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Assessing the Impact of Ground Control Point (GCP) on the Output of UAV Photogrammetry Image

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Abstract: In this modern era, in order to get an excellent mapping and high accuracy data, fundamentally by unmanned aerial vehicle. Unmanned aerial vehicle (UAV) photogrammetry has lately developed as a preferred method for obtaining high accuracy outputs with aid of Ground Control Point (GCP) required in linear mapping, such as Orthomosaic, Digital Surface Models (DSM), and Digital Terrain Models (DTM). For this, there are several fundamental issues to consider, such as what was the need for GCP in mapping while Non-GCP could also contribute data, whether UAV photogrammetry without GCP is capable or not of being applied in all types of civil engineering work, the advantages of GCP and Non-GCP output in mapping, and the importance of GCP and Non-GCP data output accuracy in Civil Engineering. The aimed of this study is to assessing the impact of Ground Control Point (GCP) output by using UAV Photogrammetry method in order to find out the accuracy effectiveness in mapping that could contribute in civil engineering field which were by comparing with Non-GCP data from the changes of shoreline, height of contour, coordinate, volume and cross section area. A DJI Phantom 4 Pro with assist RTK GNSS receiver were used to synchronous with the GPS to allocate the GCP position along 1kmx100m along Pantai Punggur, Batu Pahat. There are 14 number of GCP along the shoreline. The images were captured by the UAV in setting up the route in Pix4D Capture with the 80 percent front overlap, 60 percent side overlap and 50m of latitude in 30 minutes of fly duration in two month which is once a month. Thus, there are four orthomosaic which were two with GCP and two without GCP. From the data analyze, there were relative and absolute error. The mean RMSE for March GCP was 0.008m while May GCP was 0.006m. The Non-GCP image does not contain any RMS error as the data does not contain any prior marking in the initial processing. From the data analysis, there was a big error from an absolute error for contour

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elevation, shoreline, coordinate and orientation of the orthomosaic, And, the small error from a relative error for volume and distance point to point of the GCP. In conclusion for the accuracy work in civil engineering it reserved which was need to use the GCP while the Non-GCP can be used for something that does not require high accuracy such as obtaining a visual of a study area in general, an initial overview of a study and monitoring work.
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Keywords: Ground Control Point (GCP), Orthomosaic, Accuracy

1. INTRODUCTION

A typical image-based in all work using UAV systems necessitates image acquisition, camera calibration, and picture orientation, flight or mission planning, GCPs measurement (if not already accessible and required for geo-referencing). From this, the image from GCP collaboration could be elaborate to know the accuracy and precision of the imagery capture [1]. The accuracy is important to get a high-quality image that leads to the precise of longitude, latitude and altitude of the survey area. In the United States, [2], 80 to 90 percent of government information has a geographical component. Geographic information must be accurate in all of its components in order to be useful (i.e., spatial, temporal, topological and thematic). Images obtained by unmanned aerial vehicle (UAV) systems are extremely valuable in this context because to their great spatial and temporal resolution [3].

Moreover, in the UAV also integrated with the GPS system that could determine the coordination and position of the area parameter but how far the effectiveness of accuracy in the image quality. Ground control points (GCPs) are known coordinates on the ground. GCPs are points in an aerial mapping survey that the surveyor can precisely identify with defined coordinates, allowing for accurate mapping of large regions [4]. Thus, the use of UAV without GCP is common and normal in civil engineering field but in certain work only [5]. Based on the study [6], The 3D coordinates of these Ground Control Points (GCPs) must be determined using a suitable survey method, such as differential GPS or tachymetry. This approach necessitates the use of at least three GCPs, but many more are recommended for greater precision [7]. In general, the accuracy was important in the UAV Photogrammetry mapping in order to allocate the precision of the area coordination. The accuracy always related to the use of GCP but sometime the GCP is sufficient and restricted. The use of GCP sufficient in time and energy because it took a long time to setup the GCP at every point in work area. Thus, the UAV without GCP was use in this study to compare the effectiveness in accuracy between the UAV with GCP. If the effectiveness in UAV without GCP is relevant so the surveyor and engineer could manage their time well in all work. They do not also need to setup the GCP for their field of work.

Thus, the aim of this study is to assessing the impact of Ground Control Point (GCP) on the output of UAV Photogrammetry Image. It can exactly point out every data accuracy and precision that could compared to the non GCP use in land surveying. Then, it can reduce the displacement and improve the point of view from UAV photogrammetry. In this study, it could also clarify the effectiveness of UAV photogrammetry with GCP and without GCP in civil engineering.

2. METHODOLOGY

Focusing approach in data collecting, which has been thoroughly documented throughout several phases. For this study, the acquisition of data and data processing is a vital step. The technique and procedure for obtaining real coordinate, flight planning, and the GCP establishment are all covered.

2.1 Establish GCP

In establish the Ground Control Point, the GCP were placed across the land and at the UAV's borders study area which is along 1000m ×100m Pantai Punggur, Batu Pahat. There were 14 GCP mark positioned at the suitable study region which is shown in Figure 1.

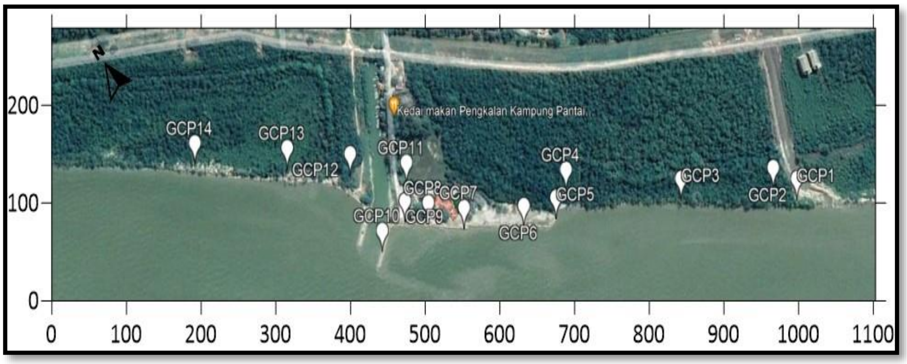

Figure 1: The location of 14 GCPs along the Pantai Punggur

2.2 Image Acquisition

In image acquisition, a DJI Phantom 4 Pro was used for imagery acquisition on all plots in the study area expansive 1000 m × 100 m from north to east along Pantai Punggur shoreline equipped with GNSS receiver, and a built-in digital camera with a sensor. The process of flying the UAV with the aid of Pix4D capture. Its plan project is represented in Pix4D Capture as one or more missions as shown in Figure 2. Its start from the bottom with the front overlap and alternately change to the side overlap on the study area. The UAV captured of acquiring images setup in 80% front overlap and 60% side overlap. The flight altitude was 50 meters, with an average speed of 0.5 meters per second for about 30-minute flying duration.

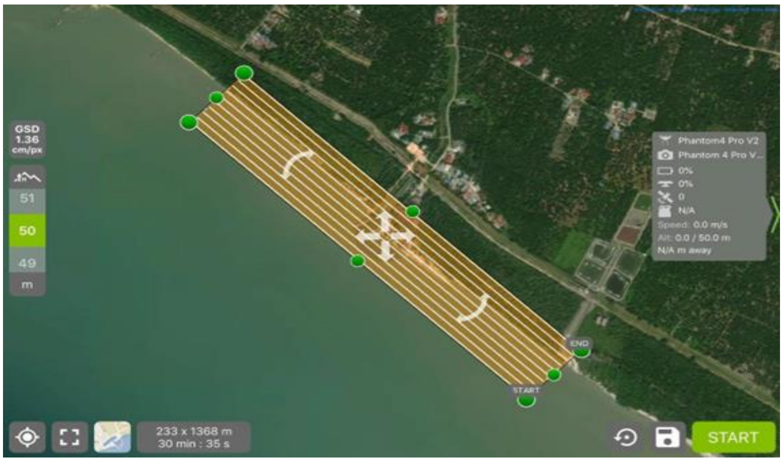

Figure 2: UAV flight route

2.3 Image Processing

In image processing, the Pix4D Mapper software (Figure 3) then used to merge and analyze all overlapping captured image to create an orthomosaic of Pantai Punggur. The outcome report, including the quality report, was detailed in PDF format. The images firstly go through the initial process to sort all of the image and calibrated using Aerial Triangulation and Bundle Block Adjustment. After that, key in the GCP coordinate at the GCP coordinate system then open the GCP/MTP manager to mark at the center of GCP mark (Figure 3). Next, proceed to the process to generate the point cloud (Figure 4). This point cloud was used to validate the whole model and confirm that the GCP location was correct. This stage is required for making orthomosaic that are exact in terms of latitude, longitude, and altitude for each image. Any noise or flaws in model can be removed by altering the point cloud. Meanwhile, for the Non-GCP data. It's basically needed to go through three process same like the process of March GCP image but no need to input the coordinate at GCP point, just direct initial process, point cloud generating.

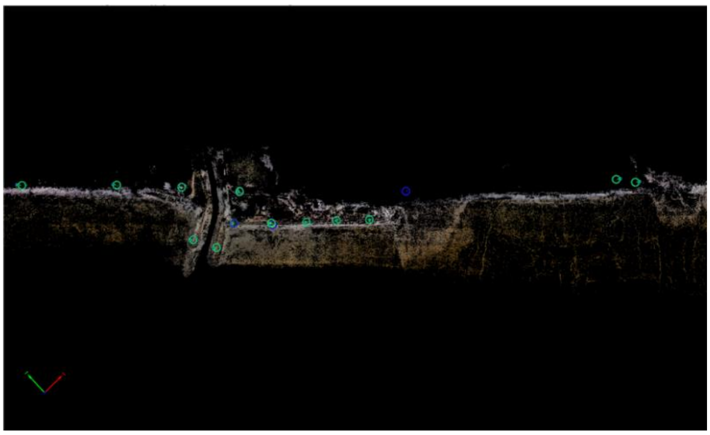

Figure 3: The 14 marked of GCP

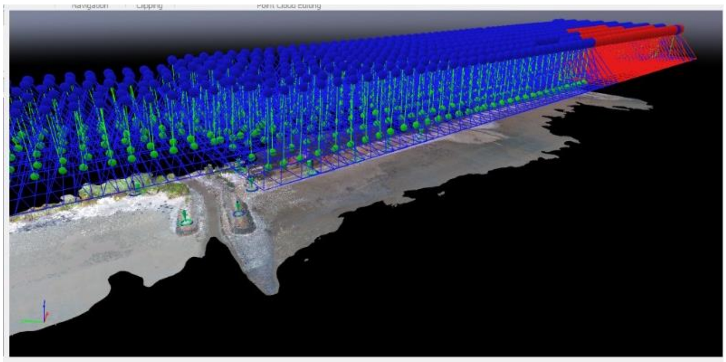

Figure 4: Point cloud densified

3. RESULTS AND DISCUSSION

Based on the data collection from the UAV, the data that had being collected in two-month period which are March and May in 2021. Then, the data was processed by using Pix4D Mapper software to create the data into the Orthomosaic (Figure 6).

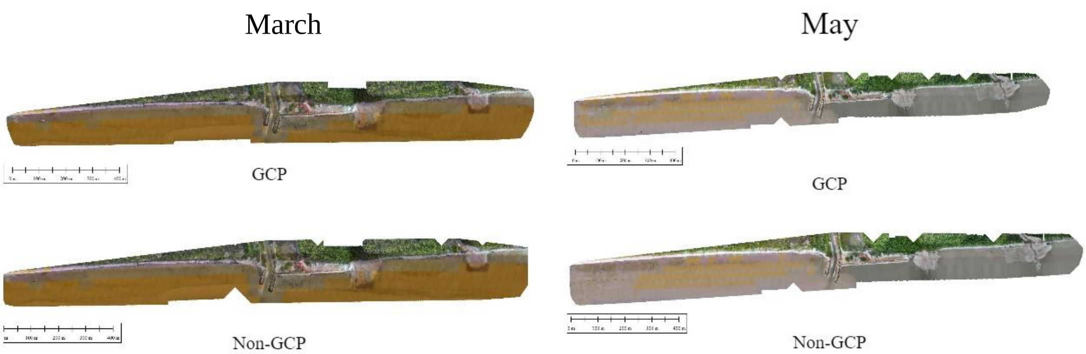

Figure 5: The Orthomosaic for March and May

3.1 Coordinate and RMSE

The coordinate was marked in all 14 GCP point as shown in figure 6 and there was a coordinate error gap in Non-GCP from the actual by overlying the orthomosaic between GCP and Non-GCP.

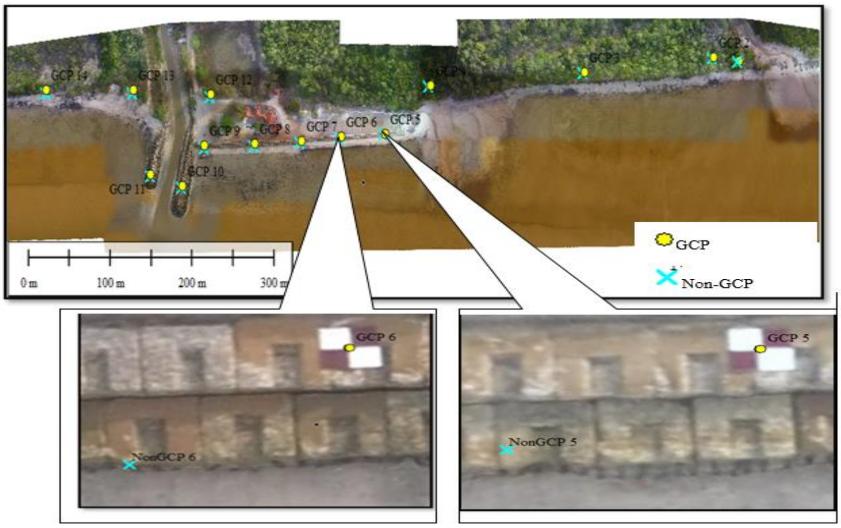

Figure 6: The 14 GCP marked point.

The data observation from quality report as in Table 1 and Table 2 shows the RMSE output, in March showed that the calculated RMSE for longitude (X-axis) is 0.004236m, latitude (Y-axis) is 0.003656m and altitude (Z-axis) is 0.009053m. The data observation in May showed that the calculated RMSE for longitude (X- axis) is 0.007882m, latitude (Y- axis) is 0.006998m and altitude (Z-axis) is 0.004801m.

Table 1: RMSE table for March 2021

GCP name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/ Marked
GCP 1	0.020/ 0.020	0.019	0.03	-0.023	0.427	5/5
GCP 2	0.020/ 0.020	-0.022	-0.031	0.028	0.546	4/4
GCP 5	0.020/ 0.020	-0.052	-0.038	0.008	0.359	5/5
GCP 6	0.020/ 0.020	0.003	0.084	0.007	0.513	5/5
GCP 7	0.020/ 0.020	0.004	-0.102	-0.031	0.469	5/5
GCP 8	0.020/ 0.020	-0.005	-0.001	-0.036	0.728	7/7
GCP 9	0.020/ 0.020	-0.07	-0.004	0.37	1.19	12/12
GCP 10	0.020/ 0.020	-0.006	-0.024	0.127	1.135	15 / 15
GCP 11	0.020/ 0.020	-0.127	0.184	-0.384	1.391	10/10
GCP 12	0.020/ 0.020	0.127	-0.175	-0.541	2.584	11/11
GCP 13	0.020/ 0.020	0.103	0.057	0.212	1.249	13 / 13
GCP 14	0.020/ 0.020	0.075	0.046	0.102	0.489	3/3
GCP 15	0.020/ 0.020	-0.007	-0.023	-0.017	0.353	4/4
GCP 4	0.020/ 0.020	0.001	-0.004	0.003	0.306	5/5
Mean [m]		0.007877	-0.00034	0.005325		
Sigma [m]		0.386285	0.129853	0.278825		
RMS Error [m]		0.004236	0.003656	0.009053		

Table 2: RMSE table for May 2021

GCP name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/ Marked
GCP 1	0.020/ 0.020	0.005	17.922	0.088	0.313	3/3
GCP 2	0.020/ 0.020	0.004	16.713	0.024	0.212	2/2
GCP 5	0.020/ 0.020	0.008	0.148	-0.045	1.872	8/8
GCP 6	0.020/ 0.020	-0.006	-0.013	0.051	0.759	7/7
GCP 7	0.020/ 0.020	0.006	-0.055	-0.021	0.997	10/10

GCP 8	0.020/ 0.020	-0.008	-2.971	0.023	1.801	3/8
GCP 9	0.020/ 0.020	0.01	-0.041	0.084	0.991	18/18
GCP 10	0.020/ 0.020	-0.009	0.048	0.017	1.236	13/13
GCP 11	0.020/ 0.020	-0.009	0.118	-0.092	0.952	14/14
GCP 12	0.020/ 0.020	0.006	-0.103	-0.085	1.345	17/17
GCP 13	0.020/ 0.020	0.006	-0.007	0.064	1.168	21/21
GCP 14	0.020/ 0.020	-0.003	0.006	-0.007	0.879	9/9
GCP 15	0.020/ 0.020	0.008	0.03	0.047	1.903	5/5
GCP 4	0.020/ 0.020	0.003	-0.103	0.01	0.994	7/7
Mean [m]		0.000408	0.006372	0.006591		
Sigma [m]		1.386961	6.252171	1.551593		
RMS Error [m]		0.007882	0.006998	0.004801		

The Non-GCP image does not contain any RMS error as the data does not contain any prior marking in the initial processing. The data does not be calibrated and use raw initial coordinate from built-in datum in the DJI Phantom drone during flight mission. The difference in GCP data is the insertion point of control point marking in initial processing. All the images were being calibrated and optimize to produce a new calibrated model of point cloud mapping. From the GCP coordinate then compare with the Non-GCP coordinate by finding different between the coordinate. Table 3 shows the coordinate error different between GCP and Non-GCP for March and May.

Table 3: Coordinate error for GCP and Non-GCP

Point	Coordinate error					
	March GCP & Non-GCP			May GCP & Non-GCP		
	Longitude[m]	Latitude[m]	Altitude[m]	Longitude[m]	Latitude[m]	Altitude[m]
GCP 1	1.836	-1.735	-27.772	-0.873	-1.326	-11.071
GCP 2	2.693	-1.703	-28.815	-1.076	-1.679	-11.123
GCP 3	2.608	-1.012	-28.421	-1.064	-1.858	-16.246
GCP 4	4.505	-4.701	-30.42	-0.593	-0.891	-17.259
GCP 5	2.49	-1.249	-30.74	-0.861	-0.299	-17.279
GCP 6	2.688	-0.498	-30.306	-0.698	0.177	-16.951
GCP 7	3.199	-0.124	-30.38	-0.604	0.398	-17.031
GCP 8	2.755	0.546	-29.256	-1.32	-2.482	-16.8
GCP 9	2.494	0.785	-29.569	-1.092	1.241	-16.735
GCP 10	2.658	0.555	-28.032	-1.314	1.15	-16.176
GCP 11	1.943	0.858	-27.473	106.36	5.298	-17.3
GCP 12	3.411	1.081	-28.789	-108.331	-2.497	-17.923
GCP 13	2.383	0.917	-29.45	-0.822	1.494	-17.979
GCP 14	3.261	1.413	-29.575	-0.287	1.815	-17.7
Total	38.924	-4.867	-408.998	-12.575	0.541	-227.573
Average	2.78	-0.347	-29.214	-0.898	0.039	-16.255

Based on the table 2, the error in coordinate for GCP and Non-GCP were not consistent, for March the longitude error 2.78, latitude error 0.35 and altitude 29.21 while, for May it lower than the March the longitude error 0.9, latitude 0.039, and altitude 16.26.

3.2 Orthomosaic Orientation

From the coordinate, the data were analyzed also in orientation in order to see the changes of the orthomosaic position that influence the coordinate error between GCP with Non-GCP as shown in Figure 7.

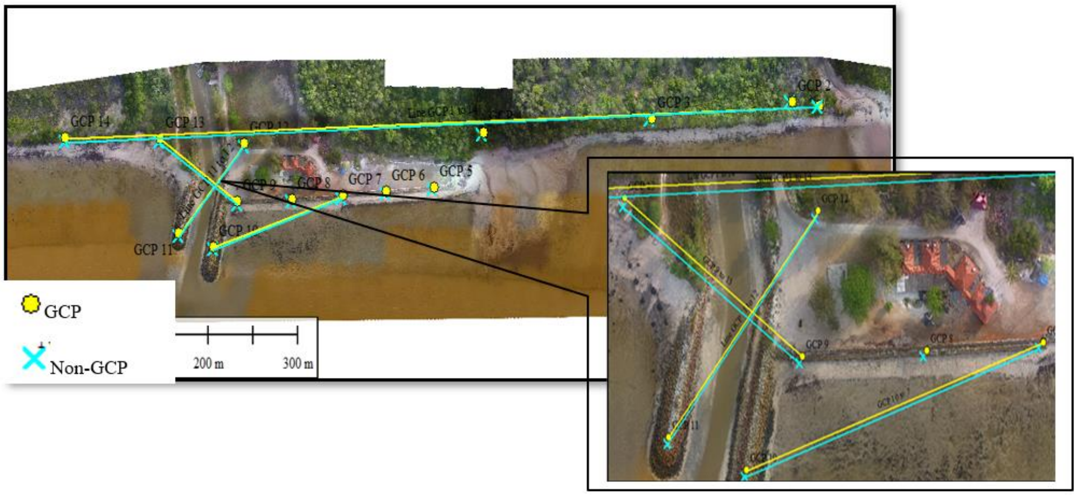

Figure 7: The orientation of Orthomosaic between GCP and Non-GCP

The GCP and Non-GCP orientation point not consistent very likely move toward between the 90-degree axis and 180-degree axis.

3.3 Distance Error

Furthermore, in order to prove the accuracy, the distance between point to point of 14 GCP had been measured for March and May included the Non-GCP orthomosaic (Figure 8) and Table 4 shows the distance error between 14 GCP.

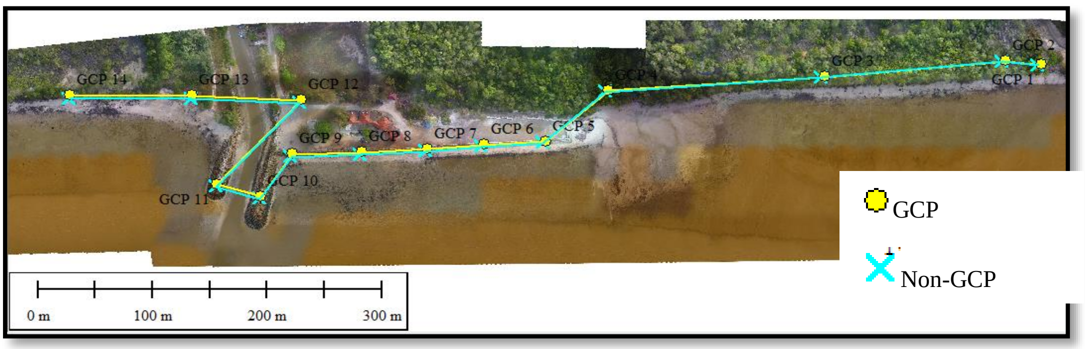

Figure 8: Distance measurement of 14 GCP

Table 4: Distance error between 14 GCP point

Point	March			May		
	Distance[m]			Distance[m]		
	GCP	NonGCP	Error	GCP	NonGCP	Error
1-2	31.350	31.386	-0.036	31.447	31.477	-0.03
2-3	158.360	158.490	-0.130	158.250	158.440	-0.19
3-4	188.870	188.950	-0.080	188.960	188.660	0.3
4-5	72.993	72.855	0.138	73.109	72.877	0.232
5-6	53.697	53.519	0.178	53.715	53.500	0.215
6-7	49.187	49.021	0.166	49.018	48.963	0.055
7-8	57.167	56.790	0.377	54.838	56.787	-1.949
8-9	61.290	60.857	0.433	63.970	60.887	3.083
9-10	47.994	47.680	0.314	47.952	47.880	0.072
10-11	40.003	39.807	0.196	39.953	39.930	0.023
11-12	107.520	106.850	0.670	107.500	107.190	0.31

12-13	95.125	94.749	0.376	95.005	94.883	0.122
13-14	106.240	105.810	0.430	106.210	106.300	-0.09
Average error			0.233			0.165615

From the table, the error was also not consistent but the gap of error between March and May not too big, for March the error 0.233m while for May the error 0.166m, so the gap for two month was 0.0067m. The length was a relative error which the GCP as an actual value and Non-GCP not an actual value, but still can be acceptable for the measurement.

3.4 Shoreline Comparison

The shoreline of the study area was semi-auto and manually generating in the Global Mapper software by setting out the elevation of the area for GCP and NonGCP output image for March and May month. From the data, there was a different of gap between the shoreline with GCP and NonGCP for those two months that divided into left, right and middle of study area (Figure 9).

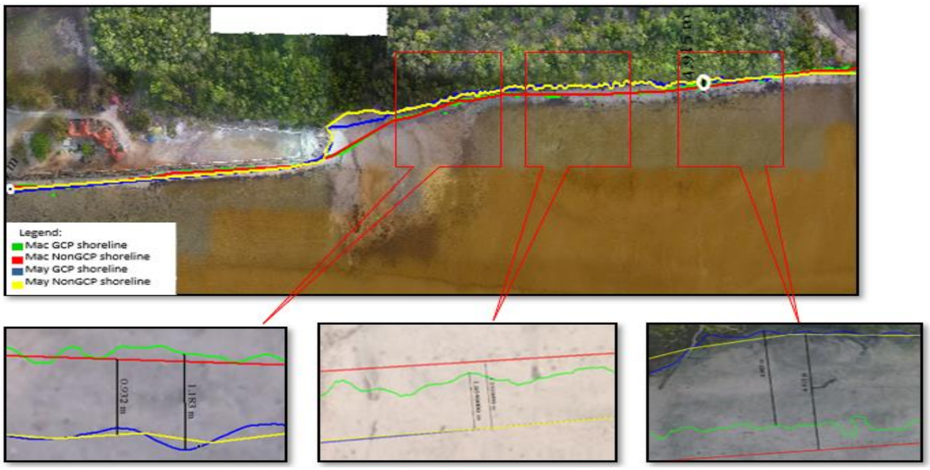

Figure 9: Shoreline comparison of GCP and Non-GCP

The error different at the middle of shoreline with GCP for March and May data is about 1.054m, while the shoreline without GCP for March and May data is about 1.252m. The error different between shoreline with GCP and without GCP for March and May month are 0.198m. At the right side of the shoreline with GCP for March and May data is about 4.005m, while the shoreline without GCP for March and May data is about 4.915m. The error different between shoreline with GCP and without GCP for March and May month are 0.91m. At the left side, of shoreline with GCP for March and May data is about 1.183m, while the shoreline without GCP for March and May data is about 0.932m. The error different between shoreline with GCP and without GCP for March and May month are 0.251m. In conclusion, the measurement of the shoreline was an absolute error, the gap error measurement at the right side of shoreline was the highest among the others 0.91m compared with the left side of shoreline 0.251m and the lowest error was at the middle of the shoreline 0.198m.

3.5 Contour Comparison

The contour line automatically generates from Global Mapper by using the Digital Terrain Model (DTM) with the 0.5m interval for each line GCP and NonGCP for March and May. The reason why DTM needed to be use to digitize the contour line that was because the contour line needed and elevation of the surface (Figure 10).

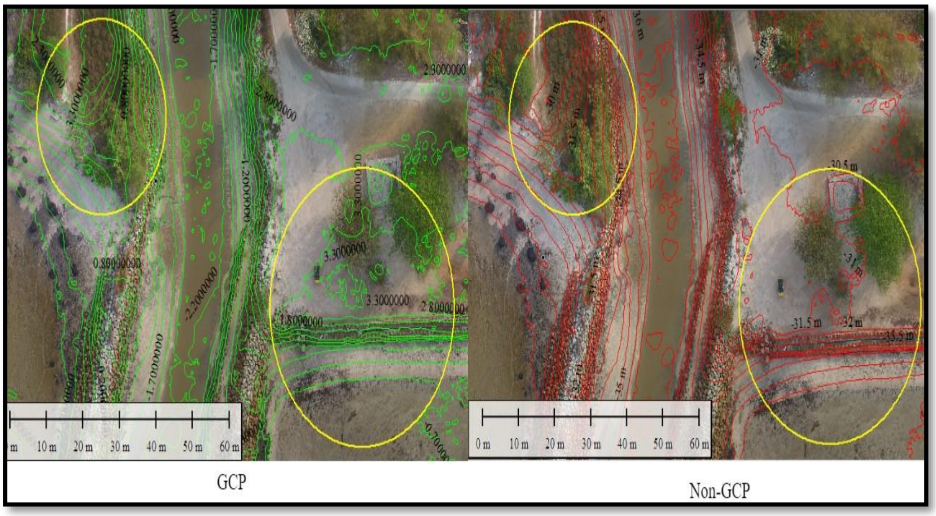

Figure 10: The contour line for GCP and Non-GCP

Based on the data, the GCP orthomosaic contour line value was 1.8m to 3.3m while the for the NonGCP orthomosaic contour line value was -30.5m to -35m. The GCP elevation is a value that has been converted into mean sea level value, while for the Non-GCP the elevation is a value from WGS 84 system, that why the Non-GCP elevation value is higher than the GCP elevation value.

3.6 Volume

The analysis of volume for the study area divided into four zone, which are zone A, B, C and D with an area of 3000m^2. This zone equally divided in Digital Surface Model of GCP and NonGCP for March and May (Figure 11).

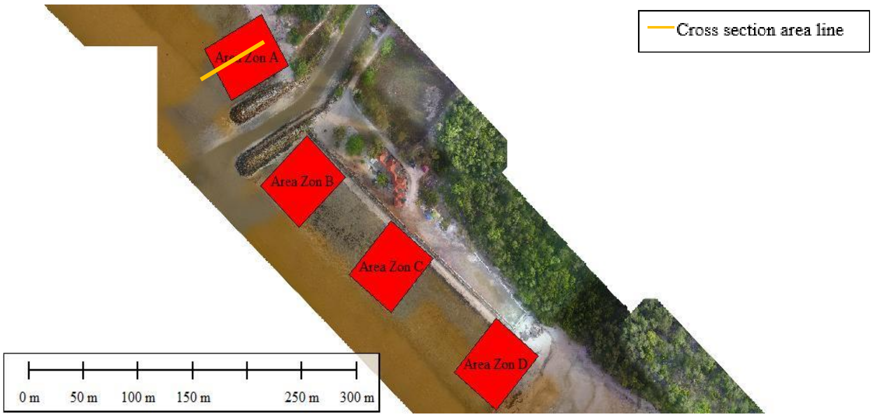

Figure 11: The zone area of volume visual in orthomosaic of GCP and NonGCP

Based on the Table 5, for area Zone A of GCP and NonGCP the volume is 560.09634 m^3 and 560.09532 m^3, so by finding the different of these two volumes, the error is about 0.00102 m^3. Next, the volume for area Zone B of GCP and NonGCP is 256.52851 m^3 and 256.52725 m^3, so the error is 0.00126m^3. Then, the volume for area Zone C of GCP and NonGCP is 326.31219 m^3 and 326.31175 m^3, so the error is 0.00044 m^3. And, the volume for area Zone C of GCP and NonGCP is 428.71125 m^3 and 428.71119 m^3, so the error is 0.00006 m^3.

Table 5: Volume of the zone

Zone	Total Volume [m3]	Error [m3]
Zone A NON GCP	560.09634	0.00102

Zone A GCP	560.09532	
Zone B NON GCP	256.52851	
Zone B GCP	256.52725	0.00126
Zone C NON GCP	326.31219	
Zone C GCP	326.31175	0.00044
Zone D NON GCP	428.71125	
Zone D GCP	428.71119	0.00006

The error from the volume is acceptable either for GCP or Non-GCP because it's centimeter accuracy which is relative error.

3.7 Cross Section Area

The area cross section for the whole zone were from the Zone area that has been marked in volume analysis refer figure 11 has their own shape and different in elevation. There was a change of elevation at the surface area for March and May. Moreover, the area cross section was at the same zone of the volume zone which were Zone A (Figure 12). The March cross section area was different with the May cross section area. In the Zone A, the elevation for March GCP cross section were from -2.5m to -0.5m and the different of the elevation,2m, while the Non-GCP were from -33.5m to -34.5m and the different of the elevation, 1m. For the May, the elevation for GCP cross section were from -0.50m to -0.25m and the different of the elevation, -0.25m, while the Non-GCP were from 17m to 16m, and the different of the elevation,1m. The different elevation for the Zone A cross section was an absolute error

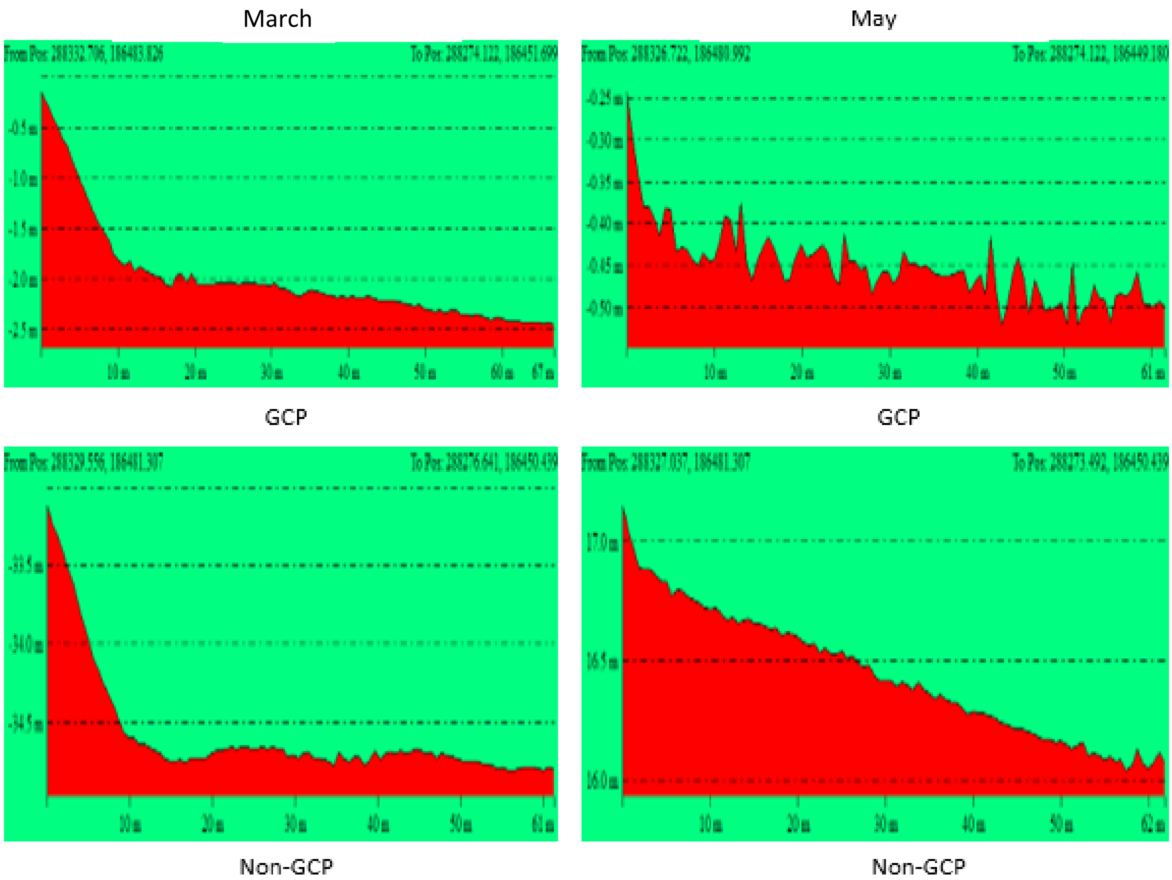

Figure 12: The cross at Zone A for March and May

In conclusion, for the cross section in all zone shows that the elevation different was a consistent different although the elevation for GCP and Non-GCP are the same value, so it's mean that the cross-section area could be measured with or without GCP but in term of accuracy for Non-GCP mapping it's not valid. There was a shift from orientation and that the reason why the surface area patterns a lot of different either for March or May in GCP or Non-GCP. The data needed to be same in coordination but there was a change as can see at the analysis of the orientation.

4. CONCLUSION

Overall, GCP greatly affects images in the form of accuracy and it's very different from images that do not have GCP. The more the GCP, the more it will influence the accuracy of the image [8]. The impact of GCP numbers and spatial distribution has been extensively researched, however the results frequently differ significantly. Moreover, the natural error also needs to be considered in this study which are caused by changing conditions in the surrounding environment. That prove in this study by observation on the shoreline and contour line. Based on the result, there a lot of comparison for NonGCP with the GCP imagery There was a big error gap in terms of coordination, shoreline and contour which are an absolute error but it was still relevant for basic analysis which is relative error like length, volume, and cross section elevation because of errors that do not have a large impact on the real value change, but slightly better error for measurement. In addition, the big different elevation for GCP and Non-GCP orthomosaic it was because the GCP elevation is a value that has been converted into mean sea level value, while for the Non-GCP the elevation is a value from WGS 84 system, that's why the Non-GCP elevation value is higher than the GCP elevation value. From the data analysis, the error for two-month March and May was not consistent for coordinate, orientation, shoreline gap and distance, so it is recommended adding further studies a few months may be able to get a consistent value for error and reduce the error gap between GCP and Non GCP orthomosaic.

For non-GCP applications, this imagery was appropriate for building inspections [9], quarrying [10], slope monitoring [11], road construction [12], construction progress [13], construction monitoring [14], and area mapping [15]. For surveying and geomatic work, its need an accuracy in coordination to make sure measurement approximate to the actual value. However, in addition to further testing of accuracy issues, technical factors of UAVs (maximum flight time, autonomous operation, and so on) must be changed to properly exploit these opportunities [16]. Basically, the Non-GCP data can be used in certain type of civil engineering work that does not use the high accuracy as mentioned before for example the data is used to get to know the area, shape of the area, elevation, and volume. This type of data was a relative error so it can be acceptable, while for the accuracy work in civil engineering it reserved which is need to use the GCP in order to get the precise data for example shoreline, contour, coordinate and others.

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