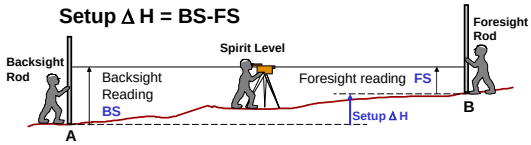
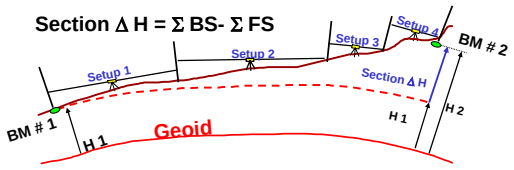
GPS and the Geoid

Mean-Sea-Level Heights from Levelling

The height of a point above mean-sea-level can be most accurately obtained using **conventional spirit levelling** techniques. Unfortunately it is costly, time consuming and laborious technique when the project area is large.

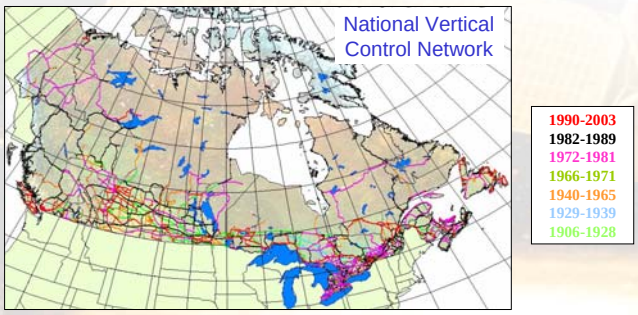
It involves making differential height measurements between two vertical graduated rods, kept approximately 100 metres apart, using a tripod-mounted **spirit level** that provides a horizontal line of sight (always tangent to the equipotential surface at the instrument).





Spirit levelling has been conducted in this fashion for more than 200 years because there was no cheaper alternative.

A national network of vertical control points (some 80,000 benchmarks) was created over the past 100 years. They were located along major roads and railways.



The Canadian Geodetic Vertical Datum of 1928 (CGVD28) was realized in 1928 by doing a national scale adjustment of all levelling. The CGVD28 was and is still to this day the **official reference surface for heights in Canada**. However it is not error-free:

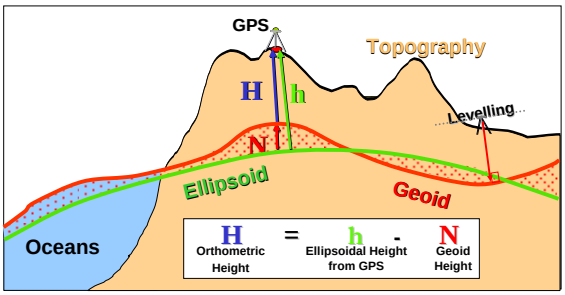
- Since 1928, new levelling was adjusted in a piece-meal fashion while permitting old published coordinates to remain unchanged.
- The levelling network contains **systematic errors**.
- Benchmarks constantly move because of **geodynamic activity** (post-glacial rebound, earthquakes) and local uplift and subsidence.

GPS and Geoid Heights

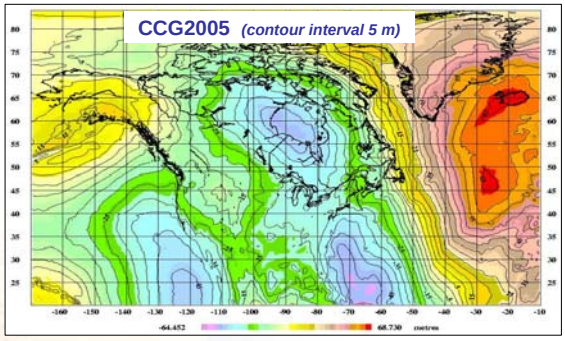
Today, GPS can provide an alternative to spirit levelling. GPS determines positions (lat, long and height) with respect to an **Ellipsoid**. Ellipsoid heights are not consistent with mean-sea-level.

The **Geoid** is the **equipotential surface** (where potential is constant and gravity is perpendicular at all points) that best represents, in a least-squares sense, the **global mean-sea-level** (reference surface for heights).

The practical way to express the geoid is through **geoid heights**. The geoid height is the distance (or separation) between the geoid and the ellipsoid. Geoid heights (N) allow the transformation of ellipsoidal heights (h) from GPS to orthometric heights (H).



For Canada, the geoid heights can be obtained from the Canadian Gravimetric Geoid model 2005 (CGG2005).



In a perfect world, the vertical datums defined by geoid modelling and geodetic levelling would be identical, but this is not the case due to systematic and random errors in the input data for their realization.

NRCan (www.geod.nrcan.gc.ca) also produces a Height Transformation (HTv2.0) whereby the CGG2000 was tweaked to conform with CGVD28 (based on GPS observations at 1926 benchmarks across the National Vertical Control Network). This manipulation to CGG2000 (or any gravimetric geoid models) is necessary to depict the inherent systematic errors in CGVD28.

- **Absolute accuracy** of HTv2.0 is estimated at +/- 5 cm in southern Canada and could reach **a few decimetres** in remote or northern regions (where GPS was not run on benchmarks).
- **Relative accuracy** (local geoid height differences) is estimated at 1-3 cm.