

# Quality Control Analysis of UAV Digital Terrain Model with GNSS Geodetic Digital Terrain Model

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## ABSTRACT

Spatial data procurement technology using an unmanned aerial vehicle (UAV/Unmanned Aerial Vehicle) system is one of the aerial image capture technologies that produce detailed spatial data. The purpose of DSM correction is to resolve altitude values from DSM information. In image processing, filtering is a local operation carried out to facilitate visual interpretation and obtain DTM data. The method used is bare earth filtering, then to identify the filtering parameters using the bare earth Digital Surface Model UAV photo method to the UAV Digital Terrain Model and to see the results of the quality control analysis of the UAV Digital Terrain Model against the Geodetic GNSS Digital Terrain model. The spatial data generated from UAV technology in this study has an accuracy of = 0.01243 meters and RMSEz = 1.420 meters. The highest quality filtering results are filtering with a slope parameter of 10° with a radius of 100 meters because from the results of the elevation comparison curve, the diagram that has the closest elevation to GNSS Geodetic is the result of filtering a slope of 10° with a radius 100 meters.

**Keywords:** Digital Terrain Model, Filtering Bare Earth, UAV GNSS Real Time Kinematic, Quality Control.

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## 1. Introduction

The Computerized Surface Model is a world surface model that describes all objects visible on the world's surface. DSM data includes land surface objects as well as ground cover structures and vegetation. The DSM display will depict the state of the world's surface as it is actually seen from satellite images or aeronautical photos and is transferred completely to DTM using the Uncovered Earth strategy (Asadul Usud,2014). DSM correction is used to resolve altitude values from DSM information. Using calculations based on the average value of the pixels around the pixel, the DSM filtering principle generates a new height value for the pixel in the DSM. Sorting is the most common way to change pixel values in a data set according to the excess of surrounding pixels. In image processing, filtering is a local operation carried out to facilitate visual interpretation and obtain DTM data. This is intended to produce a new elevation based on terrain that was previously based on surface. The results of this DTM will later be controlled with data from geodetic GPS to see the level of precision of the filtering results from DSM to DTM using the bare earth method against the results obtained from GNSS.

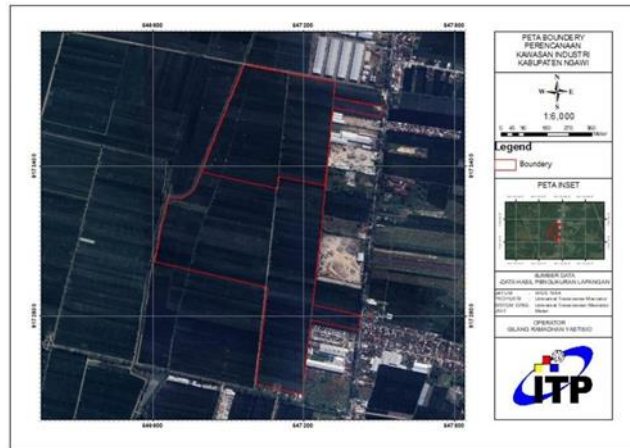
## 2. Research Methodology

The research carried out is research on the results of aerial photography using a UAV which is then exported into a DEM to be used as a reference for making topographic maps. As the DEM data produced by UAV acquisition is based on Surface or DSM, which is then filtered bare earth using SAGA GIS software to make itDTM, the parameters used are slope 10° radius 100 meters, slope 20° radius 100 meters, slope 30° radius

50 meters, slope 25° radius 75 meters and slope 50° radius 100 meters. Next, quality control of the DTM elevation values produced by aerial photography with DTM GNSS Geodetic via the ArcGIS application is carried out. This type of research is quantitative with studies determining filtering parameters and elevation quality control. This research used a lot of numbers, starting from data collection, analysis of the data obtained, and presentation of the results of elevation comparisons from DTM UAV with geodetic GNSS as an elevation reference.

**2.1 Research sites**

The research was carried out in the development plan for the Ngawi industrial area, East Java, which is located 7°21' - 7°31' South Latitude and 110°10' - 111°40' East Longitude.



**Figure 1.** Research Location

**2.2 Tools dan Materials**

The tools and materials used were 1 set of CHC i50 Geodetic GNSS, 1 set of Phantom 4 pro Drone, HP Pavilion+14 laptop, ArcMap software, Saga GIS software, Agisoftmetashape software, and Microsoft Office. Furthermore, the materials used are GPS GNSS data from the Static Method in 2023, GPS GNSS data from the Real Time Kinematic Method in 2023, AerialPhoto data in 2023, Digital Elevation Model data in 2023, and Digital Terrain Model data.

**2.2 Research Stages**

1. In the static GNSS method stage, BM and GCP points are made with concrete measuring 50 cm high, 10 cm wide and 10 cm long, then marked with red paint and a yellow premark is attached.
2. Collecting GNSS Geodetic data using the Real Time Kinematic method which was acquired with the GNSS Geodetic CHC i50 in base rover mode. This Real Time Kinematic GNSS measurement is based on the area that has been acquired with aerial photos by the mission planflight.
3. Processing the aerial photo results using Agisoft meta shape software to obtain orthophoto results and installing GCP on aerial photos as georeferencing. Filtering data DSM with the bare earth method using certain parameters to obtain DTM data results. The parameters required are slope and radius. In this research, five parameters were prepared consisting of slope and radius. As in table 1 below

**Table 1** Filtering Parameters

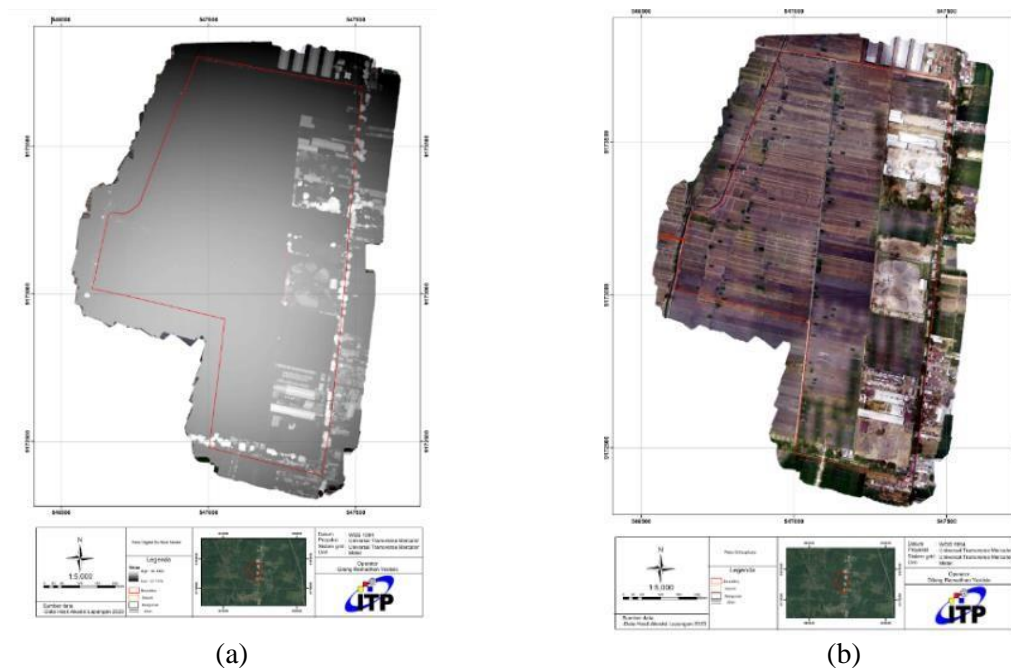
Parameter <i>Slope</i>	Parameter <i>Radius (m)</i>
50°	100
20°	100
30°	50
25°	75
10°	100

4. At this analysis stage what needs to be paid attention to is the comparison of filtering results controlled with orthophoto, comparative analysis of the elevation resulting from DSM filtering data into DTM UAV against DTM GNSS Geodetic data using the real time kinematic method. In the elevation comparison process, this is done by manually creating sample points from aerial photo DTM to determine the elevation at points that are overlaid with geodetic GNSS points, where later the aerial photo DTM and geodetic GNSS sample points will be used as a comparison for quality control.

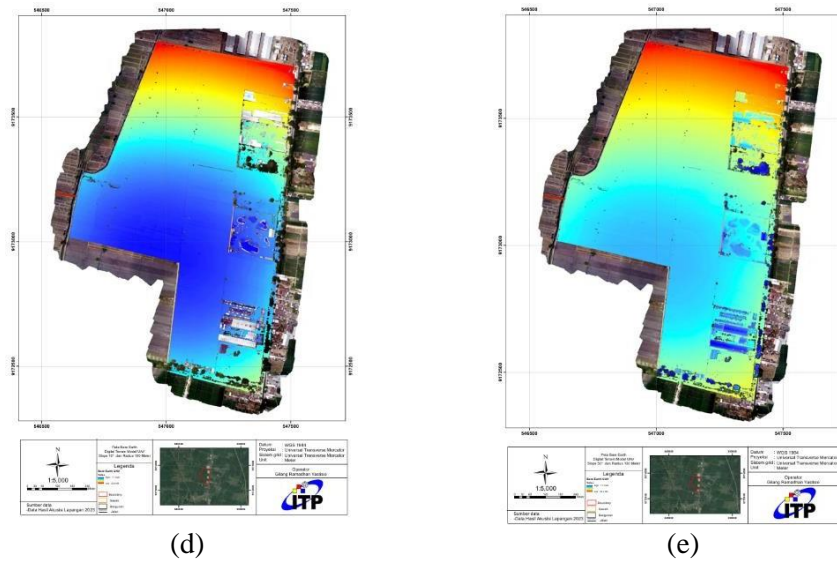
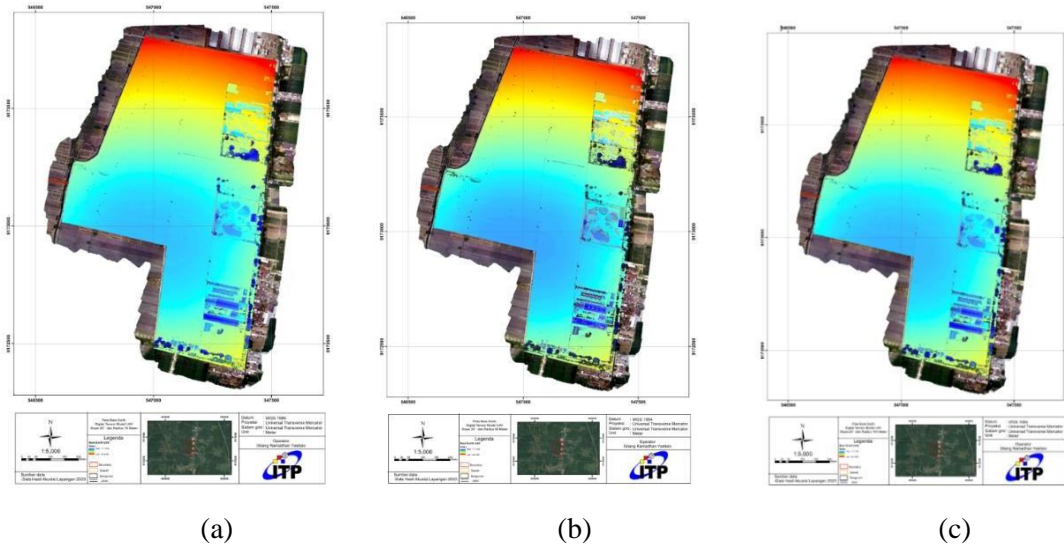
### 3. Result and Discussion

The results of static data processing are the coordinates that will be used as BM and GCP points as reference points for ICP measurements and aerial photos. Results of field measurements using the Real Time Kinematic GNSS method carried out in the industrial area planning area which is also used as an ICP point for quality control analysis of the UAV Digital Terrain Model and Real Time Kinematic Geodetic GNSS. From the results of the processed aerial photos, results were obtained in the form of Orthophoto and Digital Surface Model from the results of the aerial photos.

Based on the results of aerial photo processing, DEM and Orthophoto were obtained. The map results from this DEM will be used as basic data for carrying out bare earth filtering in terms of quality control analysis. Meanwhile, orthophoto data is used as a tester for filtering results. The results of this DEM contain elevation values based on the surface of the aerial photos, while the orthophoto data contains aerial photos of the research location.



**Figure 2** (a) is the result of aerial photo processing in the form of a DEM at the research location and image (b) is the result of an orthophoto from aerial photo processing.



**Figure 3** (a) Result of filtering

Image (a) is the result of filtering with a slope parameter of  $25^\circ$  and a radius of 75 meters, image (b) is the result of filtering with a slope parameter of  $30^\circ$  and a radius of 50 meters, image (c) is the result of filtering with a slope parameter of  $20^\circ$  and a radius of 100 meters, image (d) is the result of filtering with a slope parameter of  $10^\circ$  and a radius of 100 meters, and image (e) is the result of filtering with a slope parameter of  $50^\circ$  and a radius of 100 meters.

The results of filtering with several of these parameters are each different because they are influenced by the Slope and Radius used for filtering. The aim of doing this filtering is so that the elevation model produced from aerial photos that include trees and buildings can be filtered to get elevation based on terrain. In this research step on bare earth filtering, the slope and radius parameters are very influential in filtering the Digital Surface Model into a Digital Terrain Model. On land where the terrain is more dominant, the smaller the slope and the larger the radius, the parameters used will produce a removed object which is very good for filtering the Digital Surface Model into a Digital Terrain Model. However, for land that is denser in settlements and trees, the greater the slope and the smaller the radius, the result will be filtering the Digital Surface Model data into a better Digital Terrain Model.

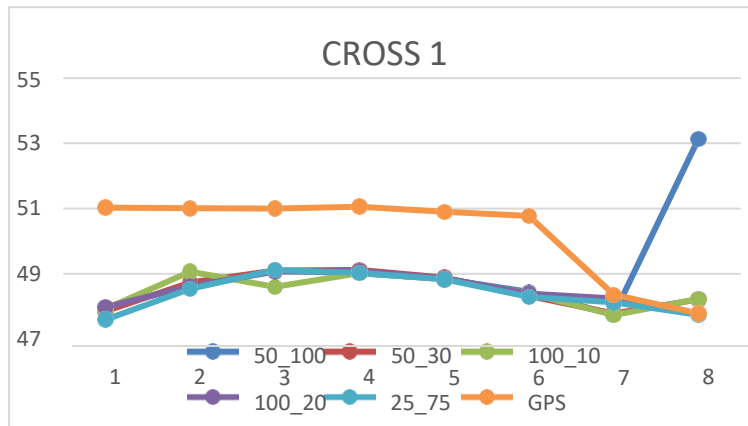
**3.1 Elevation Analysis**

Elevation analysis is carried out to see a comparison graph of elevation values produced from eachDTM data.

**Table 2** Elevation Cross 1

Point number	Parameter					GPS
	50_100	50_30	100_10	100_20	25_75	
1	47,95014	47,85255	47,92244	47,98123	47,59222	51,034
2	48,64022	48,73468	49,06213	48,62557	48,53433	51,011
3	49,09495	49,09724	48,59624	49,06158	49,11361	50,998
4	49,01528	49,11753	49,01794	49,08374	49,02696	51,055
5	48,83863	48,87704	48,83129	48,85951	48,82818	50,902
6	48,44342	48,32248	48,40339	48,39098	48,29494	50,773
7	47,7436	47,78084	47,73297	48,23695	48,12532	48,361
8	53,13865	48,21367	48,22522	47,77518	47,73932	47,784

Comparative analysis of the elevation of DTM aerial photography with DTM GNSS Geodetic on cross 1 which consists of 6 crosses as shown in Figure 4 below.



**Figure 4** Cross Elevation Comparison Cross 1

**Table 3** Elevation Cross 2

Point number	Parameter					GPS
	50_100	50_30	100_10	100_20	25_75	
1	51,84132	51,87289	48,22522	51,92954	48,22425	51,125
2	52,86908	52,8628	51,90366	51,9095	51,92539	51,608
3	53,73885	53,72694	53,58842	52,76331	52,83659	51,525
4	53,64331	53,77215	52,75421	53,5954	53,70938	51,464
5	66,17205	62,45953	53,61603	53,852	53,64198	54,772
6	54,23297	60,09267	53,10128	62,06422	61,8145	54,674
7	63,97188	52,73755	53,4773	60,88346	60,21178	

Comparative analysis of the elevation of DTM aerial photography with DTM GNSS Geodetic oncross 2 which consists of 6 crosses as shown in Figure 5 below.

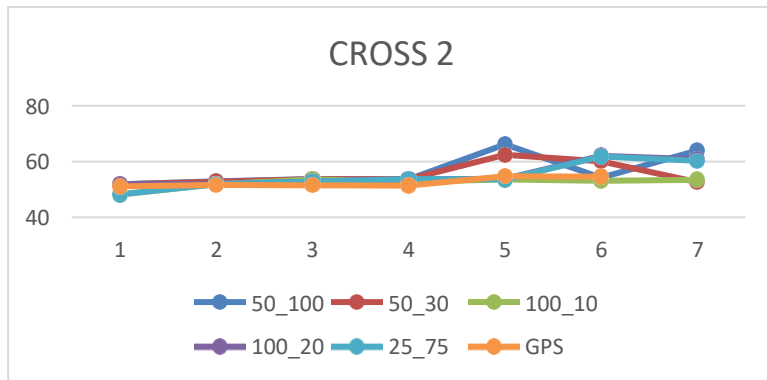


Figure 5 Cross Elevation Comparison Cross 2

Table 4 Elevation Cross 3

Point number	Parameter					
	50_100	50_30	100_10	50_100	50_30	GPS
1	59,46533	59,49791	59,57345	52,76372	52,70593	59,573
2	61,04915	61,16249	61,16282	59,50478	59,50763	57,566
3	61,5504	61,57072	61,55747	61,2125	61,02175	57,686
4	61,73368	61,69823	61,77262	61,57395	61,61289	57,023
5	61,36487	61,3406	61,34832	61,75489	61,79301	57,802
6	60,34594	60,30157	60,35544	61,36718	61,2942	57,259
7	58,37849	58,50625	58,51344	60,35624	60,36357	57,578

Comparative analysis of the elevation of DTM aerial photography with DTM GNSS Geodetic atcross 3 consists of 6 crosses as shown in Figure 6 below.

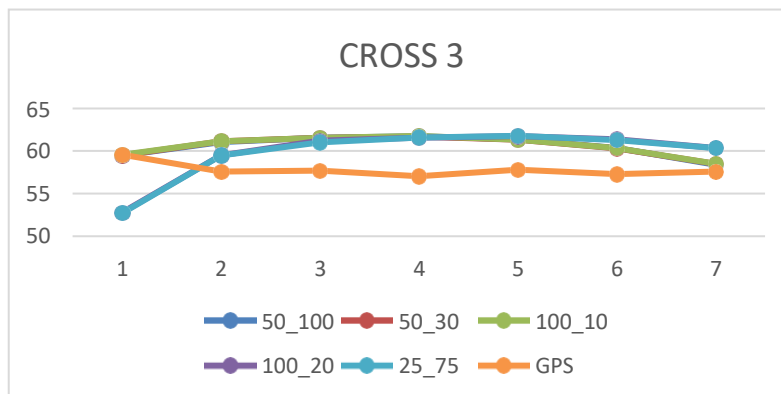
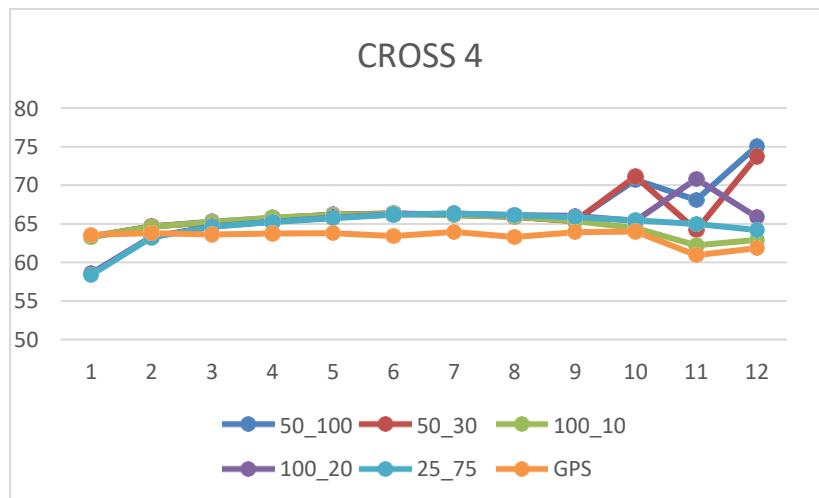


Figure 6 Cross Elevation Comparison Cross 3

**Table 5** Elevation Cross 4

Point number	Parameter					GPS
	50_100	50_30	100_10	100_20	25_75	
1	63,28868	63,34779	63,37141	58,55101	58,36756	63,601
2	64,66786	64,65872	64,61812	63,31008	63,26925	63,795
3	65,26584	65,17	65,24368	64,65995	64,63382	63,636
4	65,7442	65,74361	65,81769	65,26019	65,23494	63,764
5	66,17984	66,15112	66,14663	65,78864	65,73478	63,787
6	66,32485	66,34959	66,31404	66,18454	66,19646	63,398
7	66,16094	66,14927	66,11666	66,30948	66,33404	63,945
8	65,90266	65,91189	65,92617	66,10953	66,16899	63,284
9	65,42123	65,34269	65,34643	66,0258	65,86364	63,903
10	70,70386	71,13771	64,46272	65,36356	65,43161	63,998
11	68,10293	64,18462	62,23158	70,81573	65	60,955
12	75,0377	73,6959	62,90785	65,85283	64,21902	61,841

Comparative analysis of the elevation of DTM aerial photography with DTM GNSS Geodetic atcross 4 consisting of 6 crosses that have been overlaid as shown in Figure 7 below.

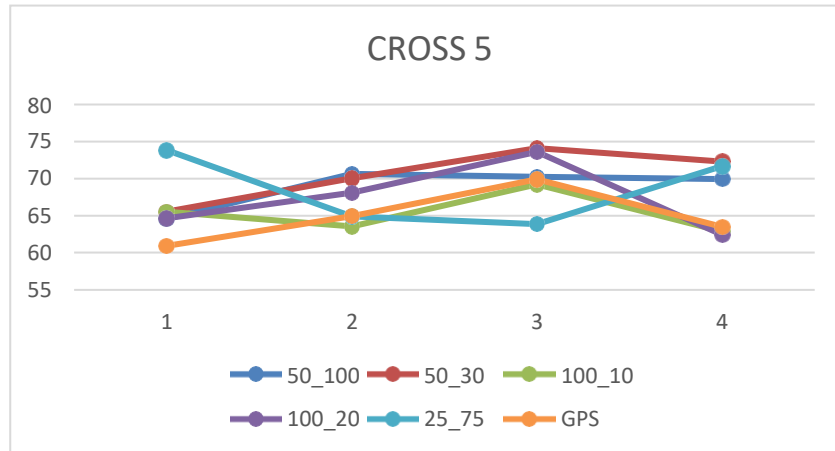


**Figure 7** Cross Elevation Comparison Cross 4

**Table 6** Elevation Cross 5

Point number	Parameter					GPS
	50_100	50_30	100_10	100_20	25_75	
1	64,58881	65,53732	65,53988	64,61992	73,83526	60,926
2	70,64443	70,03973	63,57525	68,08499	64,89599	64,936
3	70,23373	74,10685	69,21953	73,60809	63,85363	69,905
4	69,96863	72,29381	62,88253	62,40204	71,66656	63,505

Comparative analysis of aerial photo DTM elevation with GNSS Geodetic DTM at cross 5 consisting of 6 crosses as shown in Figure 8 below.

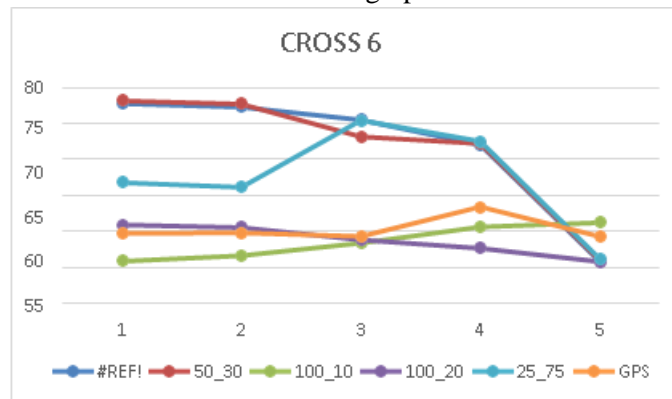


**Figure 8** Cross Elevation Comparison Cross 5

**Table 7** Elevasi Cross 6

Point number	Parameter					GPS
	50_100	50_30	100_10	100_20	25_75	
1	77,75809	78,13389	55,86356	60,923	66,7821	59,744
2	77,28277	77,70208	56,64593	60,55416	66,16614	59,811
3	75,48277	73,17118	58,38395	58,8608	75,42623	59,32
4	72,04116	72,20218	60,6434	57,68572	72,52731	63,422
5	55,84033	56,00253	61,22599	55,82565	56,20819	59,315

From the data above, the results of the elevation difference graph are obtained as in Figure 9 below.



**Figure 9** Cross Elevation Comparison Cross 5

Based on the results of the author's research and analysis regarding the quality control analysis of the Digital Surface Model UAV with the Digital Terrain Model GNSS Geodetic from the 5 highest quality filtering results, namely filtering with a slope parameter of 10° with a radius of 100 meters because from the results of the elevation comparison curve, the diagram has the closest elevation. to GNSS Geodetic, which is the result of a filtering slope of 10° with a radius of 100 meters. The slope parameter 50° radius 100 meters is shown by a blue line, the slope parameter 30° radius 100 meters is shown by a brown line, the slope parameter 10° radius 100 meters is shown by a green line, the slope parameter 20° radius 100 meters is shown by a purple line, The slope parameter of 25° radius 75 meters is shown in light blue, while the GNSS Geodetic results are shown in orange. Distance Quality Control Analysis.

Distance analysis is carried out to see the accuracy of the aerial photography results, this is to minimize position and size errors in the aerial photography results as shown in Table 7 distance comparison

**Table 7** Distance comparison

No	Orthophoto (m)	GNSS (m)	Gap (m)	Location
1	5,170	5,094	0,076	Jalan Desa sebelah Utara
2	6,4	6,6	0,20	Jalan Utama sebelah Timur
3	10,240	10,320	0,08	Sawah Utara phase 1
4	18,609	18,412	0,197	Pertigaan Selatan
5	3,830	3,798	0,032	Jalan Desa sebelah Selatan
6	37,927	38,291	0,364	Rumah Selatan
7	23,399	23,165	0,234	Bengkel PT Mira
8	76,482	76,664	0,182	Pabrik Sampoerna
9	59,943	60,094	0,151	Gerbang Perumahan
10	178,933	179,162	0,229	Pabrik Pecah Batu Selatan
11	216,969	217,330	0,361	Pabrik Pecah Batu Utara
12	119,327	119,173	0,154	Sawah sebelah Timur

From the results of the Accuracy Test Analysis with distance, the difference between the object distance measured from the orthophoto and the GNSS Geodetic measurement results was obtained. The resulting distance difference varies from the 12 objects used as samples, with an average difference of 0.188 meters. From the results of the Accuracy Test Analysis with distance, the difference between the object distance measured from the orthophoto and the GNSS Geodetic measurement results was obtained. The resulting distance difference varies from the 12 objects used as samples, with an average difference of 0.188 meters.

The results of the RMSEr calculation show that the RMSEr is 0.01243 meters. This RMSEr value was obtained from 34 ICP points and samples in the Digital Terrain Model which were tested based on easting coordinates and northing coordinates. RMSEr is calculated by

$$RMSEr = \frac{\sqrt{\sum(\Delta X - \Delta X \text{ Mean})^2 + \sum(\Delta Y - \Delta y \text{ Mean})^2}}{n - 1}$$

for CE 90 and LE 90

$$RMSEr = \frac{\sqrt{\sum(\Delta X - \Delta X \text{ Mean})^2 + \sum(\Delta Y - \Delta y \text{ Mean})^2}}{n - 1}$$

$$\text{RMS error} = \frac{\sum(0.09485433) + (0.0734147354)}{34 - 1}$$

$$= 0,4102$$

$$\text{RMSEr} = 0,0124$$

$$= 1.5175 * \text{RMSEr}$$

$$\text{CE 90} = 0,0189$$

LE90

$$= \frac{\sqrt{\sum(\text{elevation Orthopoto} - \text{Elevation ICP})^2}}{n}$$

$$\text{RMSEz} = \frac{\sqrt{\sum(Z \text{ data} - Z \text{ Cek})^2}}{n}$$

$$= \frac{\sum(2084.1456) - (2135.2972)}{36}$$

$$= 36$$

$$\begin{aligned}
 &= 51,1516 \\
 &= 1,42088 \times 1,6499 \\
 \text{LE90} &= 2,3443
 \end{aligned}$$

#### 4. Conclusion

Based on the results of the author's research and analysis regarding the quality control analysis of the UAV Digital Surface Model with the Geodetic GNSS Digital Terrain Model, it can be concluded that the way to analyze the quality control is by comparing the elevation values produced from the UAV DTM with the Geodetic GNSS DTM where the UAV DTM is obtained from the results of aerial photo processing in the form of a Digital Surface Model and filtering is carried out with Bare Earth parameters using slope and radius. In terms of identifying the slope and radius parameters that will be used in filtering the Digital Surface Model into a Digital Terrain Model based on the characteristics of the research area, to see these characteristics, one of the methods proposed by the researchers is by comparing the results of Bare Earth parameter filtering with orthophoto. Based on the results of research and analysis regarding the quality control analysis of the Digital Surface Model UAV with the Digital Terrain Model GNSS Geodetic from the 5 highest quality filtering results, namely filtering with a slope parameter of  $10^\circ$  with a radius of 100 meters because from the results of the elevation comparison curve, the diagram which has the elevation closest to Geodetic GNSS is the result of filtering a slope of  $10^\circ$  with a radius of 100 meters. The diagram that has the closest elevation to GNSS Geodetic is the result of a filtering slope of  $10^\circ$  with a radius of 100 meters. Other parameters still have quite significant differences in elevation because the object is not moved properly due to the influence of parameter values that are not optimal. The resulting difference in elevation value is an average of 1.4208 meters. Based on positional quality control, testing was carried out by measuring the distance of the object on the orthophoto with the same object which had been measured using the GNSS Geodetic Real Time Kinematic method, obtaining an average difference of 0.188 meters. Calculation of RMSEr and RMSEz produces values for RMSEr = 0.01243 meters and RMSEz = 1.420878 meters, then to determine the scale of the map that will be produced by Perka BIG No. 14 of 2015, CE90 and LE 90 calculations are carried out. Based on the results of the CE90 and LE90 calculations based on RMSE CE90 value = 0.018863 and LE90 value = 2.344306 meters. From the results of the CE90 and LE90 calculations for making maps by the provisions of Perka BIG No. 14 of 2015, the map that will be produced is in class 3 with a scale of 1:5000 and a contour interval of 2 meters.

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