

Dredging Volume Analysis using Multi Beam Echo Sounder Data

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Abstract: The Tanjung Perak port passed through by Surabaya West Access Channel (SWAC) has an important role as driving of economic growth in the field of sea transport. The rivers that flow to SWAC has bringing large of sediments that caused of shallow on that area, so that influence the effectiveness of SWAC. Hence maintenance dredging port water is needed to maintain the ideal depth. This research will conduct the calculation of dredging volume with data derived from Multi Beam Echo Sounder (MBES) survey in SWAC using Hypack and AutoCAD Civil 3D software. The results of each software will be analysed to see which software will be used in doing dredging in the sea correctly. The volume calculation method used is cross section method (average end area). The MBES data processing produces bathymetry map that indicates the study location with depth less than -13 meter with along channel 17.6 km. Total value volume obtained from calculation AutoCAD Civil 3D is 5,921,745 m³ and Hypack is 5,952,881.83 m³. These values compared to the composite method, the volume difference of Autodesk Civil 3D is only 0.67% and Hypack is 1.2%. Because of the small difference (0.5%), it means that the Autodesk Civil 3D and Hypack software have the same volume dredging at SWAC.

1 INTRODUCTION

Referring to United Nations Convention on the Law of the Sea (UNCLOS) 1983, Indonesia is one of the biggest archipelagic country in the world (Windari, 2009). This is because Indonesia has 17,504 islands and 15,056 islands that have been registered in the United Nations and the ratio between its land and ocean in Indonesia is 1:2 (UN, 2017). Therefore sea plays an important role in Indonesian economic activities. The sea has a role as communication lane means that the use of the sea for the traffic interest of inter-island, inter-country and inter-continental shipping traffic, both for passengers and goods transportation.

Surabaya is the second largest city after Jakarta in Indonesia. Therefore, the economic activities in East Java and Eastern Indonesia through the Surabaya port, namely Tanjung Perak Port. Tanjung Perak Port is the second largest port after Tanjung Priok in Jakarta. Tanjung Perak Port has a strategic role to support the traffic activities of sea transportation and as a driver of economic growth in East Java and the Eastern Indonesia.

Determination of shipping channels in terms of navigational security aspects is intended to prevent

channel from sinking during low elevation tides, growing shallows or corals, and unsafe depth of seabed to draft ships. Other than that the straits are too narrow, waters that have currents or waves that make it difficult for boat movements and other navigation barriers (Parwata, 2011). Because of the large port, many large ships with drafts of more than 10 m enter the Tanjung Perak port. For example, the North Jamrud port is one of the busiest of quay in the Tanjung Perak port. Recorded in 2011 there were 14,117 ships anchored in North Jamrud, while in 2012 it increased to 14,773 ships (Buana, 2014). It had to go through the Surabaya West Access Channel (SWAC) before entering to port.

Rivers that lead to the SWAC carry a large amount of sediment which results in siltation, which can affect the effectiveness of the SWAC (Wahyuni, et al., 2013). To solve the sedimentation problem and maintain service quality, it is necessary to pay attention to the condition of the shipping channel as the ship's entrance to the port area and the direction of the ship entering the port waters.

The depth of the shipping path that is not in accordance with the draft of the ship can cause the ship to run aground and endanger the safety of shipping. Therefore, it is necessary to carry out port

dredging maintenance to maintain the ideal depth according to the dimensions and size of the vessel.

This study will calculate the volume of dredging with data from the multibeam echosounder survey in the SWAC using Hypack and AutoCAD Civil 3D software. Then their volume compared each other and where is suitable for use in the dredging work at sea.

2 METHOD

2.1 Data and Research Area

The research location area is in the Surabaya West Access Channel – Tanjung Perak Port, Surabaya, which is geographically located between 6°50'00" S - 7°00'00" S and 112°40'00" E - 112°45'00" E. This location can be seen in the Figure 1 below.

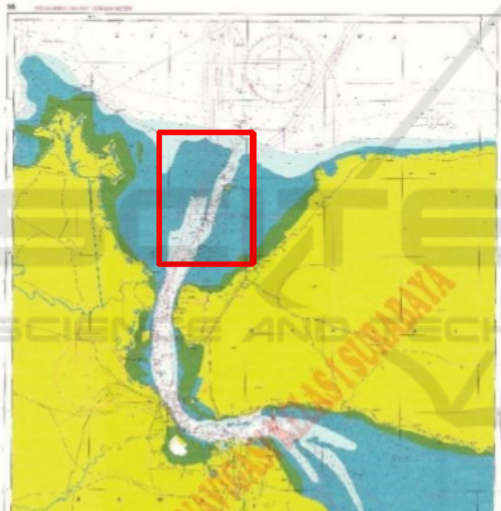


Figure 1: Research location (Disnav, 2016).

The data used in this research is the ASCII Multi Beam Echo Sounder (MBES) (Figure 2) data in Surabaya West Access Channel (SWAC) in June 2017 obtained from the Dinas Navigation Surabaya, East Java, Indonesia.

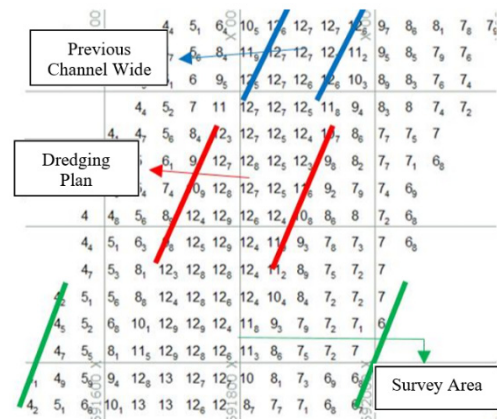


Figure 2: Spot depth of MBES data.

2.2 Method

The first step is to determine the boundary area to be calculated by dredging volume provided the depth is less than -13 meters. After that volume calculation manually used the cross section and composite method which will be used as a reference volume (true volume) as a comparison of the volume calculation results from the AutoCAD Civil 3D and Hypack software. Then the ASCII Multi Beam Echo Sounder data are plotted to the layout drawing. The next step is to form 3-Dimensional model using the principle of Triangular Irregular Network (TIN) to obtain a Digital Terrain Model (DTM) surface (Figure 3 and Figure 4).

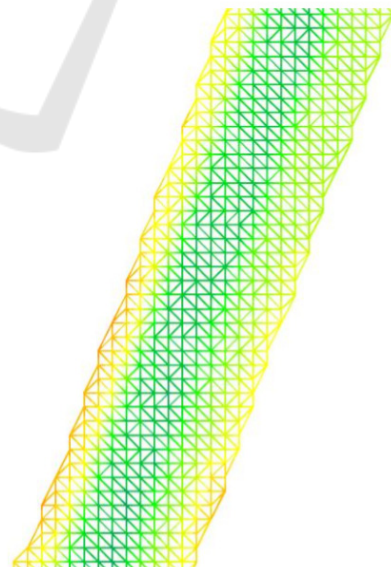


Figure 3: Triangular Irregular Network in SWAC (Autodesk, 21014).

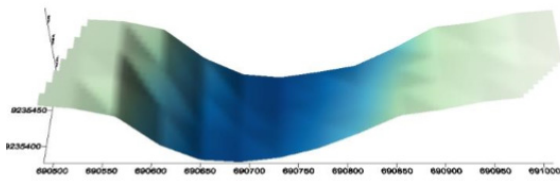


Figure 4: An example of 3-D Model at one cross station.

This surface will be used as a reference in calculating the dredging volume. The design of dredging is formed in each software with the same design specifications which has a slope of 1:5 (Figure 5).

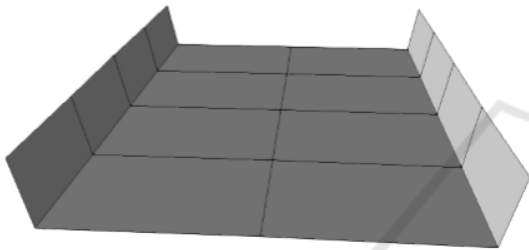


Figure 5: Template section as depth referenced (design surface of dredging) (Hypack, 2016).

Then, a cross section should be formed in each 50 m and calculate volume between one section and another section using Average End Area. Finally, analysed the volume obtained from AutoCad Civil 3D and Hypack software.

3 RESULT AND DISCUSSION

3.1 SWAC Bathymetric Map

The SWAC bathymetric map formed from MBES data shows that the shallowest depth is -4 m and the deepest depth is -13 m. This map (Figure 6) shows that the waters around this SWAC are quite shallow. Therefore, to avoid ships entering the Tanjung Perak port through SWAC, routine maintenance of the SWAC is required by dredging the sedimentation that occurs.

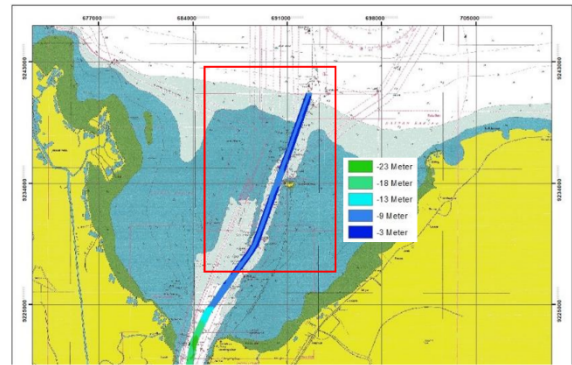


Figure 6: Disnav SWAC Bathymetric Map modification.

3.2 Volume Calculation as Referenced by Composite and Cross Section Manually Method

In this case, the volumes are used as references to compare the volume between the Autodesk Civil 3D and Hypack software are composite method and cross section method manually. Composite method is based on surface 3D models which derived from Triangulated Irregular Network (TIN) with two surfaces namely base surface (design surface) and existing surface (Labant, et al., 2013). The composite method can be seen in Figure 7 and the formula can be seen in equation 1.

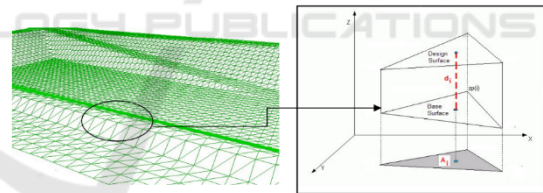


Figure 7. Illustration of Triangular Irregular Network (Labant, 2013).

$$V_i = P \frac{\sum_{i=1}^3 H_i}{3} \quad (1)$$

where V is volume, Hi is elevation and P is area of triangle prism.

While cross section method manually it means that calculate volume between a station and another station consequentially (Figure 7). Figure 8 illustrates the concept of computing volumes by the average-end area method (cross section method). In the figure, A1 and A2 are end areas at two stations

separated by a horizontal distance L. The volume between the two stations is equal to the average of the end areas multiplied by the horizontal distance L between them (see Equation 2) (Ghilani & Wolf, 2012).

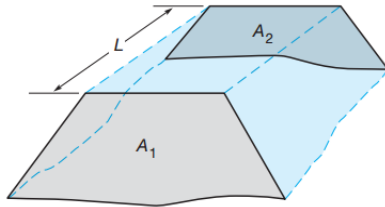


Figure 8: Cross section of volume illustrating (Ghilani, 2012).

$$V_e = \frac{A_1 + A_2}{2} \times L(m^3) \quad (2)$$

where V_e is volume, A_1 and A_2 are end area, L is distance between A_1 and A_2 .

The result of the volume calculation with the composite method is 5,881,819.17 m³ and the cross section is 5,370,694.656 m³. The dredging volume difference between cross section manually and composite method is -511,124.514 m³ (-8.7%).

3.3 Volume Calculation by Cross Section Method using Autodesk Civil 3D Software

In calculating the dredging volume in the AutoCAD Civil 3D software, two surfaces are needed, namely existing and design surface. The first surface is an existing surface containing the x, y, z coordinates of the dredging bathymetry at the SWAC. Based on the Indonesian Minister of Transportation regulation No. 455 year 2016, the minimum depth of SWAC is -13 m and the wide of SWAC is 150 m.

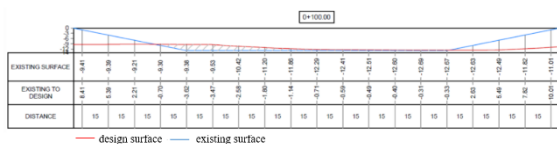


Figure 9: Cross section STA 0+100 in AutoCad Civil 3D.

The method used to calculate volume using AutoCad Civil 3D is a cross section with interval 50 m. There are 353 cross sections in this case. Figure 9 is one example of cross section at the station STA 0

+ 100.00. The smallest volume value is 35.1 m³ which located in section between STA 17 + 550.00 and STA 17 + 626.77. This is because the depth in this section approach -13 meters. Conversely the largest volume is 34,802.02 m³ which located in section between STA 12 + 100 and STA 12 + 150. This section is quite shallow, so that the existing surface above the dredge design should be cut quite a lot. The total volume from 353 cross section in this case is 5,921,745 m³.

The volume difference between the Autodesk Civil 3D cross section method and the composite method is 39,925.83 m³ (0.67%), whereas the volume difference between the Autodesk Civil 3D cross section method and the cross section manually method is 551,050.344 m³ (10.26%).

3.4 Volume Calculation by Cross Section Method using Hypack Software

The existing surface modelled by TIN will be overlaid with a dredge template (Figure 10) to calculate its volume. The size of the dredge template refers to Minister Transportation regulation No. 455 in 2016.

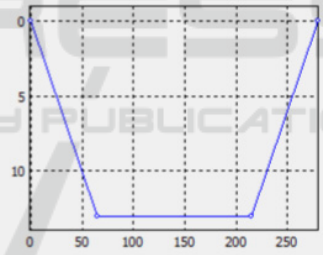


Figure 10: Template section as depth referenced.

The following Figure 11 is a side view of one section. Information on the value of the volume of each section displayed is divided into three, namely VL (Volume Left), V1 (Channel), and VR (Volume Right). Volume Left is the volume that is in the left slope area, as well as Volume Right is the volume that is in the right slope area, while V1 is the volume a channel besides the slope area in the first layer.

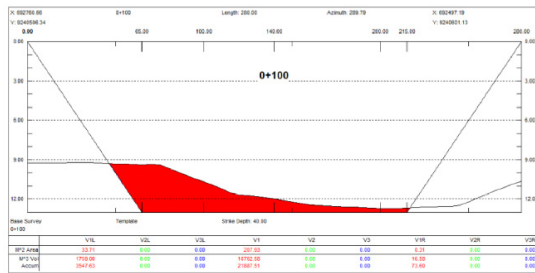


Figure 11: Cross section STA 0 + 100 in HyPack Software.

From the calculation of volume using Hypack software, the smallest volume value of 127.23 m³ is located in section between STA 17 + 550 + STA 17 + 626.77. The small value is due to the depth of the section approaching -13 meters, the existing surface above the dredge design is small. Conversely the largest volume value is 32,002,69 m³ which located in section between STA 12 + 100 and STA 12 + 150. This is because the shallow depth in the section, the existing surface above the dredge design is quite a lot to be cut.

Table 1: Volume of SWAC using Hypack.

Design	Volume (m ³)
VL (Volume Left)	839,934.84
V1 (Channel)	4,525,591.71
VR (Volume Right)	46,184.21
Total	5,952,881.83

In calculating the volume of cross section with Hypack software the results of the calculation information displayed are divided into three parts, namely the volume value in VL, V1, and VR. The total volume of SWAC with the cross section method using Hypack is 5,952,881.83 m³.

The volume difference between the Hypack cross section method and the composite method is 71,062.66 m³ (1.2%), whereas the volume difference between the Hypack cross section method and the manual cross section method is 582,187.174m³ (9.77%).

4. CONCLUSION

Conclusions that can be drawn from this study are as follows :

1. The volume difference between the composite method and the manual cross section method used as a reference to the comparison calculation is very significant at 8.7% (511,124.514 m³)
2. Difference between volume calculation using Autodesk Civil 3D and Hypack software is equal to 31,136.83 (0.52%)

The volume of Autodesk Civil 3D and Hypack results have almost the same value as the composite method with the difference 0.67% and 1.2% consecutively and compared with manual cross section are 10.26% for Autodesk Civil 3D and 9.77% for Hypack software.

REFERENCES

Autodesk, K., 2014. *Sectional Volume Methods*. s.l.:Autodesk.

Buana, P. A., 2014. *Studi Penentuan Draft dan Lebar Ideal Kapal Terhadap Alur Pelayaran*. Tugas Akhir, Jurusan Teknik Geomatika ITS, Surabaya.

Disnav, 2016. *Peta Laut Indonesia Alur Pelayaran Barat Surabaya*. Kementerian Perhubungan Direktorat Jenderal Perhubungan Laut Distrik Navigasi Kelas I Surabaya, Surabaya.

Ghilani, C. D. & Wolf, P. R., 2012. *Elementary Surveying. An introduction to Geomatics. 13th edition*. s.l.:Prentice Hall.

Hypack, S., 2016. *Volumes Calculation Method Comparison in Cross Sections and Volumes*. s.l.:s.n.

Labant, S., Stankova, H. & Weiss, R., 2013. Geodetic Determining of Stockpile Volume of Mineral Excavated in Open Pit Mine. *GeoScience Engineering*, Volume LIX, pp. No.1 p. 30-40.

Nation, U., 2017. *Identification of Islands and Standardization of Their Names. 11th United Nations Conference on the Standardization of Geographical Names*. s.n., New York.

Parwata, G., 2011. *Peran Distrik Navigasi Dalam Keselamatan Pelayaran*. Kementrian Perhubungan, Bali.

Wahyudi, N., Armono, H. D. & Sujantoko, 2013. *Analisa Laju Volume Sedimentasi di Alur Pelayaran Barat Surabaya (APBS)*. Jurusan Teknik Kelautan ITS, Surabaya.

Windari, R., 2009. *Hukum Laut, Zona-Zona Maritim Sesuai UNCLOS 1982 dan Konvensi – Konvensi Bidang Maritim*. Bakorkamla, Jakarta.