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COMPUTING AND CLASSIFICATION OF ACOUSTIC BACKSCATTER VALUES OF THE BOTTOM SUBSTRATE OF JAKARTA BAY USING MULTIBEAM ECHOSOUNDER

Komputasi Dan Klasifikasi Nilai Hamburbalik Akustik Substrat Dasar Perairan Teluk Jakarta Menggunakan *Multibeam Echosounder*

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ABSTRACT

Jakarta Bay is a semi-closed water area with numerous activities that trigger sedimentation, which can disrupt navigation and construction activities in Jakarta Bay. Sediment analysis and classification are useful to provide information on sediment types to support activities and coastal management in Jakarta Bay. The multibeam echosounder is an underwater acoustic research instrument that generates depth data and seabed backscatter with wide coverage and high resolution. The backscatter values are used to determine the type and grain size of sediments through the backscatter values, which function through angular response. This study uses data from the Lattek (Practical Training) Dikspespa Hidros XXI survey conducted by the Naval Technology College (STTAL) in collaboration with the Hydro-Oceanographic Education Center of the Indonesian Navy (Pusdik Hidros TNI-AL). The instruments used include the Teledyne Reson T-50R Multibeam Echosounder and the sediment grab sampler. The acoustic multibeam data were processed using Caris and FMGT software to produce bathymetric profiles and backscatter mosaics at depths ranging from 5 to 9 meters. The backscatter intensity ranges from -40 dB to -27 dB with ten classification categories: clay, silty clay, sandy clay, sandy silt, very fine silt, fine silt, medium silt, coarse silt, sandy mud, and clayey sand. The acoustic data were linked with sediment samples to classify and determine the sediment types. The results of the sediment sample analysis were divided into empat classes based on grain size: coarse clay, coarse silt, fine sand, and very fine sand.

Keywords: Acoustic, Backscatter, Multibeam echosounder, Sediment type

ABSTRAK

Teluk Jakarta merupakan perairan semi tertutup dengan banyak aktivitas yang memicu terjadinya sedimentasi, hal ini dapat mengganggu aktivitas pelayaran dan pembangunan di Teluk Jakarta. Analisis dan klasifikasi tipe sedimen bermanfaat untuk memberikan informasi tipe sedimen untuk mendukung aktivitas dan pengelolaan pesisir Teluk Jakarta. *Multibeam echosounder* merupakan instrumen penelitian akustik bawah air yang menghasilkan data kedalaman dan hamburbalik dasar perairan dengan cakupan luas dan resolusi tinggi. Nilai hamburbalik digunakan dalam menentukan jenis hingga ukuran butiran sedimen melalui nilai hamburbalik yang dipenrafungsi respon sudut pancarnya (*angular response*). Penelitian ini menggunakan data hasil survei Lattek (Latihan Praktek) Dikspespa Hidros XXI oleh Sekolah Tinggi Teknologi Angkatan Laut (STTAL) dan berkolaborasi dengan Pusat Pendidikan Hidro-Oseanografi TNI Angkatan Laut Pusdik Hidros TNI-AL. Instrumen yang digunakan adalah *multibeam echosounder* Teledyne Reson T-50R dan *sediment grab sampler*. Data akustik, *multibeam* diproses menggunakan *software* Caris dan FMGT untuk menghasilkan profil batimetri dan mosaik hamburbalik pada kedalaman 5 sampai 9 m. Intensitas hamburbalik berkisar antara -40dB sampai dengan -27dB dengan klasifikasi sepuluh kelas yaitu *clay, silty clay, sandy clay, sandy silt, very fine silt, fine silt, medium silt, corse silt, sandy mud,* dan *clayey sand*. Data akustik dihubungkan dengan sampel sedimen untuk mengklasifikasi dan mementukan tipe sedimen. Hasil analisis sampel sedimen terbagi manjadi empat kelas berdasarkan ukuran butirannya yaitu lempung kasar, lanau kasar, pasir halus, dan pasir halus sekali.

Kata Kunci: Akustik, Hamburbalik, *Multibeam echosounder*, Tipe sedimen

INTRODUCTION

Jakarta Bay is a semi-enclosed water area with an area of approximately 514 km2 which has an important role both ecologically, economically, and socially, in addition, Jakarta Bay is also a place where many rivers flow into which it becomes a center for anthropogenic material input from the city of Jakarta which will settle and undergo a sedimentation process (Harahap & Suyana, 2019). Shipping, fisheries, reclamation, mining, industry, and tourism activities are widely carried out in the Jakarta Bay area, there are at least more than 50 types of industries operating around the waters of Jakarta Bay (Suteja, 2016). These activities cause sedimentation or sedimentation processes to occur frequently, this will have an impact on shipping routes and development in coastal areas. The substrate/sediment in the waters of Jakarta Bay is dominated by sandy clay loam, or better known as cohesive soil, this type of substrate deposit comes from the run-off of river estuaries (Aprilia & Pratomo, 2013). Jakarta Bay is an area with a high intensity of shipping activity. The large number of river mouths and material input from the mainland causes substrate sedimentation to occur in the waters of Jakarta Bay, this can disrupt shipping routes and change the morphology of the seabed. Substrate analysis is carried out to determine the type and type of substrate, provide information on bathymetric maps and distribution of substrate types, in addition so that shipping can take place more safely, and development activities on the coast such as port construction, installation of pipes, and submarine cables can be carried out according to the conditions of the water substrate. One of the methods used to answer this problem is by using the underwater acoustic method.

Underwater acoustics is a science that studies the propagation of sound through water media. The instrument commonly used in underwater acoustic research is the multibeam echosounder (MBES) (Manik & Dwinovantyo, 2018). MBES can transmit up to 1024 beams simultaneously, of course making MBES have a better level of accuracy with a wide coverage area. The information obtained from the MBES instrument is in the form of depth data from the reflection of acoustic waves and the scattering value of acoustic signals that hit seabed objects and are called backscatter. Backscatter is the intensity of the acoustic signal reflected by the bottom of the water using the angular response function.

Backscatter research with ARA obtained results in the form of a relationship curve between the backscatter intensity value and the angular response analysis or ARA (Farihah et al., 2020). From the ARA and backscatter values, the substrate type can be determined, where different backscatter responses will be detected as different substrate types, because each substrate layer has a composition with its own physical characteristics, so it can be used to detect the type and spatial distribution of morphology of the bottom substrate of the waters (Urick, 1983). Based on the statement above, the latest research is needed to support various activities that will be carried out in Jakarta Bay. In this regard, this study aims to analyze the acoustic backscatter of the bottom substrate of Jakarta Bay using a multibeam echosounder and compare the results of the classification of the bottom substrate between the backscatter value and laboratory analysis. It is hoped that this research can be useful to complete information in the form of backscatter intensity values of the multibeam echosounder bottom of Jakarta Bay, which has a high level of accuracy so that it can support the suitability of various development, shipping and mining activities, as well as the management of the coastal area of Jakarta Bay..

RESEARCH METHODS

Place and Time

The research data collection was carried out by the Lattek (Practical Training) survey team in the XXI Hydro Officer Specialization Education activity carried out by the Naval Technology College (STTAL) and in collaboration with the Indonesian Navy Hydro-Oceanography Education Center (Pusdik Hidros TNI-AL). The survey was carried out in October 2023 in the waters of Jakarta Bay, North Jakarta, Special Region of Jakarta, consisting of 25 routes with a research area of 2.66 km2 (Figure 1).

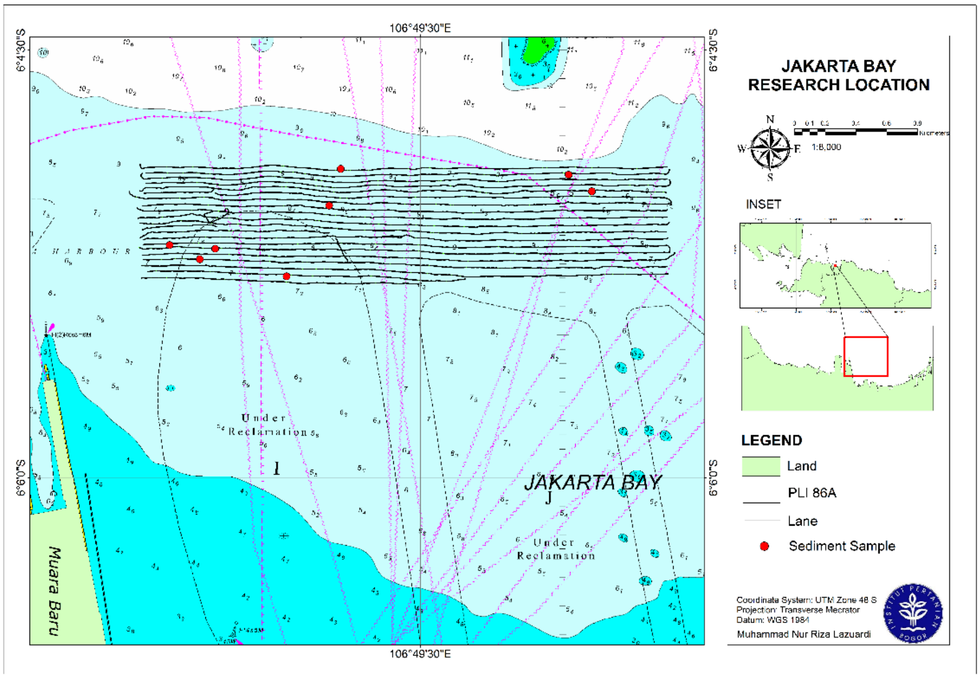

Figure 1. Map of research location

Tools and Materials

The instruments used in the survey were a Teledyne Reson T-50R multibeam echosounder operated at a frequency of 300 kHz as an acoustic data acquisition instrument, Valeport Midas Mini CTD (Conductivity Temperature Depth) for sound velocity data, Valeport tide master Tide Gauge for tidal data, and Sediment grab sampler for sediment sampling. Data processing tools include a computer with a Windows 11 64-bit operating system with an Intel Core I7-1165G7 Processor, with Caris HIPS and SIPS software, an Asus Vivobook Laptop with an AMD Ryzen 5 4000 Series Processor with Fledermaus Geocoder Toolbox (FMGT) software, Microsoft Excel 2019, and ArcMap 10.8. The materials used were raw data from MBES in the formats (*.s7k) and (*.gsf), tidal elevation data (*.TID), and sound velocity profile (SVP) data (Tichy et al. 2003). Sediment sample processing was carried out using a Memmert UN110 oven, sieve shaker, pipette, and digital scales.

Table 1. Tools and Materials

Tools and Materials	Information
Teledyne Reson T-50R multibeam echo sounder	Hydroacoustic Instruments
Teledyne TSS DMS-05	Motion sensor measurement
Mini CTD Valeport Midas	Sound speed data
Sediment Grab Sampler	Sediment sampling
Sieve Shakers	Sediment sample processing
Memmert UN110 Oven	Sediment sample drying
Survey Vessel	Data collection facilities
Fledermaus Geocoder Toolbox (FMGT)	Processing bathymetric data
Search for HIPS and SIPS	Processing backscatter data
ArcGIS 10.8	Mapping and visualization
Microsoft Excel 2019	Numeric data processing
Microsoft Word 2019	Interpretation of research results

The study began by collecting acoustic data using a Teledyne Reson T-50R multibeam echosounder instrument mounted on an iron pole on the right side of the ship, a medium-sized survey vessel with dimensions of 3.5 m high, 12 m long, and 2.4 m wide, with an average speed of 4 knots. The transducer is installed at an off-set of 90 cm, with the distance between the transducer and the motion reference unit (MRU) being 1.8 m. The antenna is mounted at the highest point of the ship. The Multibeam Echosounder will be calibrated using the patch test method using an MRU tool that functions as a Teledyne TSS DMS-05 motion sensor measurement before being used for research. This calibration process aims to calibrate the transducer alignment (miss-alignment) with the movement of the ship, by correcting systematic errors from the movement of the ship and the angle of the signal transmission (Manik, 2007). An illustration of the MBES instrument installation is presented in Figure 2.

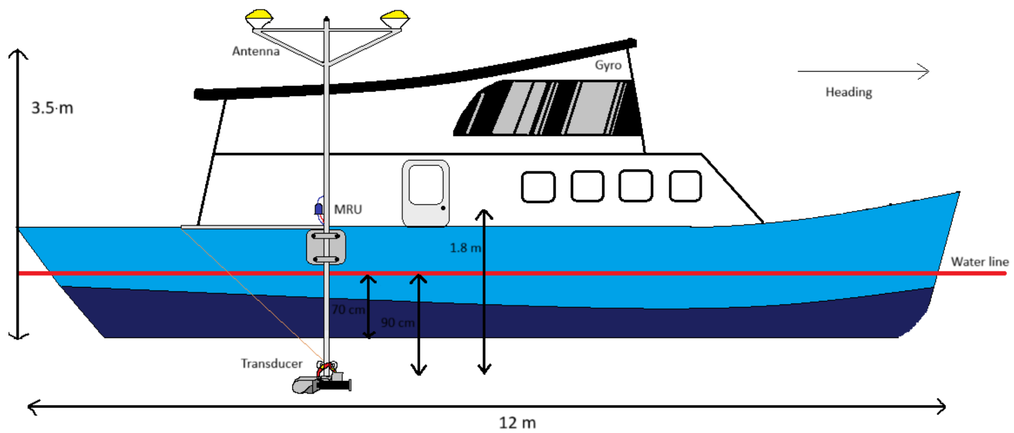

Figure 2. Installation of MBES instrument on survey vessel

Research Data Collection

Sediment sampling was carried out using a sediment grab sampler at eight sampling points. which were determined using the purposive sampling method based on the representativeness of the backscatter value, the number of eight expected points can represent the entire sounding data.

Table 2. Coordinates of sediment sampling stations

Stasiun	Longitude	Latitude
1	106°50'14.246"BT	6°5'7.517"LS
2	106°50'28.021"BT	6°5'18.413"LS
3	106°49'13.237"BT	6°4'55.011"LS
4	106°49'10.796"BT	6°5'2.721"LS
5	106°48'46.811"BT	6°5'11.801"LS
6	106°48'43.641"BT	6°5'14.028"LS
7	106°48'37.22"BT	6°5'11.021"LS
8	106°49'1.837"BT	6°5'17.615"LS

Tide data collection was carried out using the Tide Gauge Valeport tide master instrument at the Muara Baru tidal station. The data obtained were in the form of tidal elevations for 15 days, starting from October 1 to October 15, 2023. To correct the depth value of the sounding results, MSL and Z0 calculations were carried out using the following calculation formula (Ichsari et al., 2020). Where the MSL value is S0 in equations 1 and 2, which is the average sea level value. The Ai value is the calculation of the amplitude of 9 harmonic constants and n is the number of tidal harmonic constants.

$$\text{MSL} = A(S_0) \quad (1)$$

$$Z_0 = \sum_{i=1}^{n} Ai \quad (2)$$

The sound speed data in Jakarta Bay was taken using the Mini CTD Valeport Midas at five CTD station points along with the MBES data sounding. And processed with Valeport Terminal X2 software with the basis of calculations on equation 3 developed by Medwin (1975):

$$c = 1449.2+4.6\,T - 0.055\,T2+0.00029\,T3+(1.34 - 0.010\,T)\,(S - 35)+0.016\,Z \quad (3)$$

Information:
c: Speed of sound (m/s)
T: Temperatur (°C)
S: Salinity (‰)
Z: Depth (m)

The backscatter intensity is obtained from the received signal, thus producing initial information about the type of sediment recorded spatially. Further processing can be done until information is obtained about the size of the sediment type (Manik & Jaya, 2016). In general, the backscatter value of the bottom of the water is influenced by three factors, namely acoustic impedance, substrate hardness level, and differences in substrate volume. Backscatter will estimate the type of sediment and other sediment properties, such as sediment grain size, impedance index, and grain volume heterogeneity. The calculation of the backscatter of the bottom of the water sediment surface based on the angular response (ARA) can be done with the calculation function developed by (Fonseca, 2007) in Equation 4.

$$\boldsymbol{\sigma r}\;(\boldsymbol{\theta}, f) = F\,(\boldsymbol{\theta}, f;\ \varepsilon, \boldsymbol{\rho}(\varepsilon), \boldsymbol{\nu}\,(\varepsilon), \boldsymbol{\delta}(\varepsilon), \boldsymbol{\omega 2 \lambda}) \quad (4)$$

Information:
θ: Surface backscatter angle
f: Frequency
ρ: Sediment density
v: Sound speed
δ: Sound wave ratio
ω: Spectral power
ε: Total sediment volume
λ: Seabed spectral exponents

This mathematical function adopts calculations by mathematical modeling (Jackson, 1986), then developed by (Fonseca, 2007) which is known as geocoder. Backscatter processing based on its angular response can be done with Fledermaus Geocoder Toolbox FMGT software. One approach to studying the continuity between backscatter values with high resolution is to analyze the object's beam angle or Angular Range Analysis (ARA).

RESULT

Based on the data processing that has been done, the results of supporting data for acoustic research include tides, sound speed, and also bathymetry as follows. The tidal value is obtained with an MSL value of 1.30 m and a Z0 value of 0.60 m, so that the lowest ebb value is obtained at 0.7 m. The location of the tidal observer at the Muara Baru tidal station using the Admiralty 15 piantan method. The sound speed value obtained tends to fluctuate with a range between 1545.102 m / s to 1541.979 m / s. The bathymetry value obtained after data processing is between a depth of five to nine meters.

DISCUSSION

Sediment Classification

The distribution of sediment backscatter intensity in Jakarta Bay shows a range of -40 to -27 dB. The backscatter intensity map in Figure 4 shows that the size of the Jakarta Bay sediment particles is getting smaller with increasing sea depth. The deeper the water area, the calmer the waters, causing suspended sediment particles to settle, this is what makes sediment particles in the deep sea have smaller particles and tend to be finer. Therefore, the backscatter mosaic value itself is not a strong parameter to represent the acoustic response of seabed sediments (Fonseca & Mayer, 2007). One of the corrections is by analyzing the relationship between the sediment backscatter value and its reflection angle response (ARA).

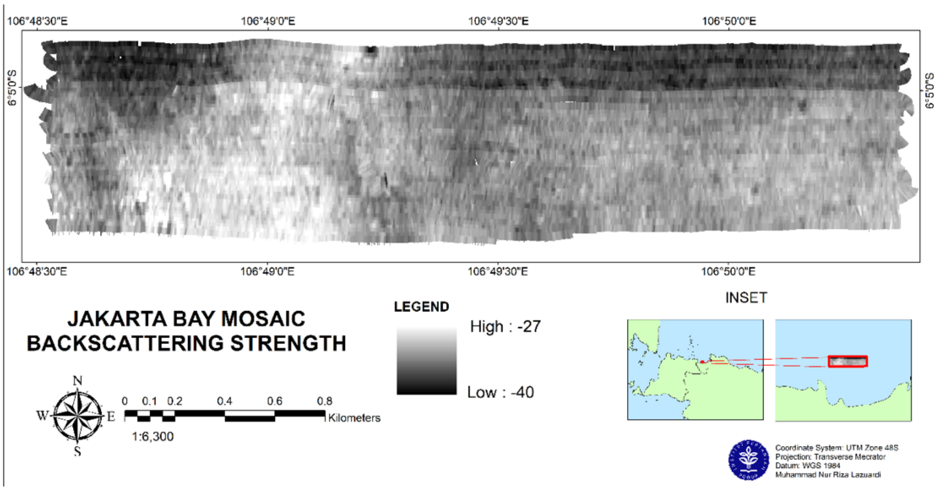

Figure 3. Sediment backscatter intensity mosaic map

The sediment types are divided into ten sediment types in three groups obtained with a backscatter intensity range of -40 dB to -27 dB. There are ten types of sediment based on their backscatter values, namely clay with a range of -40.0 dB to -29.8 dB, silty clay with a range of -32.2 dB to -28.2 dB, sandy clay with a value of -31.7 dB to -28.6, sandy silt with a range of -30.8 dB to -27.1 dB, very fine silt with a range of -31.9 dB to -31.1 dB, fine silt with a range of -31.5 dB to -31.2 dB, medium silt with a range of -31.0 dB to -30.8 dB, sandy mud with a range of -31.4 dB to -27.6 dB, coarse silt with a range of -29.1 dB to -27.6 dB, and clayey sand with a range of -26.4 dB to -26.1 dB. Based on the sediment classification distribution map, the sediment type at the research location is dominated by silt and clay types, this is indicated by the large number of areas covered with blue to green colors on the sediment distribution map in Figure 5. The characteristics of sediment backscatter vary, sediment with high hardness characteristics will produce high backscatter intensity, and vice versa (Fahrulian *et al*., 2016). Sediment with a larger size has a higher density value, the higher the density value will produce a higher acoustic backscatter value. So this will make the sediment porosity value tend to be smaller (Manik, 2012). To compare the conditions and suitability of the multibeam echosounder observation results, sediment samples were also taken in-situ at eight stations using a grab sampler. The eight stations were selected using the purposive sampling method, which was adjusted visually based on the backscatter value from the MBES observation results.

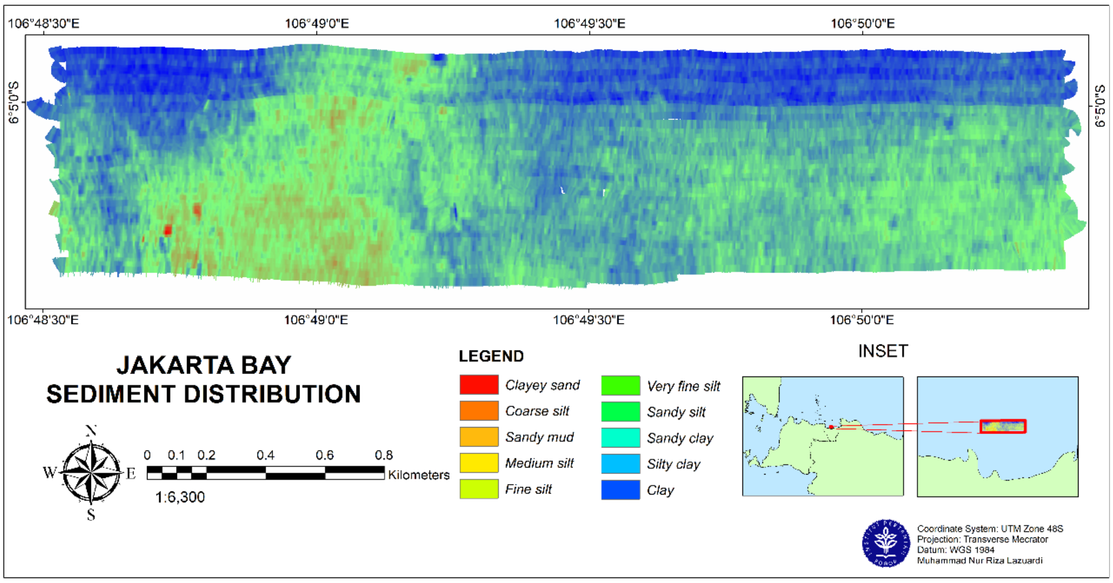

Figure 4. Map of sediment distribution in Jakarta Bay

MBES data processing classifies sediment types based on the physical characteristics of the object, ranging from backscatter, impedance, volume, grain size, to sediment roughness. This information is obtained and used to automatically classify sediment types. The results of sediment classification at eight stations are presented in Table 3.

Table 3. Results of sediment classification at eight stations

St	Longitude	Latitude	Depth	Impedance	Rudeness	Phi	Volume	*Backscatter*	Tipe
1	106°50'14.246"BT	6°5'7.517" LS	-9,1547	1,0668	3,1846	9	0,1	-34,9	*Clay*
2	106°50'28.021"BT	6°5'18.413"LS	-9,0702	1,0722	3,1369	9	0,08	-34,2	*Clay*
3	106°49'13.237"BT	6°4'55.011"LS	-9,0551	1,0668	3,6780	9	0,0	-37,1	*Clay*
4	106°49'10.796"BT	6°5'2.721" LS	-9,6829	1,0875	3,1707	9	0,06	-32,7	*Clay*
5	106°48'46.811"BT	6°5'11.801"LS	-7,1314	1,1470	3,6780	5,2	0,2	-30,4	*Sandy silt*

6	106°48'43.641"BT	6°5'14.028"LS	-7,3657	1,1758	3,6780	4,9	0,2	-29,1	*Coarse silt*
7	106°48'37.22"BT	6°5'11.021"LS	-6,9926	1,2544	3,6780	4,1	0,6	-26,2	*Clayey sand*
8	106°49'1.837"BT	6°5'17.615"LS	-7,7399	1,0568	3,6780	9	0,04	-38,1	*Clay*

Physical characteristics other than backscatter that affect sediment classification are also obtained such as impedance, roughness, grain size, and volume. If analyzed from the impedance value obtained at each station, eight stations showed variations in values that were not much different, 1.0 at stations one, two, three, four, and eight, impedance values 1.1 at stations five, six, and seven. Acoustic impedance is the ability of a rock layer to pass acoustic waves, so the greater the acoustic impedance value, the greater the acoustic backscatter value. The roughness values obtained show differences at each station and do not affect sediment backscatter. Because roughness is caused by the distribution of sediment on the surface, this is related to sediment transport caused by shallow currents and waves. Therefore, the roughness value cannot directly influence the determination of sediment type. The sediment volume value is directly related to Phi sediment or sediment grain size.

Sediment Sample Analysis

The results of sediment sample processing using a sieve shaker with the dry sieving method using the Wentworth scale sediment sample classification reference, (1922) produced four types of sediment based on the size of the sediment grains, namely fine sand, very fine sand, coarse silt, and mud. The results of sediment sample processing are presented in Table 4.

Table 4. Results of sediment sample classification on the Wentworth scale, (1922)

Sta siun	Coarse Sand Once 2 mm (gram)	Coarse Sand 1 mm (gram)	Medium Sand 0.5 mm (gram)	Fine Sand 0.25 mm (gram)	Very Fine Sand 0.125 mm (gram)	Coarse Silt 0.063 mm (gram)	Residue < 0.063 mm (gram)	Sediment Type
1	0.0807	0.2394	1.8733	3.6836	6.8974	2.2698	4.6986	Very Fine Sand
2	0.0247	0.1012	1.9610	4.2279	3.6781	3.2756	6.2117	Mud
3	0.0107	0.8980	2.9371	3.7544	2.9556	2.0381	6.8288	Mud
4	0.0000	0.4240	2.8044	3.4376	3.6208	6.4296	2.8052	Coarse Silt
5	0.0916	0.6096	2.7630	4.7954	5.1268	4.5832	1.5148	Very Fine Sand
6	0.0166	0.2171	1.7685	4.8608	6.3763	4.1298	2.1243	Very Fine Sand
7	0.022	0.3897	2.6369	5.8261	4.9892	4.2739	1.4738	Fine Sand
8	0.0114	0.2576	2.5816	3.5970	3.2740	3.3480	6.6059	Mud

Sample analysis based on sediment size that has been sieved using the dry sieving method with 3 amplitude vibrations for 15 minutes, obtained classification results with the Wentworth scale, (1922). There are 3 stations dominated by sediment measuring <0.063 mm with residue types at stations two, three, and eight, these three samples will be analyzed using the pipetting method, the pipetting method is important to determine the type of sediment that is finer than 0.063 mm or the type of mud.

In the pipetting method, analysis is carried out based on the length of time the sample has been deposited, the faster the sediment settles, the larger the sediment is classified in particle size. The results of the pipetting sediment analysis are presented in Table 5.

Table 5. Results of the pipetting sediment analysis

Stasiun 2	Weight of empty cup (g)	Weight of the cup (g)	Difference (g)	Diluent Factor	Sediment weight (g)	Sediment type
45"	40,724	40,881	0,157	20,00	3,1400	Coarse Silt
30'	36,262	36,376	0,114	23,75	2,7075	Medium Silt
1 jam	34,952	35,069	0,117	22,75	2,6618	Fine Silt
5 jam	42,268	42,422	0,154	21,75	3,3495	Coarse Clay
24 jam	38,837	38,899	0,062	20,75	1,2865	Fine Clay
Stasiun 3	Weight of empty cup (g)	Weight of the cup (g)	Difference (g)	Diluent Factor	Sediment weight (g)	Sediment type
45"	37,438	37,597	0,159	20,00	3,1800	Coarse Silt
30'	35,926	36,022	0,096	23,75	2,2800	Medium Silt
1 jam	40,090	40,186	0,096	22,75	2,1840	Fine Silt
5 jam	35,627	35,793	0,166	21,75	3,6105	Coarse Clay
24 jam	36,591	36,645	0,054	20,75	1,1205	Fine Clay
Stasiun 8	Weight of empty cup (g)	Weight of the cup (g)	Difference (g)	Diluent Factor	Sediment weight (g)	Sediment type
45"	34,290	34,489	0,199	20,00	3,9800	Coarse Silt
30'	37,108	37,223	0,115	23,75	2,7313	Medium Silt
1 jam	39,761	39,879	0,118	22,75	2,6845	Fine Silt
5 jam	36,595	36,798	0,203	21,75	4,4153	Coarse Clay
24 jam	36,606	36,661	0,055	20,75	1,1412	Fine Clay

Based on Table 5, the results of pipetting analysis on three sediment samples obtained sediment classification results dominated by coarse clay types at the three stations. Namely, the sedimentation time is 5 hours with a weight at station two of 3.3495 grams, station three is 3.6105 grams, and station eight is 4.4153 grams. The dilution factor is the amount of aquadest used to dilute the solution divided by the amount of hydrogen peroxide. The calculation of the sediment weight value is influenced by the amount of the dilution factor, where the calculation of the sediment weight is done by multiplying the difference in the weight of the cup by the dilution factor value.

CONCLUSION

Based on the research results, it can be concluded that the backscatter intensity value of Jakarta Bay sediment produces a range of values from -40 dB to -27 dB. Based on the distribution of sediment, it is divided into ten classifications of sediment types, namely clay, silty clay, sandy clay, sandy silt, very fine silt, fine silt, medium silt, corse silt, sandy mud, and clayey sand. The sediment type is dominated by mud and clay types. The results of sediment sample analysis using the dry sieving and pipetting methods at eight station points showed different values, there were four types of sediment obtained based on their grain size, namely coarse clay, coarse silt, fine sand, and very fine sand. Based on the two analysis results, it shows a match where the greater the backscatter intensity, indicating larger sediment grains.

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