4.6.2. GPS NETWORKS AND GPS MEASUREMENTS IN THE REPUBLIC OF MACEDONIA

Risto Ribarovski, Zlatko Srbinoski, Jovan Jovanov, Mitre Nasevski, Zlatko Bogdanovki

4.6.2.1. General data for GPS surveys used for defining the basic GPS network in Republic of Macedonia

The first GPS surveys in Macedonia were conducted in the period from 12-th to 17-th of August 1996 under the organization of the former Republic Geodetic Authority in cooperation with the Slovenian Authority for Geodesy and Cartography and the Federate Authority for Geodesy and Cartography from Frankfurt. At that time, GPS observation on seven points was carried out in Macedonia and those points were merged with the International ITRF Network (Fig. 4.6.2.1.).

Fig. 4.6.2.1. Points on the territory of R. Macedonia used for merging with the International Reference ITRF 94 Network

During the conduct of this observation, the following precise GPS receivers were used: Trimble 4000 SSE and Trimble 4000 SSI. Based on the information received from the Inter-national GPS Service, obtained through calculation, the coordinates for the surveyed points in the reference system ITRF 94, for the epoch 1996.6 were obtained.

The definition of the datum on the system ITRF 94 and the epoch 1996.6 was achieved by orientation of the surveys towards the four ITRF stations (Wettzell-1202, Matera,

Graz-Lustbuehel and Zimmerwald) which also belong to the same reference system and datum (Fig. 4.6.2.2.)

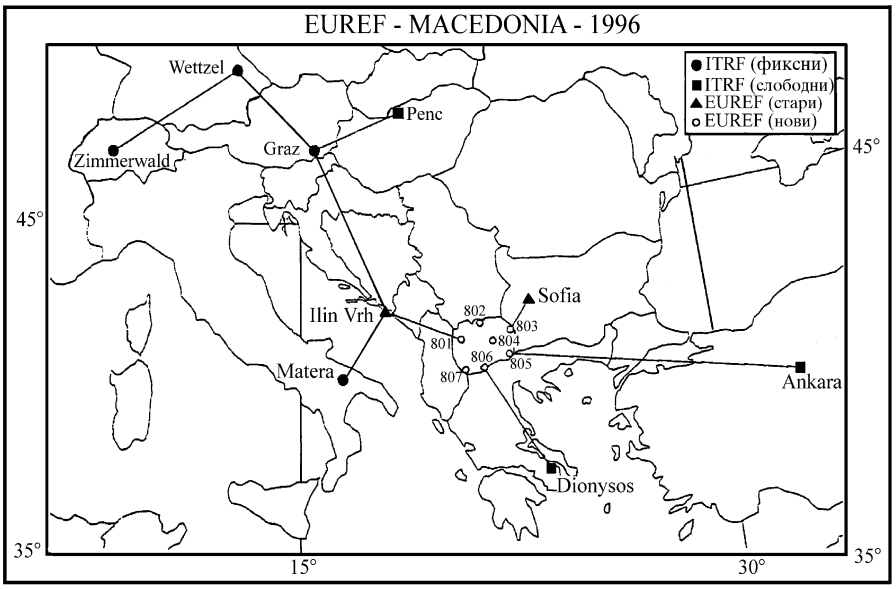

Fig. 4.6.2.2. GPS points encompassed by the strategy for triple definition of coordinates on the points for international merging with ITRF 94 – network

Table 4.6.2.1 contains approximate coordinates of all ITRF points included in the campaign.

Table 4.6.2.1.

Survey location	EUREF Number of point	φ (° ')	λ (° ')
Wettzell – 1202(D)	**0035**	**49 08**	**12 52**
Graz-Lustbuehel(A)	**0061**	**47 04**	**15 29**
Matera (I)	**0068**	**40 38**	**16 42**
Zimmerwald (CH)		**46 53**	**07 28**
Ankara (TR)		**39 53**	**32 45**
Penc (H)		**47 47**	**19 17**
Dionysos (GR)	**7515**	**38 05**	**23 56**
Ilin Vrh (HR)	**0734**	**42 29**	**18 23**
Sofia (BG)	**0556**	**42 33**	**23 23**
Korab (MK)	**0801**	**41 46**	**20 32**
Ramno (MK)	**0802**	**42 11**	**21 27**
Borova Cuka (MK)	**0803**	**42 00**	**22 52**
Bogoslovec (MK)	**0804**	**41 42**	**21 58**
Visoka Cuka (MK)	**0805**	**41 20**	**22 47**
Kajmakcalan (MK)	**0806**	**40 56**	**21 47**
Galicica (MK)	**0807**	**40 56**	**20 50**

Beside the seven points for international merging of Macedonia with the International Reference ITRF 94 Network, 25 points belonging to the zero series were additionally observed using GPS, from which a certain number of points are used to carry out GPS control in the air traffic.

4.6.2.2. Establishment of permanent stations

During the conveyance of the GPS campaign in 1996, a permanent station in Ohrid was placed, as a point being part of the European GPS Network. In the area called "Tumba", in the flat part of Ohrid, a pillar was built and an antenna was placed for permanent reception of signals, which are registered in a PC located in a specially built facility, positioned in the vicinity of the point (Fig. 4.6.2.3.).

The registration of the signals from the geodetic satellites in the permanent station in Ohrid is carried out continuously 24 hours a day, on every 15 seconds, and every registered signal is automatically transferred in the Federate Authority for Geodesy and Cartography in Frankfurt (Germany), where the signals are being processed, and after the processing, they are transferred to other users using the INTERNET.

In future, one of the top priorities of the modern Geodetic Authority in R. Macedonia shall be the establishment of more permanent stations – (local), in order to start the operation of the so called *active network*.

Fig. 4.6.2.3. Permanent GPS station in Ohrid

4.6.2.3. Latest GPS Surveys in Macedonia

At the beginning of 2004, for purposes of the survey conducted in order to produce new topographic maps in scale of 1:25000, large scale GPS surveys were undertaken by which a larger number of points on the territory of R. Macedonia were encompassed (Fig. 4.6.2.4.).

By using 9 trigonometric points from I line, 17 points from the city trigonometric points and 24 newly defined points, the territory of R. Macedonia was divided in 18 closed polygons, and between two neighboring polygons there were at least 2 colliding (mutual points). One-day three hour sessions were conducted on all points, in all polygons with appropriate GPS receivers. Using this manner, a positioning of the largest number of points on the territory of Macedonia was carried out, after the campaign EUREF 1996

GPS. Although with much lower accuracy, these surveys are very important, because they are considered to be the groundwork for new GPS campaigns in R. Macedonia.

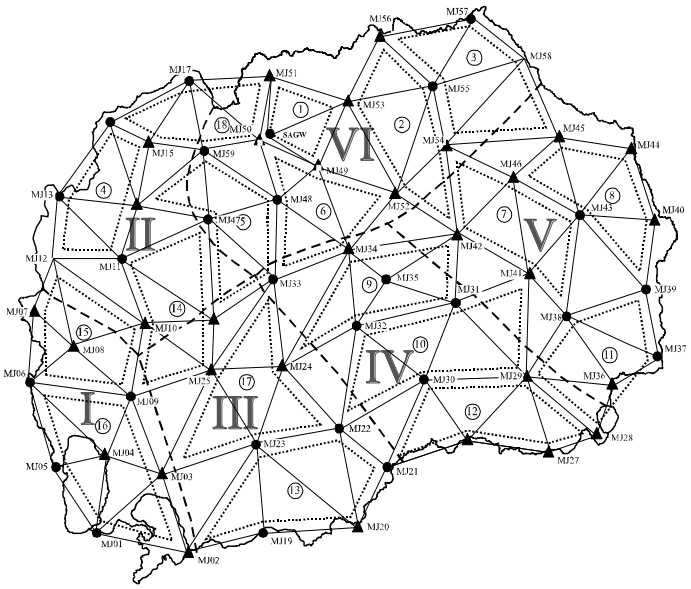

Fig. 4.6.2.4. Scheme of closed polygons for GPS surveys required for production of new maps in scale 1:25000

4.6.2.4. Current (Separate) GPS surveys in R. Macedonia

In conditions when in Macedonia the condensing of the GPS networks has not been performed, and when there are no permanent stations (i.e. when the so called "active network" does not exist) and when the detail geoids undulation has not been defined, the separate GPS surveys are performed by using the locally defined parameters of the Helmert transformation. This most applicable transformation model which establishes a direct link between the local and the global geocentric coordinate system is presented with the well known matrix equation:

(1)

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS84} = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} + m \begin{bmatrix} 1 & \varepsilon_z & -\varepsilon_y \\ -\varepsilon_z & 1 & \varepsilon_x \\ \varepsilon_y & -\varepsilon_x & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{local}$$

In order to determine the unknown transformational parameters for the entire territory of R. Macedonia, the data of 14 identical points with the known geocentric (WGS 84) and rectangle (Gauss-Krieger) coordinates in the global and the local coordinate system have been used. The transformational parameters, for the entire territory of R. Macedonia, acquired by adjustment, according to the method of indirect surveys, have the following values (Table 4.6.2.2.):

Table 4.6.2.2.

Parameters	Values
Translation round the X axis	607.148 m
Translation round the Y axis	242.159 m
Translation round the Z axis	491.510 m
Rotation around the X axis	-4.9455"
Rotation round the Y axis	-0.3197"
Rotation round the Z axis	15.2781"
Scale (ppm)	-16.4374

It should be emphasized that by using this model, a relatively high positional accuracy has been obtained, from ±0.14 m (for the Ograzden point) up to ±0.48 m (for the Ruen point). This accuracy can satisfy all mapping needs, except the accuracy required for more exact field geodetic surveys.

In order to achieve positional accuracy in more acceptable limits, a definition of se-veral regional transformational parameters has been undertaken, which can be used to perform more accurate geodetic surveys. For the area of the capital city Skopje - with the use of 6 identical points of the urban trigonometric network, the following 7 parameters for transformation of the coordinates from the local coordinate system of Bessel ellipsoid into the global (WGS 84), have been obtained (Table 4.6.2.3.):

Table 4.6.2.3.

Parameters	Values
Translation round the X axis	809.310 m
Translation round the Y axis	102.787 m
Translation round the Z axis	467.907 m
Rotation around the X axis	-3.5984"
Rotation round the Y axis	4.0441"
Rotation round the Z axis	8.9323"
Scale (ppm)	-23.3757

The local transformational parameters for the cities of Stip, Kocani, Struga, Kicevo, Debar, Gostivar are obtained by defining the coordinates through positioning of points of the urban trigonometric networks, with the help of which greater positional accuracy is acquired. An adequate equalized accuracy can not be obtained for the third dimension (the height), because the local geoids undulation is not known.

4.6.2.5. Summary

From the above-stated, it can be concluded that with the help of the methodology for determining the regional transformational parameters, the positional errors of the performed GPS surveys can be reduced to acceptable limits, but this does not apply to the third (the height) dimension.

However, in absence of fundamental solutions for performing highly accurate GPS surveys in Republic of Macedonia, the method for determining the regional transformational parameters is an extorted, but useful solution.

At the same time it can be concluded that the primary condition for solving this acute geodetic issue in R. Macedonia is to undertake adequate astro-geodetic surveys for defining the local geoid, after which, unique transformational parameters for uniform transformation of the local geodetic datum into the world geodetic system WGS84 could be determined.

4.6.2.6. References

Pecalevska, M., 2005. Defining of GPS transformation parameters for territory of city of Skopje, Diploma work, Faculty of Civil Engineering, Skopje.

Ribarovski, R., 2005. High geodesy, University "St. Cyril and Methodius", Skopje.

Ribarovski, R., Markoski, B., Srbinoski, Z., Jovanov, J., 2003. Application of UTM projection and geodetic system WGS 84, like a basic NATO standards in cartographic production in Republic of Macedonia, Scientific project, Faculty of Civil Engineering, Skopje.

Srbinoski, Z., 2001. Supplement to investigation for defining of new states cartographic projection, Doctoral dissertation, Faculty of Civil Engineering, Skopje.