International Great Lakes Datum: What You Need to Know

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Overview of IGLD

- International Great Lakes Datum (IGLD) is a common height reference system to measure and relate water levels
- Official vertical datum used for water level measurements and navigation charts throughout the Great Lakes, their connecting channels and the St. Lawrence River
- Maintained by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, a binational committee with representatives from the Governments of Canada and the United States
- IGLD is updated every 25-30 years due to Glacial Isostatic Adjustment (GIA)
- **Next update will be IGLD (2020), expected for release around 2027**

Image credit: IJC

Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

- Formed in 1953
- Ad hoc group of federal experts
- Four subcommittees
  - Hydraulics
  - Hydrology
  - Coordinated Regulation and Routing Model
  - **Vertical Control - Water Levels**
    - Update and revise IGLD
    - Standardize water level data processing

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

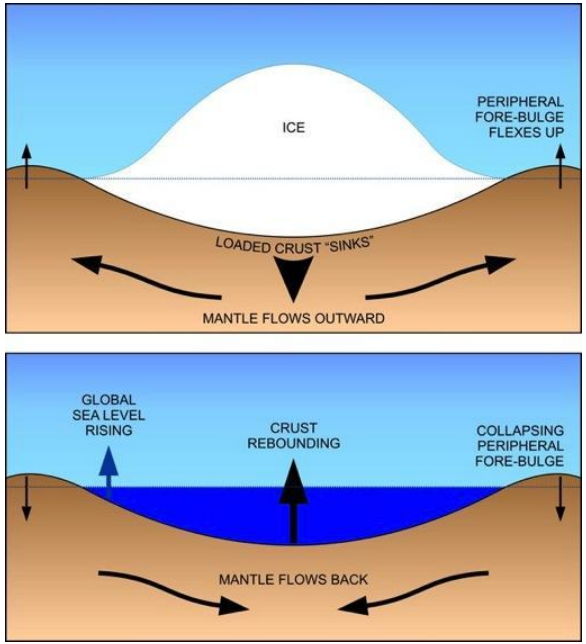
Natural Resources Canada

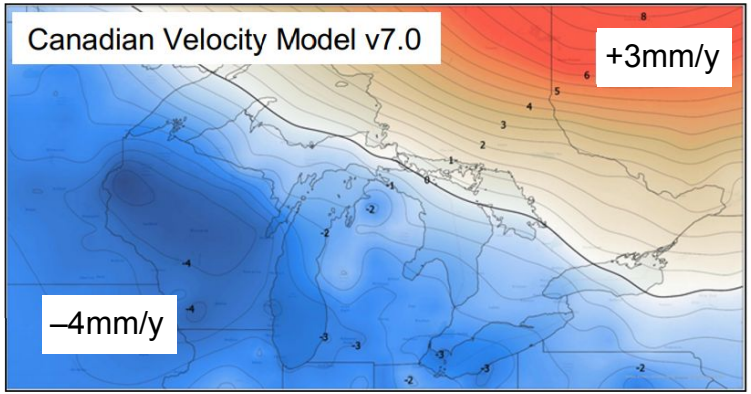
Ressources naturelles Canada

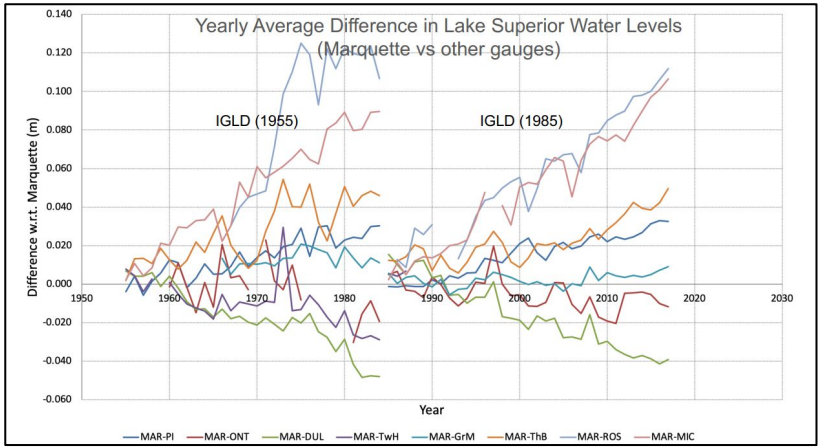
US Army Corps of Engineers

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**!



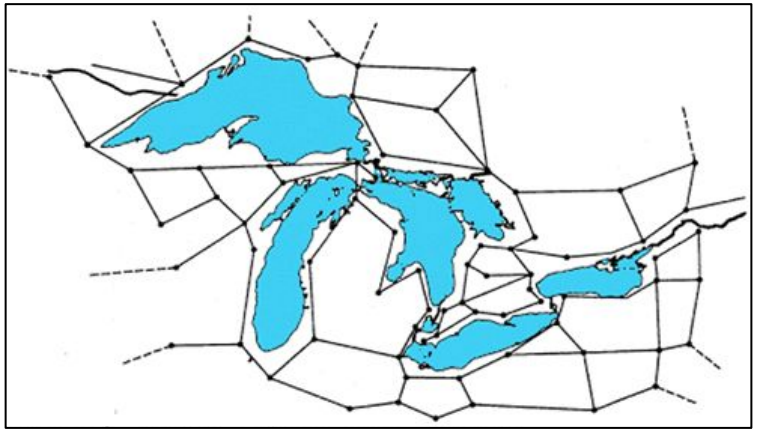




Effect of GIA on Water Level Measurements

Current IGLD (1985)

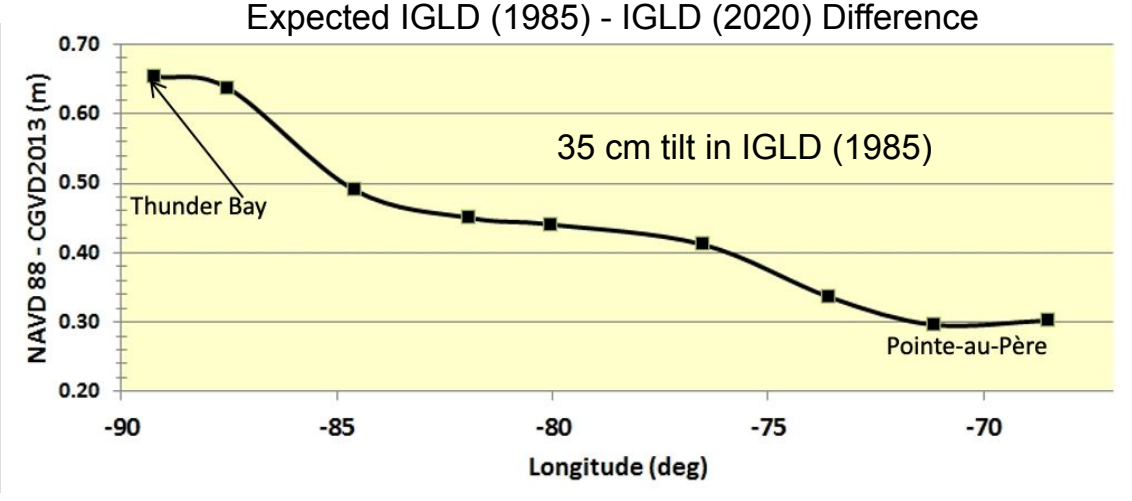
- Based on current vertical datum in U.S. (NAVD88)
- Reference zero is mean sea level at Pointe au Père & Rimouski, Québec
- Reference surface (datum) extended inland using leveling
  - Very time consuming & cost prohibitive
  - Datum accessible only where leveling bench marks exist
  - Affected by systematic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



NAVD88 Network Level Loops

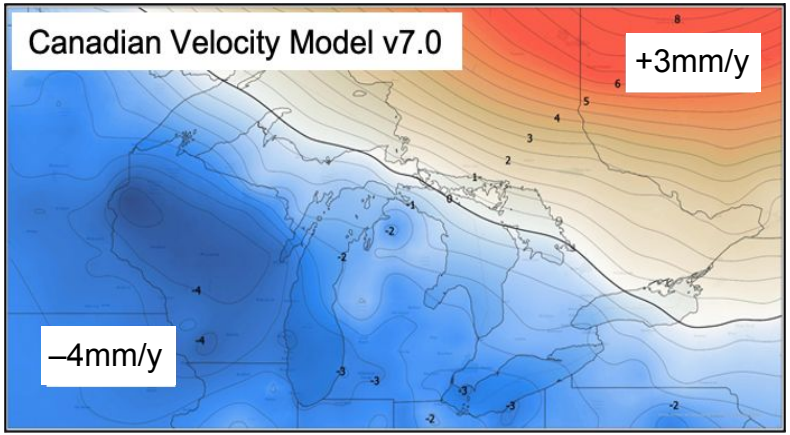
New IGLD (2020)

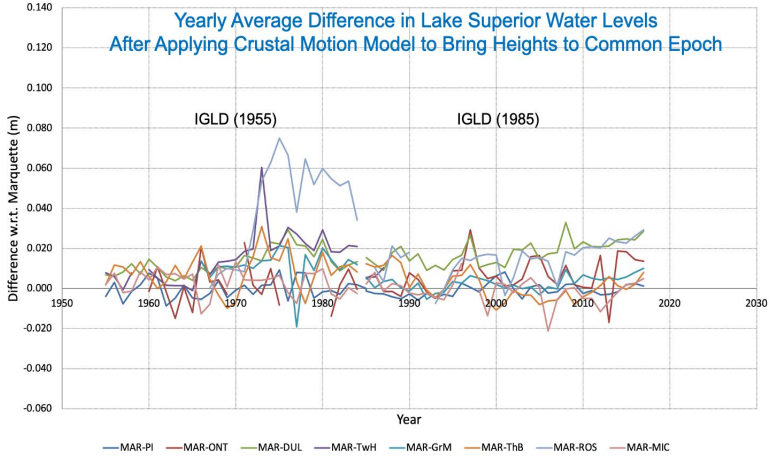
- Based on the new North American vertical datum (NAPGD2022)
- Reference zero is mean sea level around the coasts of North America
- Reference surface (datum) extended inland using a geoid model
  - Geoid model based on gravity data, not leveling
  - Defined everywhere, not only where leveling bench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





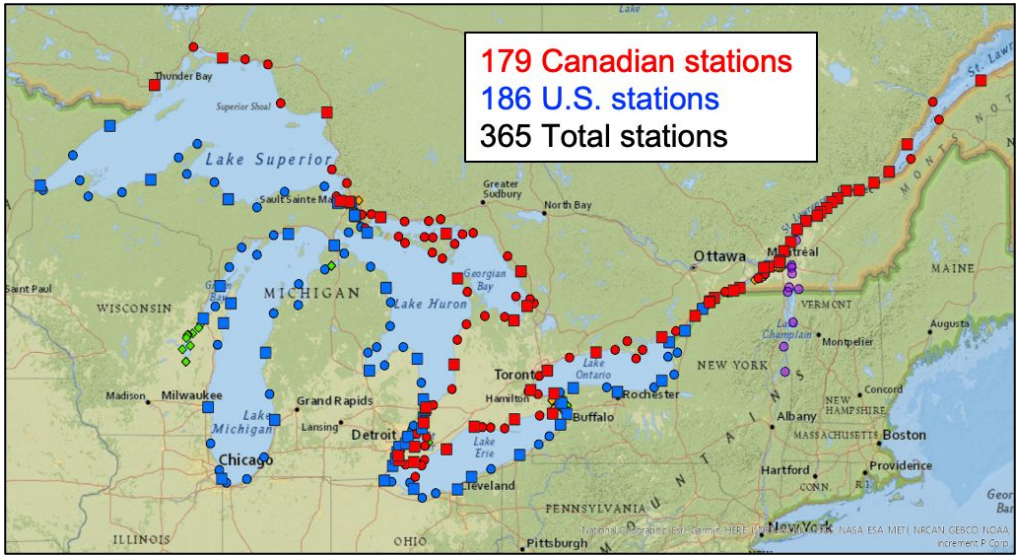
Determining Heights via GNSS

- **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)

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

Moving Water Level Gauges to IGLD (2020)

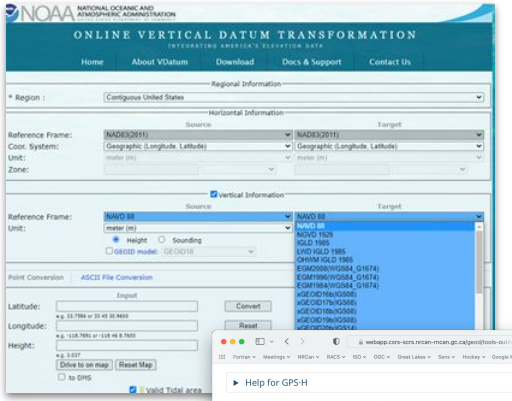
- Need to determine IGLD (2020) heights for all water level gauges/benchmarks
- Previous GPS surveys in 1997, 2005, 2010, 2015 to prepare for IGLD update
- 2022 GNSS survey completed and expanded to include:
  - Permanent gauges (CHS, ECCC, NOAA, USACE, USGS, Seaway, NYPA, OPG)
  - Seasonal gauges for determination of hydraulic correctors
- Presently processing data



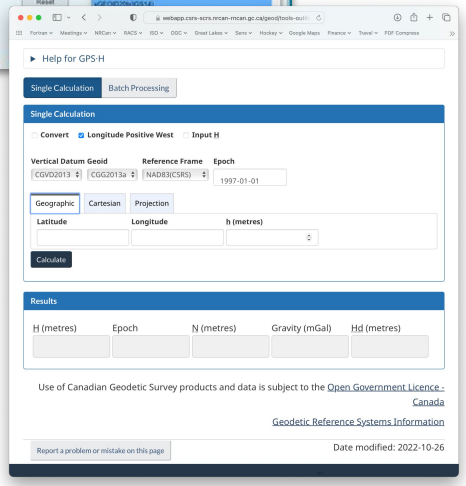
Transformations from Older Datums

- 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



Impacts of Updating IGLD

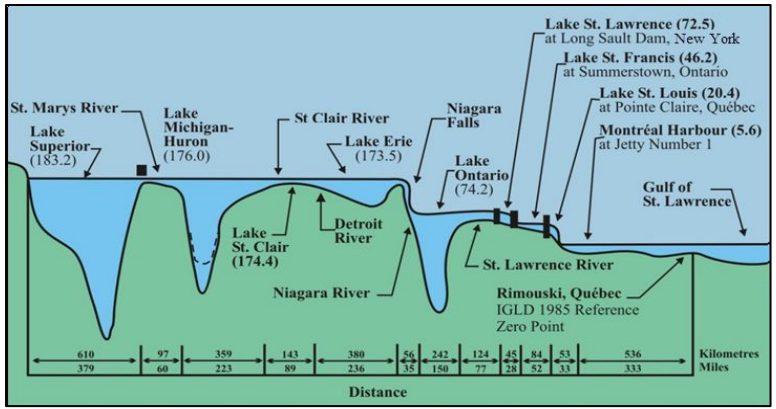
Updating water levels to a new IGLD will have significant impacts on many operations, products and services in the Great Lakes region

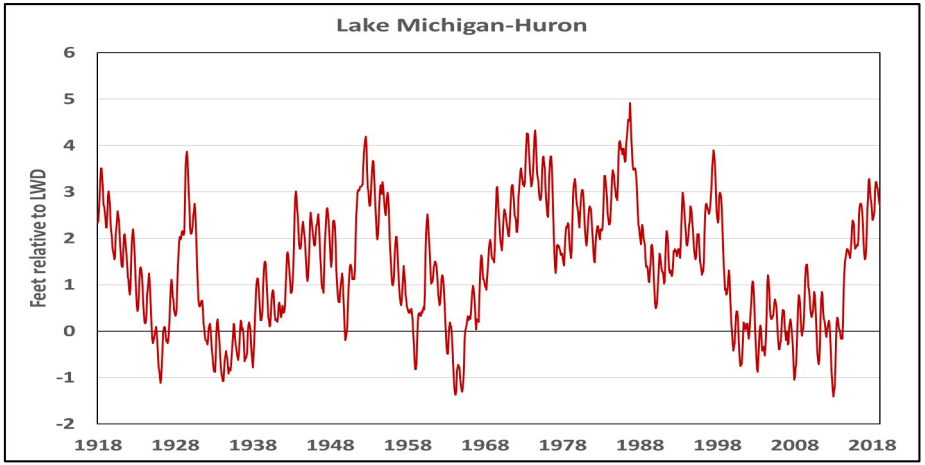
- Economic viability and safety of commercial and recreational navigation, including charts, ports/harbors and dredging of navigation channels
- Water level regulation and forecasting
- Coastal zone management and planning, including flood & erosion prediction and response, and coastal structure design, construction & maintenance
- Coastal habitat restoration under the Great Lakes Restoration Initiative (GLRI)
- Legislation may need to be updated to reflect IGLD (2020)

The Coordinating Committee is conducting outreach efforts like this one to inform and receive feedback from stakeholders

Low Water Datum (LWD)

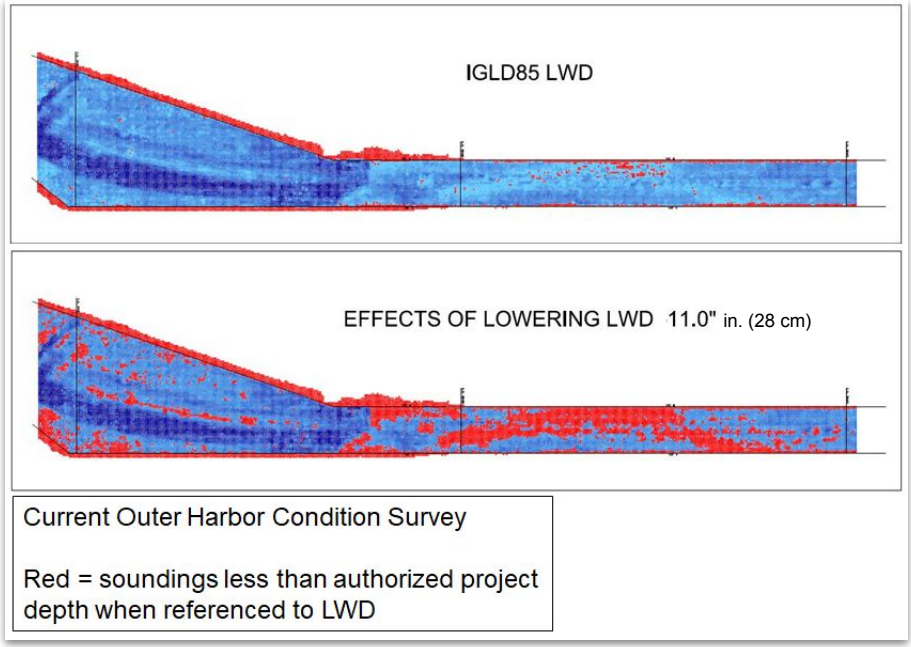
- LWD (aka Chart Datum) is the reference below which water levels seldom fall below (typically 5% of time)
    - Used as navigational chart datum, one for each of the Great Lakes and Lake St. Clair
    - Depths for harbor improvement authorizations are also referred to LWD
- LWD was established in the 1930s
- Since then low water datum levels may have been affected by channel modifications, erosion, outflow regulations, and climate change
- Reviewing LWD in conjunction with the IGLD (2020) update





Impacts of Changing Low Water Datum

- Additional dredging to maintain new depths at significant costs
- 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



Lake Superior example

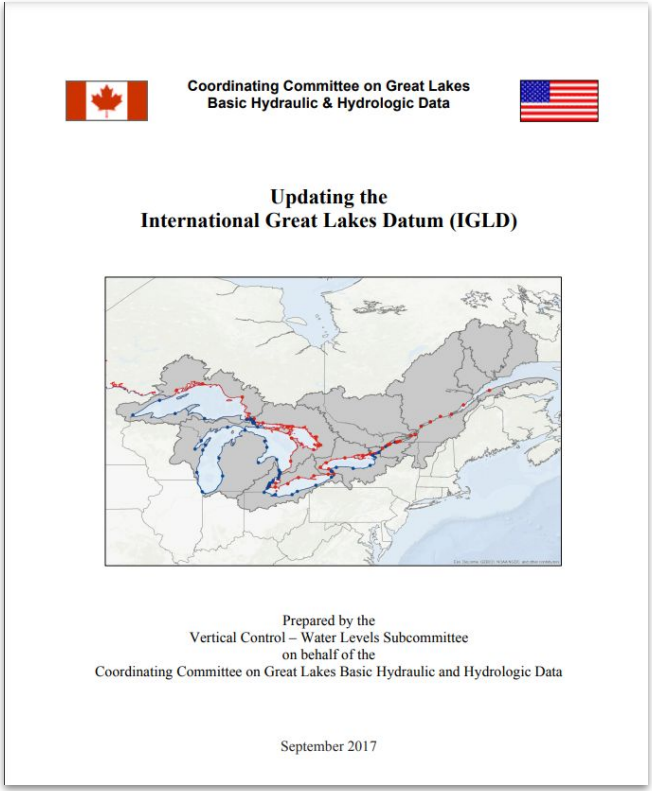
MILESTONES CHART for the 2020 International Great Lakes Datum

Activity	Timeline	Status	Lead Agency
Complete bi-national plan for IGLD (2020) and present to the Coordinating Committee for approval	2018		VC-WL-Subcommittee
Choose and adopt a Wo as the new IGLD (2020) reference zero	2015		Coordinating Committee
Identify potential partners and users who can help develop and implement IGLD (2020)	2016-2023		VC-WL-Subcommittee
Digitize and archive old leveling information, as required	2016-2023		CGS, CHS, CO-OPS, NGS
Perform annual maintenance and leveling ties at permanent water level gauges	2016-2024		CO-OPS, USACE, CHS, ECCC & Oth-ers
Perform analysis of permanent gauging requirements and prioritize new proposed gauges	2023 (CHS) complete (NOAA)		CO-OPS, CHS
Adjust and publish 2015 GPS campaign survey results	2017		CGS, NGS
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
Determine recommendation and obtain stakeholder input for LWD	2024		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
Continue annual installations of seasonal water level gauges with GPS and leveling ties	2017-2024		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
Adopt North American geoid model for IGLD (2020)	After 2025		Coordinating Committee with CGS, NGS
Create crustal movement models for the Great Lakes - St. Lawrence Rivery system using GNSS campaigns and CORS/CACS data	2023		CGS, NGS
Complete seasonal water level gauging data processing	2024		CHS, CO-OPS
Determine hydraulic correctors	2024		CGS, CHS, ECCC, CO-OPS, 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
Perform GNSS campaign survey to help 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 new IGLD (2020)	2027		Coordinating Committee
Publish final IGLD (2020) report	2028		Coordinating Committee

Resources

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

Email: info@GreatLakesCC.org



Coordinating Committee on Great Lakes
Basic Hydraulic & Hydrologic Data

Updating the
International Great Lakes Datum (IGLD)

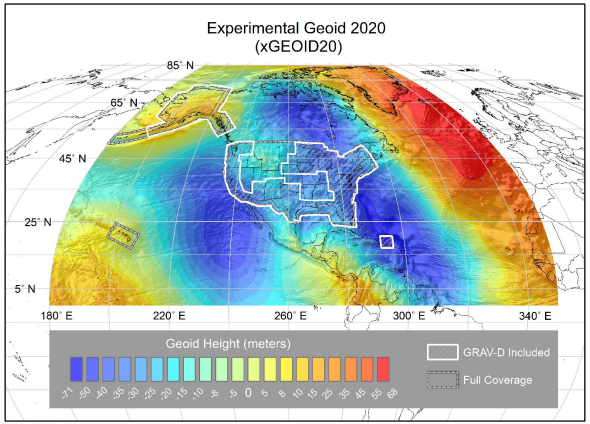
Prepared by the
Vertical Control – Water Levels Subcommittee
on behalf of the
Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

September 2017

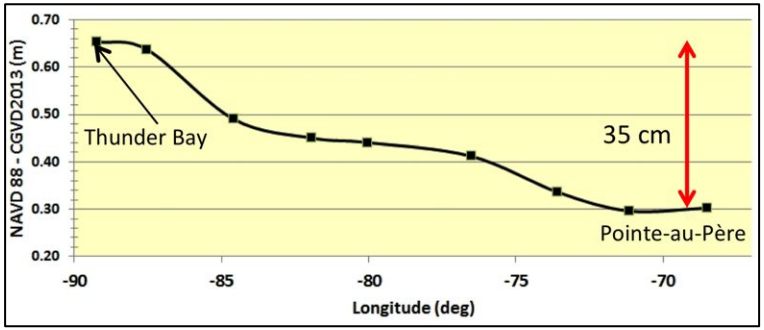
Extra Slides

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

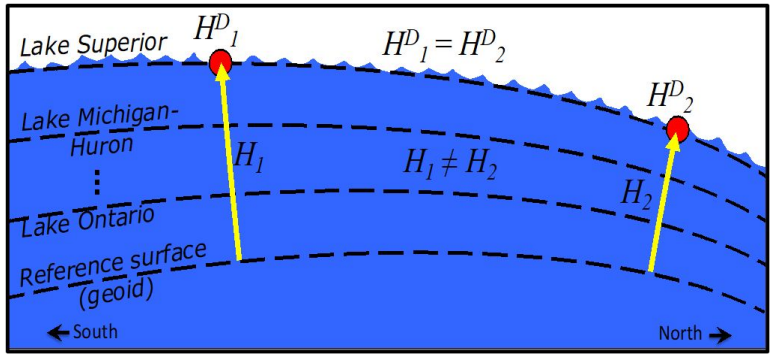


Expected IGLD (1985) - IGLD (2020)

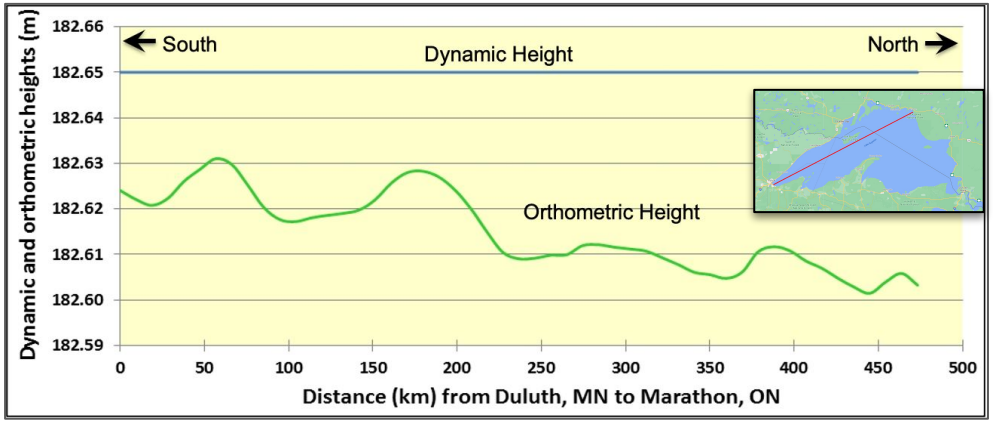


IGLD (2020) Using Dynamic Heights

- 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.



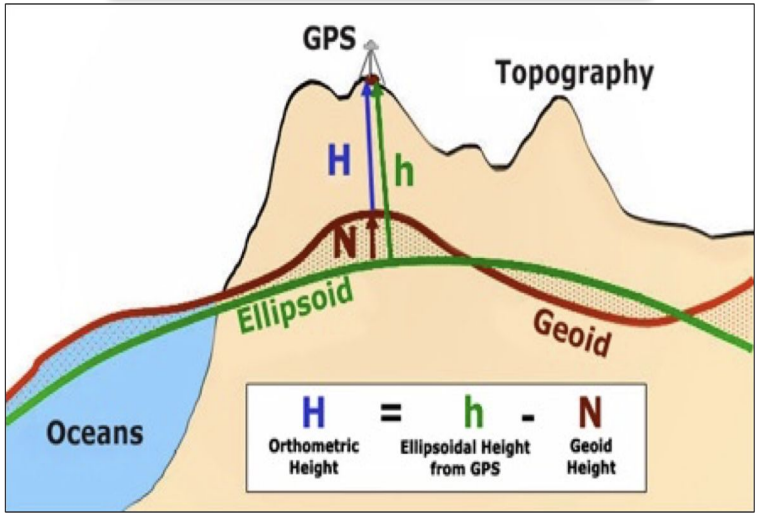
Determining Heights via GNSS

- ***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

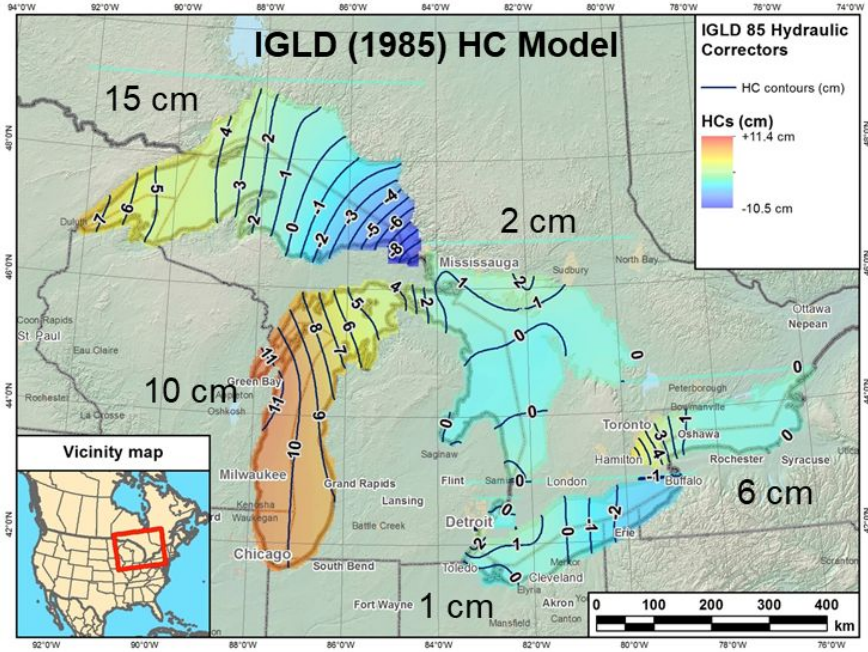
  h & N must be referenced to the same reference ellipsoid (NATRF2022)

- Online processing & conversion tools provided by CGS & NGS
- Local leveling will still be required



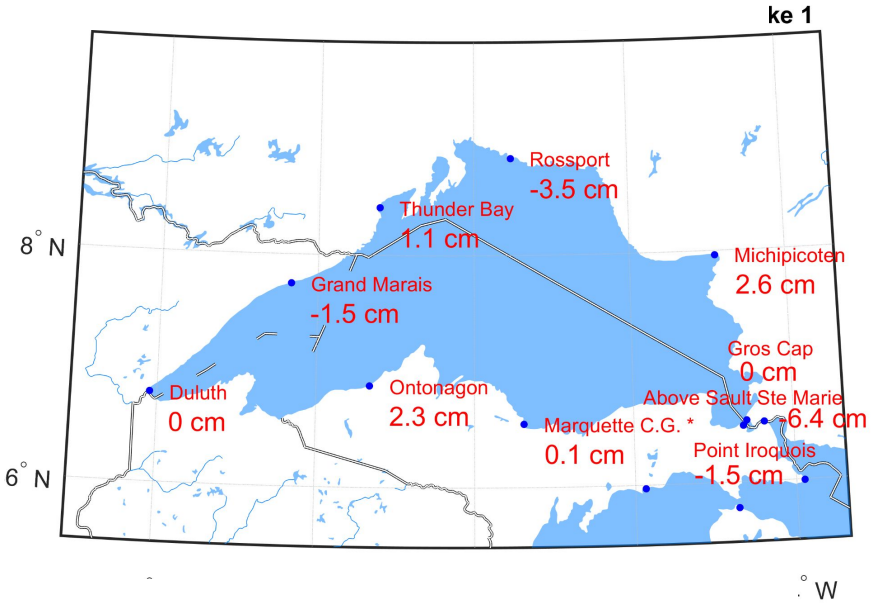
Hydraulic Correctors

- 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

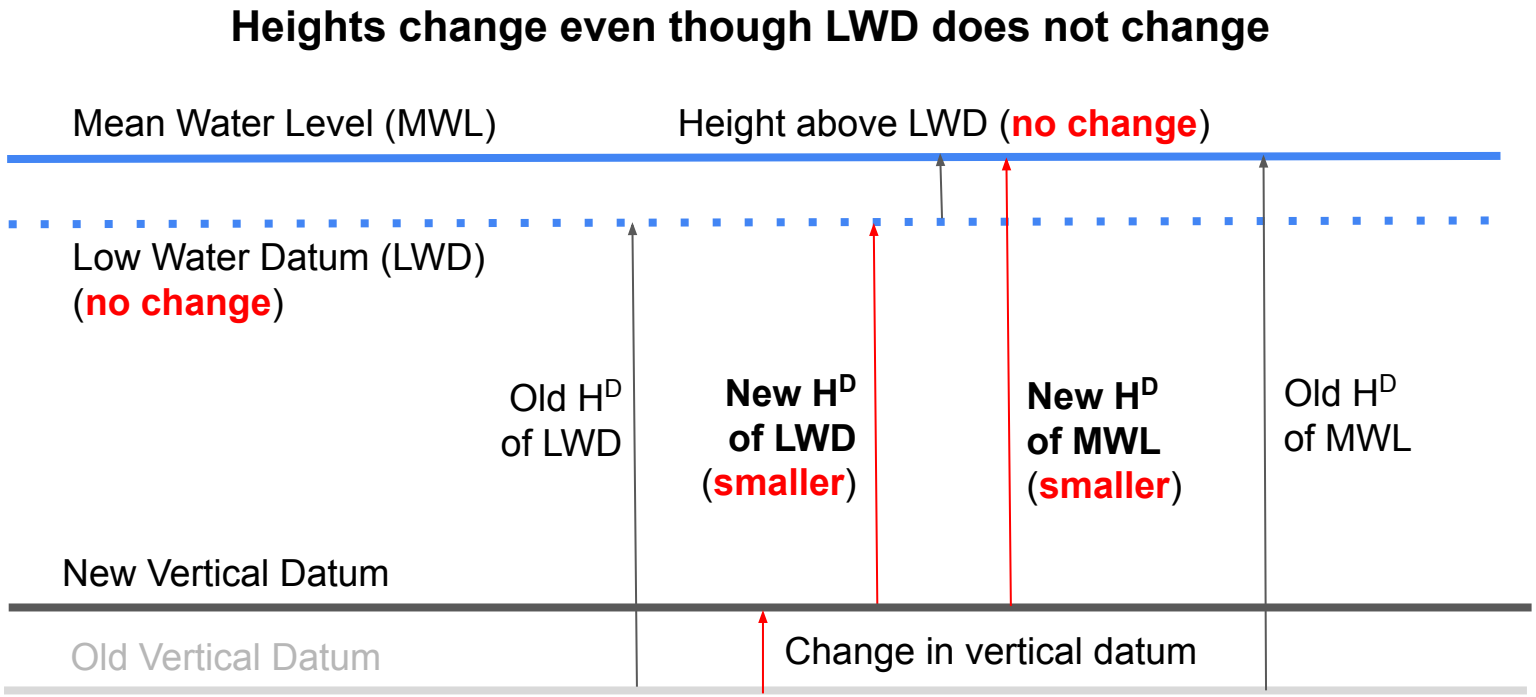


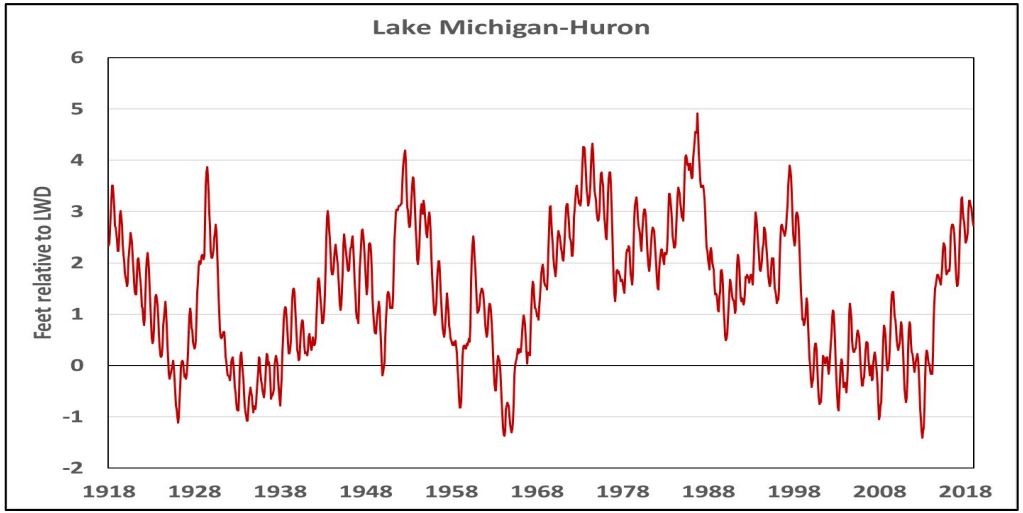
Hydraulic Correctors for IGLD (2020)

- 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)



Change in Vertical Datum with No Change in LWD

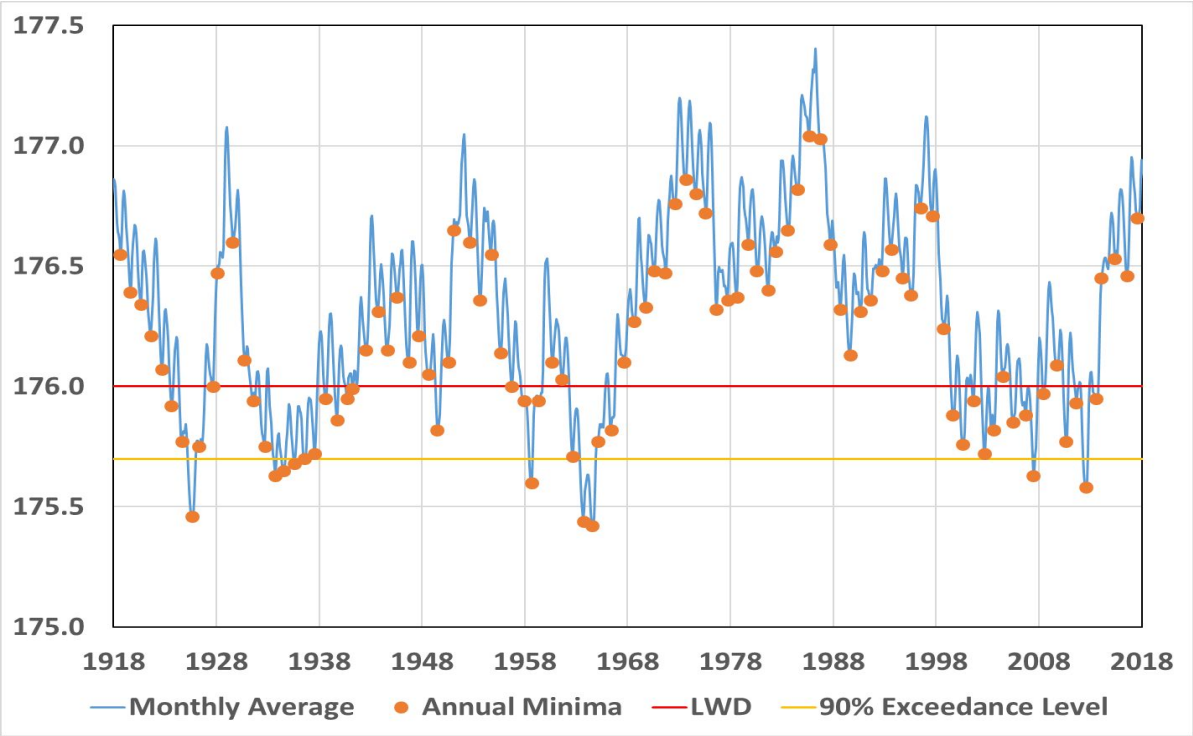




Observed Monthly Means Below LWD 1918-2021 on IGLD (1985)

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)