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Photogrammetry Technology by Using DJI Phantom 4 RTK in Batang Mahat, Lima Puluh Kota Regency West Sumatera

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Abstract
Technological developments in the field of engineering have been increasing rapidly. The use of geospatial information becomes one of the bases for decision-making related to planning, managing, and evaluating a field, especially in engineering, which includes the field of measurement and making topographic maps or Digital Elevation Model (DEM). High-resolution geospatial information can create a high-resolution Digital Elevation Model (DEM) map that can be very useful in making models or maps of flood-affected areas. This research will use the photogrammetry technology with DJI Phantom 4 RTK to create the DEM data of Batang Mahat located in Lima Puluh Kota Regency, West Sumatra Province. 28 flights at predetermined points had been carried out to measure the area of about 9 km2. All the results of photos captured by the drone will be imported to Agisoft Metashape 1.8.2 software to create the DEM data. The DEM was then compared with DEM data from DEMNAS and the measurement data of Batang Mahat by the SDABK office. The result shows that photogrammetry technology using DJI Phantom 4 RTK compared to measurement data and DEMNAS have a similar ground elevation but different river elevation. This is because the photogrammetry by using DJI Phantom 4 RTK is not equipped with LiDAR. An alternative to solve the problem is by combining the DEM data by DJI Phantom 4 RTK with data from terrestrial surveys. However, this method is quite expensive and ineffective in analyzing flood inundation compared to DEM data (8 m resolution) from DEMNAS.

Keywords: Photogrammetry, DEM, DJI Phantom RTK, UAV

Abstrak
Perkembangan teknologi di bidang engineering telah meningkat pesat. Pemanfaatan informasi geospasial menjadi salah satu dasar pengambilan keputusan terkait dengan perencanaan, pengelolaan, dan evaluasi suatu bidang khususnya bidang keteknikan yang meliputi bidang pengukuran dan pembuatan peta topografi atau *Digital Elevation Model* (DEM). Informasi geospasial beresolusi tinggi dapat membuat peta DEM beresolusi tinggi yang dapat sangat berguna dalam pembuatan model atau peta wilayah terdampak banjir. Penelitian ini akan menggunakan teknologi fotogrametri dengan DJI Phantom 4 RTK untuk membuat data DEM Batang Mahat yang terletak di Kabupaten Lima Puluh Kota, Provinsi Sumatera Barat. 28 penerbangan di titik-titik yang telah ditentukan telah dilakukan untuk mengukur luas area sekitar 9 km2. Semua hasil foto yang diambil oleh drone akan diimpor ke perangkat lunak Agisoft Metashape 1.8.2 untuk membuat data DEM. DEM tersebut kemudian dibandingkan dengan data DEM dari DEMNAS dan data pengukuran Batang Mahat oleh kantor SDABK. Hasil penelitian menunjukkan bahwa teknologi fotogrametri menggunakan DJI Phantom 4 RTK dibandingkan dengan data pengukuran dan DEMNAS memiliki elevasi tanah yang sama tetapi elevasi sungai berbeda. Hal ini dikarenakan fotogrametri dengan menggunakan DJI Phantom 4 RTK tidak dilengkapi dengan LiDAR. Alternatif untuk mengatasi masalah tersebut adalah dengan menggabungkan data DEM DJI Phantom 4 RTK dengan data dari survei terestrial. Namun, metode ini cukup mahal dan tidak efektif dalam menganalisis genangan banjir dibandingkan data DEM (resolusi 8 m) dari DEMNAS.

Kata kunci: Photogrammetry, DEM, DJI Phantom RTK.

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1. Introduction

Technological developments, especially in the field of engineering, have increased rapidly. One of these technologies is aerial imagery with Unmanned Aerial Vehicles (UAV)/drones, which are now widely used in engineering fields. The use of aerial imagery with UAV can generate geospatial information, which becomes one of the bases for decision-making related to planning, managing, and evaluating a field, especially in engineering including the field of measurement and making topographic maps [1]. For making Digital Elevation Model (DEM) maps or topographic maps, the use of UAVs using cameras is not as common as drones equipped with LIDAR (Light Detection and Ranging) and TLS (Terrestrial Laser Scanning) [2]. The technique used in making DEM maps using drone cameras is called photogrammetry. One of the UAVs that can create high-resolution geospatial information for photogrammetry is DJI Phantom 4 RTK (Real Time Kinematics). This UAV can measure elevation and provide high-resolution data, providing real-time and centimeter-level positioning data for improved accuracy on image metadata. DJI Phantom 4 RTK uses the direct georeferencing technique, which is an alternative way for the precise reconstruction of models framed within a given reference system eliminating the need to use any GCP [3]. A set of well-distributed Ground Control Points (GCPs) is usually needed to georeference the models. However, the survey of GCPs, generally performed using total stations, Global Navigation Satellite System (GNSS) receivers or TLS, which is a time-consuming task [4]. The use of onboard GNSS receiver used in Real-Time Kinematic (RTK), Network RTK (NRTK), or Post-Processing Kinematic (PPK) modes makes the use of direct georeferencing techniques with a centimeter-level accuracy of camera locations possible and enables the precise collection of the drone's position at the time of each capture [3],[5]. Therefore, such systems must promptly and accurately record the instant in which the image was captured, possibly in the same time reference of the GNSS data (typically GPS time) [2].

High-resolution geospatial information can create a high-resolution DEM map that can be very useful in making models or maps of flood-affected areas. By creating the flood affected areas the risks and costs of the hazard can be avoided and decreased by providing the public with accurate flood risk information, including the extent of inundation, to generate risk maps [6].

However, the availability of high-resolution DEM that can be accessed through the government website is only limited to 8 m resolution. Which, with this resolution the accuracy of DEM already good enough but to create the flood simulation or flood mapping it is necessary to have a higher resolution DEM.

Therefore, this research will use photogrammetry technology with DJI Phantom 4 RTK in Batang Mahat, located in Lima Puluh Kota Regency, West Sumatra Province. Batang Mahat in Lima Puluh Kota Regency administratively located in 2 (two) provinces and situated in 00°13′ – 00°25′ South Latitude and

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100°37′ – 100°56′ East Longitude. The upstream part of Batang Mahat is Pangkalan bridge in Lima Puluh Kota Regency, West Sumatra Province and the downstream part is the Koto Panjang hydropower weir intake (PLTA) in Kampar Regency, Riau Province. Batang Mahat has several tributaries, as shown in Figure 1. Namely, Batang Bulu Kasok and Batang Malagiri which also have a tributary namely Batang Samo. Batang Samo and Batang Malagiri often overflowed based on information from the community, which caused flooding in the Pangkalan area. This area was reported to be flooded in 1961, 1968, 1972, 1978, 1984, 1991, 1998, 2005, and 2017 [7], and the latest flood also occurred in 2019, 2020, and 2021.

The photogrammetry technology using DJI Phantom 4 RTK will be used to create a high-resolution DEM of the flood-affected areas of Batang Mahat. Then, the result will be compared with the DEM from the Government website (DEMNAS) and the measurement data of Batang Mahat conducted by the SDABK office.

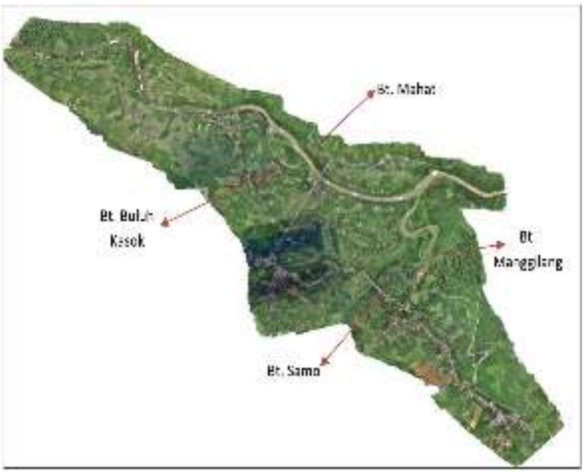

Figure 1. Batang Mahat and Its Tributaries

2. Methodology

To obtain DEM data covering the inundation area in Batang Mahat, the workflow of DJI Phantom 4 RTK can be seen as follows:

2.1. Mission Planning

It is necessary to create the flight plan before taking measurements in the field. Connect the Remote to the D-RTK 2 Mobile Station to begin creating the flight plan. Then, select plan and 2D photogrammetry. Create a boundary on the global mapper and save it in KML format to the SD card, then attach the SD card to the remote and turn it on. Choose Settings, SD Card, and Import KML Boundary. Select the boundary where the flight path will be formed after importing it. After that, configure the flight parameters, such as the drone's altitude and speed, camera settings, etc. Then select return to home when the mission is complete. The flight plan for this study area can be seen in Figure 2. By this flight plan, the drone will carry out 28 flights at predetermined points and cover an area of about 9.08 km2.

Figure 2. The Flight Plan of Flood Inundation area of Batang Mahat.

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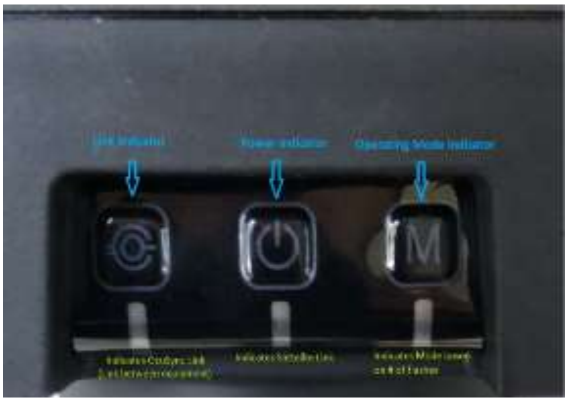
2.2. Field Operation

For the field operation, several steps need to follow:

1. Setting Up The DJI Base Station.
   DJI Phantom 4 RTK uses D-RTK 2 Mobile Station as a base station which provides real-time differential data to the drone and forms an accurate surveying solution or acquires precise location coordinates when used as an RTK rover. The base station must be installed in an area free of obstructions, with sufficient direct access to the sky and minimal interference (away from buildings, trees, cars, power lines, etc.). It is not necessary to install the base station over a prominent location. As shown in Figure 3. (b), the base station has three buttons/indicator lights. After determining a suitable location, press the middle button to turn on the DJI base station and wait for the system to initialize. There will be three lights once you have been initialized. The "link indicator" and "power indicator" should be red and green, respectively. The "operating mode indicator" should be set to Mode 1, represented by a single slow flash. If it is already, no further action is required. However, if it is flashing 2x rapidly, 3x rapidly, or not at all, press and hold the mode button until it changes.

(a)



(b)

Figure 3. (a) D-RTK 2 Mobile Station (b) The Base Station Buttons/Indicator Lights.

2. Setting Up the Controller.
   Next, power on the controller (See Figure 4.). The controller must be connected to the mobile station. Tap "fly" on the controller's main screen, then open the "RTK" menu from the general settings menu in the upper right-hand corner of the screen. Check that RTK is turned on. Select "D-RTK2 Mobile Station" as the RTK service type. The unit should automatically connect. If it's not, click the "linking" button at the bottom and press the link button on the mobile station; it should blink red and green rapidly to indicate linking. When linking is complete, both the remote controller and the Link indicator

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should be solid green. If the indicator is flashing green, this means it is connected but has a less than optimal OcuSync signal.

Figure 4. DJI Phantom 4 RTK Remote Controller

3. Setting Up the Aircraft
   Next, turn on the aircraft (see Figure 5.). If the aircraft does not automatically link, it must connect manually. To reconnect the remote to the aircraft, choose "link to aircraft" from the pop-up menu or tap the "?" button next to the prompt that says "aircraft has been disconnected." If neither of these options works, try connecting the aircraft via the RC menu page (denoted by the controller icon), which will disconnect the D-RTK 2 mobile station. Return to the RTK page and select the "D-RTK 2 mobile station" for service again, and it should reconnect without de-linking the aircraft. After connecting the aircraft, it may throw errors and claim it cannot take off. Let the system sort itself out for a minute or two; do not turn off the aircraft or base station during this time. Wait for the status bar to turn green and for the RTK status on the HUD to display "RTK FIX" on the top status bar.
   Make sure to double-check the controller's status and the base's status lights to ensure connections one last time before mission commencement.

Figure 5. DJI Phantom 4 RTK Aircraft

4. Fly the Mission
   Once all systems are set up, all indicators are green, and the desired mission created on the flight plan is selected, the mission can be started. Note that the status bar should stay green throughout the flight, and the RTK signal lock should be strong and also stay green.

2.3. Data Processing to Create the DEM

To proceed with the DEM data, all the results of photos captured by the drone will be imported and processed to Agisoft Metashape 1.8.2 software [8]. Images from the drone are imported first and included into one project. Then perform the process of aligning photos to produce a 3D initial model. The next step is to create Dense Point Clouds. Dense Point Clouds are collections of high points in the thousands to millions of points generated by aerial photogrammetric processing. The next process is Build Mesh, one of the main outputs of aerial photo processing in Agisoft Metashape.

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3. Result and Discussion

Photogrammetry technology with DJI Phantom 4 RTK in Batang Mahat was carried out for three days, from February 5 to February 7, 2022. The data collection results for three days obtained flight data covering an area of 9.26 km2 with a number of images of about 9,345 pictures. The result of survey data and DEM generated from Agisoft Metashape is seen in Table 1. and Figure 6.

Table 1. Survey Data Generated from Agisoft Metashape.

Survey Data	Result
Number of images	9,345
Flying altitude	133 m
Ground resolution	3.48 cm/pix
Coverage area	9.26 km²
Camera stations	9,345
Tie points	9,648,012
Projections	29,564,334
Reprojection error	0.875 pix
DEM resolution	13.90 cm/pix

Source: Agisoft Metashape Processing Report

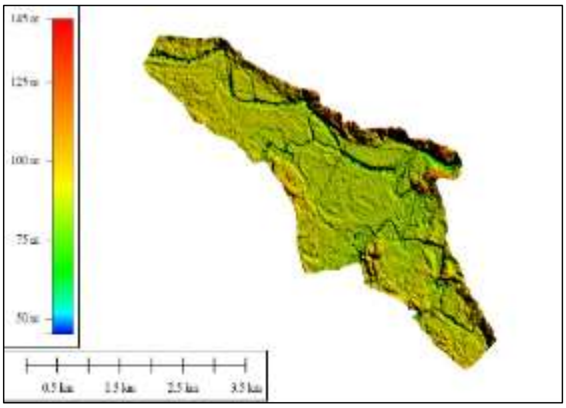

Figure 6. DEM data by using the DJI Phantom 4 RTK generated from Agisoft Metashape.

The camera location and error estimate of DJI Phantom 4 RTK generated from Agisoft Metashape can be seen in Figure 7. and Table 2.

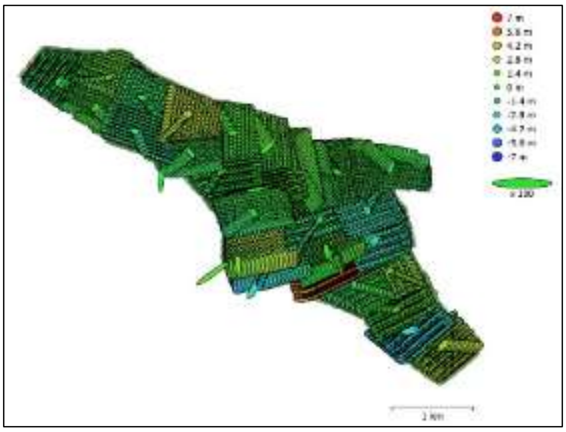

Figure 7. Camera Location and Error estimate.

Based on Figure 7, Z error is represented by ellipse color. Ellipse shapes represent X and Y errors. Estimated camera locations are marked with a black dot. This also shows the flight route and camera location identical to the flight plan.

Table 2. Average camera location error.

X error (m)	Y error (m)	Z error (m)	XY error (m)	Total error (m)
0.93547	0.858935	1.87627	1.26999	2.26567

Source: Agisoft Metashape Processing Report

The vertical error of the DEM that has been obtained is calculated. It produces the RMSE (Root Mean Square Error) and LE (Linear Error) values to be used as a reference which are then grouped according to the map scale classification based on SNI 8202:2019 (Table 3) and ASPRS 2014 (Table 4).

RMSE is the square root of the average difference in the square between the coordinate data values and the coordinate values from an independent source with higher accuracy. If the RMSE value has been obtained, the calculation can be continued to find the LE value. RMSE and LE values can be calculated by using formulas 1 and 2 below [9]:

$$RMSEz = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\Delta zi^2} \qquad 1)$$

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$$LE_{90} = 1{,}6499 \text{ x RMSEz} \qquad 2)$$

Based on Table 2, the RMSE value is calculated automatically from Agisoft Metashape. The result shows that the vertical error of DJI Phantom 4 RTK is 1.88 m. Then, the LE value is 3.096. Based on map scale classification according to Table 3 and Table 4, the DJI Phantom 4 RTK photogrammetry processing results can produce a 1:10.000 class 2 scale map. In general, the accuracy of the maps produced by DEM from aerial photography is quite good or is included in the minimum map accuracy standard according to SNI 82020: 2019 and ASPRS 2014.

This research analyzes the error in elevation result of DEM from DJI Phantom 4 RTK and compares it to measurement data from the SDABK office and DEM from DEMNAS. The location that becomes the benchmark in comparing the three data is cross-sections B.19 and B.18 in the measurement data. From each cross-section of measurement data, three points of elevation are compared: the right side of the cross section (ground elevation), the lowest elevation of river banks, and the left side of the cross-section (ground elevation).

Table 3. Map Scale Classification from SNI 8202:2019 [10].

No	Scale	Map Accuracy	
		Class 1 (LE 90)	Class 2 (LE 90)
1	1: 1.000.000	200	400
2	1: 500.000	100	200
3	1: 250.000	50	100
4	1: 100.000	20	40
5	1: 50.000	10	20
6	1: 25.000	5	10
7	1: 10.000	2	4
8	1: 5.000	1	2
9	1: 2.500	0,5	1
10	1: 1.000	0,2	0,4

Table 4. Map Scale Classification from ASPRS 2014 [11].

Vertical Accuracy Class	Absolute Accuracy		Map Scale
	NVA at 95% Confidence Level (cm)	RMSEz (cm)	
8,33	≤16,33	≤4,165	1: 500
16,67	≤32,67	≤8,335	1: 1.000
33,33	≤65,33	≤16,665	1: 2.000
83,33	≤163,33	≤41,665	1: 5.000
166,67	≤326,67	≤83,335	1: 10.000

The results of measurement data from the SDABK Office can be seen in Figures 8-10, DEM data from DEMNAS can be seen in Figures 11-13, and DEM data from DJI Phantom 4 RTK can be seen in Figures 14-16.

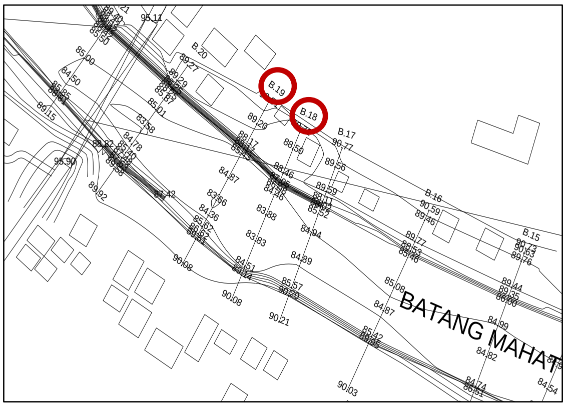

Figure 8. Detail Situation of Batang Mahat Measurement Data. Source: SDABK Office of West Sumatera Province.

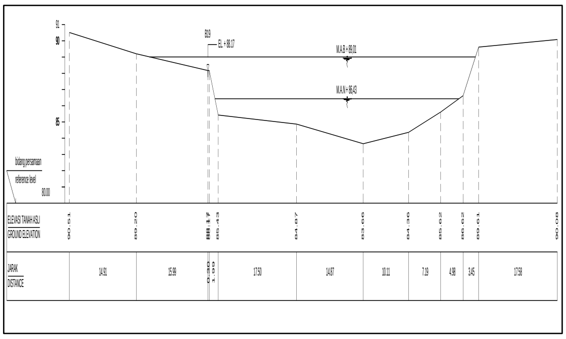

Figure 9. Cross Section B.19 of Batang Mahat Measurement Data. Source: SDABK Office of West Sumatera Province.

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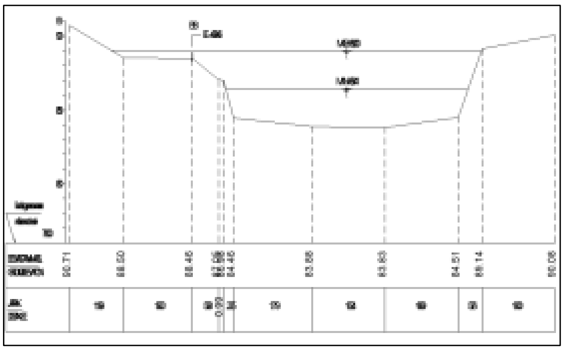

Figure 10. Cross Section B.18 of Batang Mahat Measurement Data. Source: SDABK Office of West Sumatera Province.

From Figures 8-10 elevations of cross section B.19 are 90.08 m (right), 83.66 m (lowest), 90.51 m (left), and cross section B.18 are 90.08 m (right), 83.83 m (lowest), 90.71 m (left).

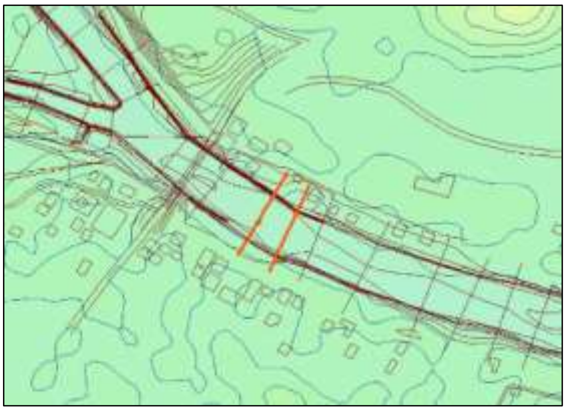

Figure 11. DEM Data from DEMNAS

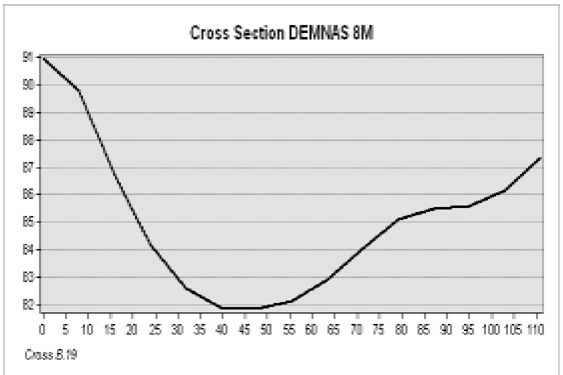

Figure 12. Cross Section B.19 DEM Data from DEMNAS.

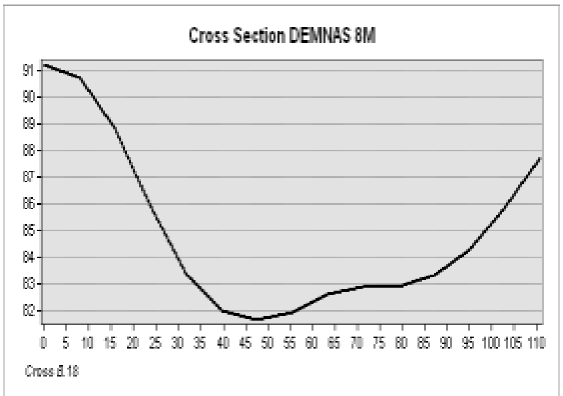

Figure 13. Cross Section B.18 DEM Data from DEMNAS.

From Figures 11-13 elevations of cross section B.19 are 87.5 m (right), 82 m (lowest), 91 m (left), and cross section B.18 are 87.3 m (right), 81.5 m (lowest), 91 m (left).

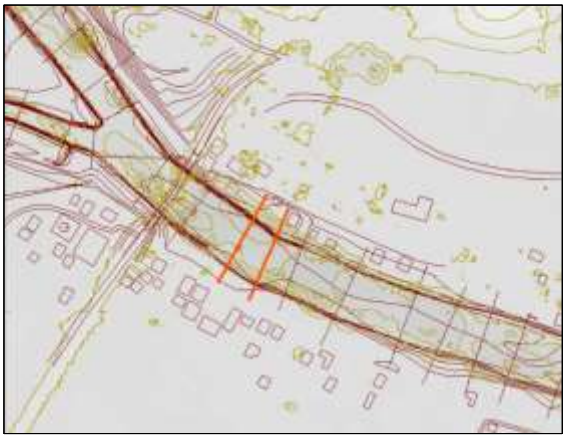

Figure 14. DEM Data from DJI Phantom 4 RTK.

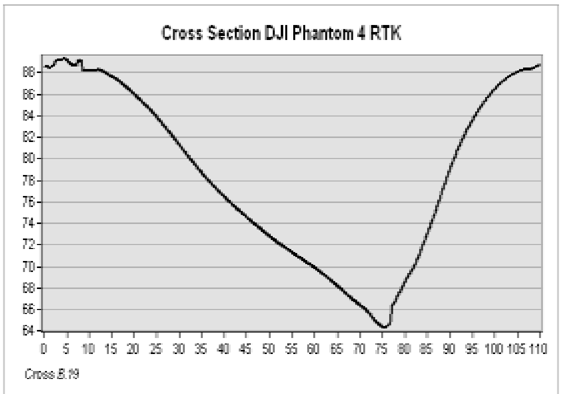

Figure 15. Cross Section B.19 DEM Data from DJI Phantom 4 RTK.

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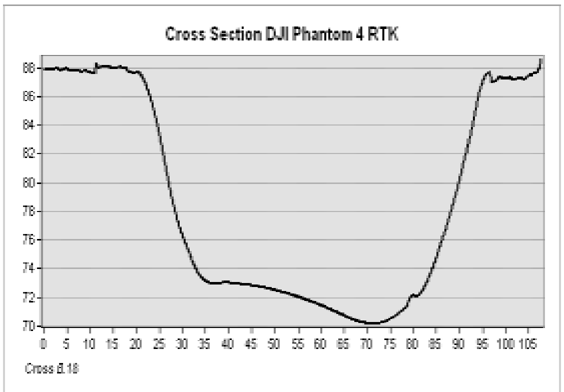

Figure 16. Cross Section B.18 DEM Data from DJI Phantom 4 RTK.

From Figures 13-15 elevations of cross-section B.19 are 89 m (right), 64 m (lowest), 89 m (left), and cross-section B.18 are 89 m (right), 70 m (lowest), 88 m (left). The summary of each elevation can be seen in Table 5.

Table 5. Elevation Summary of Measurement Data, DEMNAS, and DJI Phantom 4 RTK.

Cross Section	Elv. Measurement	Elv. DEMNAS	Elv. DJI Ph.4 RTK
B.19	90.08 (right) 83.66 (low) 90.51 (left)	87.5 (right) 82 (lowest) 91 (left)	89 (right) 64 (lowest) 89 (left)
B.18	90.08 (right) 83.83 (low) 90.71 (left)	87.3 (right) 81.5 (lowest) 91 (left)	89 (right) 70 (lowest) 88 (left)

Based on Table 6, it can be seen that the results of the three data for ground elevation show values that are almost the same. However, for river elevations, the results are different. The river elevation value from the DEMNAS data is closer to the value from the measurement data, while the elevation value from the DJI data results is quite different. For the ground elevation, the different results can be caused by the filtering method in Agisoft Metashape that can remove the surface elevation, such as vegetation and building. This method is dependend on what quality the DEM wants to create. The higher the quality of the selected dem, the longer it will take to process and the larger the file. In this research, the quality of the DEM is medium, the size of the DEM is 2.09 Gb, and it takes about 16 hours to proceed with the data. For the result of riverbed elevation, the error or the massive difference in DEM from DJI Phantom 4 RTK occurs because the photogrammetry using DJI Phantom 4 RTK is not equipped with LiDAR (Light Detection and Ranging). The LiDAR which can be used for riverbed measurements is a lidar specifically for bathymetry measurements. Where of course, the bathymetry measurement of the riverbed takes more time and costs. Latifa et.al [12] using LiDAR to create the DTM data of Gelam Timur River in Jambi. The LiDAR used in Latifa et al. [12] research only emits infrared waves and not for bathymetry measurements, so the river depth on the DTM using LiDAR is not completely penetrated by infrared waves, and the river depth shown in the DTM is only around 17 m. Infrared waves measure land topography on the earth's surface, not for waters. Because water will absorb NIR waves, the reflection received by the sensor will be very little [12]. Photos taken by drones cannot reach the riverbed.

However, Lejot et al. [13] tried to model the riverbed using photogrammetric drones. The method is based on the relationship between sunlight (sunlight wave), water surface, and light reflection from the riverbed. However, this method will experience problems in murky rivers, such as Indonesia, where sunlight cannot penetrate the riverbed.

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4. Conclusions

Photogrammetry using DJI Phantom 4 RTK can be more effective in terms of time, effort, and cost than terrestrial surveys and LIDAR. The result of the ground elevation of photogrammetry technology using DJI Phantom 4 RTK shows a similar value to the measurement data. Also, it can produce a 1:10.000 class 2 scale map where the accuracy of the maps is quite good or is included in the minimum map accuracy standard according to SNI 82020: 2019 and ASPRS 2014. However, the result of riverbed elevation from this technology cannot be used for flood analysis because the error is quite big from measurement data. Another alternative that can solve the problem is combining the data from terrestrial surveys and overlying it with the DEM data generated from photogrammetry using DJI Phantom 4 RTK. However, this method will also cost much and be ineffective because two measurement methods are carried out simultaneously. Therefore, the best and most effective data to analyze flood inundation is to use DEM data available on the government website (DEMNAS), where the available resolution is good enough (the highest is 8 m resolution).

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