

# European Vertical Reference System Influence in Latvia

A Celms<sup>1,2</sup>, I Reķe<sup>1</sup> and A Ratkevičs<sup>1</sup>

<sup>1</sup>Latvia University of Agriculture, Liela Str. 2, Jelgava, LV-3001, Latvia

E-mail: armands.celms@llu.lv

**Abstract.** Till 1 December, 2014, in Latvia the heights were determined in Baltic Normal Height System 1977. The national height system is determined by the Cabinet of Ministers and internal laws. Now for the change of the national height system to reconcile it with the European Vertical Reference System, amendments to the laws and regulations have been developed, but so far only the amendment to the Geospatial Information Law is in force, the amendment to the regulation of the Cabinet of Ministers is still not approved. This amendment declares the Latvia Height System based on the European Vertical Reference System in Latvia as the national height system.

For height transformation, there is a transformation formula for each European country. After calculations it is seen that height difference between Baltic Normal Height System 1977 and European Vertical Reference System depends on point location in the territory (coordinates). This unequal height difference between both height systems will cause unequal height values on border connection points between Baltic countries. The aim of the research is to evaluate the European Vertical Reference System in Latvia. To reach the aim the following tasks are set: 1) to evaluate the components of transformation formulas; 2) using the transformation formulas to calculate height differences between Baltic Normal Height System 1977 and the European Vertical Reference System realization EVRF2007 for the territory of Latvia and also between Baltic Normal Height System 1977 and the Latvia Normal Height System; 3) to get height differences in the European Vertical Reference System on the borderlines of Latvia – Estonia and Latvia – Lithuania.

## 1. Introduction

Levelling network is a forming element of the national height system. Levelling network ensures realization of various functions in the national economy. Using the Class I levelling results for any kind of transformations, it is necessary to know the accuracy of the established levelling network (Celms et al., 2013). Since 1 December 2014 Latvia uses the realization of the European Vertical Reference System in Latvia – Latvia Normal Height System as the national height system. Lithuania and Estonia still use Baltic Normal Height System 1977 as the national height system. In Latvia this is

---

<sup>2</sup> To whom any correspondence should be addressed.



determined by the Cabinet of Ministers. The use of the European Vertical Reference System in every European Union member state is determined under Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) and European Commission Regulation (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services. Annex II, article 1.3.3. „Compound Coordinate Reference Systems” determines that the European Vertical Reference System shall be used to express gravity-related heights within unit’s geographical scope.

## 2. Methodology of research and materials

To facilitate transformation from Baltic Normal Height System 1977 to the European Vertical Reference System, Federal Agency for Cartography and Geodesy (*BKG – Bundesamt für Kartographie und Geodesie*), Germany, and the Reference Frame Sub-Commission for Europe (EUREF) have developed a transformation formula for realization of EVRF2007 in the territory of Latvia:

$$H_{(II)} = H_{(I)} + a_1 + a_2 \cdot M_o \cdot (LAT - LAT_o) + a_3 \cdot N_o \cdot (LON - LON_o) \cdot \cos(LAT)$$

$H_{(I)}$ : height in the source system [m];

$H_{(II)}$ : height in the target system [m];

$M_o$ : radius of curvature in the meridian of GRS80 [m] in  $P_o$ ;

$N_o$ : radius of curvature perpendicular to the meridian of GRS80 [m] in  $P_o$ ;

LAT: latitude in ETRS89 [radian];

LON: longitude in ETRS89 [radian];

$P_o(LAT_o, LON_o)$ : Reference point of the transformation;

$a_1$ ...vertical translation [m];

$a_2$ ...slope in the direction of the meridian [radian];

$a_3$ ...slope in the direction perpendicular to the meridian [radian] (Description of national...).

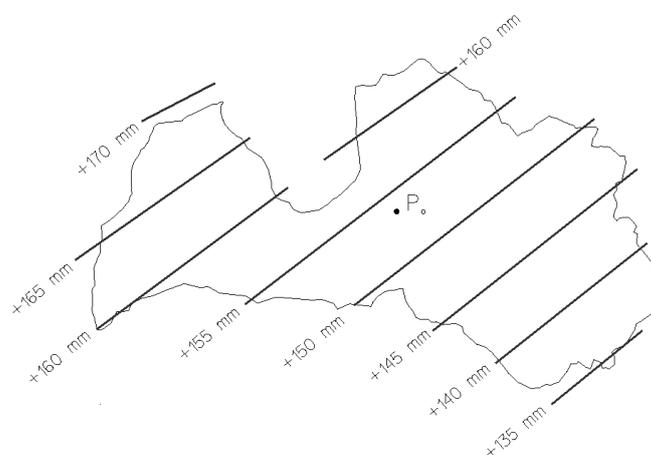
In the European Coordinate Reference Systems Database CRS-EU the values of transformation formula for the territory of Latvia are available:

$M_o = 63840416.7$  m;  $N_o = 6393195.1$  m;  $LAT_o = 56^\circ 58' = 0.99426$  radian;  $LON_o = 24^\circ 53' = 0.43430$  radian;  $a_1 = 0.15374$  m;  $a_2 = 0.01558$  sec and  $a_3 = 0.01174$  sec.

Amendment to the regulations by the Cabinet of Ministers determines the Latvia Normal Height System LAS-2000,5, the transformation formula for the Latvia Normal Height System and its parameters. The transformation formula and some of its parameters are the same as the transformation formula and parameters for EVRF2007 realization in the territory of Latvia. For unknown reasons, for the territory of Latvia slope in the direction of the meridian  $a_2 = 7.99066182789555 \text{ E}^{-0008}$  m and slope in the direction perpendicular to the meridian  $a_3 = -9.48289473646151 \text{ E}^{-0008}$  m are different from all parameters for EVRF2007. The amendment defines these two parameters in meters, but probably it must be a mistake, because parameters  $a_2$  and  $a_3$  can be determined in radians or seconds. For the calculations of height difference, the authors of research adopted the values of both parameters in radians.

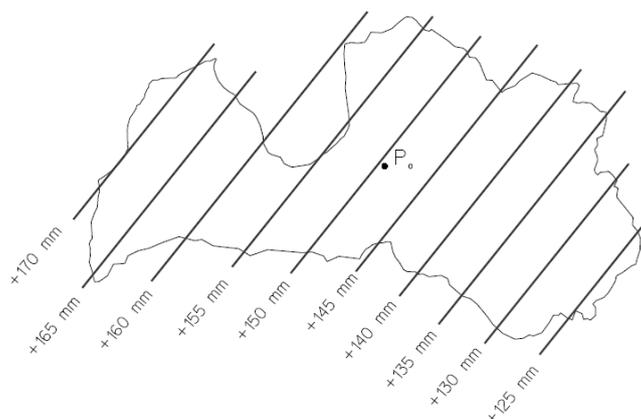
### 3. Results and discussion

After applying the transformation formula, height difference between Baltic Normal Height System 1977 and the European Vertical Reference System is not a constant value in the entire territory of Latvia, it differs from 135 mm in the south-east part of the country to 169 mm in the north-west part of the country (see figure 1) and depends on point location in the territory (coordinates).



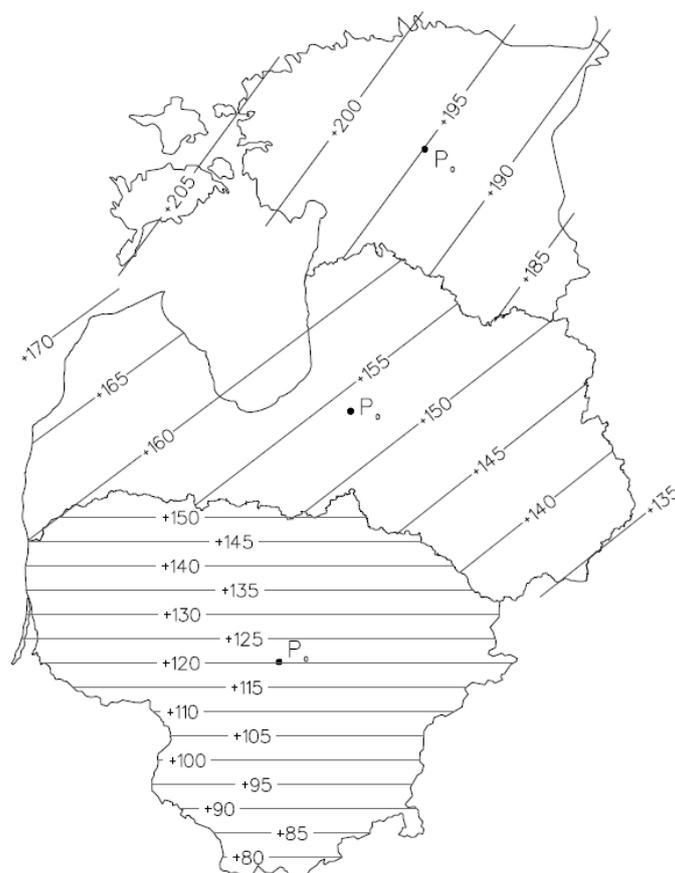
**Figure 1.** Height difference between Baltic Normal Height System 1977 and the European Vertical Reference System realization EVRF2007 for the territory of Latvia.

After calculations using the parameters for Latvia Normal Height System, the height differences between Baltic Normal Height System 1977 and Latvia Height System are from 125 mm in the south-east part of the country to 173 mm in the north-west part of the country (see figure 2). The differences constitute 48 mm, which is higher than primarily determined by EVRF2007.



**Figure 2.** Height difference between Baltic Normal Height System 1977 and Latvia Normal Height System LAS-2000,5.

In the European Coordinate Reference Database it is also possible to calculate the height difference between Baltic Normal Height System 1977 and the European Vertical Reference System realization EVRF2007 for the territory of Lithuania and Estonia. Figure 3 shows the results of the calculation.



**Figure 3.** Height difference between Baltic Normal Height System 1977 and the European Vertical Reference System realization EVRF2007 for the territory of Lithuania, Latvia, Estonia and locations of transformation points  $P_0$ .

As seen in figure 3, in Lithuania the difference between height systems changes in the south – north direction and will be 80 mm in the south part till 150 mm in the north part of the country. In Estonia the difference between height systems changes in the same direction as in Latvia – from 185 mm in the south-east part till 207 mm in the north-west part of the country.

As it is seen in figure 3, there is one serious problem – the European Vertical Reference System will cause unequal height values at border connection points (see figure 4) – on the state border the height difference of the same point in the height system of Latvia and Estonia or Latvia and Lithuania can reach 33 mm (see table 1).



**Figure 4.** 1<sup>st</sup> class leveling network border connection points with Estonia and Lithuania.

**Table 1.** Height difference of 1<sup>st</sup> class leveling network border connection points.

Border	Point No.	Point height (BAS-77), m	Point height (EVRF2007) in Latvia, m	Point height (EVRF2007) in Estonia/Lithuania, m	Difference between heights of EVRF2007 in Latvia and Estonia/Lithuania, mm
LV-EE	3433	3.21	3.373	3.407	-33.9
	2083	72.37	72.532	72.564	-32.0
	2128	50.93	51.087	51.120	-33.3
	538	78.64	78.793	78.826	-33.4
LV-LT	1684	11.01	11.170	11.150	19.6
	718	96.4	96.560	96.560	-0.5
	2285	138.9	139.037	139.030	7.4

Table 1 shows the height difference of 1<sup>st</sup> class leveling network border connection points. On Latvia – Estonia border, height difference in the European Vertical Reference system realization EVRF2007 in both countries will be from 32.0 to 33.9 millimetres, but on Latvia – Lithuania border connection point heights in Latvia and Lithuania in the European Vertical Reference System realization EVRF2007 will be from -0.5 mm to 19.6 mm. So the same point on the border will have different height value in each country’s realization of the European Vertical Reference System EVRF2007. There will be no more height connections between the Baltic countries.

For the practical testing, 2 geodetical points were measured with the GNSS instruments at the same time – Latvia 1<sup>st</sup> class leveling network point 1727 and Lithuania 1<sup>st</sup> class leveling network point 10284. Point 1727 is situated at about 5 km from Latvia – Lithuania border line and point 10284 – at 12 km (see figure 5). The measurements were made in the static mode for 3 hours.



**Figure 5.** Location of geodetic points 1727 and 10284.

After data adjustment, point heights in Baltic Normal Height System 1977 were obtained (see table 2).

**Table 2.** Point 1727 and 10284 heights.

Point	H (BAS-77), m		Height difference (BAS-77) between 1727 and 10284, m		H (EVRF2007), m	Height difference (EVRF2007) between 1727 and 10284, m
	measured with GNSS	from database	using GNSS measurements	using data from database		
1727	32.498	32.380	14.872	15.027	32.53	15.03
10284	47.370	47.407			47.56	

The height difference between both points in Baltic Normal Height System 1977 using Global Navigation Satellite System (GNSS) is 14.872 m but calculating with heights from Latvian and Lithuanian state geodetic network database the height difference is 15.027 m – 15.5 cm bigger. The reasons for 15.5 cm difference could be the inaccuracy of the geoid model.

The height difference between both points in the European Vertical Reference System realization EVRF2007 is 15.03 m. The accuracy is in cm, because the European Coordinate Reference Database gives the results in these values. Comparing height difference between both points in Baltic Normal Height System 1977 (database information) and the European Vertical Reference System realization EVRF2007, the results are almost the same. The reason for the same result is almost equal height difference between Baltic Normal Height System and the European Vertical Reference System realization EVRF2007 for the territory of Latvia and Lithuania in this area. It can be also seen in table 1 where the height difference of point 718 located in the same area in both systems in both countries is just 0.5 mm.

#### 4. Conclusions and proposals

1. The height difference between height systems using the transformation formula is not a constant value but changes in SE-NW direction and depends on point location (coordinates).
2. This varying height difference does not have significant influence on the practical land surveying works;
3. The differences between Latvian - Estonian and Latvian - Lithuanian EVRS height systems are in the range of -33.9 to +16.9 mm.
4. United EVRS height system for the common Baltic space is advisable.
5. The change from Baltic Normal Height System 1977 to EVRS system in the Baltic countries will deny the possibility of direct comparison of the Earth's vertical movement dynamics and comparison of the prior levelling results.
6. After the implementation of the EVRS height system, it is desirable to give height values for each current geodetic sign in Baltic Normal Height System 1977.

#### 5. References

- [1] Celms A, Kronbergs M, Cintina V and Baumann V 2013 Precision of Latvia Leveling Network nodal point Height *Civil Engineering '13: Proc. of fourth Int. Scientific Conf. (Jelgava, LLU)* part I, vol 4, pp 310–317
- [2] Celms A, Bimane I and Reke I 2014 European vertical reference system in Baltic countries *Baltic Surveying* **1** 49–55
- [3] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) [Available]: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:108:0001:0014:en:PDF>
- [4] Description of national Coordinate Reference Systems of European Countries [Available]: [http://www.crs-geo.eu/nn\\_159882/crseu/EN/CRS\\_\\_Description/crs-national\\_\\_node.html?\\_\\_nnn=true](http://www.crs-geo.eu/nn_159882/crseu/EN/CRS__Description/crs-national__node.html?__nnn=true)
- [5] National Coordinate Reference Systems: European Coordinate Reference Systems Database [Available]: [http://www.crs-geo.eu/nn\\_124226/crseu/EN/CRS\\_\\_Description/crs-national\\_\\_node.html?\\_\\_nnn=true](http://www.crs-geo.eu/nn_124226/crseu/EN/CRS__Description/crs-national__node.html?__nnn=true)
- [6] Project: Amendment in regulation of Cabinet of Ministers No.879. [Available]: <http://tap.mk.gov.lv/mk/tap/?pid=40335465>
- [7] Valsts augstumu izejas līmeņa noteikšana 2009 (Riga Technical University, Department of Geomatics) Scientific research project p 63