Correction of Very High-Resolution Satellite Images using Control Points Captured by Web Map Service (WMS) server: Google Earth

Ashraf M. A. Shrawai, Ateaya B. Azeez

Abstract: The recent progress for spatial resolution of remote sensing imagery led to generate many types of Very High-Resolution (VHR) satellite images, consequently, general speaking, it is possible to prepare accurate base map larger than 1:10,000 scale. One of these VHR satellite image is WorldView-3 sensor that launched in August 2014. The resolution of 0.31m makes WorldView-3 the highest resolution commercial satellite in the world. In the current research, a pan-sharpen image from that type, covering an area at Giza Governorate in Egypt, used to determine the suitable large-scale map that could be produced from that image. To reach this objective, two different sources for acquiring Ground Control Points (GCPs). Firstly, very accurate field measurements using GPS and secondly, Web Map Service (WMS) server (in the current research is Google Earth) which is considered a good alternative when GCPs are not available, are used. Accordingly, three scenarios are tested, using the same set of both 16 Ground Control Points (GCPs) as well as 14 Check Points (CHKs), used for evaluation the accuracy of geometric correction of that type of images. First approach using both GCPs and CHKs coordinates acquired by GPS. Second approach using GCPs coordinates acquired by Google Earth and CHKs acquired by GPS. Third approach using GCPs and CHKs coordinates by Google Earth. Results showed that, first approach gives Root Mean Square Error (RMSE) planimeteric discrepancy for GCPs of 0.45m and RMSE planimeteric discrepancy for CHKs of 0.69m. Second approach gives RMSE for GCPs of 1.10m and RMSE for CHKs of 1.75m. Third approach gives RMSE for GCPs of 1.10m and RMSE for CHKs of 1.40m. Taking map accuracy specification of 0.5mm of map scale, the worst values for CHKs points (1.75m&1,4m) resulted from using Google Earth as a source, gives the possibility of producing 1:5000 large-scale map compared with the best value of (0.69m) (map scale 1:2500). This means, for the given parameters of the current research, large scale maps could be produced using Google Earth, in case of GCPs are not available accurately from the field surveying, which is very useful for many users.

Keywords: WorldView-3, Very high-resolution satellite images, Geometric correction, GPS, Web Map Service (WMS) server, Google Earth.

I. INTRODUCTION

Any national development, either on the local and/or regional levels,

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depends mainly on the geometrical relationships between all existing natural features as well as artificial features on the actual surface of the Earth, within the area of interest. The simplest way of presenting such relations, with appropriate dimensions and reasonable scale, is a map sheet. Until now, representation of Earth's surface Spatial features, in the form of a map is the preferable system available to list and view the configuration and allocation of that features. Subsequently, production of different types of thematic maps demanded due to its multiple usage. Large-scale base maps considered as pre-requisite for production of such thematic maps [15]. Large-scale maps usually produced by three possible techniques: field survey, aerial survey and remote sensing images. The technology selection depends upon many factors, such as terrain conditions, accuracy standard, dimension of area and cost [13]. Nowadays, there is useful information, provided by remote sensing satellites, in the form of single and overlapped images, which could be used for the underlined purpose of large-scale mapping [12]. Large-scale mapping shows extra details than small-scale one, so a Very High Resolution (VHR) satellite imagery is required for large-scale mapping [4]-[16]. Generally, satellite images can be classified, from standard pixel size point of view, as [9]:

- <3m as "Very High-Resolution" (VHR);
- 3-8m as "High-Resolution" (HR);
- 10-20m as "Medium-Resolution" (MR); and
- >20m as "Low-Resolution" (LR).

As a matter of fact, Very High-Resolution (VHR) images <1m spatial resolution is considered an alternative for airborne photographs [8]-[14]. In this context, WorldView-3 satellite image, as a "Very High-Resolution" (VHR) satellite image, used in the current research [1]-[6].

Although Ground Control Points (GCPs) are not necessary for processing, they improve the absolute accuracy of any image. Web Map Service (WMS) servers are a good alternative when GCPs are not available. These map servers provide online georeferenced maps using a standard protocol called Web Map Service. Two well-known WMS servers are Google Maps and Bing Maps. They cover the globe but the accuracy of the geo-referencing might be low.

Therefore, it is not recommended to use them for projects that require high accuracy. Moreover, the accuracy of the data changes for different locations [11]. In the current research, within the different cases studied, Google Earth based on WMS server is used for capturing GCPs and CHKs for correction of satellite image.

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In this context, satellite images include geometric distortions that are inevitable characteristics during data recording process as well as Earth's shape and rotation. Consequently, any image that not corrected will afford unlike geometry to that of a map. Geometric correction is the process of correcting these distortions and assigning the properties of a map to an image.

Generally, two approaches can be utilized for correcting geometric distortion. First approach is to model the nature and quantity of the distortion sources, and then the output model used to setup correction formulas. Second approach based on establishment of mathematical relationships between coordinates of pixels in an image and the corresponding coordinates of those points on the ground [5]. The second approach will be used in the current research.

The best-adopted measure of precision, in case of one-dimensional position, is the variance or its squared root as standard deviation. Further, in case of two-dimensional positions, the 2-D variance covariance matrix (standard error ellipse, then precision region of different probabilities around any point determined) will be the best statistical representation [10].

For other positioning techniques, e.g. when working in terms of northing and easting (E, N) projected coordinates, like the case in the present research, variance-covariance matrix, will not be available. In this case, the assessment parameter evaluated from the corresponding Root Mean Square Error (RMSE) of discrepancies between the 2-D positions, as resulting from corrected satellite image desired for estimation to produce large-scale map, and any available reference method that is more functional [2].

On the other hand, concerning the map accuracy specifications, several international committees have proposed standards for maps. For instance, these proposed standards stated that, the horizontal accuracy is represented in terms of the root mean square error RMSE(dE) and RMSE(dN) in either E or N coordinates of the point, to be within many figures, such that: 0.25mm; 0.30mm or 0.50mm at the map scale. However, according to planimetric coordinate allowable accuracy for different map scales and in order to be conformable with different mapping organizations using satellite images in Egypt, the National Map Standards Accuracy (NMAS), of 0.50mm * map scale, will be adopted in the present research. For example, for large-scale maps scale 1:5000, allowable planimetric RMSE in easting and northing is 2.50m [3]. The main motivation behind the current research is to evaluate and assess a simple as well as low cost geo-referencing (capturing GCPs points and CHKs points) method for "Very High-Resolution" (VHR) satellite image, to produce large-scale maps, especially in case of difficulty of capturing these points on the field.

II.   TEST SITE AND DATA DESCRIPTION

Pan-sharpened World View-3 ortho product "Very High-Resolution" (VHR) satellite image, acquired on September 2018, used for the current research. Some features of the image are:
- Area covered: El-Ayyat city, south of the Giza Governorate, Egypt;

- Location: φ: 29° 36' 50'' and 29° 38' 00'' N, λ: 31° 15' 2'' and 31° 16' 12'' N, shown in Fig. 1;
- Datum: UTM – WGS-84;
- Pixel Size: 0.5m P and 2.0m MS;
- No. of Bands: Bundle MS (4) – P (1).

III.   STUDY CASES

Through current research, three study cases were carried out for correcting the satellite image under investigation and evaluate the accuracy of mapping based on the resulted geo-referenced image.

First study case, using a set of 16 Ground Control Points (GCPs) to correct the image (Fig. 2), and using a set of 14 Check Points (CHKs) to evaluate the accuracy (Fig. 3). Coordinates of both (GCPs) as well as (CHKs) were captured by field GPS campaign.
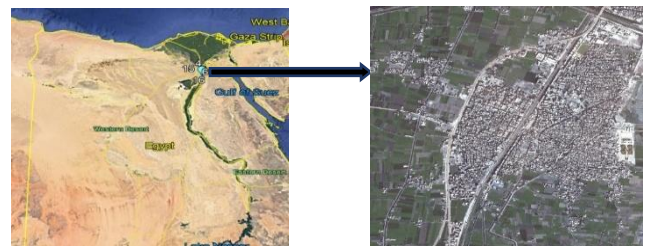

Fig. 1. WorldView-3 Satellite Image of Test Area

Fig. 2. Distribution of 16 Ground Control Points (GCPs)

Fig. 3. Distribution of 14 Check Points (CHKs)

Second study case, using the same set (used in the first study case) of 16 Ground Control Points (GCPs) to correct the image, and using the same set (used in the first study case) of 14 Check Points (CHKs) to evaluate the accuracy. Coordinates of (GCPs) were captured using Web Map Service (WMS) server (Google Earth), while coordinates of (CHKs) were captured by field GPS campaign.

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Third study case, using the same set (used in the first & second study cases) of 16 Ground Control Points (GCPs) to correct the image, and using the same set (used in the first & second study cases) of 14 Check Points (CHKs) to evaluate the accuracy. Coordinates of both (GCPs) as well as (CHKs) were captured using Web Map Service (WMS) server (Google Earth).

IV. METHODOLOGY

A. Preprocessing

- acquisition of data: satellite image (Pan-sharpened World View-3 ortho product as "Very High-Resolution" (VHR) satellite image);
- identification and ID cards of very defined sharp (GCPs) & (CHKs) appeared on all sources used in the current research (e.g. ground, satellite image and Google Earth);
- execution of field GPS campaign (coordinates of both (GCPs=16 points) & (CHKs=14 points) with total of 30 points (Global Datum: WGS-84/UTM);
- transform GPS coordinates (Global Datum: WGS-84/UTM) to the local Old Egyptian Datum (Helmert 1907/ETM);
- capturing coordinates of (GCPs) & (CHKs) with total of 30 points from Google Earth (Global Datum: WGS-84/UTM);
- transform Google Earth coordinates (Global Datum: WGS-84/UTM) to the local Old Egyptian Datum (Helmert 1907/ETM).

B. Modelling Process

As mentioned before, three scenarios are tested, using the same set of both 16 Ground Control Points (GCPs) as well as 14 Check Points (CHKs), used for evaluation the accuracy of geometric correction of that type of images. First approach using both GCPs and CHKs coordinates acquired by GPS. Second approach using GCPs coordinates acquired by Google Earth and CHKs acquired by GPS. Third approach using GCPs and CHKs coordinates by Google Earth. For all the study cases, ERDAS Imagine and ARCGIS digital image processing software packages were used for processing. Also, 1st order polynomial transformation and bilinear resampling interpolation technique used in the modelling process.

First Study Case

- correcting and geo-referencing of the satellite image using 16 points obtained by GPS (GCPs: local Old Egyptian Datum (Helmert 1907/ETM);
- calculate geometric residuals, from corrected image, for the 16 points coordinates obtained by GPS (GCPs);
- calculate planimetric discrepancies error (RMSE), from corrected image, using 14 points coordinates obtained by GPS (CHKs: local Old Egyptian Datum (Helmert 1907/ETM));
- evaluate (for the First Study Case) the accuracy for large-scale mapping.

Second Study Case

- correcting and geo-referencing of the satellite image using 16 points obtained by Google Earth (GCPs: local Old Egyptian Datum (Helmert 1907/ETM));

- calculate geometric residuals, from corrected image, for the 16 points coordinates obtained by GPS (GCPs);
- calculate planimetric discrepancies error (RMSE), from corrected image, using 14 points coordinates obtained by GPS (CHKs: local Old Egyptian Datum (Helmert 1907/ETM));
- evaluate (for the Second Study Case) the accuracy for large-scale mapping.

Third Study Case

- correcting and geo-referencing of the satellite image using 16 points obtained by Google Earth (GCPs: Global Datum: WGS-84/UTM);
- calculate geometric residuals, from corrected image, for the 16 points coordinates obtained by Google Earth (GCPs);
- calculate planimetric discrepancies error (RMSE), from corrected image, using 14 points coordinates obtained by Google Earth (CHKs: Global Datum: WGS-84/UTM);
- evaluate (for the Third Study Case) the accuracy for large-scale mapping.

C. Standards for Accuracy Evaluation

In each step (data observations and data processing), some errors may take place, which generally varying in quantity and source. Actually, geometric accuracy of large-scale mapping produced from remotely sensed data has the same importance as the information given in the maps [7].

In this context, in the current research, two measures of geometric accuracy, will be used. First measure of accuracy will be, the residuals at the control points, during as well as after performing the geometric correction. In the current research, the magnitude of this residuals will be taken within one pixel (spatial resolution= 0.50m) in case of using GCPs by GPS, as an accurate reference source, and two pixels (1.00m) in case of using GCPs by Google Earth, as an un-accurate reference source.

The second measure of accuracy is the planimetric discrepancies between the adjusted E, N ground coordinates (from corrected image for each study case), for check points (CHKs), and the corresponding original values (from the nominated reference source). These discrepancies and their RMSE in planimetry, will be a measure of the accuracy of positioning in planimetry, taking into consideration National Map Standards Accuracy (NMAS), of 0.50mm * map scale, according the well-known statistical parameters as following:

$$RMSE_E = \sqrt{\sum(E_{Ground} - E_{Photo})^2 /n} = \sqrt{\sum(\Delta_E)^2 /n}$$
$$RMSE_N = \sqrt{\sum(\Delta_N)^2 /n}$$
$$RMSE_P \text{ (planimetric positioning)} = \sqrt{(RMS_E)^2 + (RMS_N)^2}.$$

V. RESULTS

For the first case, based on 16 GPS points coordinates (GCPs) and 14 GPS points coordinates (CHKs), Tables-I & II list the results, for the corrected image, namely: residuals for the 16 common control points & discrepancies for 14 check points, as well as their RMSE, respectively. For the second case, based on 16 Google Earth points coordinates (GCPs) and 14 GPS points coordinates (CHKs), Tables-III & IV list the results, for the corrected image,

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namely: residuals for the 16 common control points & discrepancies for 14 check points, as well as their RMSE, respectively. For the third case, based on 16 Google Earth points coordinates (GCPs) and 14 Google Earth points coordinates (CHKs), Tables-V & VI list the results, for the corrected image, namely: residuals for the 16 common control points & discrepancies for 14 check points, as well as their RMSE, respectively.

Table-I Residuals (meters) of the Ground Coordinates for the 16 Common Control Points (GCPs) & their RMSE Statistical Parameters (First Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE (m)
1	2	Control	-0.005	-0.219	0.219
2	5	Control	-0.463	0.607	0.763
3	8	Control	-0.292	-0.397	0.493
4	12	Control	0.527	0.445	0.689
5	15	Control	-0.168	0.005	0.168
6	19	Control	0.498	-0.124	0.513
7	20	Control	-0.299	0.525	0.604
8	26	Control	0.063	-0.397	0.402
9	28	Control	0.449	-0.02	0.45
10	33	Control	0.01	-0.179	0.179
11	34	Control	-0.245	-0.131	0.278
12	37	Control	0.318	0.069	0.325
13	40	Control	-0.642	-0.034	0.643
14	41	Control	0.095	0.056	0.11
15	42	Control	-0.23	-0.18	0.292
16	43	Control	0.385	-0.025	0.386
		RMSE	0.3476	0.2863	**0.4503**

Table-II Discrepancies (meters) of the Ground Coordinates for 14 Check Points (CHKs) & their RMSE Statistical Parameters (First Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE(m)
1	6	Check	-0.32	0.047	0.324
2	9	Check	-0.024	-0.496	0.497
3	18	Check	1.209	-0.929	1.525
4	21	Check	0.156	0.19	0.246
5	23	Check	-0.044	0.307	0.31
6	24	Check	0.754	0.444	0.875
7	25	Check	0.321	0.522	0.612
8	29	Check	0.694	-0.117	0.704
9	30	Check	0.489	0.227	0.539
10	31	Check	-0.282	-0.385	0.477
11	32	Check	-0.634	0.489	0.8
12	38	Check	-0.133	0.313	0.34
13	39	Check	-0.794	-0.156	0.809
14	44	Check	-0.262	0.397	0.476
		RMSE	0.5464	0.4179	**0.6879**

Table-III Residuals (meters) of the Ground Coordinates for the 16 Common Control Points (GCPs) & their RMSE Statistical Parameters (Second Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE (m)
1	2	Control	-0.005	-0.219	0.219
2	5	Control	-0.463	0.607	0.763
3	8	Control	-0.292	-0.397	0.493
4	12	Control	0.527	0.445	0.689
5	15	Control	-0.168	0.005	0.168
6	19	Control	0.498	-0.124	0.513
7	20	Control	-0.299	0.525	0.604
8	26	Control	0.063	-0.397	0.402
9	28	Control	0.449	-0.02	0.45

10	33	Control	0.01	-0.179	0.179
11	34	Control	-0.245	-0.131	0.278
12	37	Control	0.318	0.069	0.325
13	40	Control	-0.642	-0.034	0.643
14	41	Control	0.095	0.056	0.11
15	42	Control	-0.23	-0.18	0.292
16	43	Control	0.385	-0.025	0.386
		RMSE	0.8438	0.7003	**1.0966**

Table-IV Discrepancies (meters) of the Ground Coordinates for 14 Check Points (CHKs) & their RMSE Statistical Parameters (Second Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE (m)
1	6	Check	-0.32	0.047	0.324
2	9	Check	-0.024	-0.496	0.497
3	18	Check	1.209	-0.929	1.525
4	21	Check	0.156	0.19	0.246
5	23	Check	-0.044	0.307	0.31
6	24	Check	0.754	0.444	0.875
7	25	Check	0.321	0.522	0.612
8	29	Check	0.694	-0.117	0.704
9	30	Check	0.489	0.227	0.539
10	31	Check	-0.282	-0.385	0.477
11	32	Check	-0.634	0.489	0.8
12	38	Check	-0.133	0.313	0.34
13	39	Check	-0.794	-0.156	0.809
14	44	Check	-0.262	0.397	0.476
		RMSE	1.0707	1.3838	**1.7497**

Table-V Residuals (meters) of the Ground Coordinates for the 16 Common Control Points (GCPs) & their RMSE Statistical Parameters (Third Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE (m)
1	2	Control	0.956	-0.091	0.96
2	5	Control	0.965	0.908	1.325
3	8	Control	-0.871	-0.41	0.962
4	12	Control	0.533	-0.083	0.539
5	15	Control	0.4	1.773	1.818
6	19	Control	-0.374	-0.281	0.468
7	20	Control	-1.391	-0.847	1.628
8	26	Control	-1.544	-0.522	1.63
9	28	Control	0.488	0.673	0.831
10	33	Control	0.299	-0.182	0.349
11	34	Control	-1.089	-0.8	1.351
12	37	Control	-0.114	0.333	0.352
13	40	Control	-0.399	0.442	0.595
14	41	Control	1.223	-0.495	1.319
15	42	Control	0.086	0.454	0.462
16	43	Control	0.833	-0.872	1.206
		RMSE	0.8436	0.7011	**1.0969**

Table-VI discrepancies (meters) of the Ground Coordinates for 14 Check Points (CHKs) & their RMSE Statistical Parameters (Third Study Case)

No.	Point ID	Type	X-res	Y-res	RMSE(m)
1	6	Check	1.377	0.77	1.578
2	9	Check	-1.006	-0.214	1.029
3	18	Check	1.086	0.996	1.473
4	21	Check	-1.4	-0.438	1.467
5	23	Check	-0.731	-0.164	0.749
6	24	Check	0.344	-0.416	0.54
7	25	Check	-1.186	-0.319	1.228
8	29	Check	1.04	1.034	1.467

9	30	Check	0.846	1.017	1.323
10	31	Check	-0.466	-0.575	0.74
11	32	Check	-0.511	0.098	0.521
12	38	Check	-0.386	0.499	0.631
13	39	Check	-0.722	1.192	1.394
14	44	Check	-0.781	-0.505	0.93
		RMSE	0.9128	0.6811	**1.389**

Table-VII Final Summary for all Study Cases

Items	Results		
Approach **(Study Cases)**	**(1)** **GCPs & CHKs** **using GPS**	**(2)** **GCPs using GPS** **&** **CHKs using Google Earth**	**(3)** **GCPs & CHKs** **using Google Earth**
Area km^2	2 x 2 = 4		
No. of GCPs	16		
No. of Check Points	14		
RMSE$_{(P)}$ **(Planimetric Positioning) m**	0.70m (Large) 1:1,400* 2,500**	1.70m (Large) 1:3,400* 5,000**	1.40m (Large) 1: 2,800* 5,000**

* Theoretical Scale.
** Practical Scale.

Consequently, taking into consideration Standards for Accuracy Evaluation mentioned in section C, and applying "First measure of accuracy", which is the residuals at the control points, during as well as after performing the geometric correction. From Table-I above for the first study case (both GCPs and CHKs obtained by GPS), RMSE for residuals of the Ground Coordinates for the 16 Common Control Points (GCPs) obtained by GPS is 0.450m, which agree with the first measure of accuracy taken within 1 pixel (spatial resolution= 0.50m). Also, from the tables-III & V above for the second (GCPs obtained by GPS and CHKs obtained by Google Earth) & third (both GCPs and CHKs obtained by Google Earth) study cases, RMSE for residuals of the Ground Coordinates for the 16 Common Control Points (GCPs) obtained by Google Earth is 1.096m, which agree with the first measure of accuracy taken within 2 pixels (spatial resolution = 1.0m). On the other hand, applying "Second measure of accuracy", which is planimetric discrepancies between the adjusted E, N ground coordinates (from corrected image for each study case), RMSE in planimetry for check points (CHKs), and the corresponding original values (from the nominated reference source). These discrepancies and their RMSE in planimetry, will be a measure of the accuracy of positioning in planimetry, based on National Map Standards Accuracy (NMAS), of 0.50mm * map scale. From Table-II for the first study case (both GCPs and CHKs obtained by GPS), RMSE for discrepancies of the Ground Coordinates for the 14 Common Points (CHKs) obtained by GPS is 0.6879m ≈ 0.7m. So, resulted map scale can by calculated as:

Map Scale from RMSE$_P$:
0.7 x 1000mm = 0.5mm x Map Scale
Map Scale = (0.7 x 1000)/0.5 = 1400 (Theoretical Scale)
Map Scale 1: 2500 (Practical Scale).

From Table-IV for the second study case (GCPs obtained by GPS and CHKs obtained by Google Earth), RMSE for discrepancies of the Ground Coordinates for the 14 Common Points (CHKs) obtained by GPS is 1.7m. So, resulted map scale can by calculated as:

Map Scale from RMSE$_P$:
1.7 x 1000mm = 0.5mm x Map Scale
Map Scale = (1.7 x 1000)/0.5 = 3400 (Theoretical Scale)
Map Scale 1: 5000 (Practical Scale).

From Table-VI for the third study case (both GCPs and CHKs obtained by Google Earth), RMSE for discrepancies of the Ground Coordinates for the 14 Common Points (CHKs) obtained by Google Earth is 1.4m. So, resulted map scale can by calculated as:

Map Scale from RMSE$_P$:
1.4 x 1000mm = 0.5mm x Map Scale
Map Scale = (1.4 x 1000)/0.5 = 2800 (Theoretical Scale)
Map Scale 1: 5000 (Practical Scale).

VI. DISCUSSION AND CONCLUSION

Recall that, in developing countries such as Egypt, there are many issues affect mapping, such as: rapid development of urban areas, large areas are poorly mapped, difficulties of access to these areas for field surveying, either for mapping using full ground surveying, or for collection of ground control points required for mapping using aerial and space photogrammetry. Furthermore, there is always an urgent requirement, for regular updating of information of basic topographic maps, needed for both economic reasons, as well as supporting scientific investigations. Consequently, there is a need for finding a low cost and simplified way for geometric accuracy and its assessment as well, in current research Google Earth used as a Web Map Service (WMS) server, as a good alternative when GCPs or/and CHKs points are not available or difficult to collect. Shifting to Table-VII, which summarizes the final results of the different study cases:

First study case, which represent the ideal case that availability of obtaining both GCPs & CHKs points using high accuracy field measurements by GPS. This case gives RMS for planimetric positioning 0.70m which satisfy large theoretical mapping large-scale of 1:1400 (practical mapping large-scale of 2:500).

Second study case, which represent the hypothesis case that availability of obtaining GCPs points using high accuracy field measurements by GPS,

while & CHKs are obtained using Google Earth to compare the effect of accuracy of these points against the last case. This case gives RMS for planimetric positioning 1.70m which satisfy large theoretical mapping large-scale of 1:3400 (practical mapping large-scale of 5:000).

Third and last study case, which represent the actual case, low cost and simplified way for geometric accuracy and its assessment as well, that availability of obtaining both GCPs & CHKs points using Google Earth, which will be compared with the previous case. This case gives RMS for planimetric positioning 1.40m which satisfy large theoretical mapping large-scale of 1:2800 (practical mapping large-scale of 5:000).

So, it is concluded that, geometric correction for the area under investigation, using GCPs from Google Earth, taking into consideration that this area is relatively flat (average height for the area is about 23m), can yield to produce large-scale maps, when GCPs or/and CHKs points are not available or difficult to collect.

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