"Environmental Engineering" 10th International Conference
Vilnius Gediminas Technical University
Lithuania, 27–28 April 2017
http://enviro.vgtu.lt

eISSN 2029-7092 / eISBN 978-609-476-044-0

Article ID: enviro.2017.215
DOI: https://doi.org/10.3846/enviro.2017.215

Analyses of Latvian National Geodetic Reference System

Ivars Liepins[1], Maris Kalinka[2]

[1, 2]Riga Technical University Department of Geomatic, Kipsalas street 6A/B, Riga and LV-1048, Latvia
E-mails: [1]ivarsa@inbox.lv (corresponding author); [2]maris.kalinka@rtu.lv

Abstract. National geodetic reference system is base for geodetic and geospatial data and information obtaining, maintenance and distribution in common reference system in country. It means, that it must be as accurate as possible and lockstep with time. Latvian national geodetic reference system (LNGRS) derives from Soviet Union geodetic reference system at beginning of 90-ties last century. Development of LNGRS was done as historical continuation of practice to use height, coordinates, Earth gravitational and geomagnetic systems and national networks. For coordinates was established new Latvian geodetical coordinate system using one week campaign data of GPS NAVSTAR. Heights were kept in Baltic normal height system epoch 1977. Earth gravitational system was established newly by absolute gravimetric measurements. Geomagnetic system was developed as repeat station system. Earth is constantly change system internally and outwardly More growing use of GIS and GNSS in agriculture, construction, logistic, military and everyday life put new challenge for LNGRS and it reliability to actual situation in top level. Main goal of publication is to analyse all aspects of LNGRS against nowadays criteria and requirements of dynamic national geodetic reference system. Results of analyses show feeble and powerful sides of LNGRS.

Keywords: National geodetic references system definition, realization, management.

Conference topic: Technologies of geodesy and cadastre.

Introduction

International Earth Rotation and Reference Systems Service provide one ideal reference system to whole Earth following definition of International Union of Geodesy and Geophysics in resolution No. 2 adopted in Vienna, 1991 (IERS 2017). Ideal reference system currently is International Terrestrial Reference System (ITRS) agreed, maintain and develop as basic geodetic coordinate system. In field, real physical points or observatories realize ITRS by long time satellite and moon laser ranging, global positioning observation and very long baseline interferometry (IERS 2017). Geodetic observation from different techniques analyses separately and then combine to achieve the best results in International Terrestrial Reference Frame or ITRF coordinate realization and precision.

ITRS is base for other continental reference systems and frames. International Association of Geodesy (IAG) Sub-Commission 1.3.a EUREF (EUREF 2017) deals with definition, realization and maintenance of European Terrestrial Reference System (ETRS89). ETRS89 is base for all national and regional coordinate systems in scope of Europe. Until year, 1997 realization of ETRS89 followed after each ITRF realization, but now latest ETRS89 realization is ETRF2000 (ETRS89 2017). There was direct sequence between ITRF realization and ETRF realization. Regional and national reference coordinate systems develop from ETRS89 by global positioning observation on definitive number of geodetic markers at each country. (EUREF campaigns 2017)

In accordance with the Resolution No. 3 of the EUREF Symposium 1994 in Warsaw, the objective of the United European leveling Network (UELN) project is to establish an unified vertical datum for Europe at the one-decimeter level with simultaneous enlargement of UELN as far as possible to the Eastern European countries. The results of the adjustment with status of end 1998 were handed over to each participating country under the name UELN95/98. One year later at the EUREF symposium 2000 in Tromsø a first definition of the European Vertical Reference System (EVRS) was adopted. The realization on the base of the UELN95/98 solution got the name EVRF2000 (EVRS 2017). Latvian data was transfer to UELN database at year 1999 checked and put in future steps because there was no data about Lithuanian first order levelling network at UELN database. After participating countries provided new national levelling data to the UELN data center new realization of EVRS was computed and published under the name of EVRF2007 which is adopted as the vertical reference for pan-European geo-information by European Commission (EVRS 2017)

Gravimetrical measurements based on absolute gravity measurements from October of 1995 performed by Finish Geodetic Institute in three points Pope, Riga and Viski (Mäkinen *et al*. 1996).

First geomagnetic measurements in independence Latvia did at 2004 as repeat station measurements on 6 stabile points all around Latvia (State Land Service 2004).

Results

Latvian geodetic coordinate system

Now-a-days officially at territory of Latvia for geospatial data and information obtaining in power is Latvian Geodetic coordinate system epoch 1992.75 or LKS-92. It created after collapse of Soviet Union, new era of national economy and fast growth of civil use of global positioning. Coordinates and geodetic data lose top-secret status, started process of data transformation from countless local systems to one common for all country.

Government of Latvia took decision to change coordinate system from Pulkova to Latvian national. In fourth of June 1992 Latvian Republic the Council of Ministers resolution No. 213 (LKS-92 1992) established LKS-92 as normative for national economy, border demarcation and state information systems. Geodetic datum is one point – satellite laser ranging station "Riga" with mark 1884. Sate 0 order global positioning network consist of three more points and observation did in September that year in EUREF-BAL 92 campaign (Madsen, F., Madsen, F. B. 1993), and that how LKS-92 established in field. At eighth of January 1996 Latvian Land Board resolution No. 2 (State Land Service 1996) determine transition time and way to use LKS-92 Transversal Mercator projection in Latvia.

In 17th of December 2009 Geospatial information law (Geospatial 2009) established that LKS-92 is part of geodetic reference system and is basic for reference in geodesy and cartography. In 15th of November 2011 the Cabinet of Minister resolution No. 879 "Geodetic reference system and topographic map system" (Geodetic 2011) order LKS-92 parameters and realization in Latvia.

LKS-92 is ETRS89 realization for Latvia via EUREF-BAL 92 campaign on four physical global positioning 0-order network points Riga, Kangari, Arajs and Indra (see Fig. 1).

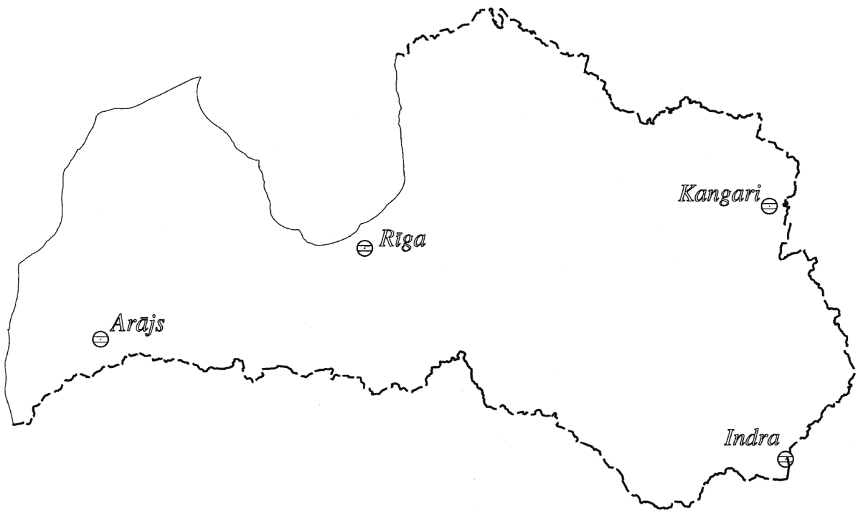

Fig. 1. Global positioning 0-order network points in Latvia

On those four global positioning 0-order network points, all state global positioning network and Latvian permanent global positioning base station network (LatPos) is based on. Further on state global positioning network and LatPos all mapping, topographic, cadastral and engineering work amended. Global positioning 0-order network point Riga is locally connect by GNSS permanent station and satellite laser ranging station – all together serve as IGS08 (IGS08 2017) realization, the only one in Baltic countries. Station Riga serve as most accurate and precise monitoring point of coordinate velocity in Latvia. Main part of geodetic global positioning observation in Latvia territory made from state global positioning geodetic network and LatPos, but non-epoch correction performed when obtain coordinates. If we compare ETRF and ITRF coordinate yearly velocity (EPN 2017) in Baltic States we can see that coordinate change speed in ITRF is at least twenty time faster than in ETRF. Nevertheless, ETRF coordinates in Riga after 25 years will maximally change by 17.5 millimeters as it provide in Table 1. That should take into account of coordinate system as part of geodetic reference system.

Table 1. Yearly velocity in ETRF and IGb08 in Baltic countries

Name of base station	Coordinate velocity ETRF2000 epoch 2005.00 (m/year)			Coordinate velocity IGb08 epoch 2005.00 (m/year)		
	VX	VY	VZ	VX	VY	VZ
1	2	3	4	5	6	7
VLNS00LTU	–0.0005 ± 0.0000	–0.0004 ± 0.0000	–0.0006 ± 0.0000	–0.0193 ± 0.0000	0.0142 ± 0.0000	0.0081 ± 0.0000

End of Table1

1	2	3	4	5	6	7
RIGA00LVA	0.0007 ± 0.0000	0.0002 ± 0.0000	0.0004 ± 0.0001	-0.0178 ± 0.0000	0.0143 ± 0.0000	0.0087 ± 0.0001
KURE00EST	0.0014 ± 0.0000	0.0006 ± 0.0000	0.0010 ± 0.0001	-0.0167 ± 0.0000	0.0145 ± 0.0000	0.0093 ± 0.0001
TOR200EST	0.0008 ± 0.0001	0.0003 ± 0.0000	0.0001 ± 0.0001	–0.0181 ± 0.0001	0.0138 ± 0.0000	0.0081 ± 0.0001
TOIL00EST	0.0008 ± 0.0000	0.0005 ± 0.0000	0.0011 ± 0.0001	–0.0183 ± 0.0000	0.0135 ± 0.0000	0.0088 ± 0.0001
SUR400EST	0.0017 ± 0.0001	0.0007 ± 0.0000	0.0017 ± 0.0001	–0.0167 ± 0.0001	0.0141 ± 0.0000	0.0095 ± 0.0001

LKS-92 definition, realization and management analyse against criteria for state-of-the-art for coordinate system done taking into account that LKS-92 have two official definition times in 1992 and 1996 by the Council of Ministers and State Land Service and 2009 by Geospatial Information law and following rules of the Cabinet. See Table 2.

Table 2. LKS-92 definition, realization and management analyse against criteria for state-of-the-art

National coordinate system requirements	Until an after 1996. State Land Service order No.2	After 2010 by Geospatial Information law and following rules of the Cabinet
Ellipsoid of revolution	Non parameters, reference to WGS-84	Yes, clearly define
Angular velocity of the Earth	No	Yes
Gravitational constant of the Earth	No	Yes
Dynamic factor of the Earth shape	No	Yes
Tides of the Earth	No	No
Epoch of coordinate system	No	Yes 1992.75
Realization of global-continental geodetic coordinate system	No	Yes ETR89
Naming of geodetic coordinate system	Yes LKS-92	Yes LKS-92
Geodetic coordinate system management way	No, cross-reference to arrangement, supervision and protection order of geodetic points	No, part about maintenance of Geodetic reference system
Responsible institution for geodetic coordinate system management	No, in points arrangement, supervision and protection engaged the Ministry of Defence department of Geodesy and Cartography	No, about state geodetic network points inspection, arrangement, observation and geodetic reference system model maintenance engaged Latvian Geospatial information agency

Latvian normal height system

Government of Latvia took decision to keep Kronstadt pail as beginning of heights (LKS-92 1992). Height value holders in Latvia declare fundamental and ground benchmarks. Baltic normal height system in epoch 1977 or BHS-77 was in power for geospatial data and information obtaining work. BHS-77 height values from catalogs, quasigeoid model LV´98 and maps use as basic for all measurement.

From 1st of December year 2014 officially at territory of Latvia for geospatial data and information obtaining in power is European Vertical Reference system realization for Latvia or Latvian normal height system in epoch 2000,5 (LAS-2000,5). LAS-2000,5 is new height system in Latvia and state levelling network 1st and 2nd classes prescribe normal heights in Latvia.

Beginning and "backbone" of LAS-2000,5 is state levelling network. State levelling first order network measured from 2000 until 2010, consists of 20 polygons, 51 levelling line and 2379 points (see Fig. 2).

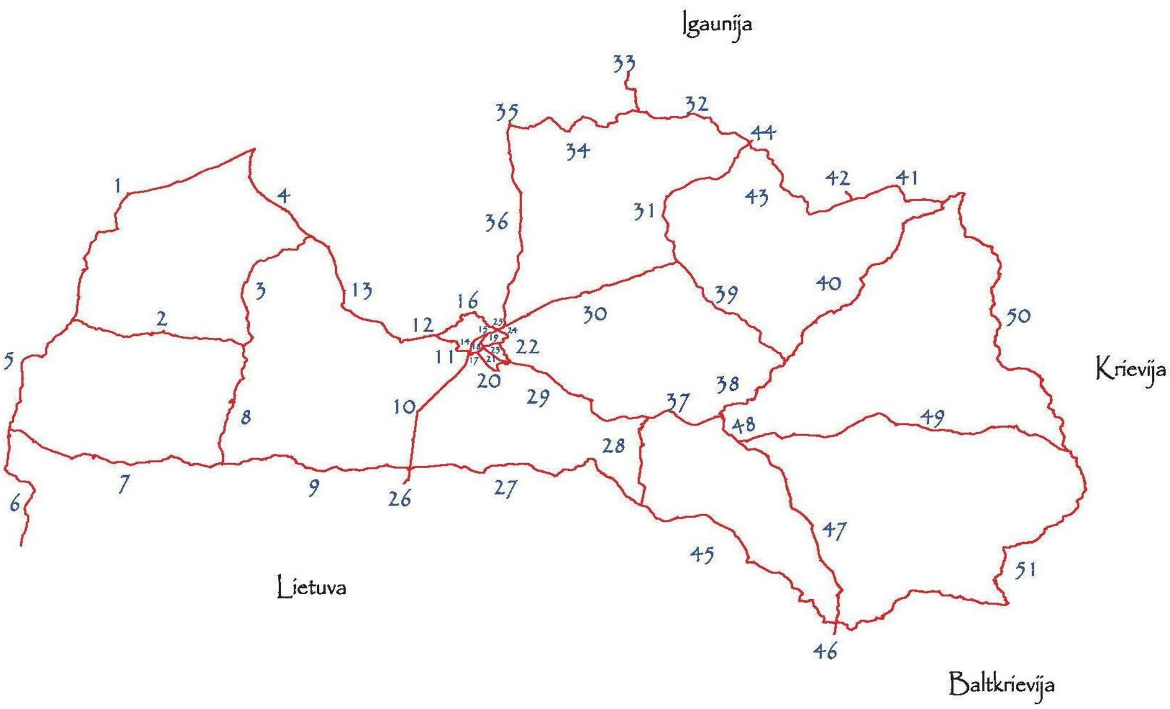

Fig. 2. State levelling first order network in Latvia

LAS-2000,5 is EVRS2007 epoch 2000,00 realization for Latvia via 16 state 1st order levelling network benchmark. Fr002, fr766, frA, fr50, fr3939, fr1484, fr1174, gr4, gr2913, gr1684, sm0718, gr2285, pp3433, gr2083, gr2128 and gr538. (see Fig. 3) Group of 16 points include connection benchmarks to neighbor countries Lithuania and Estonia.

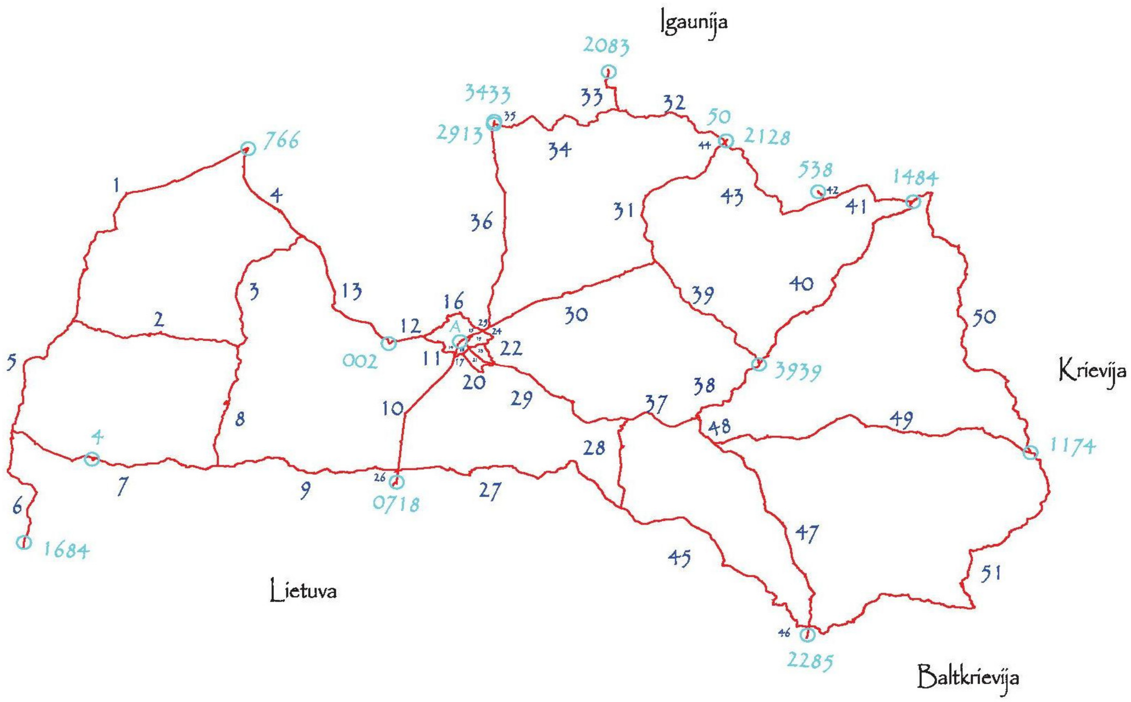

Fig. 3. 16 state 1st order levelling network benchmarks which define LAS-2000,5

Standard deviation of state levelling first order network is 0,6 mm (Levelling report 2013). Together with new height values for state levelling first order network benchmarks, transformation values from LAS-2000,5 to BHS-77 (available on CRS EU) and new quasigeoid model LV´14 delivered to society. LAS-2000,5 definition, realization and management against criteria for state-of-the-art references system and it definition. See Table 3.

Table 3. LAS-200,5 definition, realization and management analyse against criteria for state-of-the-art

National height system requirements	From 1st of December year 2014 by Geospatial Information law and following rules of the Cabinet
Ellipsoid of revolution	Yes, clearly define
Normal gravitational field	No
Tides of the Earth	No
Epoch of height system	Yes 2000,5
Realization of global-continental height system	Yes EVRS2007 epoch 2000,0
National quasigeoid model for global positioning	Yes
Naming of geodetic coordinate system	Yes LAS-2000,5
Height system management way	No, part about maintenance of Geodetic reference system
Responsible institution for height system management	No, about state geodetic network points inspection, arrangement, observation and geodetic reference system model maintenance engaged Latvian Geospatial information agency

Latvian gravitational system

Government of Latvia do not mention gravitational system or network when re-established Latvian reference system after collapse of the Soviet Union (LKS-92 1992). Cabinet of Minister Resolution No. 879 "Geodetic reference system and topographic map system" (Geodetic 2011) established the International Gravity Standardization Net 1971 or IGSN71 as reference and reduction for gravity measurements in Latvia territory. 1st and 2nd order gravitational network is realization of IGSN71 in Latvia. On all 1st order network points Riga, Pope and Viski absolute observation made in October of 1995 (Mäkinen *et al.* 1996) by Finish Geodetic Institute specialist Jaakko Mäkinen. Repeat measurements on all points by Jaakko Mäkinen done at November of 2013. All relative gravity measurements in Latvia territory based on absolute point's values observed at 1995 on three 1st order network points and it is base for quasigeoid model LV´14. Now-a-days on 1st order network absolute point Riga once a month relative gravitation measurements performed in three levels to control point and to assess the hydrology of soil layers around and above point (Mäkinen *et al.* 2016).

There is no Latvian gravitational system, but direct link to IGSN71 as reference surface. Analyse of definition, realization and management should take into account that absolutes instrument directtly establish geodetic value. Mean point is traceability to Consultative Committee for Mass and related quantities and International Association of Geodesy Strategy for Metrology in Absolute Gravimetry (CCM-IAG Strategy 2014) which is impossible.

Latvian geomagnetic system

First time officially geomagnetic is mention in Cabinet of Minister Resolution No. 879 "Geodetic reference system and topographic map system" (Geodetic 2011) with six 1st order geomagnetic network points that provide territory of Latvia connection to global geomagnetic models. On other hand, from year 2004 (State Land Service 2004) on six 1st points order geomagnetic network points once a year repeat station measurements perform and provide data to global geomagnetic models. Geomagnetic system realization by repeat absolute station, as in Latvia, wildly used in geodesy, but lack of definition and management create problems for development of system and Latvian users.

Conclusiuons

Latvian national geodetic reference system (LNGRS) consists of four independent systems that built individually each of each in last 25 years and is as historical continuation of practice to use separately heights, coordinates, Earth gravity and geomagnetic systems and national networks. Fast development of GIS and application of geospatial information in everyday life and decision making politic, together with growing request of top-level accuracy and reliability to actual situation for geospatial information, order need of new LNGRS. User of LNGRS can allot in two groups direct and indirect users of LNGRS. In each group, differ knowledge in geodesy, needs for accuracy and further use of it.

Direct users of LNGRS come from surveyors, agriculture, militarists, constructors and scientific. Indirect user come from GIS, politic makers and individuals.

LNGRS must take into account not only all urge of users, as possible, but also that Earth is constantly changing system internally and outwardly. Effects as land uplift, change of mean sea level and geoid, movement of tectonic plates horizontally and vertically, change of gravity and geomagnetic field are present in Baltic-Nordic region. New criteria and requirements for LNGRS growth from users' necessity, developments of geodesy knowledge and future trends of geospatial data use. As shown in Table 1 yearly coordinate change speed in Latvia and Baltic area indicate problem in coordinate system traditional definition, realization and management. After 25 years coordinate global change for global positioning 0-order network point Riga is 17,5 millimeters.

Requirements for LNGRS results from purpose and user needs, which can be set as minimum criteria for dynamic Latvian national geodetic reference system (DLNGRS). DLNGRS contain idea of constantly changing Earth and that after time measured geospatial data are incompatible to real situation. It based of understanding that not all users need often conversion of geospatial data, but dynamic monitoring and actual data obtaining on top-level required for reliable tracking of changing geodetic values – coordinates, heights, gravitational and geomagnetic. Reliable information about changing of geodetic values allow make pro-active steps in geospatial data renewal and better understanding of Earth changes. DLNGRS must consist of definitive minimum number of geodetic points to serve all use of geodetic data and information. DLNGRS analyse and results of four separate geodetic system feeble and powerful sides See Table 3.

Table 4. LNGRS definition, realization and management analyse against criteria for DLNGRS state-of-the-art

LNGRS sub-system	Definition	Realization	Management
Geodetic coordinate system	slightly revise	Must revise	Must revise
Normal height system	Conform	Conform	Must revise
Gravitational system	slightly revise	Must revise	Must revise
Geomagnetic system	Must revise	slightly revise	Must revise

In LDNGRS, state network categories must set up from view of it function and goal, not base on division in types and classes by methods, geodetic value and accuracy. Three level hierarchy would be sufficient for all users and purposes of DLNGRS. Higher level is Latvian dynamic global positioning references network (LATREF) together with monitoring polygon. LATREF and monitoring polygon function is dynamic, continuous, accurate connection to international coordinate, height and gravitational networks and monitoring of Earth constantly changing effects in Latvia. Monitoring polygons serve as local deformation checking and connection between geodetic values and method. LATREF goal is millimeter level DLNGRS system with changes in time. Middle level is base network. Function is serve as basic for deeper and more detail analyse of Latvia situation. Goal to connect dynamic and passive parts of DLNGRS, control LATREF and developed transformation or conversion surfaces for coordinate and heights. Last level is combine network with to part dynamic and passive. Dynamic part is LatPos and passive all other points with future plan to have as much as possible geodetic values to each state geodetic point. Function conduct coordinates, height and gravity values to all end users. Goal reliable network for all kind of geodetic works and needs.

Disclosure statement

Authors declare that do not have anykind competing financial, professional, or personal interests from other parties.

References

CCM-IAG Strategy. 2014. *Bureau International des Poids et Mesures* [online], CCM – IAG Strategy for Metrology in Absolute Gravimetry [cited 13 January 2017]. Available from Internet: http://www.bipm.org/wg/AllowedDocuments.jsp?wg=CCM-WGG

EPN. 2017. *EUREF Permanent GNSS network* [online], EUREF Permanent GNSS network Positions & Velocities [cited 11 January 2017]. Available from Internet: http://epncb.oma.be/_productsservices/coordinates/

ETRS89. 2017. *European Terrestrial Reference System 89 (ETRS89)* [online], Reference Frame Sub-Commission for Europe [cited 10 January 2017]. Available from Internet: http://etrs89.ensg.ign.fr/

EUREF campaigns. 2017. *EUREF campaigns* [online], Reference Frame Sub-Commission for Europe [cited 10 January 2017]. Available from Internet: ftp://olggps.oeaw.ac.at/pub/EUREF_camp/tests/EUREF_campaigns_test.html

EUREF. 2017. *About EUREF* [online], Reference Frame Sub-Commission for Europe [cited 09 January 2017]. Available from Internet: http://www.euref.eu/euref_abouteuref.html

EVRS. 2017. *EVRS* [online], European Vertical Reference System [cited 10 January 2017]. Available from Internet: https://evrs.bkg.bund.de/Subsites/EVRS/EN/Home/home.html

Geodetic. 2011. *Likumi.lv* [online], Cabinet of Minister resolution No. 879 "Geodetic reference system and topographic map system" [cited 11 January 2017]. Available from Internet: http://m.likumi.lv/doc.php?id=239759

Geospatial. 2009. *Likumi.lv* [online], Geospatial information law [cited 11 January 2017]. Available from Internet: http://m.likumi.lv/doc.php?id=202999

IERS. 2017. *The International Terrestrial Reference System (ITRS)* [online], International Earth Rotation and Reference Systems Service [cited 09 January 2017]. Available from Internet: https://www.iers.org/IERS/EN/DataProducts/ITRS/itrs.html

IGS08. 2017. *International GNSS service* [online], International GNSS service network [cited 11 January 2017]. Available from Internet: http://www.igs.org/network

Levellig report. 2013. *1st class levelling network of Republic of Latvia*. A report of Latvian Geospatial information agency. Latvian Geospatial information agency, Riga.

LKS-92. 1992. *About transition to Latvian geodetic coordinate system*. Latvian Republic the Council of Ministers Resolution No. 213. Latvian Journal, Riga.

Madsen, F.; Madsen, F. B. 1993. A new GPS-network in the Baltic Countries, in *Report on the Symposium of the IAG subcomission for the European Reference Frame (EUREF)*, 17–19 May 1993, Budapest, Hungary.

Mäkinen, J. *et al.* 2016. Using relative gravity measurements between surface and underground stations to assess the hydrology of the soil layers in between, in *Report at 18th International Symposium on Geodynamics and Earth Tides*, 5–9 June 2016, Trieste, Italy.

Mäkinen, J.; Petroskevicius, P.; Sildvee, H.; Kaminskis, J. 1996. Absolute-gravity measurements in Lithuania, Estonia and Latvia in 1994–1995. *European Geophysical Society, Annals Geophysicae* 14(Suppl I).

State Land Service. 1996. *About order, how transition to common Latvian coordinate system happening*. A order of State Land Service. State Land Service, Riga.

State Land Service. 2004. *Repeat measurements of Latvian magnetometric base network points*. A report made by State Land Service after field works. State Land Service, Riga.