COORDINATING COMMITTEE
COMITÉ DE COORDINATION

International Great Lakes Datum

Illinois Coastal Management Program Briefing

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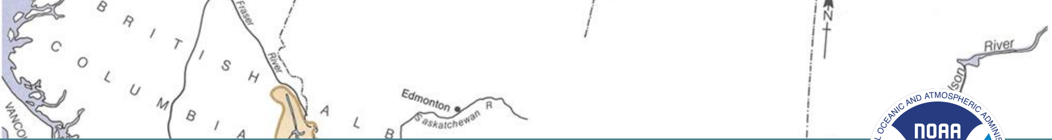
On behalf of the Great Lakes Coordinating Committee

September 4, 2024

Image: Mackinac Bridge connects Lakes Huron-Michigan



Boundary Waters

Boundary Waters Treaty of 1909

“Boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways… international boundary between the United States and the Dominion of Canada passes…”

What is IGLD?

International Great Lakes Datum

- Common height reference system needed to measure and relate water levels
- Official vertical datum used for water level measurements and navigation charts in the Great Lakes, their connecting channels and the St. Lawrence River
- Maintained by a binational committee staffed by U.S. and Canadian governments
- Updated approximately every 30 years to account for land movement

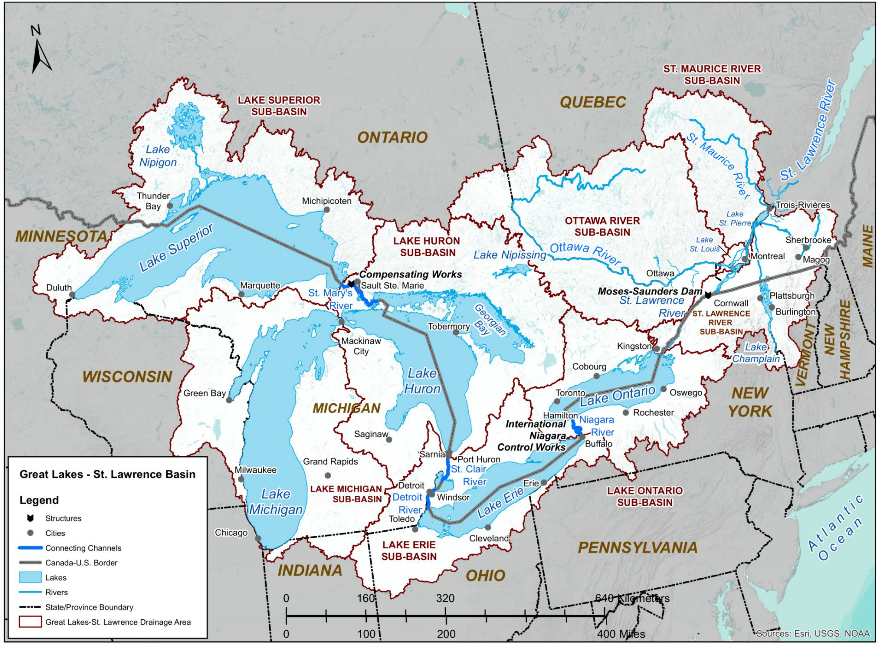


Image: Great Lakes waterways, credit: International Joint Commission

Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

- Formed in 1953
- Federal experts from both the United States and Canada
- Support the International Joint Commission and their work to uphold the Boundary Waters Treaty of 1909

Current Members

Environment and Climate Change Canada
Environnement et Changement climatique Canada

NOAA

Fisheries and Oceans Canada
Pêches et Océans Canada

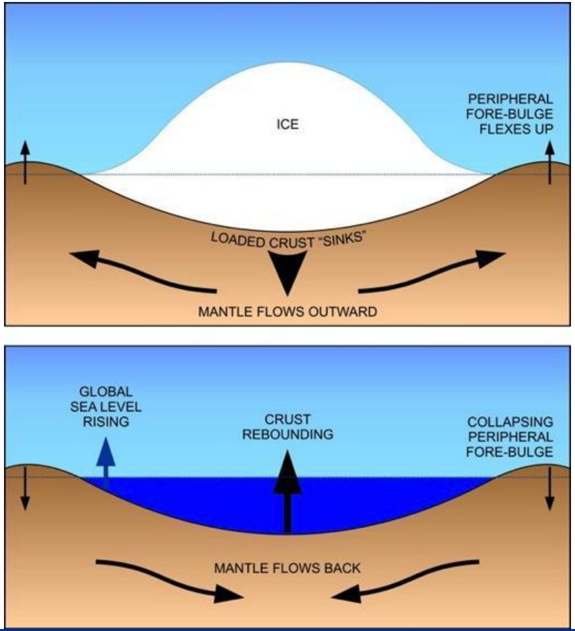
USGS
science for a changing world

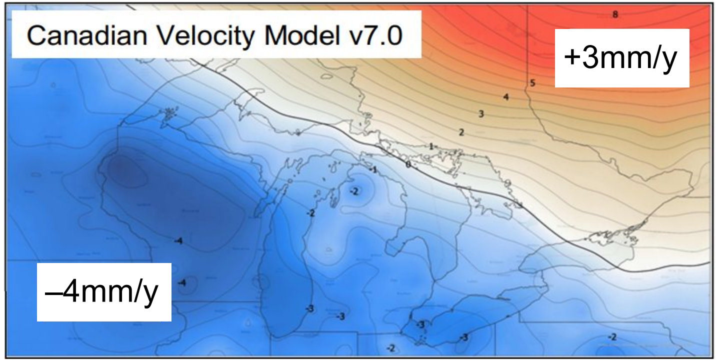
Natural Resources Canada
Ressources naturelles Canada

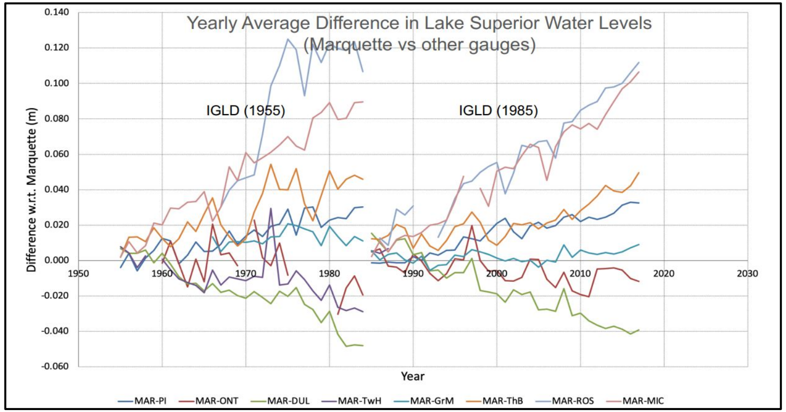
US Army Corps of Engineers

Why a new IGLD?

- Uplifting in north subsiding in south
- Overall tilting ~7 mm/year (21cm or 8” over 30 years)
- Need to update IGLD every 25-30 years => **overdue**!







Effect of GIA on Water Level Measurements

IGLD (1985)

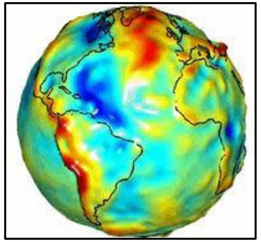
Reference surface developed through survey leveling

Land motion assumed to be static

Accessible through leveling connection to local bench marks *(metal markers in ground)*

IGLD (2020)

Reference surface defined by geoid model, based on gravity (instead of leveling), aligns with the modernized NSRS



Accounts for land motion, which will allow for more seamless updates

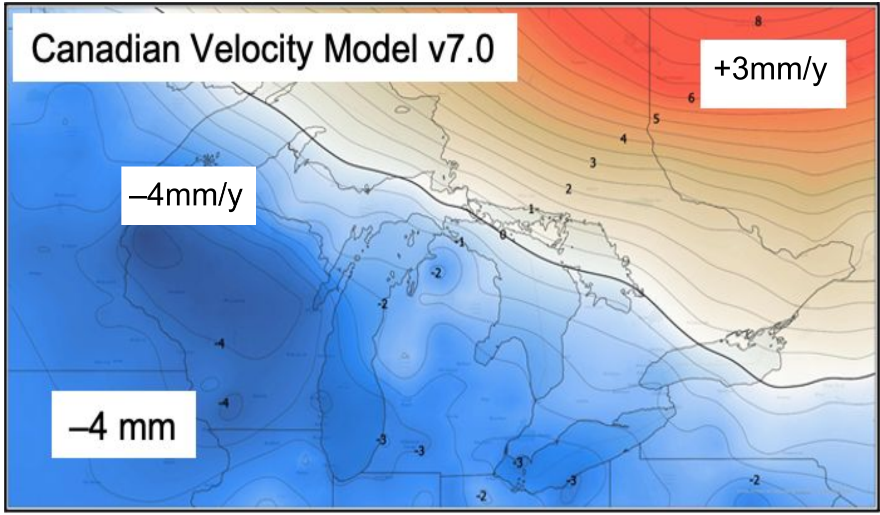
Accessible through GNSS connections to bench marks *(Global Navigation Satellite System)*

Expected Changes

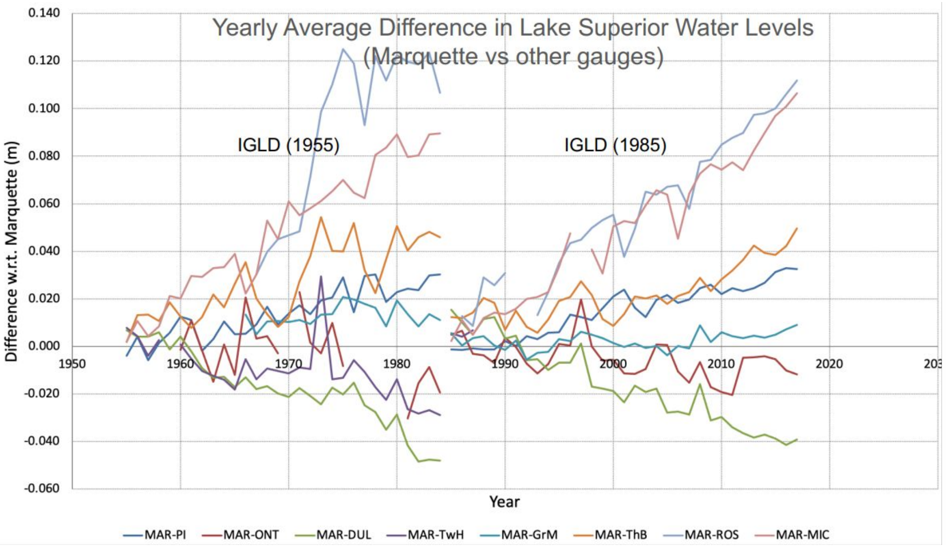
Water level reference heights expected to change 30-65 cm (12” to 26”) from the existing IGLD (1985)

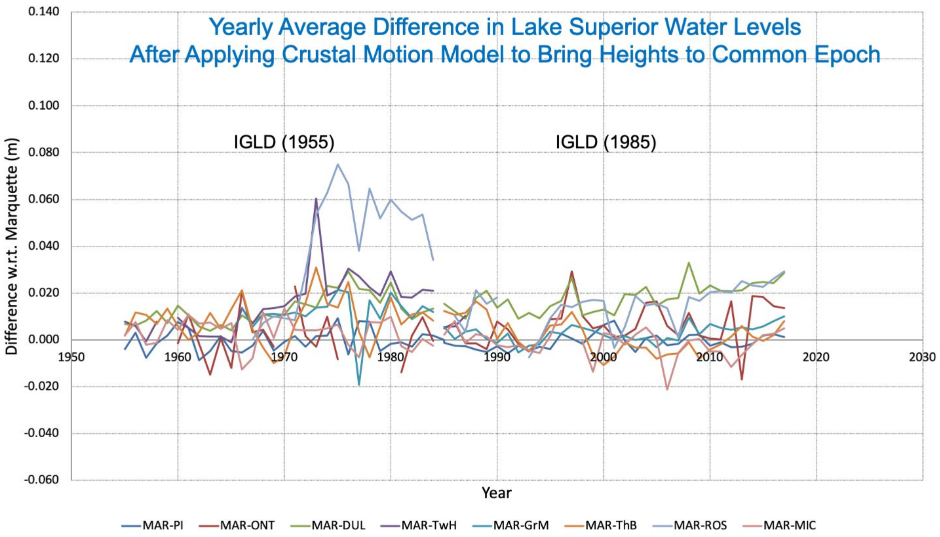
“Dynamic” Nature of IGLD (2020)

- IGLD (2020) will be a time-dependent “dynamic” datum
- Heights are changing in time due to regional & local crustal motions
- Can correct for crustal motion using a crustal velocity model estimated from GPS
- Velocity model will be provided by geodetic agencies & incorporated into commercial software (e.g., ArcGIS)
- Deciding how to implement for water levels



Water Level Measurements Corrected for GIA





Determining Heights via GNSS

GNSS Setup at Blue Water Bridge, Upper St. Clair River

- **Primary access to the new datum will be by GNSS**
  - GNSS = Global Navigation Satellite Systems such as GPS (US) and systems from other countries
  - Provides very high accuracy positioning, especially over long distances
  - Provides more accurate & direct ties to the new datum
  - Local leveling around each gauge will still be required
- Online GNSS data processing tools will be provided by the geodetic agencies (CGS & NGS)

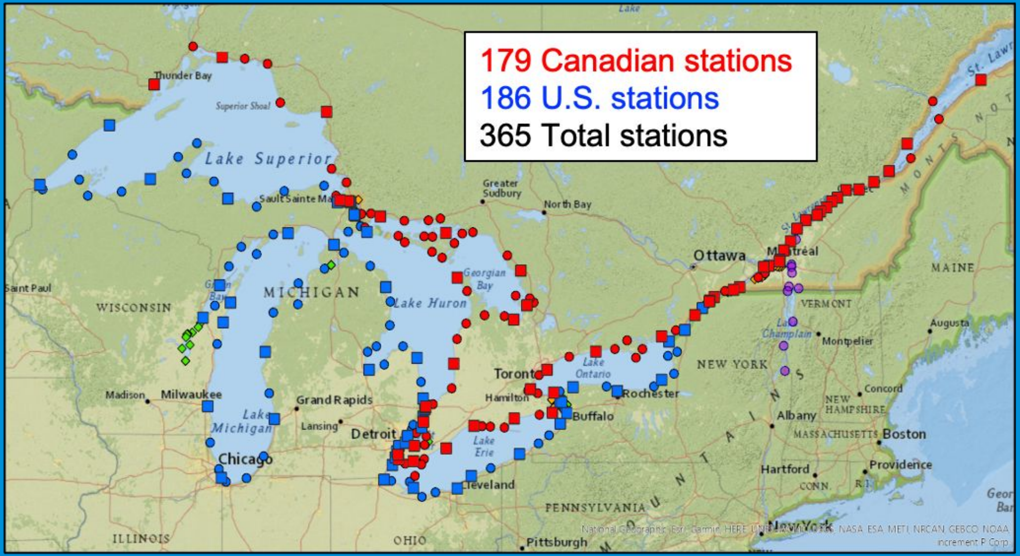
Moving Water Level Gauges to IGLD (2020)

- Conducted GNSS surveys in 1997, 2005, 2010, 2015 to prepare for IGLD update

- 2022 GNSS survey expanded to include:
    - Permanent gauges (federal, state, partners)
    - Seasonal gauges for determination of hydraulic correctors

- Processing GNSS data completed

- Next: Determining IGLD (2020) heights for all water level gauges and associated bench marks



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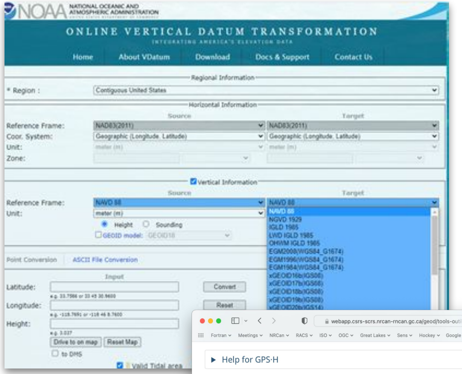
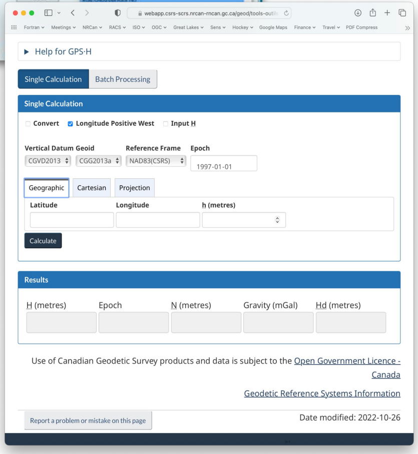
Transformations from Older Datums

- Transformation grids & tools will be needed for moving large data sets from older datums to IGLD (2020)
- Will use a common (binational) grid format based on international standards
- Transformation grids & tools will be provided by CGS & NGS
  - GPS-H (Canada)
  - VDatum (US)
- Many commercial GIS developers also committed to incorporating transformations into their GIS software

VDatum



GPS-H



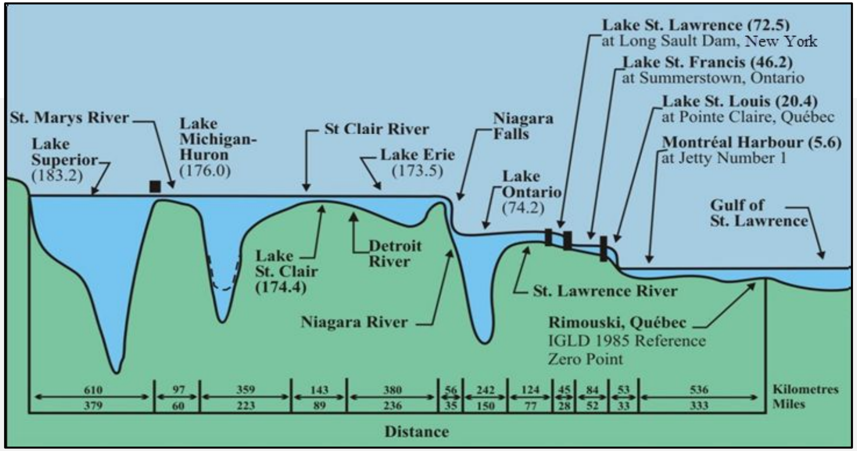
A New IGLD will impact…

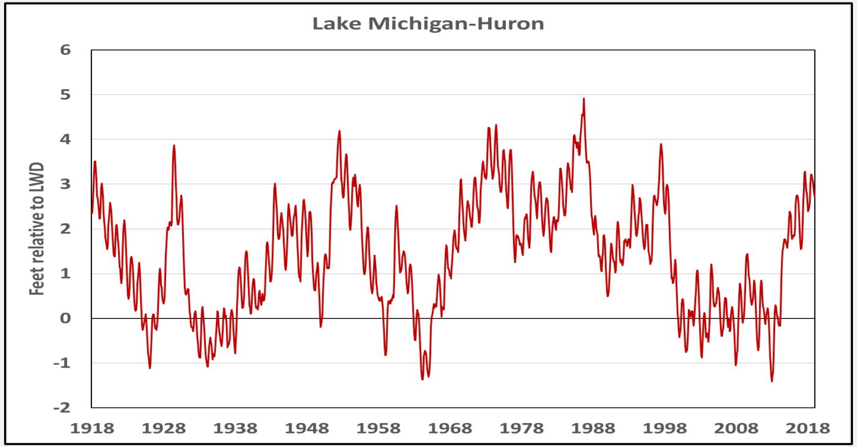
Updated water level references will need to be implemented for various operations:

- **Commercial and recreational navigation,** including charts, ports/harbors
- Water level **regulation and forecasting**
- Coastal zone management and planning, including **flood & erosion prediction and response**, and **coastal structure design, construction & maintenance**
- **Legislation** may need to be updated to reflect IGLD (2020)
- The international **Coordinating Committee is conducting outreach** efforts like this one to inform and receive feedback from stakeholders

Low Water Datum

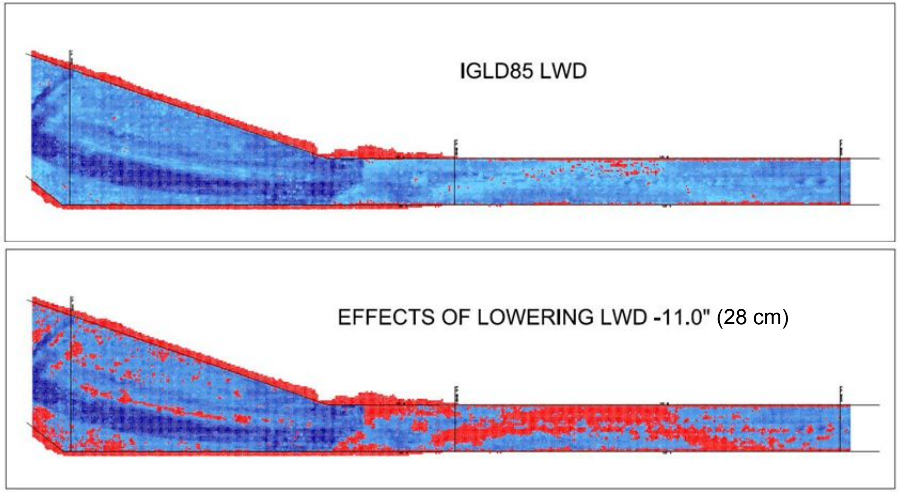
- LWD (aka Chart Datum) is **the reference/level below which water levels seldom fall** *(typically 5% of time)*
    - Used as navigational chart datum, one for each of the Great Lakes and Lake St. Clair
    - Depths for harbor improvement authorizations are also referred to LWD
- With each IGLD update, LWD simply received updated reference heights
    - Water levels may have been affected by channel modifications, erosion, outflow regulations, and climate change since the original establishment of LWD.
    - **We are reviewing LWD in conjunction with the IGLD (2020) update**





Impacts of Changing Low Water Datum

- Additional dredging to **maintain authorized project depths**
- A new LWD would require **changes to all navigational charts** for the Great Lakes and the connecting channels
- Additional dredging and changes to **navigation charts, documentation, and legislation would be very costly**



Current Outer Harbor Condition Survey
St. Marys River

Red = soundings less than authorized project depth when referenced to LWD

Lake Superior example

Milestone Chart (Completed)

MILESTONES CHART for the 2020 International Great Lakes Datum			
Activity	**Timeline**	**Status**	**Lead Agency**
Choose and adopt a Wo as the new IGLD (2020) reference zero	2015	🟢	Coordinating Committee
Perform US GAP analysis of permanent gauging requirements and prioritize new proposed gauges	2016	🟢	CO-OPS
Adjust and publish 2015 GPS campaign survey results	2017	🟢	CGS, NGS
Complete bi-national plan for IGLD (2020) and present to the Coordinating Committee for approval	2018	🟢	VC-WL-Subcommittee
Complete preparation of internationally coordinated methodologies for determining height using GNSS surveys and local leveling ties at gauges	2017-2018	🟢	CGS, CHS, CO-OPS, NGS, USACE, USGS
Complete preparation of international outreach and communications plan, and begin implementation	2017-2020	🟢	VC-WL-Subcommittee
Review historic water level data for re-evaluation of Low Water Datum (LWD)	2017-2022	🟢	CHS, ECCC, CO-OPS, USACE
Reanalyze and compare all GPS campaign surveys from 1997, 2005, 2010, 2015 to estimate preliminary rates of movement	2017-2018	🟢	CGS, NGS
Perform analysis of seasonal gauging requirements and prioritize locations	2017-2023	🟢	CHS, CO-OPS
Perform GNSS Campaign survey in Great Lakes - St. Lawrence River system, including entity gauges	2022	🟢	CGS, CHS, CO-OPS, NGS
Process GNSS Campaign data	2022-2023	🟢	NGS, CGS
Digitize and archive old leveling information, as required	Ongoing	🟢	CGS, CHS, CO-OPS, NGS

MILESTONES CHART for the 2020 International Great Lakes Datum

Activity	Timeline	Status	Lead Agency
Identify potential partners and users who can help develop and implement IGLD (2020)	Ongoing		VC-WL-Subcommittee
Perform annual maintenance and leveling ties at permanent water level gauges	Ongoing		CO-OPS, USACE, CHS, ECCC & Others
Determine recommendation for LWD recalculation	2024		CHS, ECCC, CO-OPS, USACE
Continue annual installations of seasonal water level gauges with GPS and leveling ties	2017-2024		CHS, CO-OPS
Complete seasonal water level gauging data processing	2024		CHS, CO-OPS
Determine hydraulic correctors	2024		CGS, CHS, ECCC, CO-OPS, NGS
Document and develop water level data collection and station infrastructure standards	2025		CHS, CO-OPS, ECCC, USACE
Adopt North American geoid model for IGLD (2020)	2025		Coordinating Committee with CGS, NGS

Milestone Chart (Planned/Not Started)

MILESTONES CHART for the 2020 International Great Lakes Datum			
Activity	**Timeline**	**Status**	**Lead Agency**
Perform Canadian GAP analysis of permanent gauging requirements	2025	⚫	CHS
Obtain stakeholder input and complete impacts assessment in the event of a LWD recalculation	2025	⚫	CHS, CO-OPS, USACE
Create crustal movement models for the Great Lakes - St. Lawrence River system using GNSS campaigns and CORS/CACS data	2025	⚫	CGS, NGS
Develop maintenance plan for IGLD	2024-2025	⚫	CHS, CO-OPS, CGS, NGS
Determine new Low Water Datum on lakes and rivers with respect to IGLD (2020)	2026	⚫	CHS, ECCC, CO-OPS, USACE
Determine and publish transformations between IGLD (2020) and other datums, including IGLD (1985)	2026	⚫	CGS, NGS
Publish new IGLD (2020)	2027	⚫	Coordinating Committee
Perform GNSS campaign survey to validate velocities at permanent gauges	2027	⚫	Coordinating Committee
Update and publish Gauge Histories	2027	⚫	Coordinating Committee
Update connecting channels step charts to IGLD (2020)	2027	⚫	Coordinating Committee
Publish final IGLD (2020) report	2028	⚫	Coordinating Committee

Key Takeaways

1

Datums are the foundation for shoreline and waterway management

2

NOAA's NWLON and CHS' PWLN gauging networks are the backbone of our work and its data is needed to develop water level datums

3

IGLD (1985) is being updated to IGLD (2020) and our work in the Great Lakes is internationally coordinated

4

Lake levels are being studied to determine if a recalculation of Low Water Datum may be warranted

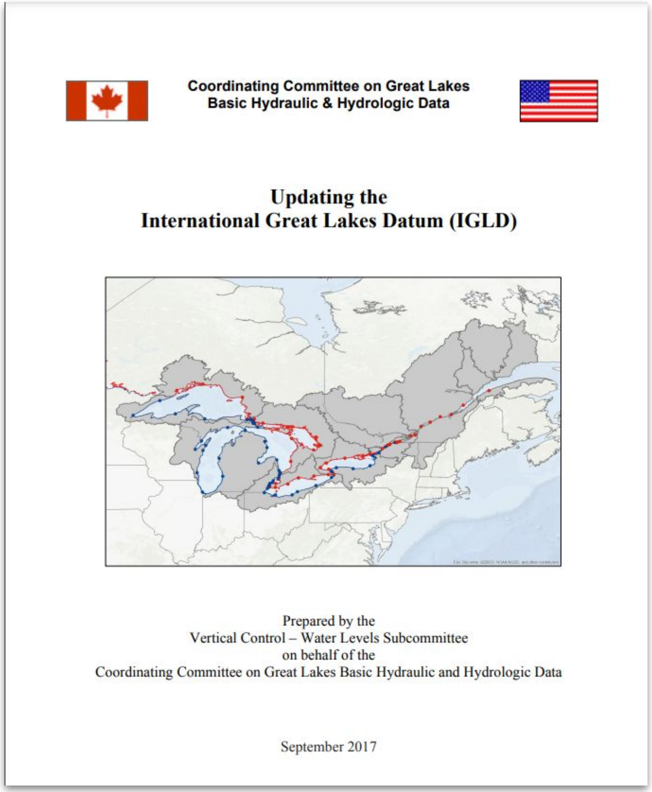
5

If LWD is recalculated, this will have many impacts, including the need to dredge to reach authorized depths below the new datum

Resources

https://www.greatlakescc.org/en/international-great-lakes-datum-update/

[Email: info@GreatLakesCC.org](mailto:info@GreatLakesCC.org)


Coordinating Committee on Great Lakes
Basic Hydraulic & Hydrologic Data

Updating the
International Great Lakes Datum (IGLD)

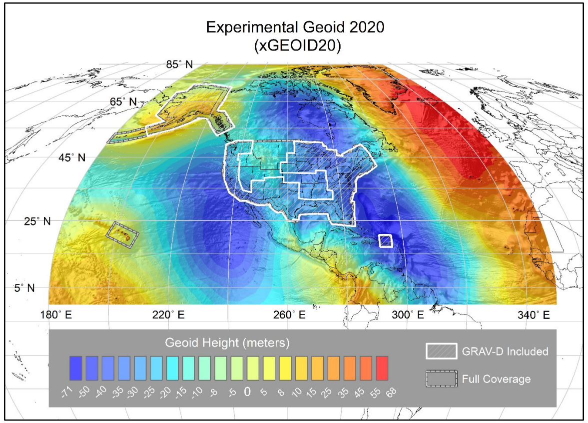
Prepared by the
Vertical Control – Water Levels Subcommittee
on behalf of the
Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

September 2017

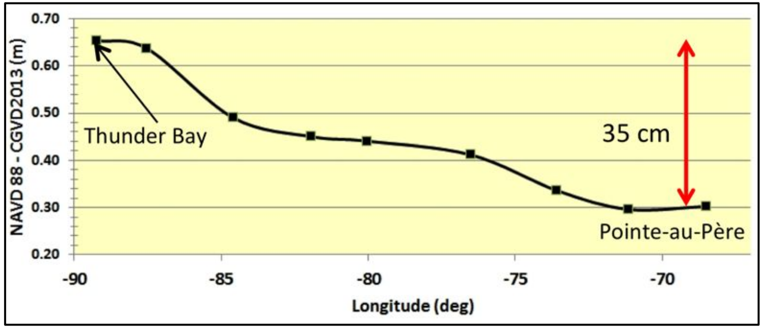
Extra Slides

New IGLD (2020)

- Reference Zero
  - A geopotential value representing mean sea level around the coast of North America
  - Same value as geoid-based North American-Pacific Geopotential Datum of 2022 (NAPGD2022) and the geoid-based Canadian Geodetic Vertical Datum of 2013 (CGVD2013)
- Reference Surface
  - NAPGD2022 geoid model representing the reference zero
  - Defined everywhere over the Great Lakes – St. Lawrence River system, not only where leveling and bench marks exist
- Reference Epoch
  - 2020.0 is the reference epoch for the heights
  - Same as the central epoch of the 7-year water level observation period of 2017–2023



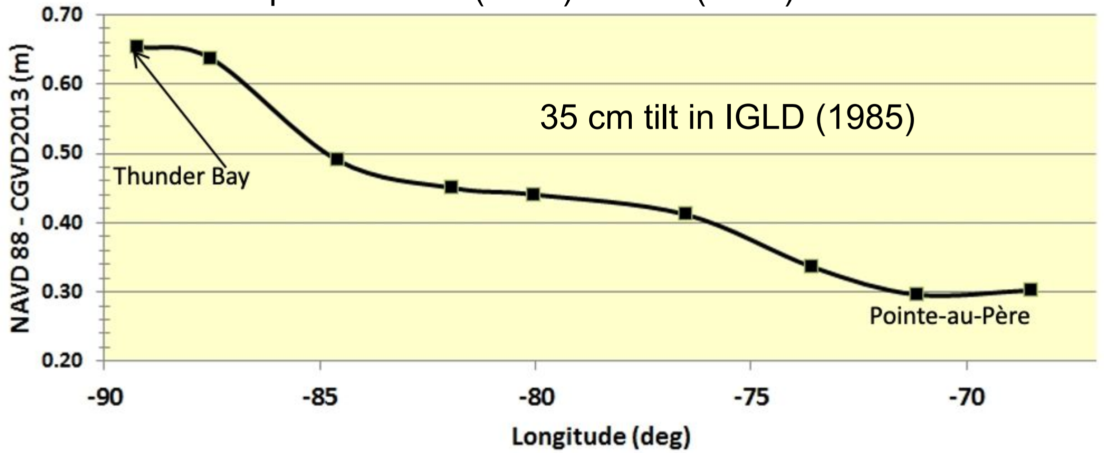
Expected IGLD (1985) - IGLD (2020)



New IGLD (2020)

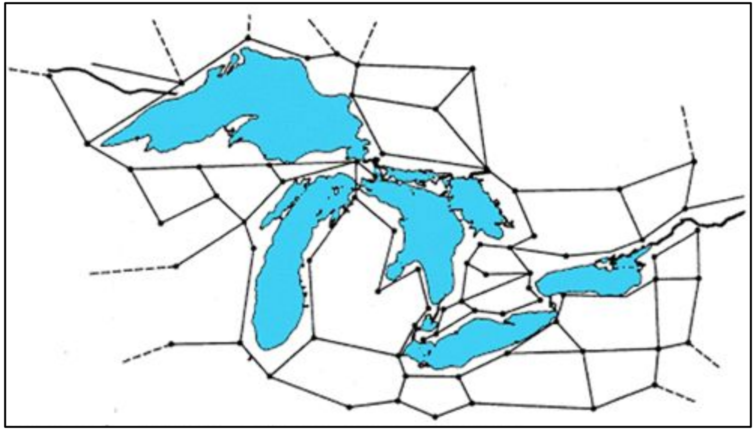
- Based on the new North American vertical datum (NAPGD2022)
- Reference zero is mean sea level around the coasts of North America
- Reference surface (datum) extended inland using a geoid model
  - Geoid model based on gravity data, not leveling
  - Defined everywhere, not only where leveling bench marks exist
- Using dynamic heights
- Heights defined at reference epoch 2020.0 (mid-point of 7 year water level obs period)
- **Heights expected to change 30-65 cm (12”-26”)** from existing IGLD (1985)

Expected IGLD (1985) - IGLD (2020) Difference



Current IGLD (1985)

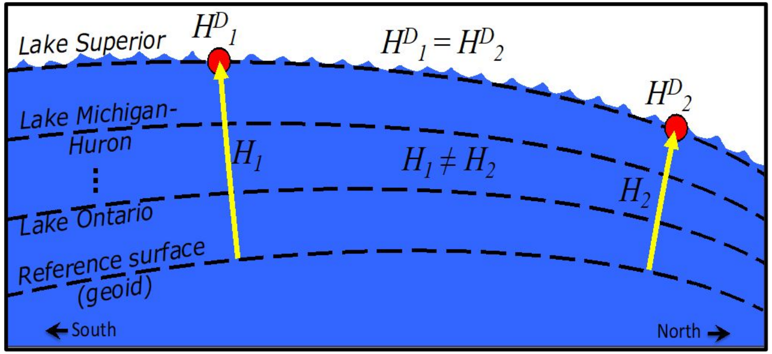
- Based on current vertical datum in U.S. (NAVD88)
- Reference zero is mean sea level at Pointe au Père & Rimouski, Québec
- Reference surface (datum) extended inland using leveling
  - Very time consuming & cost prohibitive
  - Datum accessible only where leveling bench marks exist
  - Affected by systematic errors in long leveling loops
- Uses dynamic heights for measuring hydraulic head – dynamic heights are constant along a level surface (e.g., undisturbed lake)



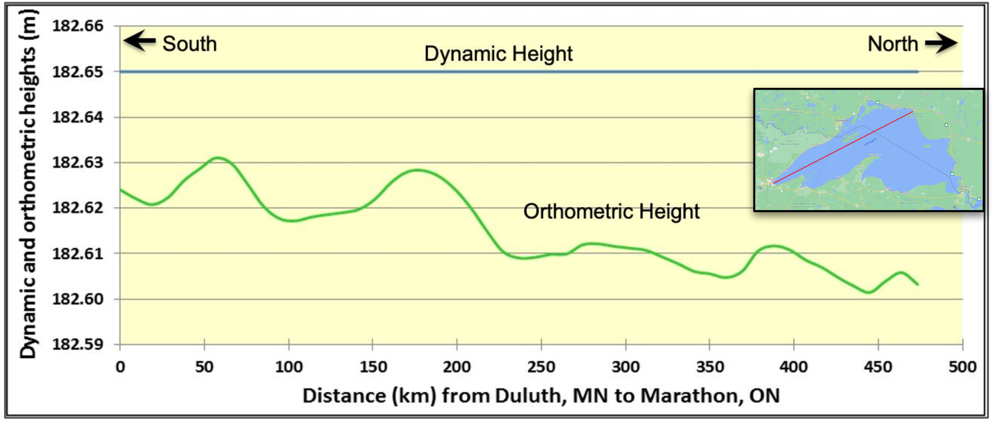
NAVD88 Network Level Loops

IGLD (2020) Using Dynamic Heights

- Orthometric heights (H)
  - Typical heights used in most applications
  - Physical distance above reference surface (geoid)
  - Not constant along a level surface (like a lake) because equipotential convergence as you go north
  - Geopotential numbers scaled by local gravity
- Dynamic heights (H^D)
  - Geopotential numbers scaled by a constant gravity value
  - Constant along a level (lake) surface by definition
  - Enables the measurement of hydraulic head for water level management
  - Used by all IGLD realizations



Dynamic heights, H^D, and orthometric heights, H.



Determining Heights via GNSS

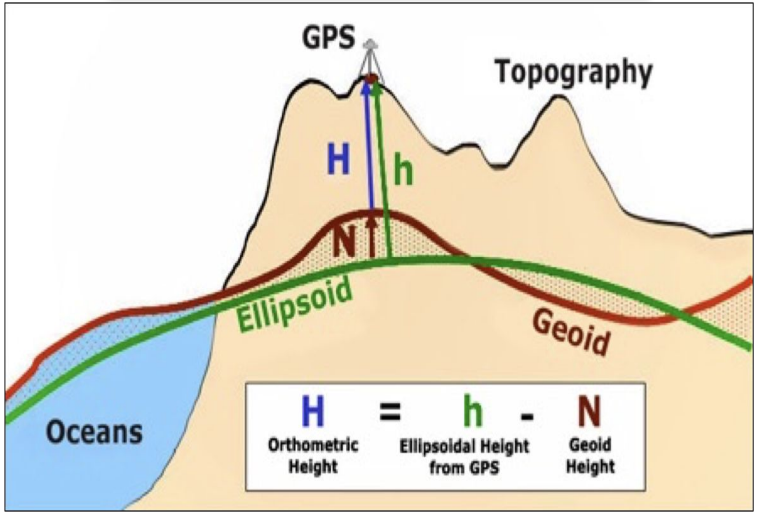
- ***Primary access to the datum will be via GNSS***

  h = ellipsoidal height obtained from GNSS
  N = geoid height obtained from geoid model
  (provided by CGS & NGS)
  H = Orthometric height

  h & N must be referenced to the same reference ellipsoid (NATRF2022)

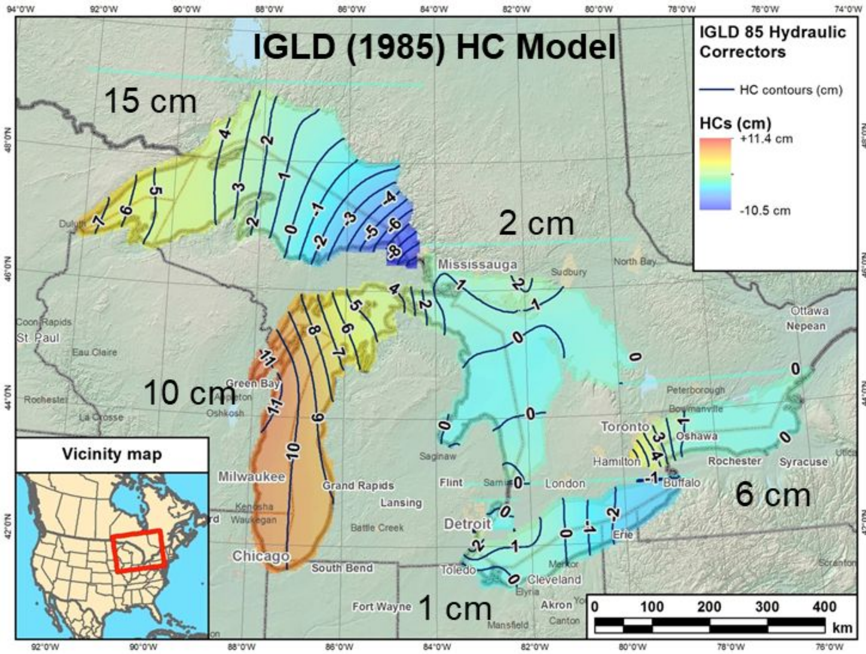
- Online processing & conversion tools provided by CGS & NGS

- Local leveling will still be required



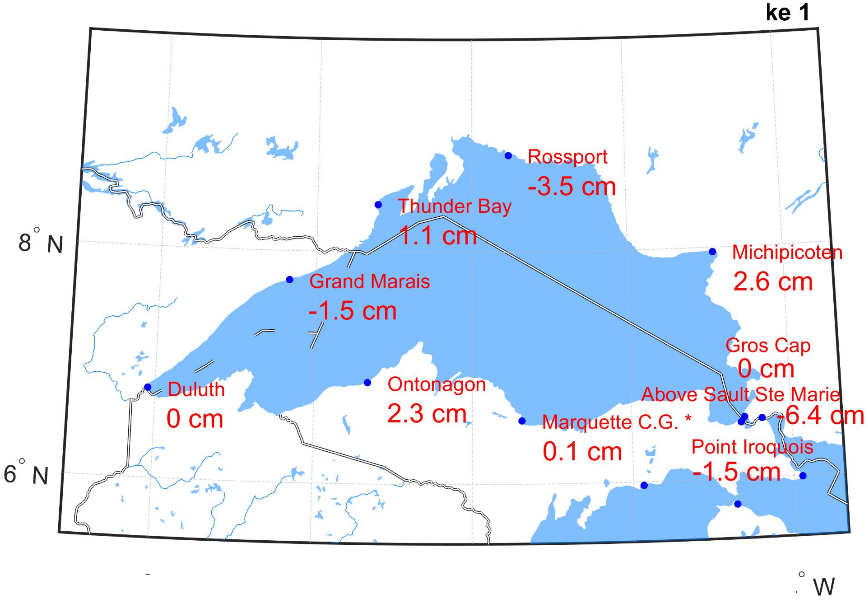
Hydraulic Correctors

- Dynamic heights should be the same at all gauges on a level lake
- In reality this is not the case because of
  - IGLD (1985) mainly affected by systematic errors in leveling
  - Currents, river discharge, temperature/density variations, prevailing winds, outlet drawdown create a Lake surface “topography”
- Hydraulic correctors (HCs) adjust the dynamic height at each gauge to agree with a single “master” gauge on each lake
- Used only for heights of water levels on the Lakes



Hydraulic Correctors for IGLD (2020)

- Hydraulic correctors for IGLD (1985)
  - Dominated by errors in leveling around each lake
  - Effectively correcting for those errors as well as lake topography
- Hydraulic correctors for IGLD (2020)
  - No errors in levelling to contend with
  - Will represent true lake topography
  - Recent analyses have shown the corrections are much smaller than for IGLD (1985)
  - The map on the right show preliminary estimates for Lake Superior indicating values about an order of magnitude smaller than for IGLD (1985)



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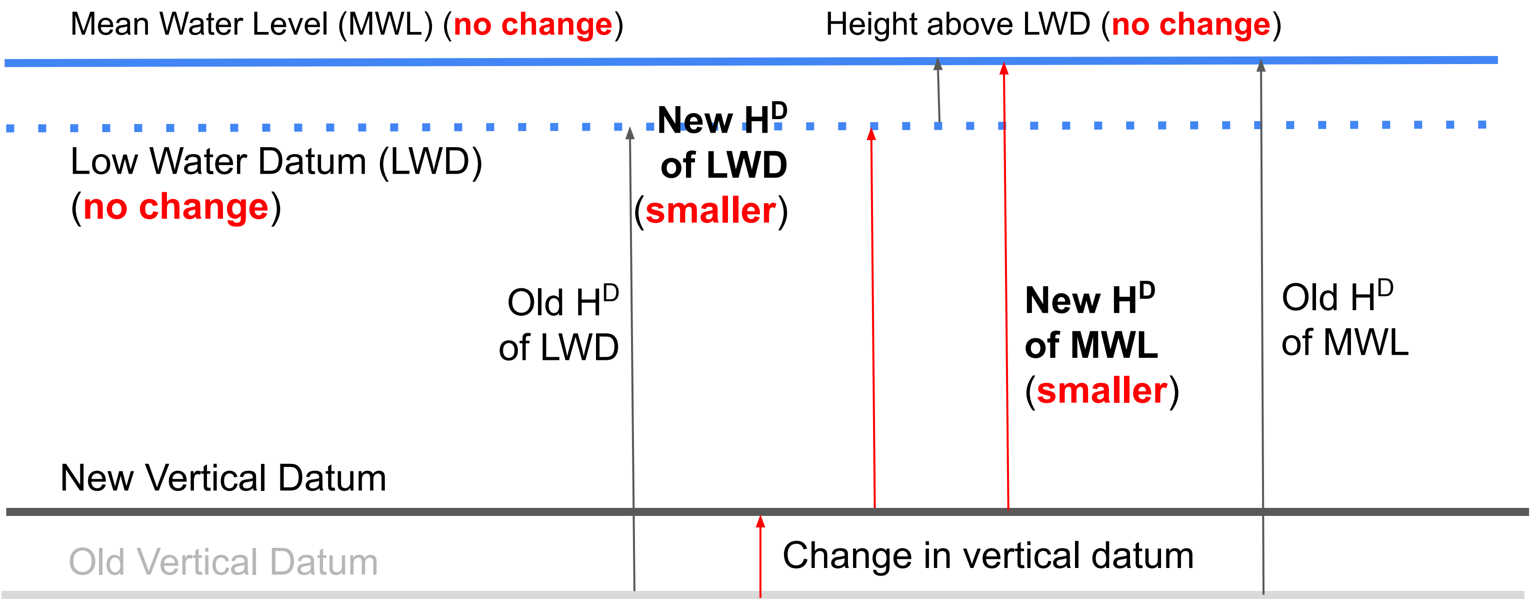
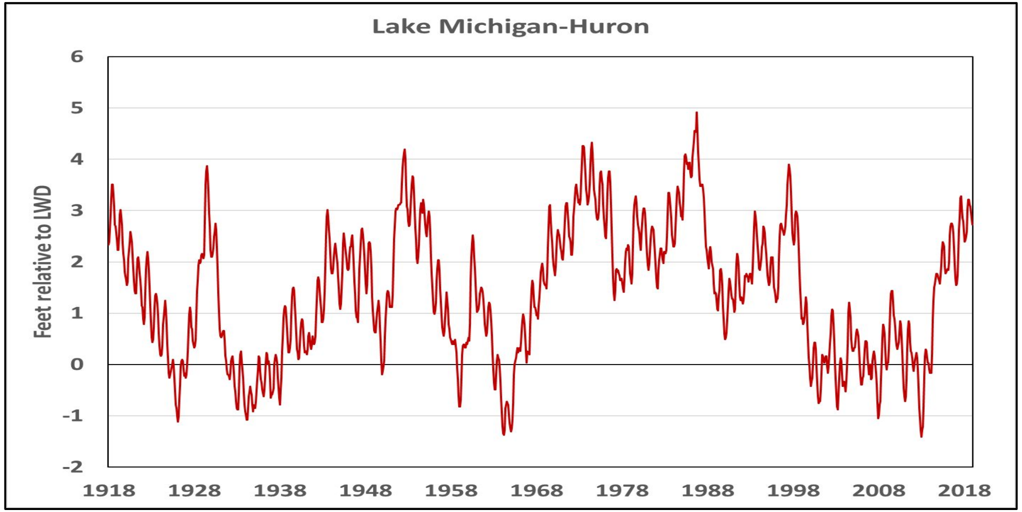
Change in Vertical Datum with No Change in LWD

Heights change even though LWD does not change

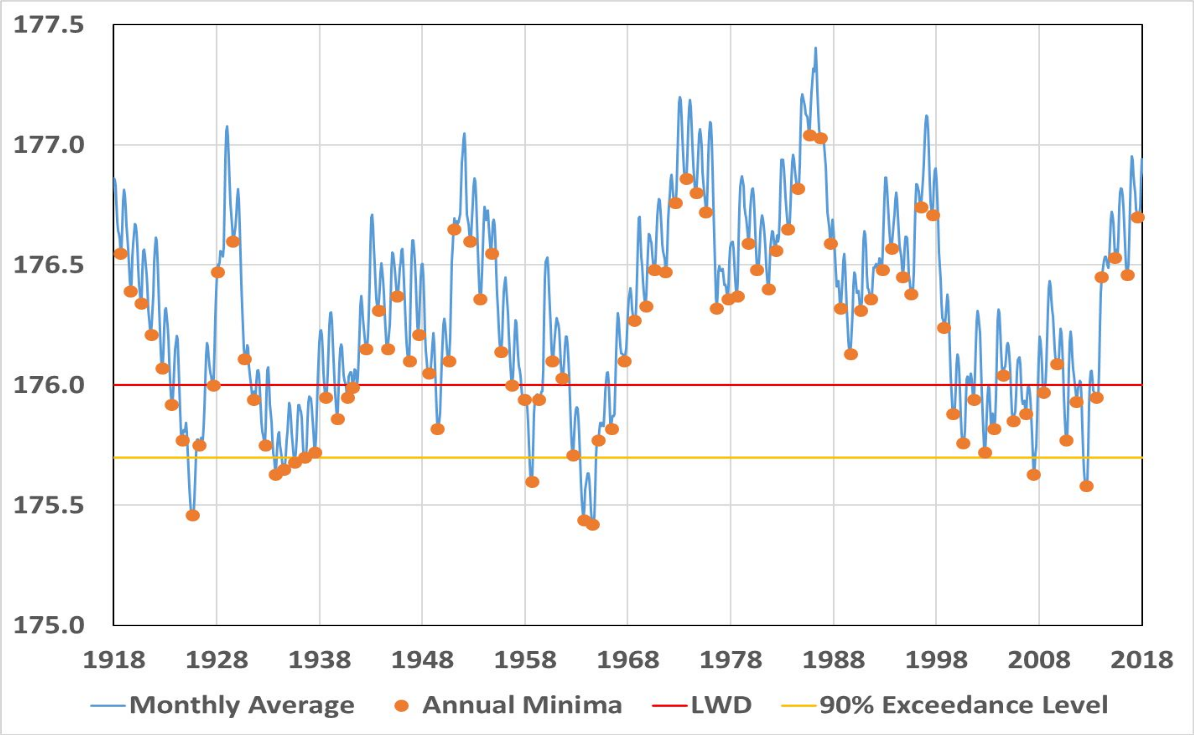




Observed Monthly Means Below LWD 1918-2021 on IGLD (1985)

Lake	Number of months below LWD	Percentage of months below LWD	Number of years with any month below LWD	Percentage of years with any month below LWD
Superior	185	15%	42	41%
Michigan-Huron	186	15%	28	27%
St. Clair	68	5%	26	25%
Erie	43	4%	9	9%
Ontario	54	4%	11	11%

MICHIGAN-HURON MONTHLY LAKE LEVEL RESULTS FROM COORDINATED GREAT LAKES ROUTING AND REGULATION MODEL (CGLRRM)



37 of 100 modelled annual minima fell below the existing LWD (red)

90% annual exceedance probability level --- 10 of 100 fall below a lowered LWD (yellow)

RESULTS OF EXTREME VALUE ANALYSIS

Lake	85% Exceedance Level	90% Exceedance Level	95% Exceedance Level
	cm (LWD)	cm (LWD)	cm (LWD)
	Historical Record (1918-2018)		
Superior	-15 (-6 in)	**-20 (-8 in)**	-27 (-11 in)
Michigan-Huron	-13 (-5 in)	**-20 (-8 in)**	-30 (-12 in)
St. Clair	-11 (-4 in)	**-20 (-8 in)**	-33 (-13 in)
Erie	+7 (+3 in)	**-1 (0 in)**	-12 (-5 in)
Ontario	0	**-7 (-3 in)**	-18 (-7 in)
	Supply/Routing Model (1918-2018)		
Superior	-20 (-8 in)	**-24 (-9 in)**	-29 (-11 in)
Michigan-Huron	-22 (-9 in)	**-30 (-12 in)**	-40 (-16 in)
St. Clair	+3 (+1 in)	**-4 (-2 in)**	-14 (-6 in)
Erie	+15 (+6 in)	**+8 (+ 3 in)**	0
Ontario*	+4 (+2 in)	**-4 (-2 in)**	-17 (-7 in)