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Rijkswaterstaat Ministerie van Infrastructuur en Waterstaat

Height datum modernization based on **GNSS** leveling

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Motivation





Contents

- Leveling based height system
- Geoid based height system
- Hybrid height system
- Experiment and results



Leveling based height system

Traditional realization of height datum through leveling network

- + Accurate over short distances
- + Physical realization available to users (benchmarks)
- + Long time series
- Time consuming, costly
- Requires fit of geoid to height datum, h-H-N≠0



H^o: orthometric height
— : equipotential surface W = const.

Image: Featherstone and Kuhn (2006)



Leveling based height system: NAP

1st order network

- About 300 underground BM
- Heights relative to Amsterdam, readjusted in 2004, based on 5th primary leveling (1996-1997)







Leveling based height system: NAP

2nd order network

- Heights relative to 1st order BM
- About 30000 benchmarks
- 3000 km leveling each year
- Stable areas: every 10 years
- Deforming areas: every 5 years





Leveling based height system: NAP

1) R Klees and I Prutkin (2010), The combination of GNSS-levelling data and gravimetric (quasi-) geoid heights in the presence of noise. J Geod 84: 731-749







Geoid based height system

Height datum defined by gravimetric geoid realization

- + Allows direct conversion of GNSS height to physical height
- + Benifical for large countries that lack country-wide leveling infrastructure or where maintenance is too costly (eg. Canada, US)
- + Not affected by systematical errors from leveling
- No (actual) realization through BM
- Accuracy depends on geoid errors and GNSS errors, difficult to validate



Hybrid height system

Realization of a height system based on 1st order leveling network and network of GNSS leveling points





Test setup

- 5th primary network with leveling connection to GNSS points
- LS adjustment using GNSS leveled heights at 84 points:

$$H_{GNSS} = h_{GNSS} - N_{grav}$$

$$\sigma_{H_{GNSS}} = 5 \text{ mm}$$

- 2 solutions computed:
 - 1. Pseudo LS adjustment: 84 heights fixed
 - 2. Weighted LS adjustment: 84 heights adjusted
- Results compared to adjusted NAP heights (H_{NAP}) at the 84 points:

$$\Delta H = H_{GNSS} - H_{NAP}$$





Images: Brand (2004)



















Concluding remarks

- Results showed feasible approach to height datum modernization
- Utilizes the quality of the GNSS measurements, gravimetric geoid and high relative accuracy of leveling
- Direct conversion of GNSS heights to physical heights using gravimetric geoid
- Realization through benchmarks for users
- No fit of innovation function required, but results could be used as alternative method of corrector surface estimation