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Mapping of Catchment's Drainage Networks in Bakri Muar, Johor Using Unmanned Aerial Vehicle

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Abstract: In a advance technology, unmanned aerial vehicle (UAV) can be used to monitor and mapping the recent condition of drainage networks. Recent UAV model are more user friendly for a study with low operational cost. In this study, the problem of this study is the tidal occur at downstream of Muar River and heavy rain at the upstream perhaps one of the reasons this flash flood could happen. Sungai Terap as the tributary of Sungai Muar need to channel the storm water into the retention pond. The most nearest pond connected by this river is located near the upstream of Sungai Terap at Parit Keling. Inadequate profile of river may result overflowing water from the river. Hence by conducting this study which is focused with three main of objective including capture and collect aerial photograph image using unmanned aerial vehicle, process and combine data in form of image using software to classify the drainage condition and last produce a map of drainage networks around catchment area in Bakri Muar, the solution for the problem can be suggested. The study area is focused on the rainwater catchment area in Bukit Bakri, Muar Johor, to be exact along the Sungai Terap which has been hit by floods recently. By applying the latest technology, which is UAV mapping, the raw data in the form of pictures obtained from unmanned aerial vehicles will be processed using the Agisoft Methashape application and further strengthened with additional applications such as QGIS. As a result, and orthomosaic and DEM was produced and analyze. In this current study the accuracy of the project is set to be 0.005m and error generated by this software is ±0.00135m. For DEM analysis, it can see the trend of elevation of UAV mapping and from Google Earth showing same behavior. From the result, an effort can be made to the authorities to implement the recommendations that have been made to benefit the community in the area.

Keywords: Unmanned Aerial Vehicle, UAV Mapping, Digital Elevation Mapping, Flood Study

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1. Introduction

Flash flood is natural disaster that become common in South East Asia recently. Climate changes involve in rising of rainfall volume over period in monsoon season. Flash flood are being called because of the duration of flood which is dramatically instant. According to Korotky et al, (2015) water could rise in a meter only in 10 to 30 minutes [1]. This phenomenon resulting in route shutdown and loss of property. Contradict from flash flood, a normal flood also can happen from a non-stop heavy rain over a day. June 2020 witnessed the flash flood incident in Bakri Muar. Heavy rain starting at 5 am continued throughout the day causing water to rise along the Jalan Bakri Batu 9, Jalan Bakri Batu 10, Jalan Kangkar Senangar and Jalan Dato Haji Kosai causing the route to be cut off.

In a advance technology, unmanned aerial vehicle (UAV) can be used to monitor and mapping the recent condition of drainage networks. Recent UAV model are more user friendly for a study with low operational cost. Monitoring, observation and remote sensing is some of the examples that can be done by UAV. The data from this study could help in finding a solution of flash flood on the area. A topography map can be produced to study the influence of downstream and upstream condition of Muar River. This geographic interface data can provide additional information in a flood barrier study. A predetermined flight path over hotspot area is design by considering location of drainage networks, sluice location and catchment pond. Site visit for a preflight preparation will confirm the environment condition. Data which is in form of image then will be process on the post-flight procedure using a software. A certain software is being identified to be used in this study.

Hence, the used of UAV in this study may be very relevant alternative and cost friendly. The result also can be analyzed in a short period to provide fast result. A solution can be proposed by this map to the local authority or responsible agency. Besides this map from the study can be used in a further study.

1.1 Problem statement

The tidal occur at downstream of Muar River and heavy rain at the upstream perhaps one of the reasons this flash flood could happen. The location of Bakri which is at the center between the stream can be the hotspot for this study. A recent flood event also happens in this radius of location. Sungai Terap as the tributary of Sungai Muar need to channel the storm water into the retention pond. The nearest pond connected by this river is located near the upstream of Sungai Terap at Parit Keling. Inadequate profile of river may result overflowing water from the river. Drainage network change over period due to natural phenomenon. Besides, many factors can influence the flow of drainage include waste dump over Sungai Terap and rapid construction development around the area. The aerial photogrammetry study to observe and monitoring this drainage networks must be conducted. The forecast mentioned before may be proof by monitoring and observing drainage networks over a hotspot area.

The exact location of problematic drainage networks can be determined by analyzing the result map from this study. The existence of recent aerial mapping is needed to analyze the drainage networks. The conventional online mapping is not detailed enough to extract the data of geographical interface. By using UAV, more focus and detailed image can be obtained and process to form a map of recent drainage networks around the hotspot area.

In order to form a solution for the problem of flood around the area, the map of detailed geographical information must be made. By adapting recent technology such as UAV, detailed map can be produced with accuracy and up to date information. From all of this information, further study can produce a solution thus preventing this flood phenomenon happen again.

2. Literature Review

A detailed and comprehensive understanding regarding flood disaster, drainage network, unmanned aerial vehicle, post-processing software and formatted map will be covered. The theorical framework functions as a support for this study to ensure the credibility and accuracy of the result. Besides, literature reviews provide deep exploration of the important step for designing pre-flight phase

and post-flight phase. The information from previous study can be used to draft and to see the bigger picture of using UAV in mapping purpose.

2.1 Using unmanned aerial vehicle for mapping

In a study of Tziavou et al., (2018), For at least a decade, UAVs have been used in civil engineering, focusing primarily on structural visual monitoring, geological surveys and site observation, especially in cases where rapid assessment is needed, such as after a natural disaster [2]. Compared to traditional techniques, unmanned aerial vehicles (UAVs) allow effective surveillance of large areas of land and existing infrastructure within a very short time, a desirable feature, particularly in cases where immediate intervention is needed [3].

Remondino et al., (2012) mention in their study, applications such as topographic surveys, photogrammetric solutions, progress tracking, disaster analysis, archaeological mapping, agriculture and forestry are certainly the key uses of UAVs in 3-dimensional (3D) mapping, visualization and modelling [4]. As for now, its two major carriers, satellite and manned aircraft, UAV and UAV, have outgrown their capability [5]. Over the years, UAVs have been used to maximize the use of many other features. Wildlife body heat monitoring mechanism [6] water mapping including marine fauna observatory [7] and vegetation remote sensing (Krishna, 2016) including aquatic remote sensing are among the roles of UAV monitoring bodies and agriculture [9].

As referred to Remondino et al., (2012) as referred to as an unmanned aerial vehicle, this vehicle is operated by a ground pilot station, allowing it non-human flight operation. In geomatic cultures, the term UAV is widely used [4], but in many other types of unmanned aerial vehicles such as Remotely Pilot Vehicle (RPV), Remotely Operation Aircraft (ROA) and Remote Control Helicopter (RC), each of which is called in the scale, weight, endurance and flying altitude categories.

As reported by [10], UAV can provide more accurate data than any other form, as the lowest height that can be flown is 10m and, in particular, along the hard-to-reach coastal region. This method will improve the inspection of coastal changes in Malaysia. It consumes less time than normal inspection and is very effective in terms of productivity. A comparison between structural orthophoto-based geological maps and one generated using traditional techniques indicated that the amount of precision is the same and the spending time is at least 5 times lower when using a UAV [2].

2.2 The Muar River

The Muar River sits on the western coast of the Malaysian Peninsula, neighboring the states of Negeri Sembilan and Pahang. Its catchment has consistently been affected by sustained, major floods, which have triggered extensive damage and impacts on people, industries and infrastructure [11]; the disruptions have been compounded by severe rapid changes over the last decade, which have changed flow regimes and flood processes. Significant previous flood disasters occurred in 2006, 2007, 2011, and 2015, leading to the relocation of tens of thousands of local people in the Muar catchment alone. Along all Malaysia, an estimated 5 percent of the country is at risk of floods [12].

2.3 Flash flood criteria

According to Tziavou et al, (2017) flash floods are becoming a advective storm-related event that causes the most fatalities per year. In the case of flooding, the chances of a flash flood are greatly impacted by factors such as historical rainfall, the extent of the reservoir, the topography of the watershed and the amount of residential usage within the watershed. In order for a flash flood to occur, heavy precipitation must occur in a region with adequate hydrological conditions in place.

The basic explanation of flash floods is "too much water, too little time" [1]. While the previous one is definitely descriptive, it also underlines the difficulty of reaching a description that will serve all interests. For instance, what do we imply when we say "too much water" or "too little time" The

response may vary from geographical location to a variety of hydrological, geographical and meteorological factors. In general, the concept of flash flooding includes high-speed flows that arise within a brief period of time, the study said. Flash floods are distinct from slow-rising floods, as flash floods appear to develop at the same time-and spatial scales as extreme precipitation, leading to fast warning and reaction times. Slow-rise floods cause considerable damage annually in the United States, but flash floods cause almost all of the flood-related deaths.

3. Methodology

This chapter will clarify the method and mapping process of catchment's drainage networks. For overall, this study is divided into three phase which is include pre-flight planning phase, data collection phase and post-processing phase. To guarantee the smoothness of the study, details step and requirement must be systematically arranged. For instance, the pre-flight planning phase must consider the authority permission, weather forecast and many more detailed particular that will be stated more in this chapter. Figure 3.1 below show the overall process of this study including where the objective of this study achieved marked with red numbered.

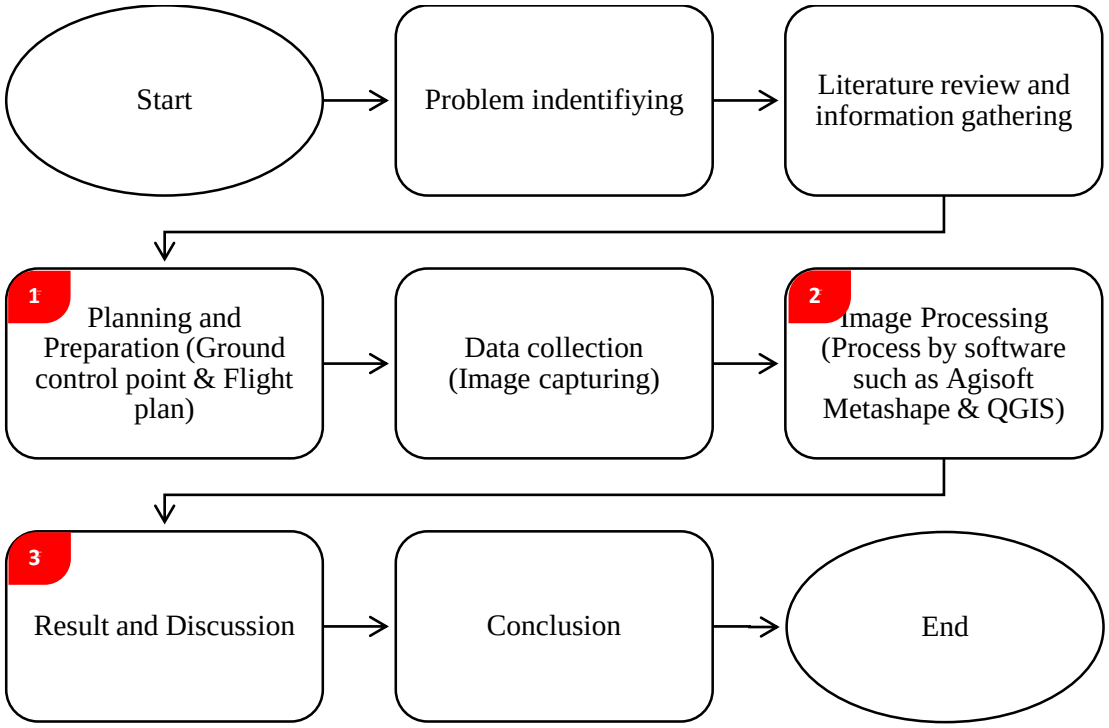

Figure 3.1: Overall study flowchart

3.1 Planning and preparation

In this step, details particular will be take into consideration such as authority permission, location, coordination and many more. This is crucial in order to prevent the last minutes problem arise. UAV mapping includes the implementation of regulations and the introduction of general guidelines for field surveys. These include authorization for surveys in conservation areas and private land and clear criteria for areas such as designated military zones. Provision is also provided for numerous laws impacting UAV activities, including pilot training courses and registration.

3.2 Flight mission and data collection

In order to achieve accuracy and model texture consistency, it is advised to mix top, oblique and horizontal photography in manual or autonomous flights. This mixture increases self-calibration and model consistency, thus reducing deformation of the model. The oblique views blend top and

horizontal photography from land or low UAV flight paths and ensure that overhanging river banks and bank topography hidden by treetop cover are captured. Sunlight visibility and water surface reflectance also impact efficient preparation and scheduling of flight missions.

3.3 Image processing

Raw data in form of image taken by the unmanned aerial vehicle or UAV then will be processed with several software to produced dedicated map. Using Agisoft Metashape as preliminary and QGIS secondary will help the result with enhanced outcome. Figure 3.2 below shows the process conducted through the software in order to produces the information map such as digital elevation and orthomosiac map.

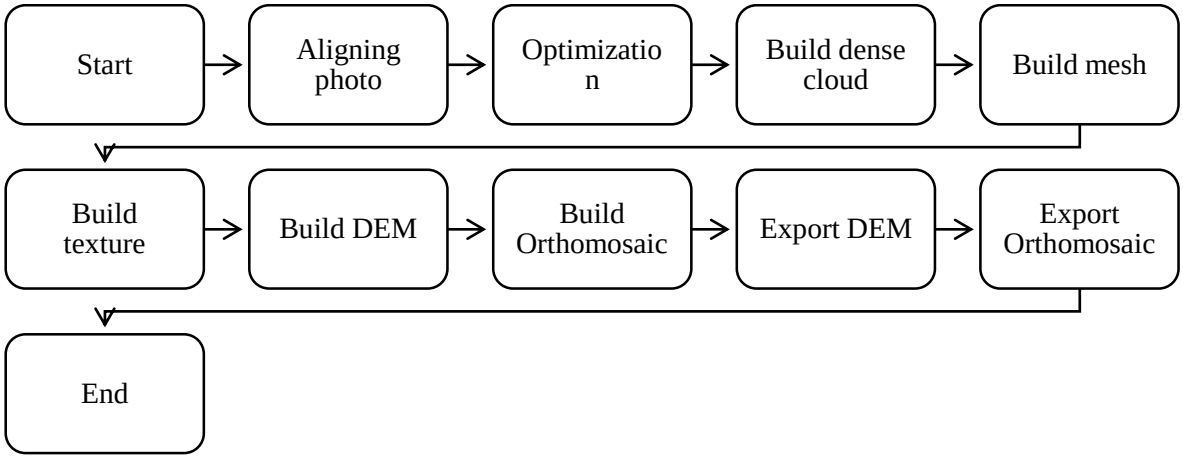

Figure 3.2: Flowchart process of Agisoft Metashape

4. Result Analysis and Discussion

In this chapter of study, data are being analyze and process under several software including Agisoft and Qgis. In this chapter, the result of study is being analyze and compare. A consequence discussion is made bass on the result obtained. As the episode of pandemic of covid-19 is not over, data for this study has been limited due to travel ban by government of Malaysia throughout the country under movement control order.

4.1 Orthomosaic Mapping

By using Agisoft Methashape software, the orthomosaic mapping of Sungai Terap is produced by processing the point cloud and matching them by each cloud individually. As per data, 641 images are processed into point cloud across the Sungai Terap and then being processed for the following process such as building mesh, building texture and lastly building orthomosaic. The figure 4.1 showing the Sungai Terap orthomosaic maps divided into two part which is north region and south region.

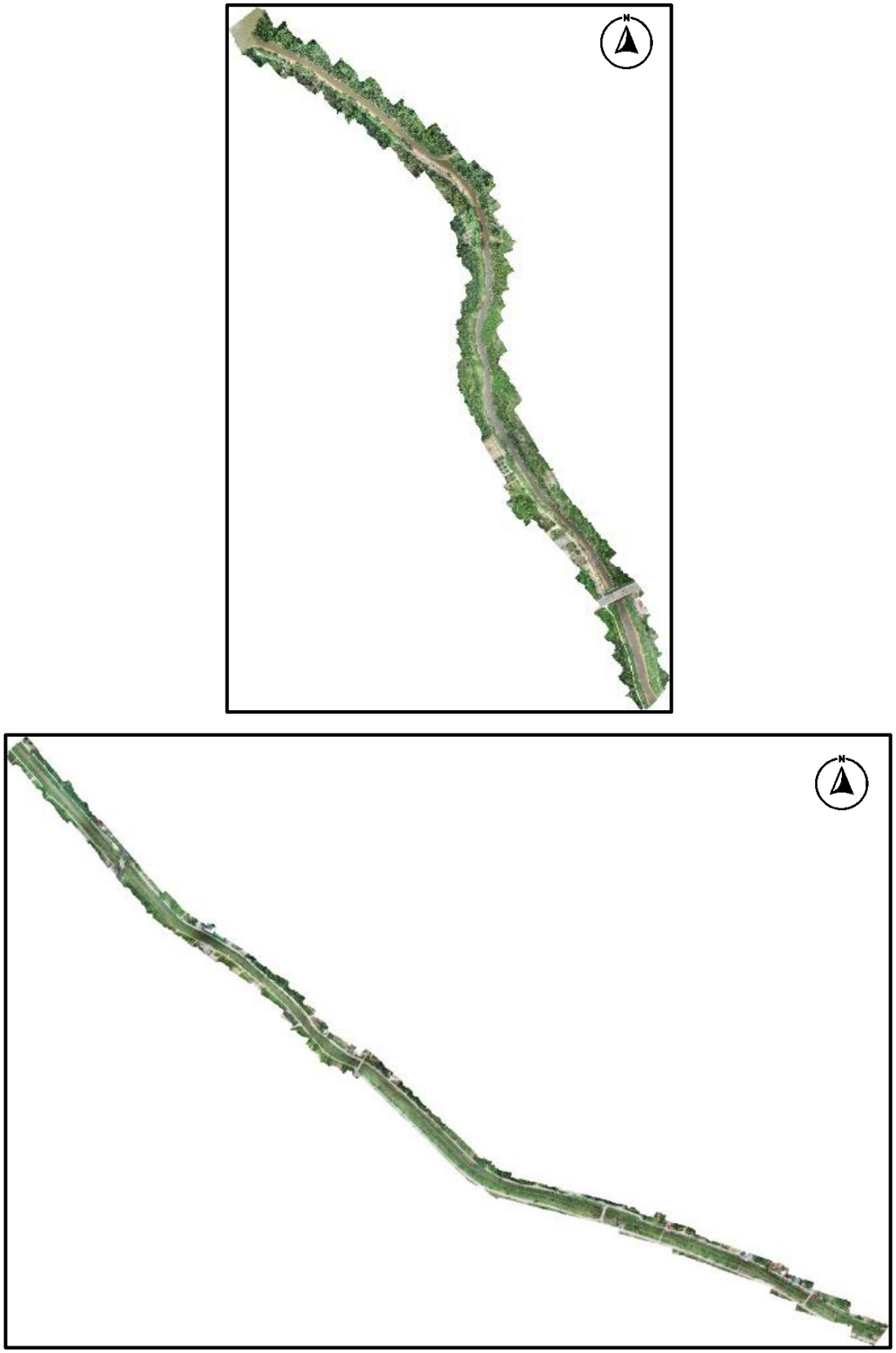

Figure 4.1: Detailed orthomosaic mapping of Sungai Terap using UAV mapping technique (north and south region)

Based on the figure 4.2, if we compare to the latest online mapping of Sungai Terap, UAV mapping product are seemed to be clearer and details. The orthomosaic from UAV mapping is more focus to the study area. This data can be used to ensure the smoothness of stream flow from upstream

to downstream. This method of UAV mapping is suggested to run a visual inspection of river as it has a simple procedure and process needed. The time required to process the data is taking a single day which is faster compared to other method of mapping. Plus, UAV mapping is effective at area that are not reachable. The following figure of comparison show a specific area at downstream of Sungai Terap. As it can see, the current and latest condition of Sungai Terap can be observed including the tide, top profile, and vegetation around the river. This comparison provides and instant result of the current river condition. For flood study, this instant result can give more accurate data and helping to get faster solutions.

Figure 4.2: Downstream of Sungai Terap from Bing Areal by Maxar Technologies compared to image of downstream Sungai Terap by UAV Mapping

4.2 Digital elevation map

From Agisoft, the data has been processed to form an elevation by matching the cloud point generated by the software. Additional reference as GCP is important to ensure the accuracy of elevation of the map. Unfortunately, the GCP data taken using GPS theodolite is corrupted and cannot be used. By considering the project progress, the uses of online GCP is applied by using Google Earth altitude information.

As for the reference setting, along the mapping there are 11 markers being set with the altitude from google earth. The following information is important as we can't solely depends on geotag data from the photo as it might be misconfiguration for the flight elevation details. The following details are being

extracted as follows. By referring to this marker, the elevation of the UAV mapping can be more accurate into below 10m accuracy.

As the map is incomplete at the center, the study of the DEM is divided into two part which is north region and south region. This elevation then later to be compare from Google Earth Elevation data. From the comparison it shows that difference of elevation between to dem produce is show in the table 4.1 as below;

Table 4.1: North region comparison

Map	Upstream	Downstream	Elevation Lost/Gain
UAV Mapping	6.55m	4.71m	1.84m
Google Earth	12.76m	8.03m	4.73m

From the UAV mapping, shows the elevation loss in range of 1.84m from upstream to downstream of the region. While from the Google Earth Elevation, 4.73m of elevation loss was recorded. This make the difference between UAV Mapping and Google Earth elevation on the region is 2.89m. For the south region (including mission 1, 2, 3, 4, and 5) the following data is extracted and compared with Google Earth data. The following comparison is showed in table 4.2 as follows.

Table 4.2: South region comparison

Map	Upstream	Downstream	Elevation Lost/Gain
UAV Mapping	9.22m	7.57m	1.65m
Google Earth	12.01m	12.88m	0.87m

For south region, from the UAV mapping, shows the elevation loss in range of 1.65m from upstream to downstream of the region. While from the Google Earth Elevation, 0.87m of elevation gain was recorded. This make the difference between UAV Mapping and Google Earth elevation on the region is 0.78m. For the full DEM, by using Agisoft, the DEM with mode of single band pseudo colour can be produce. To enhance the detail of DEM Map, the map has been divided into two part, which is North Region and South Region. Figure below show the DEM Map produce after processing the cloud data in Agisoft Metashapes.

For the full DEM, by using Agisoft, the DEM with mode of single band pseudo colour can be produce. To enhance the detail of DEM Map, the map has been divided into two part, which is North Region and South Region. Figure below show the DEM Map produce after processing the cloud data in Agisoft Metashapes. The following figure 4.3 and 4.4 shows the digital elevation map of the study area along the Sungai Terap.

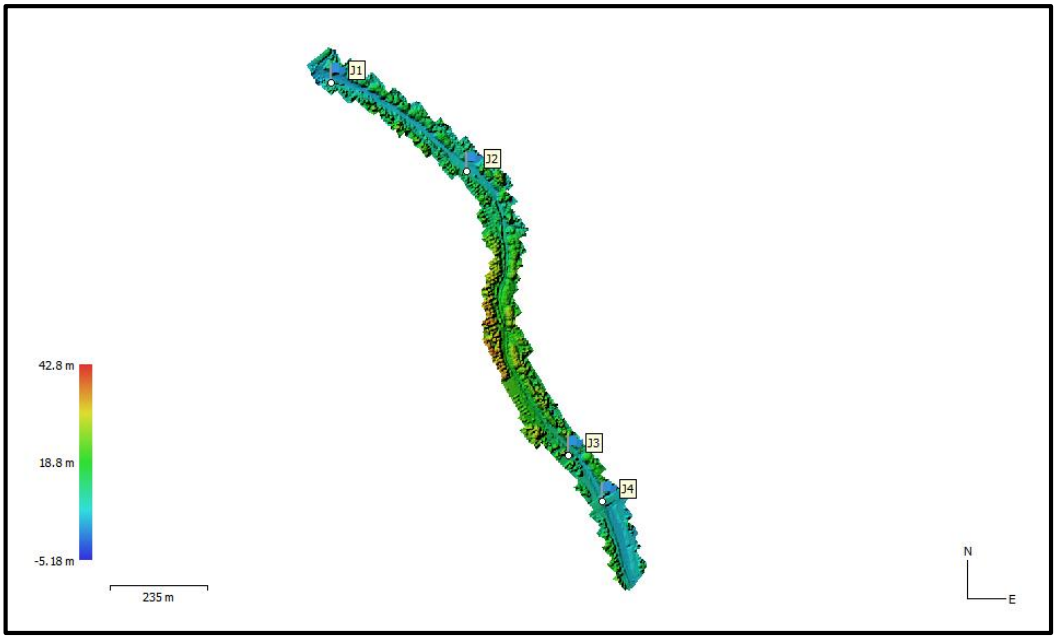

Figure 4.3: DEM Map of north region of Sungai Terap produce by UAV mapping technique

Figure 4.4: DEM Map of south region of Sungai Terap produce by UAV mapping technique

4.3 Elevation of Sungai Terap across chainage

The analysis of elevation along Sungai Terap is important to predict the high possibility of flooding area. When the problematic situation happens, which is tidal at downstream and heavy rain at upstream of Sungai Muar make it the tributary river such as Sungai Terap at risk of flooding if the river unable to channel the excessive stream to the retaining pond located near at the upstream of Sungai Terap.

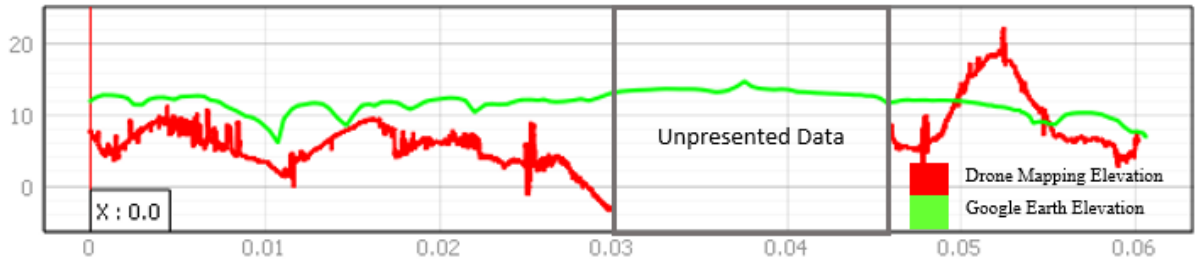

Figure 4.5: Elevation comparison

From the data derived in the figure 4.5, the location area within chainage (0 set to be at the upstream and 0.006 set to be at the downstream) we can predict that location at lowest area are prone to flood during the problematic situation mention before. For the UAV mapping elevation, the uneven spike across the graph is due to the outlier cloud that cross the elevation path. We can see the incline and decline of the elevation. At the point where the data is not present, we can see the decline behavior from the upstream that can be conclude the location at those area is also prone to flash flood and Figure 4.6 below show the location from map of those location

Figure 4.6: Prediction of location that prone to have flash flood according to elevation.

By considering this data, there are several actions can be taken at those area to control or slow the rate of flood by widening or deepening the river profile. The bigger the profile of the river, the more water that it can be channel or accommodate in a time before this water flow to the retaining pond at Parit Keling. It is also advisable to maintaining and re-profile the sewerage that connect Sungai Terap with retaining pond. By considering Malaysia that have tropical weather, it is profitable to take this action rather than conducting damage control every time the disaster hit those area.

Also, from the graph on the Figure 4.8 above, we can see the trend of elevation of UAV mapping and from Google Earth showing same behavior. The only difference in elevation is due to the difference in datum format between EPSG 4326 and EPSG 3857 and the uses of GCP that generated from Google Earth. This can be improved by using more accurate GCP from surveying using GPS theodolite and more point of GCP.

Besides, in this study the map is more focusing on a river which is have an average width of 10m make it narrow and less area capture in a picture. By considering more width coverage of the river, the accuracy of elevation can be improved by placing more GCP. The algorithm in the software can interpolate the map into more accurate elevation. In this current study the accuracy of the project is set

to be 0.005m and error generated by this software is ±0.00135m. Image overlapping from the UAV also increase the accuracy of the map. By conducting, 50% of overlap area in an image can increase the accuracy by double. This overlapping image can produce double point cloud hence increase match point and tie point. This process resulting more accurate data on map elevation.

5. Conclusion

By way of conclusion, this study shows the usability of UAVs in producing information maps such as digital elevation maps and orthomosaic. By using UAV, monitoring, and observing work are more easier as technology take place. This method must be one of the new alternatives to obtain the information regarding flash flood in a second and provide the solution as soon as possible. Hence the first objective of this study is achieved.

The limitation in this study is the situation of tide downstream and heavy rain in the upper reaches of the Sungai Muar which causes river water to overflow and cause flash floods in areas along the river including tributaries such as Sungai Terap. The results of the study by examining the DEM map found that there are some areas along the Sungai Terap that are lower than other areas that have the potential for flash floods. Proposals to widen and deepen the river have been made to ensure that the river can hold the water before it is channelled to the water reservoir area near the Parit Keling. Information from the DEM map is very useful and helpful in this study of flood prevention in Bakri, Muar. The third objective of this study is achieved by this result.

In addition, the second objective of this study also found that the use of UAVs as a mapping tool is very user -friendly and low operating costs as well as fast map results. This is because, the use of UAVs for mapping work does not require special skills and other equipment when compared to mapping using satellites which is time consuming and expensive. The use of the software of Agisoft Metashape and QGIS smoothens the flow of the process Therefore, this mapping method using UAVs is highly recommended for the future by adapting technology to simplify and speed up the process and actions performed.

The uses of UAV in mapping technologies is opening a new page in the world of mapping. A study using this technology needs to be carried out with different uses such as monitoring of buildings, roads, and more. In the aspect of mapping, the use of UAVs is expected to help speed up the production process apart from saving operating costs. In this study, the results obtained by using this UAV method are very positive and helpful in this study of flood prevention in Bakri Muar.

The hope for this study is to complete data that could not be completed as a result of movement control orders from the government. By completing the data, an effort can be made to the authorities to implement the recommendations that have been made to benefit the community in the area. As we all know, prevention is better than cure. Action must be taken before there is a loss in the form of property or life.

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