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Application of Fixed-Wing UAVs to Develop Digital Terrain Model on Coastal Peatland Bengkalis Island

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Abstract

Destructive abrasion is currently occurring in Teluk Papal Village. The coast of Teluk Papal Village has a humus soil structure with soil conditions with a type of peat that is relatively easy to decompose. The cause is along the coast because of the absence of coastal protection plants (mangroves). To prevent the increasing abrasion rate, a comprehensive plan is needed by involving relevant stakeholders in both short and long-term planning. One of the efforts in controlling the abrasion rate is the construction of breakwater buildings. Before the construction is carried out, a study is needed to support the breakwater construction. One of the supports is to make a topographic or contour map. The field data acquisition process uses Unmanned Aerial Vehicle (UAV) technology. This data processing technique uses photogrammetric data processing techniques with the stages of flight path planning, measurement of Ground Control Point (GCP), and Benchmark points, which are then tied to BIG's CORS points to produce higher control point accuracy, Dense Cloud Point to create Digital Elevation Model (DEM) or Digital Terrain Model (DTM), and orthophoto embellishment. Furthermore, horizontal and vertical position accuracy tests were conducted using the calculation method issued by BIG regulation No. 15/2014 to provide information on how far the accuracy of the resulting map is. The results of the Digital Terrain Model (DTM) and orthophoto data accuracy test research based on the results of the accuracy test obtained a LE90 value of 0.6757 meters, then for the CE90 value of 0.1543 meters so that it meets the map requirements at a scale of 1:2500 at class 1 horizontal accuracy and class 2 vertical accuracy.

Keywords: Digital Elevation Model, Ground Control Point, Orthophoto, Topography, Unmanned Aerial Vehicle

1. Introduction

Teluk Papal is one of the villages in the Bantan sub-district, a settlement with most of the population as fishermen. The coast of Teluk Papal Village has a humus soil structure with soil conditions that are a type of peat that is relatively easy to decompose. Lack of coastal protection plants (mangroves) as a binder, causing a severe abrasion problem along the coastline of Teluk Papal Village.

According to Sutikno (2014), the coast of Bengkalis Island, which experiences abrasion per year, has increased with an average of 59.02 ha/year for the last 26 years.

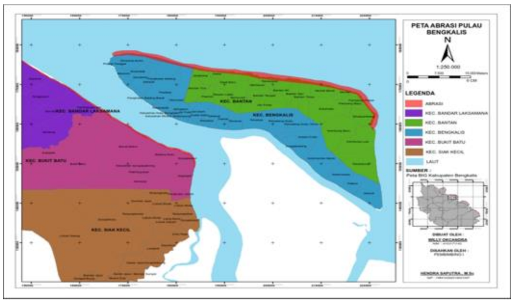

Fig 1. Abrasion map of Bengkalis Island

The Central Government, through the National Development Planning, designated Bengkalis Regency, Riau Province, as a priority National Strategic Activity Center (PKSN) in the 2020-2024 National Medium-Term Development Plan (RPJMN). This is a big hope for the local government to bring Bengkalis even further forward. To realize this, support from the Riau Provincial Government is needed to accelerate ministries and institutions together.

Development requires a plan, be it long-term, medium-term, or short-term. Infrastructure development planning and countermeasures in abrasion-prone areas need to be supported by several data. One supporting data required is the abrasion map of Teluk Papal Village. Therefore, it is necessary to do topographic mapping and its appearance. The map information can support further planning for developing and preventing abrasion vulnerability in Teluk Papal Village. The process of field data acquisition for making abrasion maps directly in the field with an area of ± 400 hectares will undoubtedly require a long time, a considerable cost, and much personnel. However, the development of mapping technology will undoubtedly facilitate the field data acquisition process, and various field data acquisition methods are currently developing. With the guidance to produce fast, inexpensive map data with few personnel and the maps created can be accounted for, a suitable field data acquisition method is needed.

One is the field data acquisition method using the Unmanned Aerial Vehicle (UAV) aerial photo shooting method. Shooting with aerial photography is favored because of its low cost, few personnel, and fast field data acquisition.

Unmanned aircraft technology, which is now gaining popularity, often referred to as Unmanned Aerial Vehicles (UAVs) or drones, is one of the new alternative technologies for mapping, especially aerial photography. Foreign and domestic researchers and practitioners increasingly use and develop UAVs for mapping applications. UAVs have become an alternative to cheap remote sensing technology as a source of spatial data (Bendea, H et al., 2008; Adam S.M et al., 2011; Rokhmana, 2012).

This research aims to conduct topographic mapping of abrasion disaster in the Desa Teluk Papal area, Bantan Bengkalis District, Riau Province, by utilizing UAV shooting data to produce elevation data (DTM / DEM) that is accurate and has high accuracy. The results of this study are expected to be used as information in making efforts to reduce the risk of disasters that may occur for interested parties and the government and as a reference for rehabilitating the environment for the sustainability of the coastal area of Teluk Papal Village.

2. Data and Methodology

2.1. Aerial Photography

Wolf (1993) Aerial photographs are photographs obtained from aerial surveys, namely shooting through the air in certain areas with specific photogrammetric rules. The result is a detailed record of the earth's surface, influenced by several factors, such as the camera lens's focal length, the aircraft's altitude, and the shooting time. Aerial photographs are further classified as vertical aerial photographs and inclined aerial photographs. Vertical aerial photography is when the camera axis at the time of shooting is entirely vertical or slightly tilted by no more than three. Most of the aerial photographs belong to the type of vertical aerial photographs. The second type of aerial photograph is a skewed aerial photograph, which is when the axis of the photograph is tilted between 3° and 90° from the vertical position. If the horizon is not visible, it is called inclined. If the horizon is visible, it is called highly inclined. Then in more detail, according to Wolf (1993), aerial camera orientation is divided into three: vertical, slightly inclined, and highly inclined.

2.2. Aerial Photography

Unmanned Aerial Vehicle (UAV), or Unmanned Aerial Vehicle (PUNA), is an aircraft that can operate without a crew. UAVs operate with an aircraft control operator outside the aircraft. In contrast, the aircraft operates automatically according to the command of the control operator, who is a visualization of the UAV aircraft.

Historically, UAVs were used by the military to practice shooting, where UAVs became the object of firing targets. Until now, the military world is still using UAVs as military tools. Besides the military world, in the private and civilian world, UAVs are also widely used for image capture tools because UAVs have embedded cameras. The general function is as a documentation tool for both photos and videos. However, its particular function is as a mapping survey tool. Aerial photography surveys using UAVs are much cheaper than aerial photography surveys using manned aircraft. Then to monitor conflict areas is also safer because there are no human operators on the aircraft. The flying ability of the UAV itself varies depending on the specifications of the UAV itself, but the recommended flying altitude is no more than 120 meters. At the same time, the maximum flying altitude, according to applicable law, is a flying altitude of no more than 150 meters.

2.3. Global Positioning System (GPS)

According to (Abidin, 2011), GPS is a radio navigation and positioning system using satellites owned and managed by the United States. Because it is based on satellites, GPS receiver observations do not have to be visible to each other (intervisibility), the important thing is that the receiver can capture GPS signals (satellite visibility) until it is sufficient. In principle, the greater the number of satellites that can be captured, the better the quality of GPS position acquisition. By utilizing the signal from the satellite then, the GPS receiver performs a backward binding to the specified base point (differential method). Then in terms of position observation using GPS, at least two GPS receivers are used. Then in recording data, the receiver must be in a static or stationary state because the observations are observations for one point. In GPS observations, the mandatory components include GPS receivers, sufficient satellites, and users.

2.4. Ground Control Points (GCP)

Ground control points are objects on the earth's surface that can be identified and have spatial information by the mapping reference system. Spatial information in the form of X, Y, Z, or Latitude-Longitude coordinates and the height of each GCP is measured using a sub-meter accuracy geodetic GPS. The essential need for GCP is the georeferencing process of photo processing results so that it has a reference system for what is needed in the mapping results. GCP is also used during data processing to help the geometric correction process on the orthophoto mosaic so that the accuracy of the resulting map will be high. Specifically, GCP also functions as:

a. The determining factor of geometric accuracy of photo processing results (orthophoto, DSM, DTM), the more thorough the GCP, the better the geometric accuracy of the output (with the rules of GCP placement being met).

b. Factors that facilitate the process of relative orientation between photos so that the presence of GCPs can improve the geometric accuracy of photo maps.

c. A correction factor for photo processing results in a ball effect or error that causes the 3D model to be convex in the center of the measured area.

d. Factors that make it easier to unify the results of separate data processing, for example, processing data for areas A and B more quickly and effectively, rather than the unification process based on the entire point cloud (millions of them), which will take much time.

Fig 2. GCPs of the Research Site Plan

The use of GCPs is optional. GCPs help to increase the accuracy of the resulting map (up to ± 10 cm), so the consequence of not using GCPs is only that the accuracy of the resulting map becomes low (between ± 6 - 12 m). The use of GCPs is also regulated according to the Indonesian National Standard (SNI), which is a maximum distance between GCPs of 2.5 kilometers. GCP installation takes quite a long time, with a capacity of 6-10 GCPs/day (according to field conditions), which is done before the aerial photography data acquisition process. For the case of making topographic maps, the role of GCP is quite essential. By using GCPs, the resulting topographic map can have a high Z accuracy so that the geographical conditions in the area can be analyzed with high confidence.

Each GCP must have a premark or mark to be visible on aerial photographs. The premark can be a circle or a cross (+) that has 4 wings and intersects the control point. The premark that will be installed is an orange fabric mark, with the minimum size of the premark on aerial photos being 10 pixels long and 3 pixels wide for each premark.

Each wing of the premark. The actual premark size in the field adjusts the ground resolution value of the aerial photography or about 100 x 40 cm.

The coordinates of the control points will be measured using Geodetic GPS with the RTK system. RTK (Real-Time Kinematic) system is a commonly used acronym for differential real-time positioning systems using phase data. To realize the real-time demands, the reference station must transmit phase and pseudorange data to the user in real-time using a specific data communication system. All GCPs are tied to one Benchmark of the Geospatial Information Agency (BIG) located around the area as a local base. Using this method, the resulting map will conform to mapping standards and have a global coordinate reference.

2.5. Geometry Accuracy Test

Geometry Accuracy is a value that describes uncertainty in the position coordinates of an object on the map compared to the position coordinates object that is assumed to be its actual position. The geometric accuracy component consists of Horizontal accuracy and vertical accuracy. The position accuracy test was carried out to get the map's confidence level of 90% Circular Error and Linear Error. Test Positional accuracy is determined using satisfactory test points

provisions of the object used as a test point, namely:

1. Can be identified in the field and on the map to be tested.
2. It is an object that remains relatively unchanged over a period of time short time.
3. Have an even distribution throughout the area to be tested.

Positional accuracy testing refers to the difference in coordinates (X,Y,Z) between points

test on an image or map with the actual location of the test point on ground level. Accuracy measurement using root mean square error (RMSE) or circular error. On the necessary two-dimensional mapping taken into account are the (X,Y) coordinates of the test point and the actual position at the field. Analysis of positional accuracy using root mean square error (RMSE), which describes the value of the difference between the test point and the actual point. RMSE is used to describe accuracy, including random error, and systematically (Head of BIG No. 15, 2014).

2.6. Basic Map Geometry Accuracy

The accuracy of the orthophoto map is tested by following the accuracy of the Fine Map Bumi Indonesia (RBI) issued through the Regulation of the Head of the Agency Geospatial Information (BIG) No 15 of 2014. According to the Regulation of the Head of BIG No. 15 of 2014, the geometric accuracy of the map is obtained based on the provisions as follows:

Table 1. RBI Map Geometry Accuracy Standards

No.	Skala	Interval kontur (m)	Ketelitian Peta RBI					
			Kelas 1		Kelas 2		Kelas 3	
			Horizontal (CE90 dalam m)	Vertikal (LE90 dalam m)	Horizontal (CE90 dalam m)	Vertikal (LE90 dalam m)	Horizontal (CE90 dalam m)	Vertikal (LE90 dalam m)
1.	1:1.000.000	400	200	200	300	300,00	500	500,00
2.	1:500.000	200	100	100	150	150,00	250	250,00
3.	1:250.000	100	50	50	75	75,00	125	125,00
4.	1:100.000	40	20	20	30	30,00	50	50,00
5.	1:50.000	20	10	10	15	15,00	25	25,00
6.	1:25.000	10	5	5	7,5	7,50	12,5	12,50
7.	1:10.000	4	2	2	3	3,00	5	5,00
8.	1:5.000	2	1	1	1,5	1,50	2,5	2,50
9.	1:2.500	1	0,5	0,5	0,75	0,75	1,25	1,25
10.	1:1.000	0,4	0,2	0,2	0,3	0,30	0,5	0,50

Will qualify if Circular Error (CE90) and Linear Error (LE90) get a confidence level of 90% or not more than the accuracy that has been determined according to the scale of the resulting image.

2.7. Tools and Materials

Tools and materials used in this research:

1.Hardware
- a) Laptop
- b) UAV Fixed Wings
- c) Trimble R8s Geodetic GPS
- d) Camera
- e) Handheld GPS
- f) Tie point tarpaulin (pre-mark)

2.Software
- a) Agisoft Metashape Professional 64bit
- b) Google Earth Pro
- c) Global Mapper 18.0
- d) ArcGIS 10.7
- e) Mission Planner
- f) Microsoft Office 2010 and Microsoft Excel 2010

2.8. Model and Design

The model and design carried out in this study are as follows:

1. Photogrammetric data acquisition results and Ground Control Point (GCP)
2. Results of Geometry Accuracy Analysis Based on Perka BIG No.15 (2014)
3. Modeling of Digital Surface Model (DSM) and Digital Terrain Model (DTM)
4. Abrasion orthophoto map of Teluk Papal Village
5. Abrasion topography map of Teluk Papal Village
6. 3D contour map of Teluk Papal Village abrasion

2.9. Data Collection and Analysis Techniques

Data collection and analysis techniques must be taken in research to answer the problems contained in the scope and limits of the problems that have been determined. The stages that must be carried out in conducting this research are as follows: Preparatory stages

1. Preparation Stage
2. Data Collection
3. Data Analysis

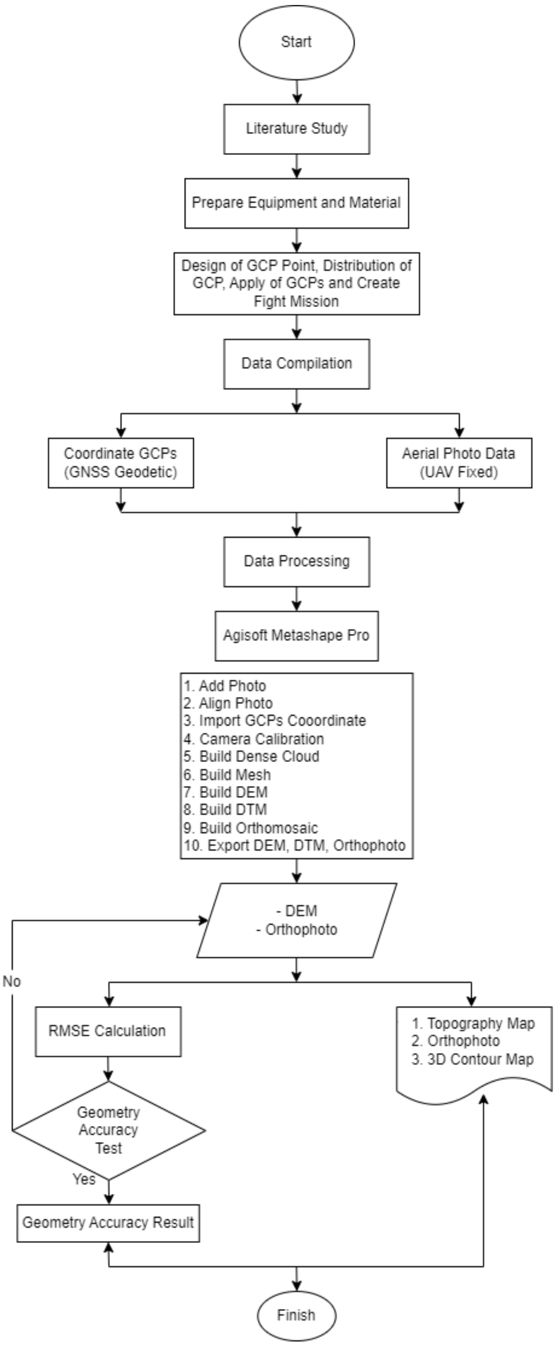

Fig 3. Research Flow Chart

3. Results and Discussion

This section explains in detail the research conducted, including the research location, the data used, and the methodology applied.

3.1. Photogrammetric Data

Photogrammetric data acquisition using UAV Fixed wings produced a total of 536 photos. Of the total photos, several photos were not optimal when acquiring aerial photo data. Therefore, researchers checked the entire data and selected unusable photo data. The results of the data elimination process were obtained from as many as 534 photos, which were used for processing.

3.2. Trimble 8s Geodetic GPS Data

Acquisition of ground control points (GCP), The process of acquiring ground control points requires an observation time of ± 10 minutes for one observation point. GCP result data is obtained in Table 1.

Table 2. Geodetic GPS GCP data

Point	Easting (m)	Northing (m)	Altitude (m)
BM_Pmntrip	197860.817	171841.175	3.635
GCP 1	197891.486	171861.053	3.986
GCP 2	198294.183	171609.069	4.119
GCP 3	198657.138	171686.190	4.136
GCP 4	199041.553	171785.883	4.599
GCP 5	199409.304	171704.830	3.850
GCP 6	196994.902	171982.488	3.991

Table 2 is the value of Ground Control Point data acquisition in the coastal land area of Teluk Papal Village, which is used to correct geometry and elevation data in photogrammetry to produce high orthophoto accuracy data. The observation method used in this research is the Real Time Kinematic (RTK) observation of the Indonesia Continuously Operating Reference Station (Ina-Cors) system. To find out the distribution of GCP control points can be seen in Figure 4.

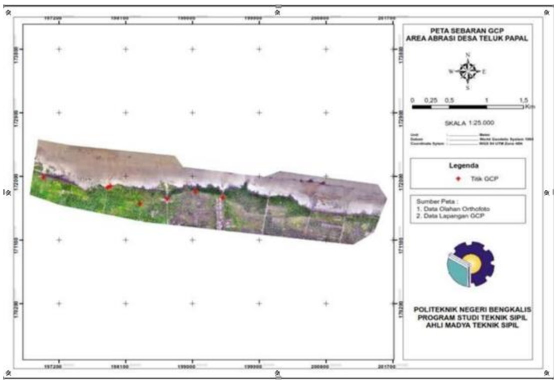

Fig 4. Distribution Map of Ground Control Points on Orthophoto

3.3. Data Processing

Data processing is carried out to combine aerial photography data with ground control point (GCP) data to provide detailed information on the topography of the Teluk Papal Village Coast. At this stage, the photo data is processed using Agisoft Metashape software. The steps of processing aerial photography data using Agisoft Metashape software are described as follows:

1. Add Photos
2. Align Photos
3. Import GCP Coordinates and Identify GCP Points
4. Build Dense Clouds Point
5. Build Mesh
6. Build Digital Elevation Model (DEM)

Digital Elevation Model is a digital terrain model in raster or grid format. From DEM data, elevation information such as cut and fill can be derived for other modeling. There are two terminologies related to DEM: DSM (Digital Surface Model) and DTM (Digital Terrain Model).

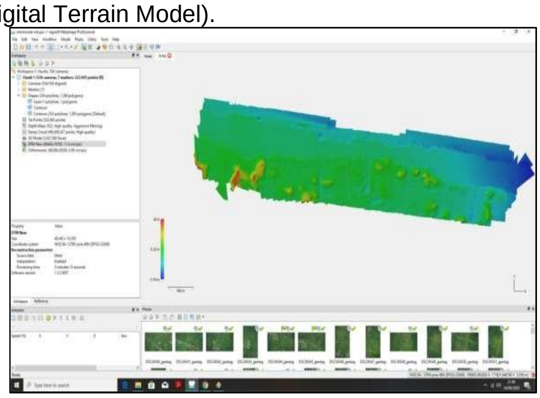

Fig 5. Digital Elevation Model (DEM)

3.4. Report Results from Processing Using Agisoft Software

The results of survey data obtained from processing using Agisoft Software are as follows :

- A total of 536 photos are included, after filtering, a total of 534 photos were obtained.
- Average height 320 m.
- The area is 4.31 Km^2.
- The total Tie Points are 522,693.
- Total Projections 1,665,780.
- Total Reprojection Error 0.785 Pix.
- Result in Ground Resolution 5.72 cm/pix.

3.5. Ground Sampling Distance (GSD) Result

GSD or ground sampling distance measures the pixel resolution of the results in aerial photographs, both aerial photographs with a metric camera and aerial photographs with a non metric camera. The GSD value is often used as a benchmark for quality resulting aerial photographs. By setting the GSD value, the user requires flying height and camera resolution with clear parameters. Determine the GSD value using the following formula :

$$GSD = \frac{Flight\ Height}{Focal\ Length} \times Pixel\ Size \quad (1)$$

The following is a valid table of shooting results in the field using Sonny A6000 series cameras processed with Agisoft Software :

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
ILCE-6000 (20mm)	6000 x 3376	20 mm	4.19 x 4.19 µm	Yes

Table 3. Camera Report

With the formula above, you can find the value.

$$GSD = \frac{320\ m}{20\ mm} \times 4.19\mu m = 6.701\ cm/pix$$

From the above results, it can be seen that the difference from the ground sampling distance value (GSD) the calculation results obtained are 6.701 cm/pix, while the values in the report agisoft software obtained are 5.72 cm/pix. These results have a difference of 0.981 cm/pix.

3.6. Horizontal Accuracy

Position accuracy testing refers to the difference in coordinates (X, Y) between the test points on the map and the actual test points on the ground surface.

Accuracy measurement uses root mean square error (RMSE). RMSE used to describe accuracy includes random error, and systematically, this RMSE can be calculated when the coordinate transformation is complete with the formula:

$$CE90 = 1.5175 \times RMSE_r \quad (2)$$

$$(RMSE)_r = \sqrt{((2 * ((RMSE)x)^2)} \quad (3)$$

Table 4. RMSEr and CE90 Calculation Results

Point	X Ortho (m)	X Field (m)	DX	DX^2	Y Ortho (m)	Y Field (m)	YX	YX^2	$DX^2 + YX^2$
GCP 1	197891.591	197891.486	0.105	0.011	171861.009	171861.053	-0.044	0.002	0.013
GCP 2	198293.746	198294.183	-0.437	0.191	171609.321	171609.069	0.252	0.064	0.255
GCP 3	198657.047	198657.138	-0.091	0.008	171686.249	171686.190	0.059	0.004	0.012
GCP 4	199041.580	199041.533	0.027	0.001	171785.623	171785.883	-0.260	0.068	0.068
GCP 5	199409.186	199409.304	-0.118	0.014	171704.880	171704.830	0.050	0.003	0.016
GCP 6	196994.813	196994.902	-0.089	0.008	171982.481	171982.488	-0.007	0.000	0.008
							∑		0.372
							Means		0.062
							RMSEr		0.1017
							CE90		0.1543

Based on table 4 shows the total horizontal RMSEr (X,Y) value worth 0.1017 m. The orthophoto accuracy value is the value (Circular Error) CE90 of 0.1543 for horizontal accuracy, which means that the position error orthophoto does not exceed the accuracy value with a 90% confidence level obtained by using the standard geometric accuracy in table 1.

3.7. Vertical Accuracy

RMSEz calculation results obtained from the calculation of the difference in value Z field and Z on DTM is 0.4095 m and the value is LE90 in this study is equal to 0.6757m. The DEM accuracy value is (Linear Error) LE90 for vertical accuracy, which means that the vertical error does not exceed the accuracy value with a confidence level of 90%. This RMSE can be calculated when the coordinate transformation is complete with the formula:

$$LE90 = 1.6499 \times RMSE_z \quad (4)$$

Table 5. RMSEz and LE90 Calculation Results

Point	Z DTM (m)	Z Field (m)	(DX)	DX^2
GCP 1	3.811	3.986	-0.175	0.031
GCP 2	3.619	4.119	-0.500	0.250
GCP 3	2.778	4.136	-1.358	1.844
GCP 4	3.122	4.599	-1.477	2.182
GCP 5	2.534	3.850	-1.316	1.732
GCP 6	3.979	3.991	-0.012	0.000
		∑		6.038
		Means		1.006
		RMSEz		0.4095
		LE90		0.1543

3.8. Results of Geometry Accuracy Analysis Based on Perka BIG No.15 (2014)

The accuracy of the map is based on the regulation of the Head of the Geospatial Information Agency (BIG), each map generated using aerial photo data has map class accuracy value. The accuracy of the map class can be known by calculates CE90 and LE90 values, CE90 values for horizontal precision and LE90 for vertical accuracy. After knowing the value of CE90 and LE90 Of course, it can be done by dividing the map accuracy class at a specific scale.

The accuracy of the 1:2500 Scale Map is as follows:

Table 6. CE90 and LE90 Test values Scale

Accuracy	CE Test Results and LE 90	Accuracy Map Scale 1:2500		
		Class 1	Class 2	Class 3
Horizontal	0.154	0.5	0.75	1.25
Vertical	0.676	0.5	0.75	1.25

It can be concluded in table 6 that the results of the CE90 and LE90 tests are known included in the map scale of 1:2500 with horizontal accuracy of class 1 and vertical accuracy in class 2.

3.9. Orthographic Map of Abrasion in Teluk Papal Village

Orthophoto maps are the results obtained from shooting aerial photographs using unmanned vehicles. Orthophoto maps are produced after several processes, including in-camera orientation correction, out-of-camera orientation correction, transforming model coordinates into ground coordinates, and making aerial photo mosaics. Making map layouts using ArcGIS 10.7 Software on the Universal Transverse Mercator Zone 48North (UTM 48N) coordinate system: map information, grid, map source, and other information as in making maps in general.

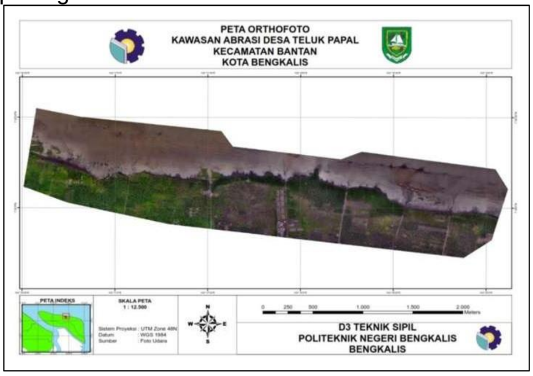

Fig 6. Orthophoto Map of Abrasion Area of Teluk Papal Village

3.10. Abrasion Topography Map of Teluk Papal Village

Topographic map results are obtained by processing from the Agisoft Metashape application to produce Digital Terrain Model (DTM) data. The process carried out to produce DTM data is the result of Ground classification and extracting areas that contain information, such as buildings and trees around aerial photographs, after generating data to produce a Digital Terrain Model (DTM) in the form of information on the state of land contours in the abrasion area of Teluk Papal Village.

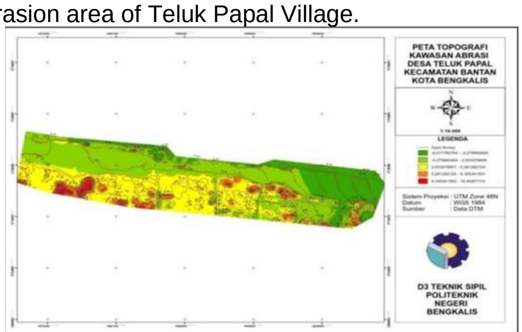

Fig 7. Topography Map of Abrasion Area of Teluk Papal Village

Topographic maps classified with Agisoft Metashape Profesional software can be displayed as ten contour profiles in the land area towards the sea. Teluk Papal Village.

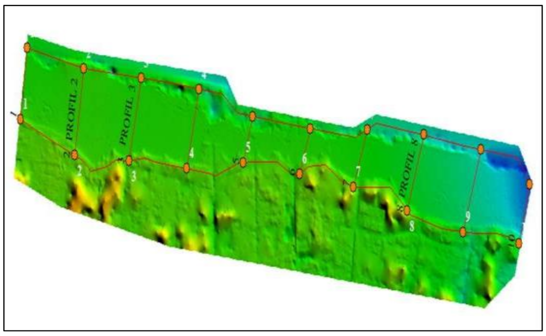

Fig 8. Profile division

The profile data shows that the Digital Terrain Model (DTM) data generated from the extraction process has data quality close to the land's actual topography.

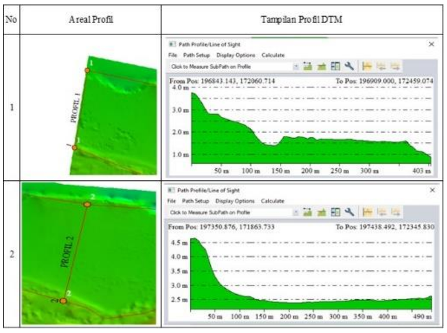

Fig 9. Cross Section of profile 2

3.11. DSM Export Results

In processing aerial photos using Agisoft Metashape Professional software, geometry formation is also carried out, which will produce DSM. The following will show the results of the build geometry that produces DSM.

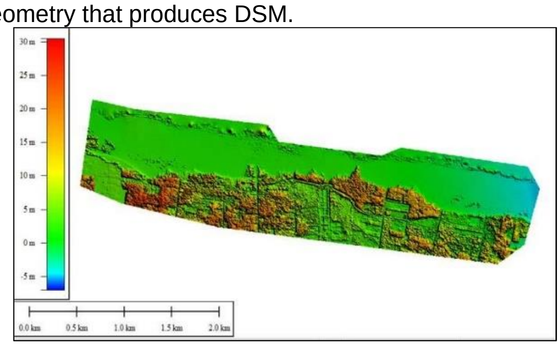

Fig 10. DSM Result

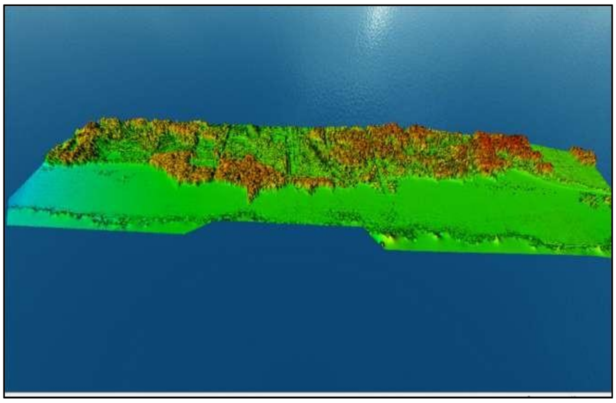

Fig 11. 3D DSM Result

Figures 9 and 10 show that the Digital Surface Model (DSM) data generated from the extraction process has data quality that is close to the topography of the land and the projections on the actual land.

3.12. 3D Contour of Abrasion of Teluk Papal Village

In obtaining 3D contour data, the data that must be prepared is contour data with elevation values with DTM data. Furthermore, the two data will be overlaid using arc scene software to generate the appearance of a 3D map.

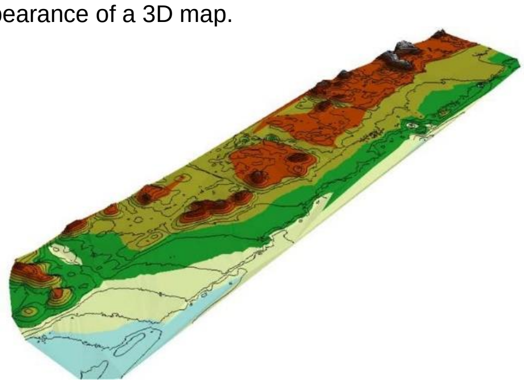

Fig 12. 3D Coastal Village of Teluk Papal

4. Conclusions and Suggestions

After conducting the research, there are conclusions from the author as follows:

1. Unmanned Aerial Vehicle (UAV) technology can be utilized to map an area of ± 400 hectares with a single flight of ± 350 hectares, depending on the battery capacity and size of the UAV. Data acquisition is carried out for four days, so using this technology will save time, energy, and costs.
2. Digital photogrammetric processing utilizing 6 GCPs can be optimized for the study area with an area of ± 400 hectares and on a not-so-flat land contour area. This is evident from evaluating the accuracy of photogrammetric processing maps using Agisoft Metashape Software according to

the standards used. The 3D contour map generated through aerial photo acquisition provides 3D visualization information of the abrasion area of Teluk Papal Village using the ArcScene application.

3. The results of the calculation of vertical accuracy of DTM data have an RMSEz value of 0.4095 m and a LE90 value of 0.6757 m. The vertical accuracy value based on the standard accuracy of the RBI map in BIG regulation No.15 of 2014 meets the accuracy standards at a scale of 1:2500 class 2 with a maximum error not exceeding an error of 0.75m. Moreover, calculating the horizontal accuracy of Orthophoto data obtained an RMSEr accuracy value of 0.1017 m and a CE90 value of 0.1543 m. The value of orthophoto accuracy based on the standard accuracy of the RBI map in BIG regulation No.15 of 2014, the resulting orthophoto meets the accuracy standards at a scale of 1:2500 class 1 with a maximum error not exceeding an error of 0.5 m.

4.1. Suggestions

Based on this research, many shortcomings need to be considered. Suggestions that can be given from this research are as follows:

1. For better orthophoto quality and accuracy, GCP distribution of GCPs should be evenly distributed in the research area.
2. We recommend comparing with other tools in photogrammetric mapping because, in data processing for elevation, there is still an error with determining good elevation from processing with Agisoft Metashape Software.
3. Further research is recommended to use free checkpoints. Independent Control Point (ICP) aims to test the accuracy of GCP ground control points and the accuracy of geometric correction.
4. Further research is recommended to use the Arial Control Point (ACP) method, meaning that the aircraft as a rover is connected to the Base and does not need to use GCP as a reference coordinate point in the field.

5. Conflict of Interest Statement

The authors declare no conflict of interest in this research (The authors declare no competing interest).

Reference

Adam, Stuart M and Carol J.F., (2011). A survey of Unmanned Aerial Vehicle (UAV) usage for imagery collection in disaster research and management.

Abidin, H.Z., Jones, A., Kahar, J. (2011): Survei dengan GPS, PT. Pradnya Paramita: Jakarta.

Badan Informasi Geospasial Nomor 15 tahun 2014. 2014. “Peraturan Kepala Badan Informasi Geospasial Nomor 15 tahun 2014 tentang Pedoman Teknis Ketelitian Peta Dasar”. Cibinong : Badan Informasi Geospasial.

Bendea H., P. Boccardo. 2008. Low-cost UAV for post-disaster assessment.

IAPRS Proceedings, vol. XXXVII. ISSN 1682-1750. Beijing.

Irawan, L. (2012). photogrammetry rentang dekat atau close range photogrammetry. JurusanTeknik Geodesi, FTSPITB: Bandung.

Muklas. 2014. “Pembuatan Digital Surface Model (DSM) Dari Citra Foto UAV Menggunakan Agisoft Photoscan Profesional Versi 0.9”. Institut Teknologi Nasional Malang.

Micheletti, N., Chandler, J. H., & Lane, S. N. (2015). Structure from Motion (SfM) Photogrammetry. In British Society for Geomorphology Geomorphological Techniques (Vol. 2, Issue 2). www.photosynth.net

Octori, O., dan Cahyono A.B. Foto Udara menggunakan Wahana UAV Jenis Fix Wing. Institut Teknologi Sepuluh November. Surabaya. Jurusan Teknik Geomatika FTSP

Sutikno, S., Sandhyavitri, A., Haidar, M., & Yamamoto, K. (2017). Shoreline Change Analysis of Peat Soil Beach in Bengkalis Island Based on GIS and RS. *International Journal of Engineering and Technology*, *9*(3), 233–238. https://doi.org/10.7763/IJET.2017.V9.976

Wolf, P. R. (1993): Elemen Fotogrametri, Gadjah Mada University Press : Yogyakarta.