Correction of cadastral maps of scale 1:5000

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The main purpose of this paper is to determine the reliable transformation parameters between the Egyptian Datum, where coordinates are from cadastral maps of scale 1:5000, and the WGS84 datum. Firstly, a description of the Egyptian network was presented. Then, various solutions to the Egyptian control network were introduced. Some points were defined at a cadastral map of scale 1:5000. Their coordinates were determined according to Helmert 1906 datum. The same points, in the field, were observed using a single frequency receiver to determine the coordinates related to WGS84 datum. Another set of coordinates were used to check the obtained results. Finally, the reliable transformation parameters were determined. To perform this task, a software was created using visual basic language.

الغرض الأساسى من هذا البحث هو تحديد معاملات التحويل الصحيحة من نظام الاحداثيات المصرى المحلى إلى نظام الاحداثيات العالمى WGS84 وذلك للخرائط مقياس ١:٥٠٠٠. ففى بداية البحث تم عرض وصف لشبكات المثلثات المصرية والحلول السابقة لهذه الشبكة. فى الجزء العملى لهذا البحث تم تحديد نقط معينة فى خرائط تفصيلية بمقياس ١:٥٠٠٠ وتم الحصول على احداثيات هذه النقط منسبة إلى النظام المصرى المحلى EGD، ثم تم تعيين مواقع هذه النقط فى الطبيعة وتم رصدها بجهاز مستقبل GPS أحادى التردد وحصلنا على احداثيات هذه النقط منسبة إلى النظام العالمى WGS84 . وعند استخدام معاملات التحويل المتعارف عليها من المحاولات السابقة والحصول على احداثيات هذه النقط بالتحويل من نظام إلى آخر ومقارنة هذه الإحداثيات بالقيم المرصودة حصلنا على أخطاء كبيرة تصل إلى مئات الأمتار. ومن هنا تم اكتشاف الخطأ فى خرائط مقياس ١:٥٠٠٠ ولذلك استخدمنا البيانات المرصودة لدينا فى الحصول على معاملات تحويل مناسبة لهذا المقياس ١:٥٠٠٠ من الخرائط التفصيلية، وتم عرض النتائج فى نهاية البحث.

Keywords: WGS84, EGD, GPS, Cadastral maps

1. Description of the Egyptian network

The first order geodetic horizontal control networks of Egypt consists of two main networks: network 1 and network 2. Network 1 consists of 195 stations divided into ten sections forming approximately a T shape, with a fundamental point F1 on the Mokattam hills to the east of Cairo. Network 1 covers the cultivated area of the Nile valley from Cairo to Adindan near the Sudanese borders, and the north coast area from Al Arish in the east to Alsaloum in the west.

Network 2 covers the area of the Eastern Desert, Red Sea coast, part of Sinai and part of the Western Desert. This network consists of 207 stations forming three main blocks divided into 13 sections. It was connected to network 1 through 19 common stations.

The geodetic triangulation, of both networks 1 and 2, was carried out by means of chain quadrilaterals with all angles observed. The average length of sides range from 40 to 50 kilometers, and as far as possible, the sides are kept in this range. Details concerning techniques of observations, types of used instrumentation and followed specification for all observed quantities along the Egyptian networks can be found in [1].

2. Various solutions to the Egyptian control network

The adjustment of any geodetic horizontal control network, relative to an adopted geodetic datum, requires the appropriate definition of such a datum. Such datum is usually taken as an ellipsoid of rotation rigidly fixed with respect to the earth's gravity field (the geoid), at a fundamental point, known as the datum initial point. At the initial point, a set of six positional parameters, defining the relation between the ellipsoid and the geoid, must be determined [1].

Several investigators have attempted to derive reliable sets of transformation parameters, from EGD to WGS84, which vary in their assumptions and available data used.

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It can be stated that any trial carried out by any investigator, to derive a set of transformation parameters, will depend upon several factors, such as: the mathematical model approach to be adopted, the number of considered transformation parameters, the type of GCPs data (finnmap or HARN), the number of available common points, and the technique of least squares adjustment (combined or parametric). Consequently, it is logically expected that, the obtained results, that is the sought transformation parameters, will be different for each investigator, depending upon the number and type of these factors that were taken into account. Table 1 summarizes the previous trials, from the year 1988 to 2000, for estimating the transformation parameters from EGD to WGS84 for the entire country.

Furthermore, table 2 depicts two trials, by dividing the Egyptian territory to several adjacent (or overlapped) small regions or zones, depending upon the available number of sufficient common points between EGD and WGS84. The data used in such trials, were taken from three sources, namely: finnmap project, HARN network, and GPS network carried out by the Egyptian Aviation Authority. From this table, it can be seen that the derived seven transformation parameters are varying from zone to the other, and each set varies also from the unique set taken for the entire country. However, the discrepancies in the transformed coordinates, using different sets for different zones are found to be less than the case considering one sets for the entire country. Nevertheless, this approach, although seems to be more accurate, it is not desirable in practice, as it introduces some problems around the zone edges, and provides inconsistent results [2].

Table 1
Previous trials for defining the transformation parameters from EGD to WGS84 based on closed matrix form as a unique set for the entire country

Investigators	Model/ number of parameters	Number/ types of common points	Adjustment technique	x_o (m)	y_o (m)	z_o (m)	ω_x (arcsec)	ω_y (arcsec)	ω_z (arcsec)	k (PPM)
ESA-Finnmap (1988)	Bursa/ Molodensky / 7	8/ finnmap	Parametric	-156.918	119.297	-24.434	-1.539	-1.062	0.49	-5.855
Al Nagar (1990)	Bursa/ 7	8/ finnmap	Parametric	-186.069	149.976	6.091	-1.221	-2.024	0.907	4.867
	Bursa/ Molodensky / 7	8/ finnmap	Parametric	-119.69	124.48	-8.598	-	-	-	-
	Molodensky / 7	8/ finnmap	Parametric	-119.31	124.38	-7.81	-1.22	-2.02	0.9075	4.827
Nassar (1994)	Molodensky / 7	8/ finnmap	Parametric							
Fayed (1997)	Bursa/ 7	8/ finnmap	Combined	-120.26	124.14	-9.06	-0.92	-0.97	-0.4	3.59
	Bursa/ 5	8/ finnmap	Combined	-146.5	118.74	-11.06	-0.93	-0.97	-0.4	3.59
	Bursa/ 3	8/ finnmap	Combined	-112.69	73.41	-20.36	-	-	-1.77	3.59
	Bursa/ 3	8/ finnmap	Combined	-120.74	124.88	-9.37	-	-	-	-
El Tokhy (2000)	Bursa/ 7	15/ HARN	Combined	-78.11	62.3	-47.65	-1.3574	0.6185	-2.8926	0.5178
	Bursa/ 7	15/ HARN	Combined	-116.21	62.11	-18.74	-0.1671	-0.1354	-1.9069	3.1374
	Molodensky / 7	15/ HARN	Combined	-125.517	109.321	-12.883	-1.3574	6.185	-2.8926	0.5178
	Molodensky / 7	15/ HARN	Combined	-125.93	112.29	-9.61	-0.1671	-0.1354	-1.9069	3.1374

Table 2
Previous trials for defining the transformation parameters from EGD to WGS84 based on closed matrix forms as unique sets varying according to different zones

Investigator / Model	Zone	Type/ number of common points	Number of common points	x_o (m)	y_o (m)	z_o (m)	ω_x (arcsec)	ω_y (arcsec)	ω_z (arcsec)	k (PPM)
Bolbol et. al. (1997)/ Molodensky	Z1	HARAN 15 / Finnmap 8 / National Aviation Authority (NAA) 11	6	-128.857	117.961	-12.471	-2.50611	1.146852	-0.875517	5.160225
	Z2		5	-128.39	115.998	-11.488	1.46991	-2.468121	0.071074	3.672545
	Z3		5	-126.578	114.598	-11.411	-1.425743	-0.801284	-0.860107	9.669190
	Z4		3	-127.36	111.974	-10.41	-2.292069	6.311047	-5.287076	4.204549
	Z5		4	-119.548	114.118	-6.464	3.731866	-0.646882	-6.405419	3.002384
	Z6		9	-128.274	116.982	-11.81	-1.192489	-0.480838	-1.147418	5.051378
	Z7		6	-122.204	114.183	-8.575	2.551665	2.375729	-7.062613	5.697832
	Z8 / Most of the country		15	-127.845	115.706	-11.243	-.990766	-0.539708	-1.049534	4.966314
El Sagheer (2000) (at different airports / Bursa)	Cairo	National Aviation Authority (NAA)		-83.335	142.772	-209.486	-3.570978	5.370846	-0.010878	8.337171
	Embaba			-131.832	144.32	-139.899	-2.584853	2.91813	0.730813	8.419232
	Port said			-190.133	149.133	-164.418	-8.968097	3.847608	3.734537	-11.500307
	Asuite			-53.879	91.896	-31.912	2.2835338	1.234295	-6.384842	7.322175
	Cairo – Embaba			-92.133	153.766	-203.513	-3.662441	5.085052	-0.380104	8.111312
	All airports			-120.842	23.713	-17.428	1.800488	0.083166	-3.525928	9.42138

3. Detection of the problem

The surveying work depends on geodetic control networks. Egyptian triangulation networks started before 1907 as second order in the delta area. The first order networks were initiated in 1907. The first order geodetic horizontal control networks of Egypt consists of two main networks, network1 and network2. Network1 was adjusted by ESA in sections by the method of condition equations, in two-dimensional.

The Egyptian survey Authority transforms the system of coordinates and mapping from the Egyptian datum with Egyptian Transverse Mercatore (ETM) to the WGS84 with UTM projection.

The relationship between different geodetic datums and the center of gravity of the earth is one of the important tasks for the geodesists. The advantages of such knowledge are clear in determining the transformation parameters, which are used to transform coordinates from one datum to another. In the areas where several datums have been established, confusion can result unless these transformation parameters are available.

The geodetic datum for a country can simply be defined as an ellipsoid rigidly fixed to the actual earth relative to a well-defined geocentric (worldwide) coordinate system. In the last two decades, GPS proved itself as a strong geodetic and surveying tool. Accordingly, surveyors are using GPS in most of their applications to obtain high precision, easiness and low cost related to the traditional techniques.

The combination between terrestrial and GPS networks has become very essential to benefit from the great accuracy of the GPS positioning. This combination is usually performed through the determination of a set of transformation parameters between the national and the GPS coordinate system [3].

The Egyptian first order control networks have been adjusted simultaneously in 1997 by

Awad at Ain Shams University. This solution was performed relatively to the Egyptian datum on the ellipsoid of Helmert 1906 and using F1 as initial point and using the positional parameters defined by the Egyptian Survey Authority as given in [4] as:

$$\phi_{F1} = 30^o\ 01'\ 42.8691''\ N$$
$$\lambda_{F1} = 31^o\ 16'\ 33.6000''\ E$$
$$\zeta_{F1} = 3.93''$$
$$\eta_{F1} = 0.00''$$
$$N_{F1} = 0.00\,m$$
$$\alpha_{O1-B1} = 252^o\ 42'\ 01.21''$$

The used data has been reduced gravimetrically using the ASU-93 geoidal model computed by El – Tokhey in 1993. The results of this solution showed that the differences in coordinates from ESA51 solution were in the order of 1.0 m for network 1 (sections 1 – 10). However, these differences were very large and reached 20 m for the stations of networks (sections 11 – 21) since the published coordinates for these stations are provisional.

In 1997 the Egyptian Survey Authority (ESA) published the final report of the results of the final adjustment of the new national geodetic networks. This project has been performed by ESA with technical and financial support from the United States for International Development (USAID) and the Deutsche Grsellschaft fur Technische Zusammenarbeit (GTZ).

The main purpose of this research is the determination of reliable transformation parameters between the Egyptian Datum, where the coordinates are from the cadastral map of scale 1:5000, and the WGS84 datum. Consequently, many GPS data points, related to WGS84 are obtained using a single frequency receiver and the same points are defined at the cadastral map of scale 1:5000 and its coordinates were determined according to Helmert 1906 datum. Another set of coordinates was used to check the obtained results.

To perform this task, a software was created using visual basic language. El-Tokhey [3] introduced estimated transformation parameters for transformation between EGD and WGS84; as:

$$x_o = -125.517\ m\ ,\ y_o = 109.321\ m\ ,\ z_o = -12.883\ m$$
$$(\omega_x = -1.3574\ arcse\ ,\ \omega_y = 6.185\ arcse\ ,)$$
$$\omega_z = -2.8926\ arcse$$
$$k = 0.5178\ ppm$$

These parameters were applied to 9 check points distributed in three cadastral maps of scale 1:5000. Two sets of coordinates were available for checking the correctness of the coordinates of cadastral map of scale 1:5000. The first set contains the coordinates on the Egyptian datum as scaled from these cadastral maps which will be referred here by EGD. The second set contains the coordinates of the same points relative to the WGS84 which were observed with single frequency GPS receivers and tied differentially to a fixed point (Alx1) of known absolute coordinates [5]. These coordinates were available in both curvilinear and Cartesian systems. The first set of coordinates were transformed to Geocentric coordinates via geographic coordinates. By using El-Tokhey transformation parameters the coordinates of these points relative to EGD were transformed to coordinates relative to WGS84. The statistics of RMS errors of this operation are given in table 3.

The first column of table 3 shows the label of cadastral map; the second column shows the used seven transformation parameters; the third column shows the point number; the fourth column shows the Cartesian coordinates of points from transformation; the fifth column shows the actual coordinates of check points relative to WGS84; the sixth column to eighth shows the difference of coordinates dx, dy, dz between two sets of coordinates; actual and transformed; the ninth column shows the position error P as determined by:

$$(P)_{point} = \sqrt{(dx)^2 + (dy)^2 + (dz)^2}$$

and the tenth column shows the RMS as determined by:

$$RMS = \sqrt{\frac{(P_1)^2 + (P_2)^2 + (P_3)^2}{3}}$$

From the previous table it can be noticed that the error for transformation from map coordinates to WGS84 datum when using these parameters are as follows:

Average dx = 194.19 m , dy = 220.11 m, dz = 345.79 m , and the average root mean square error is 493.36 m. This shows that there is a fatal mistake in the grid system of this version of cadastral maps of scale 1:5000. To confirm the presence of this mistake a comparison was carried out between the grid systems of maps of scale 1:5000 and maps of scale 1:25000. To determine the grid error in coordinates (dE, dN) two sets of coordinates are determined; the first set of coordinates are from cadastral map of scale 1:5000 and the second set of coordinates are from map of scale 1:25000. The errors of grid coordinates between two sets of coordinates was found 13.5 ± 17.5 m in east direction and 434.82 ± 19.42 m in north direction which shows that a mistake exists in the grid system of ESA cadastral map of scale 1:5000. This gross error is so big that it can be referred to as discrepancies in spheroid determination.

4. Determination of the corrected transformation parameters

Because these errors are very big and not acceptable, it was found necessary to define new transformation parameters valid for these maps. Many trials were carried out using different combinations of GCPs to determine these parameters. The point coordinates were obtained from three adjacent cadastral maps. The determination of these parameters was carried out four times, one for each map, and an additional one for the whole of the three maps. The statistics of RMS errors of this operation are given in tables 4-6 and 7.

The format and the structure of these tables are similar to table 3.

5. Conclusions

From the previous tables, one can notice that when the GCPs are from one map, better results are obtained, than to the case of when the GCPs are from three adjacent maps. The different sets of GCPs give different transformation parameters but the transformed coordinates from all sets are approximately identical. Thus, it can be considered that the transformation parameters give minimum RMS. The obtained results showed that the standard error of the positional differences is about 4.22 m and the corresponding transformation parameters are:

$x_o = 161.3\ m$, $y_o = 726.56\ m$, $z_o = -1581.07\ m$
$\omega_x = 623.69\ arc\sec$, $\omega_y = 205.015\ arc\sec$, $\omega_z = -117.57\ arc\sec$
$k = 6529.3\ ppm$

Table 3
Output coordinates and error in case of using El-Tokhy seven parameters for cadastral map of scale 1:5000

1	2							3	4			5			6	7	8	9	10
map label	xo	yo	zo	wx	wy	wz	k	Point #	coordinates of check points after transformation from map			actual coordinates for check points from GPS			dX	dY	dZ	P	RMS
	m	m	m	sec	sec	sec	ppm		Xt (m)	Yt (m)	Zt (m)	X (m)	Y (m)	Z (m)	m	m	m	m	m
								86	4730387.46	2724320.96	3287800.82	4730298.50	2724736.44	3287569.69	88.96	415.48	231.12	483.69	
								91	4729434.55	2725045.82	3288579.64	4729582.03	2725178.75	3288243.30	147.48	132.93	336.34	390.57	556.67
								84	4730508.54	2724221.64	3287712.88	4730189.79	2724878.35	3287611.60	318.76	656.71	101.28	736.97	
								5	4732074.80	2723631.69	3285983.58	4732269.59	2723734.85	3285603.63	194.79	103.16	379.95	439.26	
	-125.517	109.321	-12.883	-1.3574	6.185	-2.8926	0.5178	30	4732551.95	2723968.00	3285019.95	4732752.10	2724069.53	3284633.47	200.14	101.53	386.48	446.91	431.24
								68	4731566.63	2725065.61	3285503.67	4731732.78	2725183.94	3285152.06	166.15	118.34	351.61	406.50	
								39	4733568.01	2721806.93	3285324.53	4733782.00	2721953.63	3284881.15	213.99	146.70	443.38	513.71	
								50	4733947.66	2721048.40	3285398.98	4734158.98	2721203.69	3284952.40	211.32	155.29	446.59	517.89	512.15
								76	4732919.13	2722174.01	3285948.50	4733125.22	2722324.90	3285513.12	206.08	150.89	435.38	504.77	

Table 4
Molodensity seven parameters for cadastral map (5,) of scale 1:5000

1	2							3	4			5			6	7	8	9	10
GCPs #	xo	yo	zo	wx	wy	wz	k	Point #	Check points coordinates after transformation from map			actual coordinates for check points from GPS			dX	dY	dZ	P	RMS
	m	m	m	sec	sec	sec	ppm		Xt (m)	Yt (m)	Zt (m)	X (m)	Y (m)	Z (m)	m	m	m	m	m
79,87,88	1538.57	2138.4	824.953	-2640.59	1365.95	1130.6	3779.23	84	4730686.59	2724322.96	##########	4730678.05	2724334.95	3287361.52	8.54	####	2.71	#####	#####
								86	4730564.71	2724422.01	##########	4730558.76	2724428.21	3287451.09	5.94	6.20	3.75	9.37	
								91	4729604.86	2725143.64	##########	4729605.29	2725142.98	3288233.50	0.43	0.66	2.95	3.05	
79,87,88,81	2087.06	2328.46	1413.59	-3313.3	1887.92	1574.52	2355.18	84	4730685.30	2724324.35	##########	4730678.05	2724334.95	3287361.52	7.25	####	1.91	#####	8.91
								86	4730563.58	2724423.24	##########	4730558.76	2724428.21	3287451.09	4.82	4.97	3.06	7.57	
								91	4729604.69	2725143.37	##########	4729605.29	2725142.98	3288233.50	0.60	0.38	3.42	3.50	
79,87,88,81,89	1115.54	1888.39	866.943	-2472.25	998.802	797.149	2426.36	84	4730685.36	2724324.50	##########	4730678.05	2724334.95	3287361.52	7.31	####	2.09	#####	8.75
								86	4730563.63	2724423.29	##########	4730558.76	2724428.21	3287451.09	4.87	4.92	3.11	7.59	
								91	4729605.30	2725143.04	##########	4729605.29	2725142.98	3288233.50	0.01	0.06	2.26	2.26	
79,87,88,81,89,95	-792.32	-32.7428	36.7398	-133.802	-524.75	-869.195	-2889.83	84	4730682.14	2724326.88	##########	4730678.05	2724334.95	3287361.52	4.09	8.07	3.81	9.82	6.48
								86	4730560.91	2724425.16	##########	4730558.76	2724428.21	3287451.09	2.15	3.05	2.09	4.28	
								91	4729607.56	2725142.18	##########	4729605.29	2725142.98	3288233.50	2.26	0.80	2.36	3.36	
79,87,88,81,89,95,82	-881.476	166.809	-119.847	-167.457	-639.068	-929.956	-1435.87	84	4730683.63	2724325.69	##########	4730678.05	2724334.95	3287361.52	5.58	9.25	2.10	#####	7.36
								86	4730562.24	2724424.07	##########	4730558.76	2724428.21	3287451.09	3.48	4.14	0.59	5.45	
								91	4729607.71	2725141.73	##########	4729605.29	2725142.98	3288233.50	2.42	1.25	2.07	3.43	
79,87,88,81,89,95,82,90	-873.765	203.157	-204.441	-122.744	-626.496	-935.002	-935.739	84	4730683.64	2724325.58	##########	4730678.05	2724334.95	3287361.52	5.59	9.37	2.33	#####	7.33
								86	4730562.19	2724424.02	##########	4730558.76	2724428.21	3287451.09	3.42	4.19	0.84	5.48	
								91	4729607.11	2725142.19	##########	4729605.29	2725142.98	3288233.50	1.82	0.80	1.65	2.58	
79,87,88,81,89,95,82,90,83	-922.094	364.303	-368.806	-117.093	-705.84	-958.359	400.455	84	4730684.88	2724324.30	##########	4730678.05	2724334.95	3287361.52	6.83	####	1.13	#####	8.50
								86	4730563.28	2724422.86	##########	4730558.76	2724428.21	3287451.09	4.52	5.35	0.20	7.01	
								91	4729607.15	2725141.90	##########	4729605.29	2725142.98	3288233.50	1.86	1.08	1.29	2.51	
79,87,88,81,89,95,82,90,83,92	-733.201	643.605	-260.819	-447.61	-578.589	-773.642	1198.06	84	4730685.22	2724324.27	##########	4730678.05	2724334.95	3287361.52	7.17	####	0.07	#####	8.61
								86	4730563.56	2724422.88	##########	4730558.76	2724428.21	3287451.09	4.80	5.33	1.10	7.26	
								91	4729606.84	2725142.11	##########	4729605.29	2725142.98	3288233.50	1.54	0.88	1.01	2.04	
79,87,88,81,89,95,82,90,83,92,93	-733.201	643.605	-260.819	-447.61	-578.589	-773.642	1198.06	84	4730685.46	2724324.22	##########	4730678.05	2724334.95	3287361.52	7.41	####	0.54	#####	8.75
								86	4730563.76	2724422.87	##########	4730558.76	2724428.21	3287451.09	5.00	5.35	1.63	7.50	
								91	4729606.66	2725142.24	##########	4729605.29	2725142.98	3288233.50	1.36	0.75	0.86	1.78	

Table 5
Molodensity seven parameters cadastral map (6), or scale 1:5000

1	2							3	4			5			6	7	8	9	10
									Check points coordinates after transformation from map			actual coordinates for check points from GPS							
GCPs #	xo m	yo m	zo m	wx sec	wy sec	wz sec	k ppm	Point #	Xt (m)	Yt (m)	Zt (m)	X (m)	Y (m)	Z (m)	dX m	dY m	dZ m	P m	RMS m
1, 66, 62	-1001.17	227.06	414.66	-679.90	-276.96	-1466.87	-3470.57	13	4732216.15	2723918.68	3285531.75	4732216.97	2723921.15	3285525.00	0.82	2.46	6.74	7.22	11.81
								31	4732706.16	2724097.64	3284683.80	4732714.37	2724085.34	3284676.81	8.21	12.30	6.99	16.35	
								61	4732572.36	2724086.36	3284881.55	4732576.44	2724078.08	3284877.87	4.08	8.29	3.68	9.94	
1, 66, 62, 26	-911.55	451.95	-232.04	-296.52	-335.73	-1298.13	147.41	13	4732217.70	2723914.90	3285533.13	4732216.97	2723921.15	3285525.00	0.73	6.25	8.13	10.28	8.67
								31	4732709.39	2724092.52	3284681.64	4732714.37	2724085.34	3284676.81	4.98	7.18	4.83	9.99	
								61	4732575.15	2724081.68	3284880.17	4732576.44	2724078.08	3284877.87	1.29	3.61	2.30	4.47	
1, 66, 62, 26,56,67,63	-944.28	776.59	-412.07	-411.06	-495.00	-1223.21	2291.95	13	4732217.45	2723912.11	3285536.72	4732216.97	2723921.15	3285525.00	0.48	9.04	11.71	14.80	10.48
								31	4732709.60	2724090.41	3284683.11	4732714.37	2724085.34	3284676.81	4.77	5.06	6.31	9.39	
								61	4732575.22	2724079.48	3284882.17	4732576.44	2724078.08	3284877.87	1.22	1.40	4.30	4.68	
1, 66, 62, 26,56,67,63,27	-967.11	912.26	-583.65	-372.44	-533.88	-1237.87	3569.31	13	4732218.24	2723910.79	3285536.85	4732216.97	2723921.15	3285525.00	1.28	10.36	11.84	15.79	10.26
								31	4732710.85	2724089.19	3284682.03	4732714.37	2724085.34	3284676.81	3.52	3.85	5.22	7.38	
								61	4732576.34	2724078.28	3284881.36	4732576.44	2724078.08	3284877.87	0.11	0.20	3.49	3.50	
1, 66, 62, 26,56,67,63,27, 57	-957.96	933.77	-593.08	-383.01	-544.12	-1214.21	3703.87	13	4732218.18	2723910.45	3285536.90	4732216.97	2723921.15	3285525.00	1.22	10.70	11.89	16.05	10.34
								31	4732710.83	2724088.86	3284681.95	4732714.37	2724085.34	3284676.81	3.54	3.51	5.14	7.16	
								61	4732576.31	2724077.95	3284881.32	4732576.44	2724078.08	3284877.87	0.13	0.13	3.45	3.45	
1, 66, 62, 26,56,67,63,27, 57,3,69	-994.27	775.81	-381.27	-438.02	-526.23	-1276.45	2146.56	13	4732217.76	2723912.52	3285535.55	4732216.97	2723921.15	3285525.00	0.79	8.62	10.55	13.65	9.72
								31	4732709.66	2724091.03	3284682.02	4732714.37	2724085.34	3284676.81	4.71	5.69	5.21	9.04	
								61	4732575.34	2724080.05	3284881.06	4732576.44	2724078.08	3284877.87	1.11	1.97	3.19	3.91	
1, 66, 62, 26,56,67,63,27, 57,3,69,64	-960.37	772.21	-374.98	-439.44	-474.91	-1267.52	2113.57	13	4732217.67	2723912.50	3285535.57	4732216.97	2723921.15	3285525.00	0.71	8.65	10.56	13.67	9.74
								31	4732709.78	2724090.99	3284682.19	4732714.37	2724085.34	3284676.81	4.59	5.65	5.38	9.05	
								61	4732575.41	2724080.01	3284881.19	4732576.44	2724078.08	3284877.87	1.03	1.93	3.32	3.98	
1, 66, 62, 26,56,67,63,27, 57,3,69,64,28	-976.88	847.17	-449.14	-437.36	-516.05	-1262.86	2734.73	13	4732218.05	2723911.81	3285535.55	4732216.97	2723921.15	3285525.00	1.09	9.33	10.55	14.12	9.56
								31	4732710.30	2724090.39	3284681.54	4732714.37	2724085.34	3284676.81	4.07	5.05	4.73	8.03	
								61	4732575.89	2724079.41	3284880.69	4732576.44	2724078.08	3284877.87	0.56	1.33	2.82	3.17	
1, 66, 62, 26,56,67,63,27, 57,3,69,64,28,5 8	-983.68	871.04	-467.69	-441.37	-529.11	-1264.01	2912.22	13	4732218.30	2723911.41	3285535.47	4732216.97	2723921.15	3285525.00	1.34	9.74	10.46	14.36	9.49
								31	4732710.59	2724090.04	3284681.28	4732714.37	2724085.34	3284676.81	3.78	4.70	4.47	7.51	
								61	4732576.16	2724079.05	3284880.47	4732576.44	2724078.08	3284877.87	0.28	0.97	2.60	2.79	
1, 66, 62, 26,56,67,63,27, 57,3,69,64,28,5 8,65,29	-990.73	978.37	-561.58	-447.20	-535.08	-1278.70	3756.28	13	4732218.83	2723910.42	3285535.54	4732216.97	2723921.15	3285525.00	1.86	10.73	10.53	15.15	9.53
								31	4732711.49	2724089.26	3284680.62	4732714.37	2724085.34	3284676.81	2.88	3.92	3.81	6.18	
								61	4732576.95	2724078.25	3284879.99	4732576.44	2724078.08	3284877.87	0.51	0.17	2.12	2.19	
1, 66, 62, 26,56,67,63,27, 57,3,69,64,28,5 8,65,29,59	-993.66	991.04	-560.46	-447.20	-541.26	-1278.38	3806.39	13	4732218.90	2723916.90	3285542.63	4732216.97	2723921.15	3285525.00	1.94	4.25	17.63	18.24	15.22
								31	4732711.56	2724095.75	3284687.66	4732714.37	2724085.34	3284676.81	2.81	10.40	10.85	15.29	
								61	4732577.03	2724084.73	3284887.04	4732576.44	2724078.08	3284877.87	0.58	6.66	9.17	11.35	
1, 66, 62, 26,56,67,63,27, 57,3,69,64,28,5 8,65,29,59,60	-971.62	975.66	-546.66	-458.71	-525.96	-1254.47	3688.58	13	4732218.61	2723910.41	3285535.45	4732216.97	2723921.15	3285525.00	1.65	10.74	10.45	15.07	9.50
								31	4732711.30	2724089.23	3284680.62	4732714.37	2724085.34	3284676.81	3.08	3.88	3.82	6.25	
								61	4732576.76	2724078.22	3284879.97	4732576.44	2724078.08	3284877.87	0.32	0.14	2.10	2.13	

Table 6
Molodensky seven parameters for cadastral map (6) of scale 1:5000

GCPs #	xo (m)	yo (m)	zo (m)	wx (sec)	wy (sec)	wz (sec)	k (ppm)	Point #	Check points coordinates after transformation from map: Xt (m)	Yt (m)	Zt (m)	actual coordinates for check points from GPS: X (m)	Y (m)	Z (m)	dX (m)	dY (m)	dZ (m)	P (m)	RMS (m)
22,35,75	180.97	828.28	-1807.16	745.09	281.52	-165.75	7874.53	39	4733780.5	2721952.2	3284886.6	4733782.0	2721953.6	3284881.2	1.50	1.44	5.42	5.81	4.85
								41	4733852.9	2721753.5	3284943.6	4733852.0	2721757.2	3284938.9	0.88	3.66	4.67	6.00	
								76	4733125.4	2722323.9	3285513.2	4733125.2	2722324.9	3285513.1	0.16	0.98	0.13	1.00	
22,35,75,70	165.59	839.06	-1774.89	707.15	266.54	-176.77	7789.41	39	4733780.7	2721952.1	3284886.1	4733782.0	2721953.6	3284881.2	1.27	1.57	4.96	5.36	4.71
								41	4733852.9	2721753.5	3284943.6	4733852.0	2721757.2	3284938.9	0.88	3.66	4.67	6.00	
								76	4733125.7	2722323.6	3285512.8	4733125.2	2722324.9	3285513.1	0.47	1.29	0.27	1.40	
22,35,75,70 ,36,77,71,2 4	165.99	616.69	-1584.67	721.14	296.54	-189.49	6070.71	39	4733780.7	2721952.4	3284885.9	4733782.0	2721953.6	3284881.2	1.25	1.23	4.76	5.07	4.55
								41	4733852.8	2721754.2	3284943.3	4733852.0	2721757.2	3284938.9	0.79	2.98	4.39	5.36	
								76	4733126.7	2722323.3	3285511.5	4733125.2	2722324.9	3285513.1	1.50	1.58	1.67	2.74	
22,35,75,70 ,36,77,71,2 4,37,78,72	186.10	679.48	-1596.82	677.80	251.97	-118.56	6395.63	39	4733780.7	2721951.9	3284885.8	4733782.0	2721953.6	3284881.2	1.25	1.69	4.62	5.08	4.63
								41	4733852.8	2721753.7	3284943.1	4733852.0	2721757.2	3284938.9	0.76	3.54	4.21	5.55	
								76	4733126.8	2722323.1	3285511.7	4733125.2	2722324.9	3285513.1	1.55	1.83	1.38	2.77	
22,35,75,70 ,36,77,71,2 4,37,78,72, 38,73	188.19	728.75	-1650.32	683.29	225.20	-94.63	6821.77	39	4733781.0	2721951.5	3284885.4	4733782.0	2721953.6	3284881.2	0.97	2.12	4.28	4.87	4.66
								41	4733853.1	2721753.1	3284942.8	4733852.0	2721757.2	3284938.9	1.05	4.05	3.90	5.72	
								76	4733126.9	2722322.9	3285511.7	4733125.2	2722324.9	3285513.1	1.67	2.01	1.38	2.96	
22,35,75,70 ,36,77,71,2 4,37,78,72, 38,73,40	166.83	737.05	-1590.08	622.93	203.71	-107.99	6612.87	39	4733781.0	2721951.8	3284885.1	4733782.0	2721953.6	3284881.2	1.03	1.84	3.96	4.49	4.38
								41	4733853.0	2721753.4	3284942.4	4733852.0	2721757.2	3284938.9	0.99	3.75	3.50	5.22	
								76	4733127.0	2722322.9	3285511.5	4733125.2	2722324.9	3285513.1	1.79	2.03	1.65	3.17	
22,35,75,70 ,36,77,71,2 4,37,78,72, 38,73,40,74	161.30	726.56	-1581.07	623.70	205.01	-117.56	6529.29	39	4733781.0	2721952.0	3284884.9	4733782.0	2721953.6	3284881.2	1.00	1.67	3.77	4.25	4.22
								41	4733853.1	2721753.6	3284942.2	4733852.0	2721757.2	3284938.9	1.03	3.56	3.31	4.96	
								76	4733127.1	2722323.0	3285511.2	4733125.2	2722324.9	3285513.1	1.86	1.92	1.90	3.28	

Table 7
Molodensky seven parameters for cadastral map (6, 5, 6) of scale 1:5000

1	2							3	4			5			6	7	8	9	10
GCPs #	xo	yo	zo	wx	wy	wz	k	Point #	Check points coordinates after transformation from map			actual coordinates for check points from GPS			dX	dY	dZ	P	RMS
	m	m	m	sec	sec	sec	ppm		Xt (m)	Yt (m)	Zt (m)	X (m)	Y (m)	Z (m)	m	m	m	m	m
79,1,22,87, 66,35,62	-2047.610334	1881.654166	-160.9406548	-1560.174622	-1479.982515	-2173.939062	5668.358559	84	4730694.92	2724319.05	3287352.05	4730678.05	2724334.95	3287361.52	16.88	15.89	9.47	25.04	26.65
								86	4730572.43	2724416.80	3287441.90	4730558.76	2724428.21	3287451.09	13.67	11.42	9.18	20.04	
								91	4729609.91	2725128.49	3288236.03	4729605.29	2725142.98	3288233.50	4.62	14.49	2.53	15.42	
								13	4732223.16	2723921.55	3285515.89	4732216.97	2723921.15	3285525.00	6.19	0.40	9.11	11.02	
								31	4732712.08	2724107.51	3284658.01	4732714.37	2724085.34	3284676.81	2.29	22.16	18.80	29.15	
								61	4732578.25	2724094.81	3284858.33	4732576.44	2724078.08	3284877.87	1.80	16.73	19.54	25.79	
								39	4733779.82	2721941.08	3284909.52	4733782.00	2721953.63	3284881.15	2.18	12.54	28.37	31.10	
								41	4733854.25	2721743.05	3284964.09	4733852.03	2721757.19	3284938.92	2.23	14.14	25.17	28.95	
								76	4733127.90	2722298.64	3285544.52	4733125.22	2722324.90	3285513.12	2.68	26.26	31.40	41.02	
79,1,22,87, 66,35,62,93, 26,75	-2034.43961	1674.124279	34.05147417	-1563.3721	-1457.416143	-2160.812412	3985.687263	84	4730697.29	2724319.11	3287348.30	4730678.05	2724334.95	3287361.52	19.24	15.83	13.22	28.21	26.86
								86	4730575.00	2724416.70	3287437.99	4730558.76	2724428.21	3287451.09	16.23	11.51	13.09	23.82	
								91	4729614.04	2725127.26	3288230.70	4729605.29	2725142.98	3288233.50	8.75	15.73	2.80	18.22	
								13	4732223.14	2723922.21	3285515.38	4732216.97	2723921.15	3285525.00	6.17	1.06	9.63	11.48	
								31	4732711.34	2724107.83	3284658.99	4732714.37	2724085.34	3284676.81	3.03	22.49	17.82	28.85	
								61	4732577.71	2724095.16	3284858.95	4732576.44	2724078.08	3284877.87	1.27	17.08	18.92	25.52	
								39	4733777.12	2721944.97	3284910.16	4733782.00	2721953.63	3284881.15	4.87	8.66	29.01	30.66	
								41	4733851.42	2721747.26	3284964.64	4733852.03	2721757.19	3284938.92	0.61	9.94	25.72	27.58	
								76	4733126.25	2722301.95	3285544.03	4733125.22	2722324.90	3285513.12	1.03	22.95	30.91	38.51	
79,1,22,87, 66,35,62,93, 26,75,70,88, 56,81,67,36	-2077.073492	1743.85029	9.937081841	-1599.803938	-1517.521085	-2176.570688	4368.683828	84	4730696.17	2724319.86	3287349.29	4730678.05	2724334.95	3287361.52	18.12	15.09	12.23	26.56	26.26
								86	4730573.85	2724417.46	3287439.07	4730558.76	2724428.21	3287451.09	15.09	10.75	12.02	22.08	
								91	4729612.70	2725128.08	3288232.48	4729605.29	2725142.98	3288233.50	7.41	14.91	1.02	16.68	
								13	4732222.10	2723923.24	3285515.14	4732216.97	2723921.15	3285525.00	5.14	2.09	9.86	11.31	
								31	4732710.23	2724109.13	3284658.32	4732714.37	2724085.34	3284676.81	4.14	23.78	18.49	30.41	
								61	4732576.61	2724096.40	3284858.39	4732576.44	2724078.08	3284877.87	0.17	18.33	19.48	26.74	
								39	4733776.67	2721945.46	3284908.89	4733782.00	2721953.63	3284881.15	5.33	8.16	27.74	29.40	
								41	4733851.02	2721747.68	3284963.34	4733852.03	2721757.19	3284938.92	1.01	9.52	24.42	26.22	
								76	4733125.70	2722302.43	3285543.26	4733125.22	2722324.90	3285513.12	0.48	22.47	30.14	37.60	
79,1,22,87, 66,35,62,93, 26,75,70,88, 56,81,67,36, 95,63,77,82, 27	-2046.331654	1619.385791	76.05454992	-1553.172711	-1440.685302	-2191.354648	3587.092554	84	4730696.51	2724318.48	3287349.35	4730678.05	2724334.95	3287361.52	18.46	16.46	12.17	27.57	27.09
								86	4730574.25	2724416.02	3287438.99	4730558.76	2724428.21	3287451.09	15.49	12.19	12.10	23.13	
								91	4729613.51	2725126.19	3288231.27	4729605.29	2725142.98	3288233.50	8.22	16.79	2.24	18.83	
								13	4732221.97	2723921.88	3285517.30	4732216.97	2723921.15	3285525.00	5.00	0.73	7.71	9.22	
								31	4732710.02	2724107.46	3284661.28	4732714.37	2724085.34	3284676.81	4.35	22.12	15.53	27.37	
								61	4732576.43	2724094.78	3284861.16	4732576.44	2724078.08	3284877.87	0.01	16.70	16.71	23.63	
								39	4733775.68	2721945.62	3284912.54	4733782.00	2721953.63	3284881.15	6.32	8.01	31.39	33.01	
								41	4733849.97	2721748.00	3284967.02	4733852.03	2721757.19	3284938.92	2.06	9.19	28.09	29.63	
								76	4733124.96	2722302.40	3285546.09	4733125.22	2722324.90	3285513.12	0.26	22.50	32.97	39.92	

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