Realization of the vertical datum and height system of Lithuania

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Abstract. The vertical datum and height system adoption is crucial in development of national geodetic reference. The gravity and height systems should be related with the geocentric geodetic coordinate system. In Lithuania such a system was adopted in 1994 as a Lithuanian Coordinate System (LKS 94). It consist with European Terrestrial Reference System 1989. Since 1998 the main Lithuanian geodetic activities were related to the development of the Lithuanian National Geodetic Vertical Network. The network should implement unified system of heights in the territory of Lithuania and guaranty reliable connection with other European height systems. The NGVN should be continuously updated for the purpose of heights and their accuracy determination. Institute of Geodesy, VGTU is involved in establishment of National Networks. The main geodetic activities of Lithuania are supervised by the Department of Geodesy and Cadastre at National Land Service under Ministry of Agriculture. The development of NVGN is finished and it is planning to adopt Lithuanian vertical system in 2007.

Keywords. Vertical datum, height system, levelling network, normal heights.

1 Introduction

The height systems adoption is crucial in development of national geodetic reference. Successful solution of this question guarantees the reliable determination of geopotential heights, usage of modern geodetic space techniques, maintenance of the navigation, geodetic and cartographic works, solution of geodynamic tasks, support the relations between the similar systems of other countries.

The Baltic Sea height system defined by Kronstadt datum is still in use in Lithuania. Therefore Lithuania is participating in the United European Levelling Network (UELN) and European Vertical Network (EUVN) and “Baltic Sea Level” (BSL) [22–23].

The United European Levelling Network (UELN) is a continental height system, which was planned at first in 1955 as a levelling network for Western Europe with the reference point Amsterdam (NAP). The results of the first adjustment of 1960 were published as UELN-55 [10].

At present the work at the UELN was continued within the scope of the IAG Subcommission for Europe (EUREF) under the name of UELN-95. The development, results and status of UELN was well reported in each year [11–15]. In January of 1999, the results of the adjustment version UELN-95/13 were handed over to the participating countries as the UELN-95/98 solution [16, 17].

Following the Resolution of the EUREF Symposium adopted in Bad Neuenahr–Ahrweiler in 1998 requesting to extend and improve the vertical network around the Baltic Sea, Lithuanian geodesists prepared the data for connecting the state levelling network to UELN [16, 17].

The Lithuanian reference levelling network was included into UELN in 2000 (Fig. 1).

The levelling data of different epochs fit to each other at 1 mm per kilometre accuracy. The connecting lines between national networks of neighbouring countries also coincide at the same accuracy level. The accuracy of Lithuanian
levelling network is at the same level as that of the levelling networks of biggest part of other participating countries. To achieve a higher accuracy the observations of the Lithuanian fundamental network should be finished as soon as possible. Also, these data will improve the geokinematics height network and will be a basis for adoption of the European Vertical System 2000 (EVS2000).

EUVN was started to develop in 1997. It joins the European Reference Frame (EUREF) permanent GPS sites, UELN of Western Europe and United Precise Levelling Network (UPLN) of Eastern Europe points. EUVN campaign was supported by the 33 European countries. There are three points – VILNIUS, SIAULIAI and MOLAS – in EUVN.

BSL project started in 1990. Participate all countries surrounding the Baltic Sea. Lithuania joined the GPS campaign of 1993. In 1997 was organized joined BSL and EUVN GPS campaign.

As a result of EUVN the coordinates and ellipsoidal heights of the points in ETRS89 and the normal heights connected to UELN were obtained. So the points of EUVN were connected to Amsterdam datum and European Vertical Reference System.

European Combined Geodetic Network (ECGN) should combine the spatial and height reference system with Earth gravity field parameter estimation [24, 25]. So the stations of ECGN shall combine the various geodetic techniques: GPS, levelling, gravity and tide gauge observations in costal zones.

The Lithuania proposed for the ECGN stations VILNIUS and KLAIPEDA. VILNIUS is EUREF permanent GPS station, UELN and National vertical network node, absolute gravimetric measurements point. KLAIPEDA is European Sea Level Service observing site and International GPS service TIGA-PP project station, including tide gauge, meteorological sensors, permanent GPS station and absolute gravimetric measurements point.

The data and results of the international projects create the good conditions for the adoption of the Lithuanian height system. The points VILNIUS, SIAULIAI, MOLAS, KLAIPEDA became the most accurate fundamental geodetic points. They will be the basis for the development of the modern geodetic reference of Lithuania.

3 Existing levelling network analysis

The present reference levelling network of Lithuania is combination of levelling line of different epochs, therefore its accuracy at the same level as that of the levelling networks of biggest part of other European countries. For example, the parameters of the adjustment are the following [16]:

- Number of fixed points: 1,
- Number of unknowns: 1466,
- Number of measurements: 1490,
- Minimum length of the loop: 14.2 km
- Maximum length of the loop: 785.8 km
- Average length of the loops: 303 km
- Degrees of freedom: 24,
- Standard deviation: 0.902 kGal×mm/km
- A-posteriori standard deviation referred to a levelling distance of 1km: 0.92 kGal×mm,
- Mean value of the standard deviation of the adjusted geopotential differences: 1.41 kGal×mm,
- Mean value of the standard deviation of the adjusted geopotential heights: 8.62 kGal×mm,
- Biggest value of the standard deviation of the adjusted geopotential heights: 11.32 kGal×mm,
- Average redundancy: 0.016.

The adjustment of geopotential heights differences of enlarged UELN95/15, including levelling networks of Poland and three Baltic states, was performed as an unconstrained adjustment linked to the reference point 13600 in Amsterdam, geopotential height of which was set to 0.70259 kGal×m, and normal height to 0.71599 m. The same network was adjusted with reference point of temporal Lithuanian height system 53V12421, geopotential height of which was set to 63.76000 kGal×m, and normal height 64.963 m, and with reference point Kronstadt gauge, geopotential height and normal height of which was set to 0.000 m. Normal heights received are presented in the Table 1 (accordingly H1, H2 and H3).
Average height differences between H1 and H2 is 14 cm, that is well-known differences between UELN and UPLN normal heights. Therefore direct computation of normal heights from Amsterdam and Kronshad gives average difference about 10 cm [16].

Normal height differences in different epochs for single line is presented in Table 2.

The levelling line Mikyta–Klaipeda is in the south-west part of Lithuania. The normal height differences do not exceed the levelling accuracy. So, it is proofs, that the geodynamic processes in this part of Lithuania are not very significant.
Height differences between benchmarks of vertical network are determined by precise levelling. Two sets of digital levels *Wild NA3003* and precise bar coded invar staffs *GPCL3* were used for height differences determination.

Precise coded staffs *GPCL3* are calibrated every year by vertical automated laser comparator at the Finnish Geodetic Institute. Digital levelling system calibration is performed since 2004. Results of levelling system calibration, refraction and tidal effects were taken into account.

Accuracy characteristics of precise geometric levelling (standard deviations of 1 km double-run levelling) are presented in Table 2, and misclosures of loops are presented in Table 3.

![Diagram of Lithuanian National Geodetic Vertical Network](image)

**Table 2. Accuracy characteristics of levelling**

<table>
<thead>
<tr>
<th>Year of levelling</th>
<th>$m_{\text{lev}}$, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>0.48</td>
</tr>
<tr>
<td>1999</td>
<td>0.42</td>
</tr>
<tr>
<td>2001</td>
<td>0.39</td>
</tr>
<tr>
<td>2002</td>
<td>0.41</td>
</tr>
<tr>
<td>2003</td>
<td>0.43</td>
</tr>
<tr>
<td>2004</td>
<td>0.47</td>
</tr>
<tr>
<td>2005</td>
<td>0.44</td>
</tr>
<tr>
<td>2006</td>
<td>0.46</td>
</tr>
</tbody>
</table>

**Table 3. Preliminary misclosures of network loops**

<table>
<thead>
<tr>
<th>Loop No.</th>
<th>Loop perimeter, km</th>
<th>Preliminary actual misclosure, mm</th>
<th>Allowable misclosure, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>491.1</td>
<td>+4.67</td>
<td>33.24</td>
</tr>
<tr>
<td>2</td>
<td>517.8</td>
<td>+14.41</td>
<td>34.13</td>
</tr>
<tr>
<td>3</td>
<td>575.6</td>
<td>–10.83</td>
<td>35.99</td>
</tr>
<tr>
<td>4</td>
<td>451.1</td>
<td>+11.21</td>
<td>31.86</td>
</tr>
<tr>
<td>5</td>
<td>499.9</td>
<td>–10.73</td>
<td>33.54</td>
</tr>
</tbody>
</table>

Total number of points in the network is 1374. All ground benchmarks (totally 691) were observed by GPS campaigns, and ellipsoidal heights were computed.

The vertical datum and type of state heights system is not adopted in Lithuania yet. Therefore it seems that Lithuania will follow the resolution of the EUREF Symposium in 1996 in Ankara, and the normal heights system will be adopted. The normal gravity field of the Geodetic Reference System 1980 (GRS80) was adopted as part of Lithuanian Coordinate System 1994 (LKS 94).

So the way to adopt the Lithuanian national height system (LHS) could be as follows:
It should be realization of European Vertical Reference System based on UELN data.

2. It should utilized normal heights.

3. Apply the zero system for the permanent tide.

4. Do not implement the land uplift model. Set the reference epoch to 2000.0.

5. Obtain the geopotential number at VILNIUS (UELN ID 12002) site from a UELN adjustment relative to NAP. This is the vertical datum of LHS.

6. Adjust the Lithuanian NGVN in this datum.

5 Conclusions

1. Lithuania participates in the all main European projects related to height system development. That creates the strong premises for the Lithuanian height systems adoption.

2. The data of existing Lithuanian levelling network entered the UELN data base. It makes possible to integrate Estonian, Latvian and Lithuanian levelling networks into UELN. The accuracy of Lithuanian levelling network is at the same level as that of the levelling networks of biggest part of other participating countries.

3. Observations of Lithuanian National Geodetic Vertical Network are finished. Total number of points is 1374. The average accuracy (standard deviation of 1 km double-run levelling) of 0.44 mm was achieved. All ground benchmarks (totally 691) were observed by GPS campaigns, and ellipsoidal heights were computed.

4. Lithuanian National Geodetic Vertical Network is completed in 2006 and the country is ready to introduce the national height system, which should be the realization of European Vertical Reference System.

References


