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THE GEODETIC INFRASTRUCTURE OF UNGHENI DISTRICT OF THE REPUBLIC OF MOLDOVA

BY

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Abstract. Starting from 1999 a new geodetic reference system MOLDREF99 based on the ITRF97 and ETRS89 was established in Republic of Moldova. The realization of MOLDREF99 is the national GNSS Network with density about 1 point per 15 sq. km. However, this density is insufficient for large spectrum of applications (landslide and floods monitoring, environmental research, geohazard prediction, etc.). In 2011 national positioning service MOLDPOS was put on function with 10 permanent GNSS stations to provide real time positioning services. In order to improve the accuracy of digital terrain models along the Prut River the local quasigeoid model is necessary to develop taking in consideration GNSS/Levelling differences and gravity data. This article is focused on improvement of geodetic infrastructure of the Ungheni district in order to ensure precise and homogenous geodetic data interpretation along the Prut River for flood risk assessment and development of flood risk management plans.

Keywords: geodetic; levelling; gravity; quasigeoid; network.

1. Introduction

In 1999 Government of Republic of Moldova adopted European Terrestrial Reference System 1989 (ETRS89) based on Geodetic Reference

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System 1980 (GRS80) as a base for national geodetic reference system MOLDREF99. Introduction of new reference system generate necessity to transform a huge amount of geodetic data based on former soviet system of coordinates 1942 (SC42) based on Krasowsky ellipsoid and Gauss-Kruger map projections.

Starting from 1999 a new World Geodetic System WGS84 and Universal Transverse Mercator map projection UTM for navigation and small scale mapping from 1:25 000 to 1:500 000 was adopted by Government decision (Vlasenco A., 2016).

Fig. 1 – Reference systems and map projection used in Republic of Moldova.

Late in 2001 a new reference system MOLDREF99 based on European Terrestrial Reference System (ETRS89) and Transversal Mercator for Moldova (TMM) map projection was established to provide large scale mapping from 1:500 to 1:10 000 (Fig. 1).

This article is focused on geodetic infrastructure of the Ungheni district in order to ensure precise and homogenous geodetic data interpretation along the Prut River to create flood risk maps for flood risk assessment and development of flood risk management plans.

In order to develop a local geodetic infrastructure, it is necessary to take in account previous geodetic works: development of new geodetic network using Global Navigation Satellite System (GNSS) technologies, reconstruction of levelling network and creation of national gravity network.

The results of this study could be used by Land Relation and Cadastre Agency for argumentation of necessity to continue maintenance of National Geodetic and Levelling Networks and densification of National Gravity Network in order to achieve high accuracy quasigeoid model.

2. The Geodetic network

The Geodetic network development started in 1999 with five EUREF sites, one of them is situated in Ungheni district. The accuracy of Ungheni zero-order EUREF site (120 hours GNSS measurements) is 1.5 and 2.5 mm horizontally and 2.6 mm vertically. The first order network was developed as densification of the EUREF sites (24 hours GNSS measurements) with accuracy 5-15 mm horizontally and 10-30 mm vertically. The second order network was developed as densification of the first order sites (1 hour GNSS measurements) with accuracy 20 mm horizontally and 40 mm on vertically. Densification networks were created mostly in urban area for topographical and cadastral works with accuracy 10mm + 1ppm.

Fig. 2 – Geodetic network of Ungheni district.

However, existing geodetic network is insufficient for many geodetic applications at the local level. In order to provide real time positioning services the decision to pass from “passive” to “active” network in 2010 was adopted by Land Relation and Cadastre Agency.

To provide real time positioning and navigation service on the territory of Republic of Moldova a new project of GNSS Permanent Stations Network and MOLDPOS service was supported by Norwegian Government. In 2011 GNSS Permanent Stations Network and MOLDPOS service were put on function with 10 permanent GNSS stations integrated with 5 ROMPOS GNSS stations under agreement between Moldavian Agency for Land Relation and Cadastre and Romanian National Agency for Cadastre and Land Registration.

Ungheni district is well covered by three GNSS permanent stations (Falesti, Nisporeni and Iasi) that ensure the accuracy of RTK measurements less than 3 cm horizontally and 4 cm vertically taking in account ionospheric, tropospheric and orbit errors.

3. The Levelling network

In the period from 1997-2008 the systematic levelling work activities were continued by the Agency of Land Relations and Cadastre. The old first order levelling network was combined with second order network to form four polygons (Fig. 3).

Fig. 3 – Reconstruction of National Levelling Network and integration in ULEN.

The first order fundamental benchmark 231 could be used for connection of Moldavian and Romanian levelling networks in order to join Unified European Levelling Network (UELN) and to have the same height reference system along the Prut River (Fig. 3).

Fig. 4 – The levelling network of Ungheni district.

The levelling network of Ungheni district consist of 44 first-order levelling benchmarks with accuracy 0.8 mm/km, 42 second-order levelling benchmarks with accuracy 2 mm/km, 92 third-order levelling benchmarks and 841 fourth-order levelling benchmarks with accuracy 4 mm/km (Fig. 4). The density of benchmarks along the Prut River is good enough for evaluation of existing Digital Terrain Models (DTM) and cvasigeoid modelling using GNSS/levelling data (Chiriac V, 2017).

4. The Gravity network

In 2006 the Land Relations and Cadastre Agency of Republic of Moldova in cooperation with the National Geospatial-Intelligence Agency (NGA) of United States of America performed gravity campaign to establish a new gravity network MOLDGRAV06 (Chiriac V. *et al.*, 2006).

Gravity measurements were carried out at 20 base stations. In order to constrain the relative gravity measurements 3 absolute gravity stations were determined using FG5 absolute gravimeter with total uncertainties about 5 μGal . The relative gravity stations and local vertical gradients have been measured using three LaCoste & Romberg G meters. The first-order gravity network was designed as polygons. The accuracy of the first-order relative gravity stations and they satellites is better than 10 μGal (Fig. 5).

Fig. 5 – The first and second order National Gravity Network (Chiriac V., *et al.*, 2006).

The gravity network of Ungheni district consist of one first-order relative gravity base station with accuracy $10 \mu\text{Gal}$, 8 second-order relative gravity base station with accuracy $20 \mu\text{Gal}$ (Fig. 5).

Fig. 6 – The gravity network of Ungheni district.

The density of gravity base stations in the Ungheni district is not enough for local quasigeoid modelling and needs densification about one gravity station per 16 square km.

5. Cvasigeoid modelling

In order to generate and distribute height anomalies for real time normal height determination from GNSS measurements using MOLDPOS service, height reference surface based on precise GNSS/Levelling, first quasigeoid model for Republic of Moldova territory was calculated in 2005 by Ukrainian Research Institute of Geodesy and Cartography, using 803 GNSS/levelling sites and European Gravimetric Geoid 1997 (EGG97), transformed to Baltic Sea 1977 normal height system.

The second quasigeoid model was calculated by Technical University of Moldova in collaboration with Karlsruhe University of Applied Science using 904 GNSS/Levelling sites and Earth Geopotential Model 2008 (EGM2008). The quasigeoid model GM2010 was calculated using digital finite element height reference surface representation as polynomial solution (Chiriac V. *et al.*, 2011).

In 2012 the fourth quasigeoid model GM2012 was determined by the Royal Institute of Technology in Stockholm (KTH) applying the Least Squares

Modification of Stokes' formula with Additive corrections (LSMSA), also called the KTH method (Danila U., 2012).

In 2014 the Land Relations and Cadastre Agency performed GNSS measurements on 40 first and second order levelling network benchmarks to estimate the accuracy of existing quasigeoid models for the Republic of Moldova territory.

The comparative analyses of height anomalies calculated from GNSS/levelling and quasigeoid models showed the accuracy of 5-6 cm that is not enough for floods and landscapes monitoring using Real Time Kinematic (RTK) methods.

6. Conclusions and recommendations

To use flood risk maps for flood risk assessment and development of flood risk management plans focusing on methods accounting for more process interactions in flood risk systems the existing Digital Elevation Models have to be evaluated. To use GNSS technologies for large scale flood risk mapping the existing quasigeoid models have to be evaluated at the local level.

In order to improve the accuracy of height anomaly determination along the state border a quasigeoid undulations to be determined from GNSS/Levelling points related to 1st, 2nd order levelling networks, and carefully selected 3rd and 4th order benchmarks.

For a higher accuracy future gravimetric quasigeoid model densification of Gravity Network is necessary that at least one gravity station per 16 sq. km to be measured.

The high accuracy quasigeoid model allows the real time GNSS services to provide GNSS-based normal height real time determination for flood risk assessment and identification of flood mitigation measures in order to provide advice on actions to be taken before and during a flood.

A new regional geodetic infrastructure including high accuracy quasigeoid model and local transformation parameters will be used for large spectrum of applications (landslide and floods monitoring, environmental research, geohazard prediction, etc.).

The results of this study could be used by Land Relation and Cadastre Agency for argumentation of necessity to continue maintenance of National Geodetic and Levelling Networks and densification of National Gravity Network in order to achieve high accuracy quasigeoid model.

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INFRASTRUCTURA GEODEZICĂ ÎN RAIONUL UNGHENI A REPUBLICII
MOLDOVA

Rezumat. Începând din 1999, un nou sistem geodezic de referință MOLDREF99 bazat pe ITRF97 și ETRS89 a fost stabilit în Republica Moldova. Realizarea MOLDREF99 este rețeaua GNSS națională cu densitate de aproximativ 1 punct pe 15 km pătrați. Cu toate acestea, densitatea actuală nu este suficientă pentru un spectru larg de aplicații (monitorizarea alunecărilor de teren și a inundațiilor, cercetarea mediului ambiant, predicția hazardurilor, etc.). În 2011, serviciul de poziționare național MOLDPOS a fost pus în funcțiune cu 10 stații permanente GNSS pentru a furniza servicii de poziționare în timp real. Pentru a îmbunătăți acuratețea modelelor digitale a terenului de-a lungul râului Prut la modelarea cvasigeoidului local trebuie să fie luate în calcul diferențele GNSS/Nivelment și datele gravimetrice. Acest articol se focusează pe îmbunătățirea infrastructurii geodezice în districtul Ungheni pentru a asigura interpretarea precisă și omogenă a datelor geodezice de-a lungul râului Prut pentru evaluarea riscului de inundații și dezvoltarea planurilor de gestionare a riscului de inundații.