS in 2013 and the water level response.

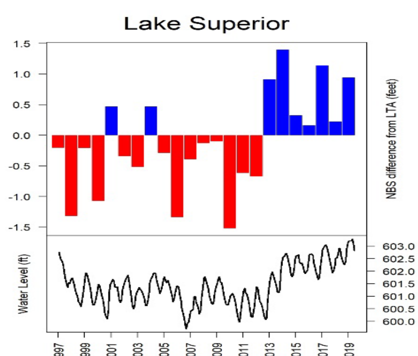


Figure 13: Annual NBS difference from LTA and Monthly Mean Water Levels for Lake Superior from 1997-2019.

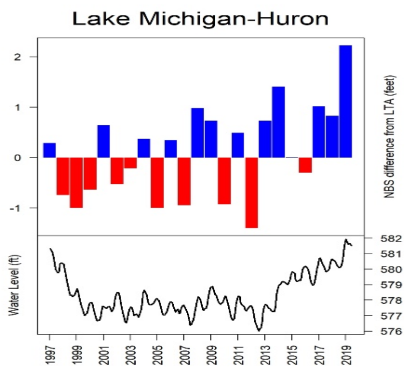


Figure 14: Annual NBS difference from LTA and Monthly Mean Water Levels for Lake Michigan-Huron from 1997-2019.

Lake Erie's 2017 Annual NBS was its 8th highest in 119 years. Its Annual NBS was above average in all but one year in the 2013-2019 time frame.

Continuously High NBS results in Record-Breaking 2019

Record-high water levels matched or set in 2019 on Lakes Superior, St. Clair, Erie, and Ontario are shown in Figure 15 below.

LAKE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SUP	1986	1986	1986	1986	2019	2019	2019	2019	2019	1985	1985	1985
M-H	1987	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986	1986
STC	1986	1986	1986	1986	2019	2019	2019	2019	2019	1986	1986	1986
ERI	1987	1987	1986	1985	2019	2019	2019	2019	2019	1986	1986	1986
ONT	1946	1952	1952	1973	2017	2019	2019	1947	1947	1945	1945	1945

Figure 15: Table showing which months record-high monthly mean water levels were set in 2019.

Lake Michigan-Huron did not reach record high water levels in 2019. However, its record high 2019 Annual NBS resulted in the lake being within an inch of record-high levels in June, July, and December. Its July-December water level decline in 2019 was just 5 inches – 50% of its historical average - leading to a record-high January level in January 2020, according to preliminary data. In addition, by the end of 2019, all of the lakes were 13 to 36 inches above LTA.

Record-High Precipitation Catapults NBS

Consistently above average precipitation may be the most significant catalyst for the recent record-high NBS and water levels. Lake Superior's annual precipitation was above average each year from 2013 to 2017, the first time it had been above average 5 years in a row since the record-high water level period of the mid-1980s. Annual precipitation for Lakes Erie and Ontario were above average 3 and 4 years, respectively, in that 5-year stretch. Lake Michigan-Huron's annual precipitation, while closer to average than the other lakes, was below average only one year during that time. USACE's official Great Lakes precipitation statistics are only coordinated through 2017.

According to the NWS, the state of Wisconsin, of which significant portions lie in the Lake Superior and Michigan-Huron basins, experienced above average precipitation for 7 consecutive years (2013-2019). Three of the state's top five wettest years have taken place in the past 5 years (2015-2019). Moreover, the state received record-high annual precipitation in 2018, and again in 2019. In addition, estimates from the Midwest Regional Climate Center (MRCC) indicate that 2019 annual precipitation for Michigan and Minnesota were their highest on record. Also, the MRCC data indicated that precipitation in 2018 in the Midwest region, which includes 6 Great Lakes states, was the highest in the Center's period of record. Remarkably, the 2019 Midwest precipitation exceeded the 2018 record-high.

A below plot of the 5-year running total of estimated precipitation in the U.S.-only portion of the Great Lakes basin, by NOAA's National Centers for Environmental Information (NCEI), shows the stretch of precipitation from 2015-2019 is the highest five-year total since the beginning of the NCEI's period of record in 1895.

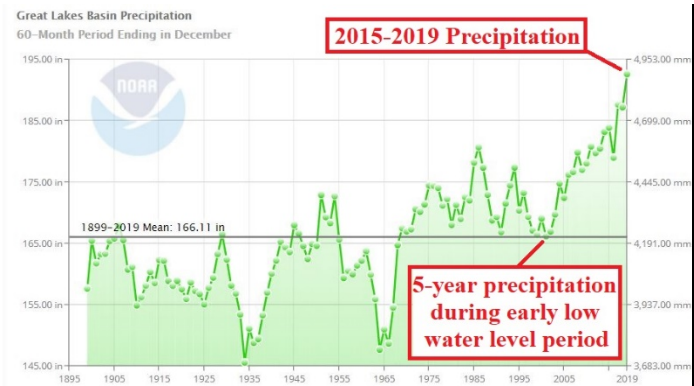


Figure 16: Plot of 60-month cumulative precipitation totals from 1895-99 to 2015-2019 by NOAA's NCEI.

Several of the lowest 5-year precipitation totals, post the 1960's droughts, are from the early years of the 1998-2014 low-water period.

Another significant factor in this current high water level period is runoff. Soil moisture and streamflow can be indicators of extent of runoff. In contrast to the low water level period, the fraction of months of below normal soil moisture during the high-water years has been substantially lower, implying a shift to higher runoff. Figure 17 represents the change to higher soil moisture during this high-water period.

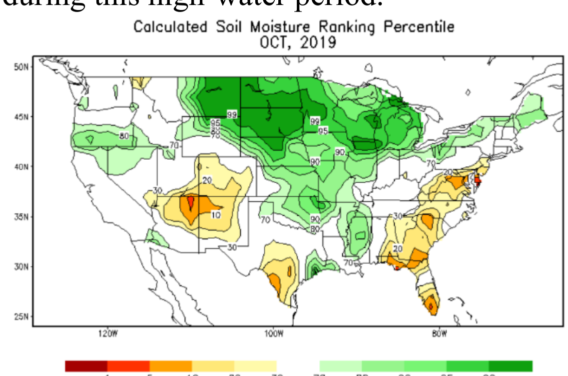


Figure 17. Soil Moisture Percentile Ranking in the United States, October 2019.

Streamflow is the quantity of water flowing in rivers in a watershed. In general, the higher the streamflows, the higher the runoff. The below map from the USGS's 2018 Annual Summary of Streamflow shows the streamflows within the Great Lakes Basin in Water Year 2018 (October 2017-September 2018) were the 11st highest since 1930.

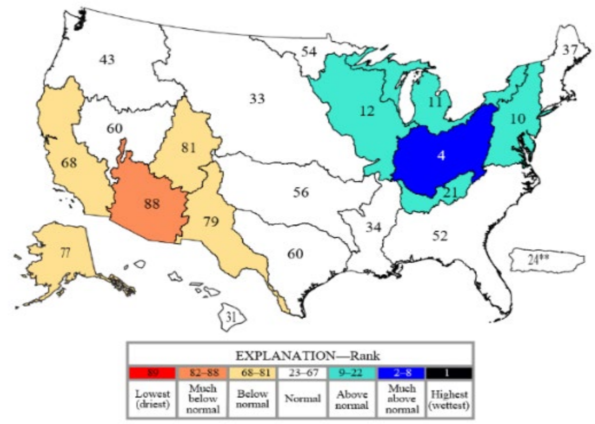


Figure 18: Rankings of streamflow in Regional U.S. Watersheds in Water Year 2018 relative to the period of record (1930-2018).

How long will High Water Levels Continue?

Unless there are continuous dry conditions in the Great Lakes basin for an extended period of time, water levels will remain very high for the time being. Official forecasts of Great Lakes water levels extend out six months. To see the latest 6-month forecast, visit:

Monthly Bulletin of Great Lakes Water Levels

Beyond six months, it is difficult to say with certainty how high water levels will be. Water levels of the Great Lakes cannot be fully controlled through regulation of outflows. More importantly, the major factors that affect the water supply to the Great Lakes - over-lake precipitation, runoff, and evaporation - cannot be controlled, nor can they be accurately predicted in the long term. Great Lakes levels will continue to fluctuate from low to high and back, and we need to be prepared for that variability.