

# Modernization of the Canadian Height Reference System.....

Presentation to AMLS & APEGM  
18 January 2011

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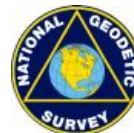
# Canadian Height Modernization Project

- Defining a new datum for Canada that:
  - Resolves the limitations of the current system
  - Is easily accessible at any point in the country
  - Enables cost-saving of Global Navigation Satellite System (GNSS) technologies
  - Is compatible with international standards
  - Is less sensitive to geodynamic activities and the deterioration of benchmarks
- Such a system would be based on a geoid model.

# Height Modernization Proponents



Information Services Corporation of Saskatchewan



## Height Modernization Proponents

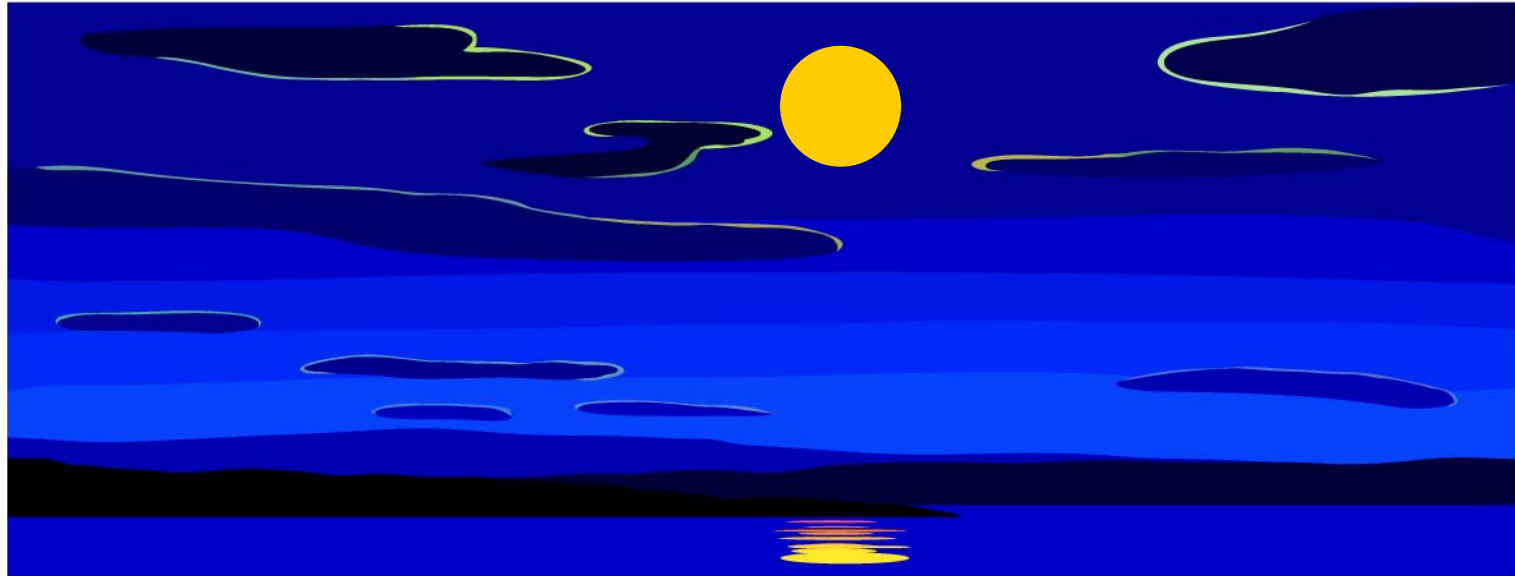
- The **Canadian Council On Geomatics** (CCOG) is a federal-provincial-territorial group dedicated to building geomatics partnerships, and sharing information and data.
- The **Canadian Geodetic Reference System Committee** (CGRSC) is a working committee of the CCOG created to plan, maintain and improve the geodetic reference system in Canada

## Why a Height Reference System?

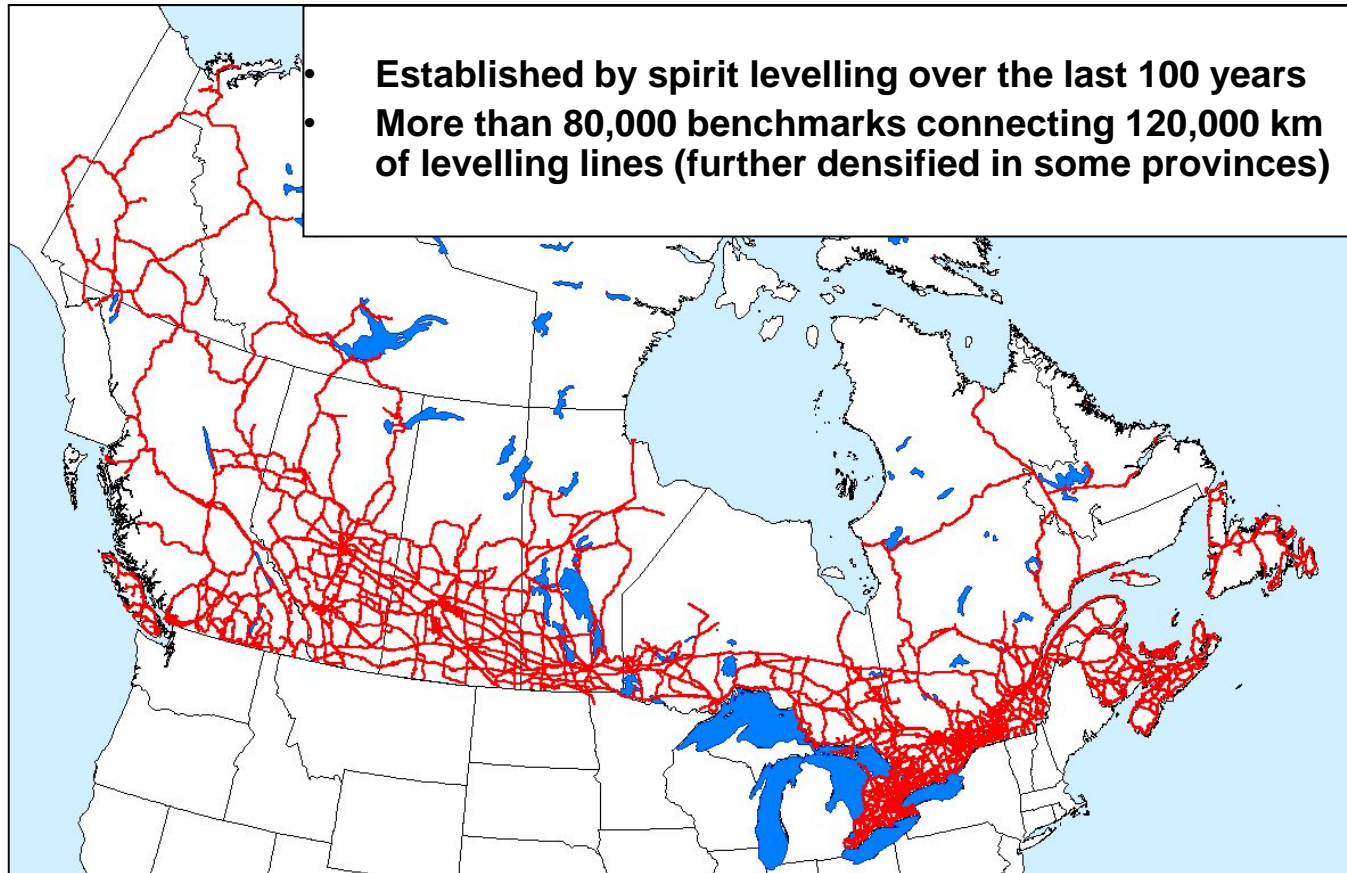
- Height surveys require elevations relative to a reference surface known as a datum
  - A point, line or surface used as a reference
- Vertical datums are either:
  - Tidal, based on sea levels
  - Geodetic, based on ellipsoid models of the earth
  - Regional, based on an arbitrary value
- A common reference surface is mean sea level (MSL)
- The current datum in Canada
  - Canadian Geodetic Vertical Datum 1928 (CGVD28)
  - A MSL datum adopted in 1935
- Propagated through Canada by first-order spirit leveling

## What is Mean Sea Level?

- MSL was determined from measurements at 5 tide gauges on the coasts over a 19 year period (metonic cycle)



# First-Order Levelling Network in Canada

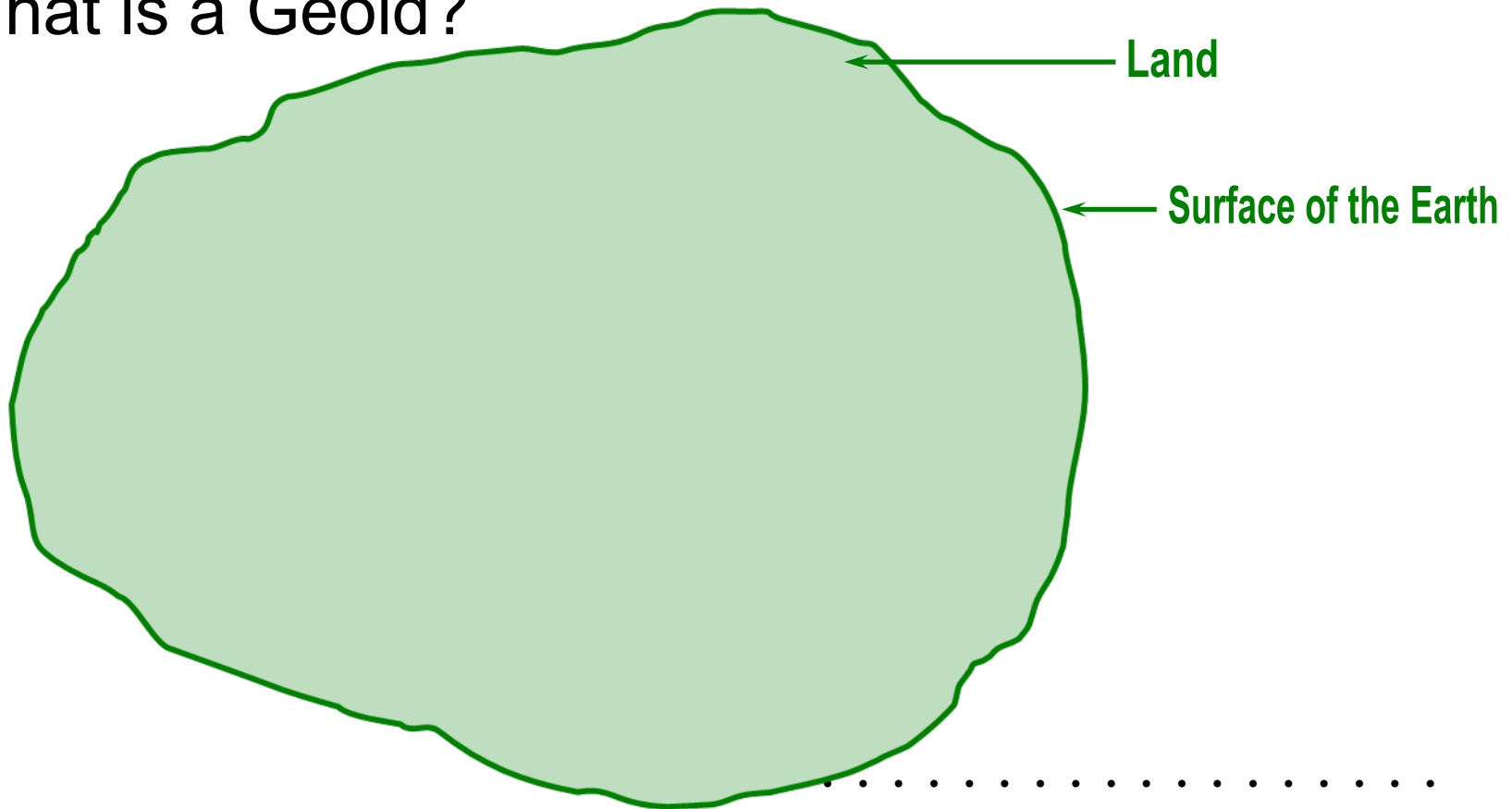


## Problems of Current System

- Primary network is very expensive to maintain
  - No major physical upgrade since 1996
  - Estimated 20% degradation rate per 20 years
- Has significant distortions for various reasons
  - Discrepancies of 1.5m from coast to coast
- Is not accessible nation-wide
  - Majority of levelling network exists in the south
  - Sparse or non-existent in the north
- Not compatible with NAVD88 (U.S.)
- Not easily compatible with GNSS

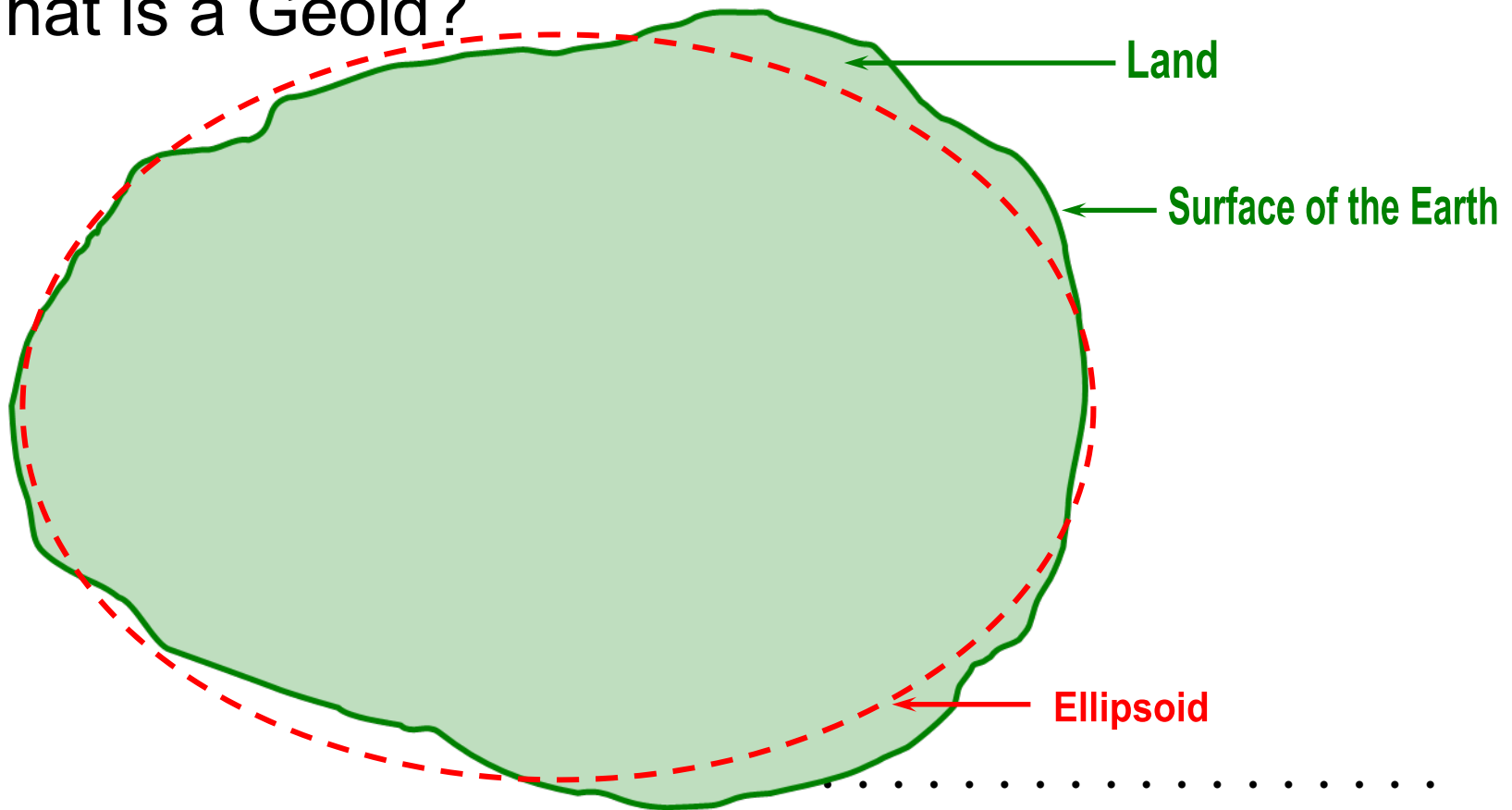
# The Geoid

- What is a Geoid?



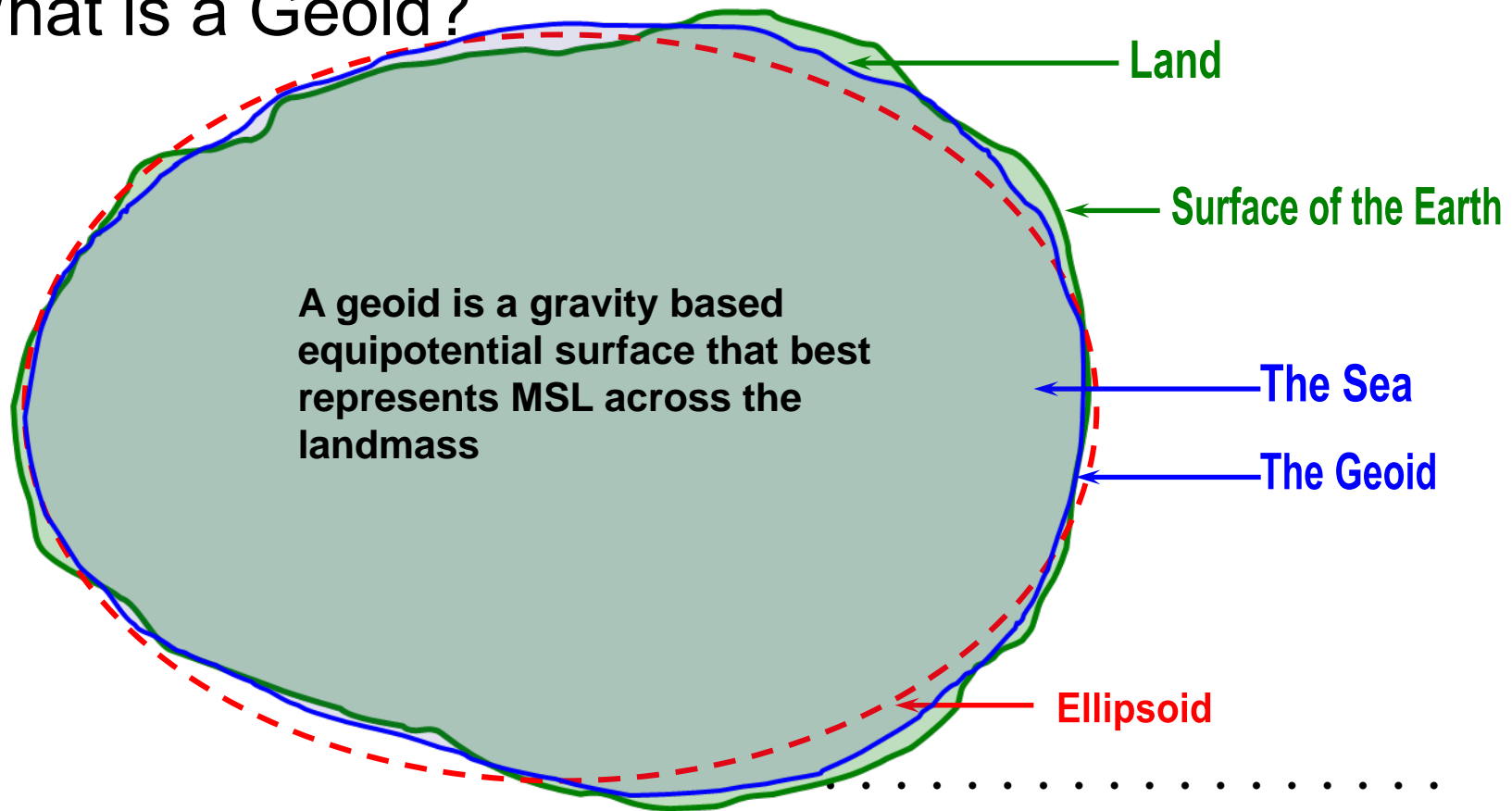
# The Geoid

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# The Geoid

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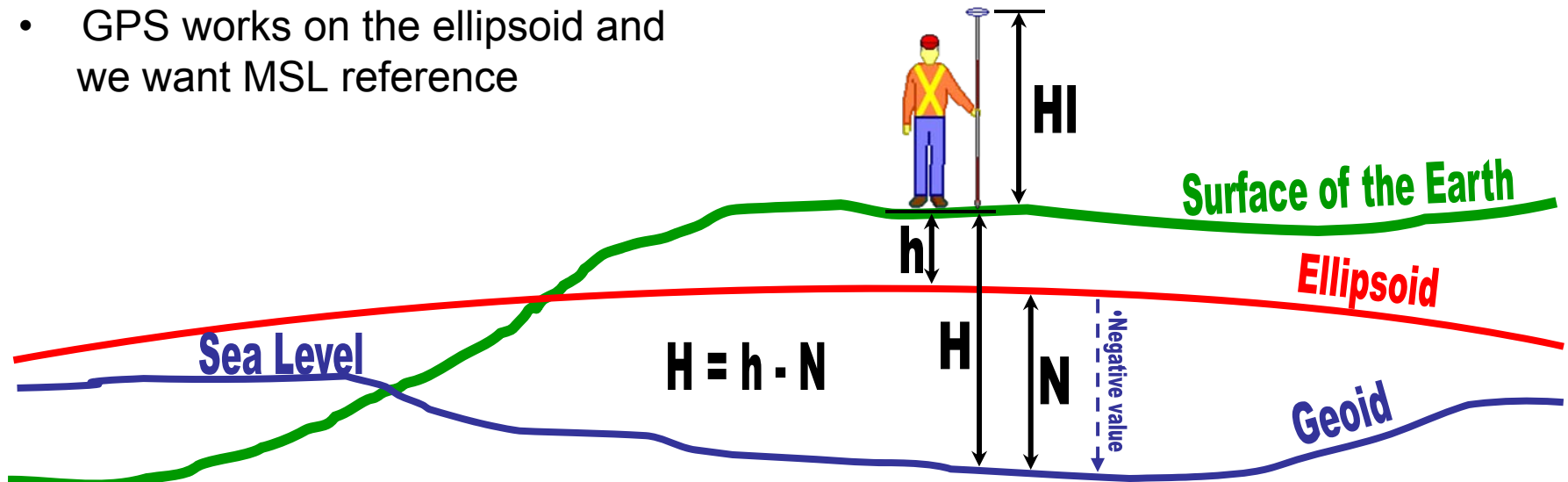


## The Geoid (cont'd)

- The surface that most closely approximates sea level in the absence of winds, ocean currents, and other disturbing forces.
- The Earth's shape resembles an ellipsoid, but it is not a perfect ellipsoid.
- Departures from the ellipsoid are represented by the geoid elevation above or below the ellipsoid.
- The geoid can be as low as 106 m below the ellipsoid or as high as 85 meters above
- In MB the geoid is below the ellipsoid

# Heights

- GPS works on the ellipsoid and we want MSL reference

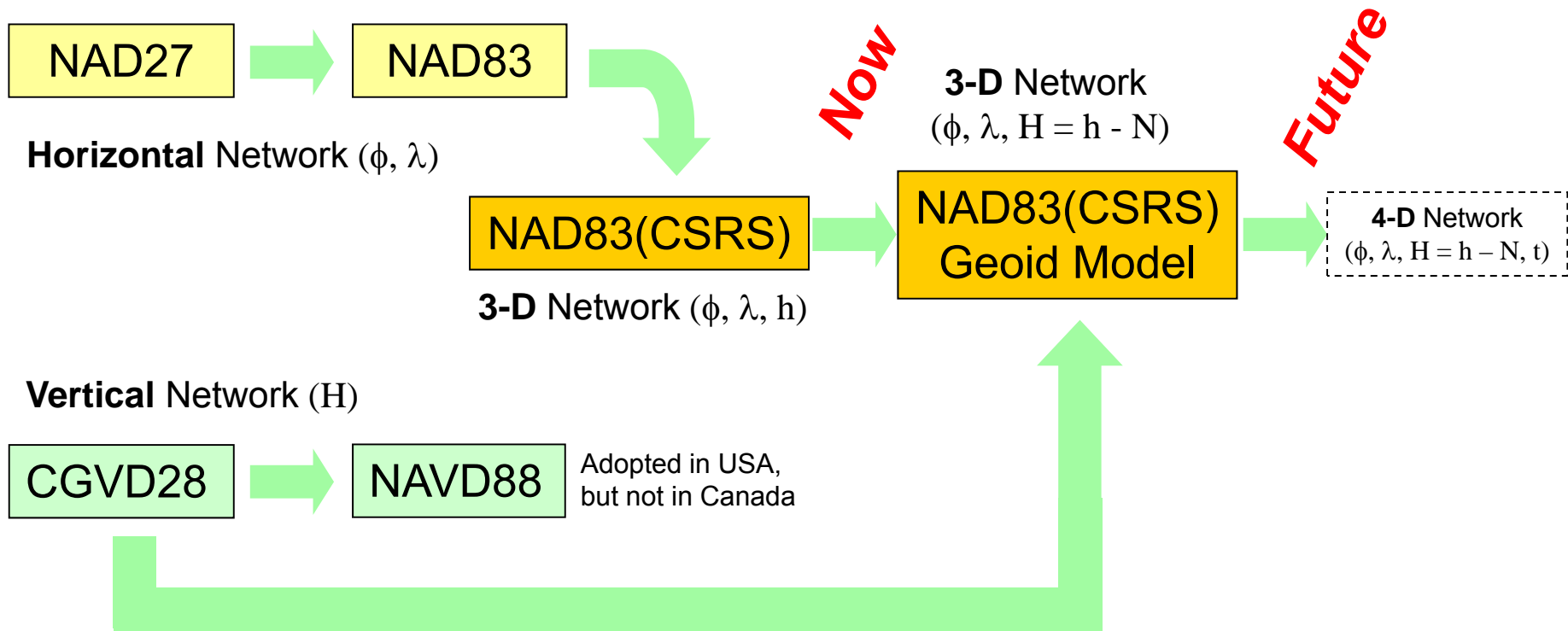


- $h$  = Height above ellipsoid
- $H$  = Height above geoid
- $N$  = Height of geoid above ellipsoid (negative for Canada)
  - e.g.  $309.652 - (-26.54) = 336.192$  m above the geoid (orthometric height)
- To get to MSL we must reference to a vertical datum

## Why Modernize?

- Benefit from new technologies
  - Global Navigation Satellite Systems (GPS, GLONASS, Galileo)
  - Satellite gravity missions (CHAMP, GRACE and **GOCE**)
- Offer full coverage of the Canadian territory
- Reduce cost of maintaining the existing network and of extending it to the North (~\$500/Km)
- Overcome limitations caused by existing distortions in the current standard, CGVD28
- Realise operational efficiencies in user applications and economies in reference frame provision
- Move towards the unification of the horizontal and vertical networks into NAD83(CSRS)

# Unification of horizontal and vertical networks



## The New Height System

- The current geoid model CGG2005 may be adequate
- Accessible directly through GNSS positioning as well as the monumented networks
  - 3D NAD83 (CSRS) positions ➔ new datum heights
- Prior to release in 2013 NRCCanada will:
  - Confirm adequacy of geoid for new datum
  - Develop user tools for transformation ↔ CGVD28
  - Adjust the leveling network to new datum\*
- New heights will differ from published MSL:
  - Less than 1.000m at any single point
  - More than 0.100m at most locations
- Relative differences will remain consistent. . . . .

# Preliminary Differences: CGG2005 vs. CGVD28

- Changes to CGVD28 elevations at selected Canadian cities with respect to:
  - Equipotential surface (WR) coinciding with the mean water level at the tide gauge in Rimouski, Québec (NAVD88)

Cities	Bias	Cities	Bias	Cities	Bias
Tuktoyaktuk	-5	Whitehorse	+58	Yellowknife	-7
Vancouver	+50	Banff	+75	Edmonton	+26
Regina	+1	Winnipeg	-2	Thunder Bay	+23
Toronto	-5	Montréal	-7	Rimouski	0
Halifax	-36	Charlottetown	-19	St-John's	-9

- Equipotential surface (W0) representing best, in a least-squares sense, the global mean sea level.

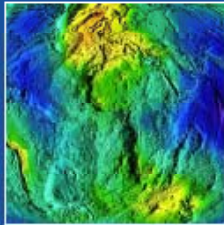
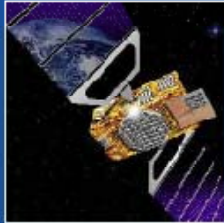
Cities	Bias	Cities	Bias	Cities	Bias
Tuktoyaktuk	-33	Whitehorse	+35	Yellowknife	-36
Vancouver	+22	Banff	+46	Edmonton	-3
Regina	-26	Winnipeg	-32	Thunder Bay	-4
Toronto	-34	Montréal	-37	Rimouski	-27
Halifax	-64	Charlottetown	-47	St-John's	-37

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## Coexistence of Old and New

- Dissemination of heights in old and new datums for existing benchmarks (dual height reference system)
- Deterioration of benchmark network will contribute to the acceptance of the new datum





## Final Report

# Stakeholders Consultation for the Development of the Canadian Height Reference System Modernization Implementation Plan

## Stakeholder Concerns (HAL Consultation)

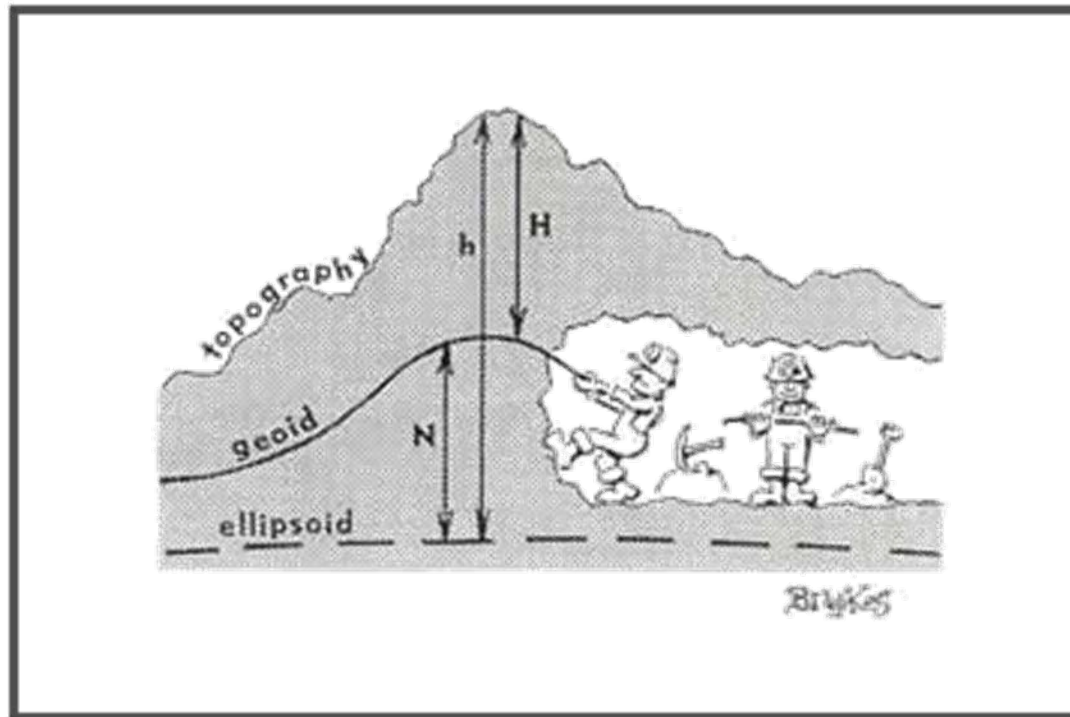
- A geoid model as reference
  - Accuracy and long-term stability of the model
  - Possibility of frequent updates with new realisations
- Differences between CGVD28 and CGG datums
  - Possible confusion leading to errors in regions with centimetre level differences
- Physical network degradation
  - Reduced availability of benchmarks (no more maintenance)
  - Vulnerability introduced by dependency on GNSS technologies
- Financial considerations
  - Training of staff, new equipment acquisition and conversion of legacy data
- Legal implications
  - Liability situations resulting from inadvertent errors
  - Possible requirement to review and amend wording of legal documents

## Long Term User Impacts

- Access to CGVD28 will become more difficult as benchmarks disappear or deteriorate (become unstable)
- The vertical datum will be accessed mainly through space-based technologies (GNSS, radar altimetry, ...)
- Local and regional surveys will still be performed with spirit levelling but the use of GNSS technology may be required to access the reference and provide quality control
- Maintenance of a sparse infrastructure of monumented high-precision 3D control will be required to support differential GNSS processing and monitor the reference frame stability (combination of federal CBNs and *provincial HPNs*)

## Conclusion

- In terms of accuracy and accessibility, CGVD28 does not satisfy today's user needs for precise height determination.
- The most viable alternative for the realization of a lasting and sustainable vertical datum in Canada, compatible with GNSS technologies and international standards, is a geoid model.
- The new datum will change the heights assigned to benchmarks within a range of one metre across Canada. However, local height differences will maintain the same relative precision of a few mm.
- NRCanada, in cooperation with provincial and territorial geodetic agencies, is moving ahead with the implementation of a modernized height reference system for 2013.
- Stakeholder interaction, tools development, education and data dissemination will be essential components of this initiative.



In Search of the Geoid – W. Brookes

## Height Modernization Links

- [http://www.geod.nrcan.gc.ca/hm/index\\_e.php](http://www.geod.nrcan.gc.ca/hm/index_e.php)
- <http://www.hal.ca/height/index.htm>
- [http://www.geod.nrcan.gc.ca/edu/geod/index\\_e.php](http://www.geod.nrcan.gc.ca/edu/geod/index_e.php)

Questions?

