Development of Sediment Grain Size Maps from Sidescan Surveys of the Lower Severn River, Maryland

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Abstract:

Sidescan sonar can be used to conduct high-resolution mapping of the coastal ocean floor to determine local bathymetry, bottom characteristics and features. However, this technology does not directly yield data on the properties of sediments. In December 2015, a sidescan survey of the lower Severn River, Maryland was conducted using an EdgeTech 6205 Swath Bathymetry and Sidescan Sonar system deployed from the *R/V Daiber* from the University of Delaware. Concurrent with the survey, discrete sediment grab samples were collected from the survey area and analyzed for sediment grain size. In this study, sidescan sonar backscatter amplitude data was correlated to sediment grain size values measured from grab samples to create high-resolution sediment grain-size contour maps of the lower Severn River, Maryland. Results demonstrate an approach for rapid assessment of the sedimentological environment in coastal, estuarine environments such as the lower Severn River. Contour maps like those created in this study can potentially be used to develop simple, first-order models of sediment erodibility, transport, and geotechnical stability under different hydraulic regimes which can ultimately enhance Navy and Marine Corps operations in the littoral zone.

Study Area and Methods:

Figure 1. Survey area of the lower Severn River, MD (in yellow) showing the U.S. Naval Academy (USNA) and the locations of 22 sediment sampling stations chosen based on prior knowledge of the study area. The symbol for each sampling location designates a ~30 m radius around the sampling point.

A sidescan survey of the lower Severn River (**Fig. 1**) was conducted on 02 DEC 2015 from the *R/V Daiber* (University of Delaware) using an EdgeTech 6205 Swath Bathymetry and (multi-phase) Sidescan Sonar system (**Fig. 2**). Sediment grab samples were also collected at 22 sites from a small boat on 02 & 10 DEC 2015. These samples were analyzed for sediment grain size (gravel, sand, fines) in the Hendrix Oceanography laboratory at USNA. Raw sidescan survey data were corrected for pitch, roll, salinity, and temperature to produce geo-reference backscatter amplitude and bathymetry values. This data was averaged over a 30 m radius which matches survey grid line spacing (**Fig. 3**) and correlated to Wentworth Scale mean grain size (ϕ_{AVG}) values, which were derived from volume and porosity corrected grain size ($d50_{AVG}$ (mm)) data from the sediment grab samples. Results were analyzed using MATLAB, Surfer, and ENVI software and displayed in Google Earth.

Figure 2. *R/V Daiber* (University of Delaware) underway at USNA with an EdgeTech 6205 Swath Bathymetry and Sidescan Sonar system, and MIDN 1/C Margo Darragh in Narraganset Bay conducting geophysical surveys with a Gavia Autonomous Underwater Vehicle (AUV).

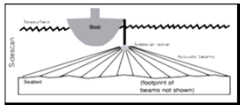

Figure 3. Conceptual image of the acquisition geometry of sidescan sonar (from Fig. 1, Collier and Brown, 2005).

Sidescan Survey Results:

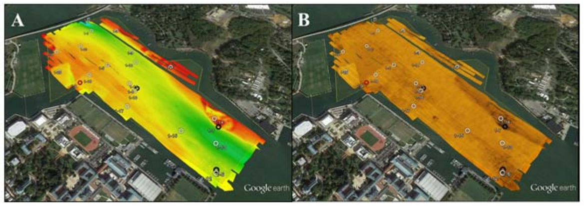

Figure 4. Google Earth layers of processed (**A**) bathymetry and (**B**) backscatter amplitude from data for the lower Severn River collected by the EdgeTech 6205 Swath Bathymetry and Sidescan Sonar system from the *R/V Daiber* on 02 DEC 2015.

Figure 4 shows the processed bathymetry (**Fig. 4A**) and sidescan backscatter amplitude (**Fig. 4B**) data from the geophysical survey of the lower Severn River on 02 DEC 2015. This data was analyzed using a kriging method to develop high-resolution contour maps of bathymetry (**Fig. 5A**) and backscatter amplitude (**Fig. 5B**) for the survey area. There is a clear, deeper channel (up to ~ 8+m) in the lower Severn River that generally coincides with a region of lower backscatter amplitude. Shallower areas (< 5 m) tend to have higher backscatter amplitude values.

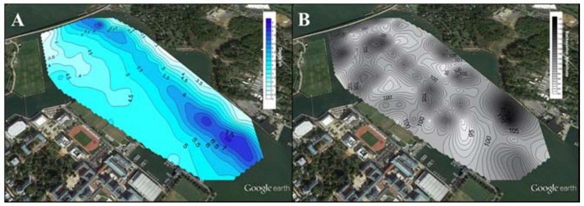

Figure 5. Google Earth layers for (**A**) bathymetry and (**B**) backscatter amplitude contours for the lower Severn River developed by kriging data collected by the EdgeTech 6205 Swath Bathymetry and Sidescan Sonar system from the *R/V Daiber* on 02 DEC 2015.

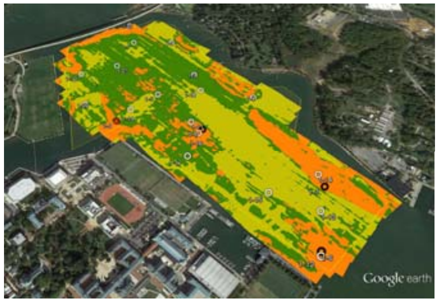

Figure 6. Processed backscatter amplitude in the survey area categorized and grouped into three primary return classification using ENVI software.

Backscatter amplitude data was processed utilizing Environment for Visualizing Images (ENVI) software to statistically categorize the data into three major return classifications (**Fig. 6**). Areas with the higher return values represented ~36% of the survey area, where the lower values represented ~21% of the survey area. ~41% of the survey area was classified as having intermediate return. As noted with the processed and contoured data, these backscatter categories tend to follow bathymetry closely.

Correlations to Grain Size:

Table 1. Values from sediment grain size analysis shown with average backscatter amplitude ($BS_{AMP-avg}$), $d50_{avg}$ (mm) , ϕ_{avg} and estimated phi values (ϕ_{est}).

SampleID	%Gravel	%Sand	%Fine	$BS_{AMP-avg}$	d_{50-avg} (mm)	ϕ_{avg}	ϕ_{est}
120215_1-1	7%	71%	22%	102.3	0.97	0.04	0.15
120215_1-2	2%	72%	26%	100.3	0.78	0.35	0.26
120215_1-3	0%	75%	25%	99.4	0.73	0.44	0.31
120215_1-4	1%	93%	6%	100.2	0.93	0.10	0.26
120215_1-5	3%	73%	23%	99.9	0.85	0.23	0.29
120215_1-10	6%	91%	4%	100.7	1.11	-0.15	0.24
120215_1-11	8%	71%	21%	99.4	1.02	-0.03	0.31
121015_1-12	10%	75%	15%	104.7	1.14	-0.19	0.00
121015_1-13	6%	73%	21%	105.8	0.97	0.04	-0.06
121015_1-14	3%	90%	7%	105.7	1.00	0.00	-0.06
121015_1-15	2%	74%	24%	100.3	0.79	0.33	0.26
121015_1-16	1%	76%	24%	99.3	0.76	0.39	0.32
121015_1-17	1%	67%	32%	99.4	0.72	0.48	0.31
121015_1-18	3%	74%	22%	99.3	0.87	0.20	0.32
121015_1-19	1%	74%	26%	100.9	0.75	0.42	0.23
121015_1-20	2%	64%	35%	99.8	0.69	0.53	0.29
121015_1-21	1%	77%	22%	102.2	0.80	0.32	0.15
121015_1-22	2%	95%	3%	102.8	0.99	0.01	0.11

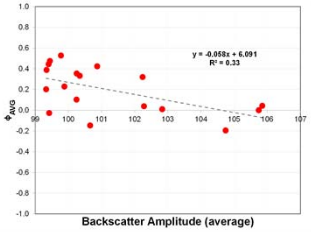

Figure 7. Linear relationship between ϕ_{avg} and $BS_{AMP-avg}$ values that used to estimate phi values (ϕ_{est}) for the entire survey area.

In the survey area, there is some correlation between backscatter amplitude and bathymetry (**Fig. 4 & 5**). **Table 1** and **Figure 7** show the correlation between ϕ_{avg} from discrete sediment grabs and $BS_{AMP-avg}$ values within 30 m of the grab site. This correlation was used to estimate phi values (ϕ_{est}) based on backscatter amplitude over the entire survey area. This data was then interpolated using a kriging method to develop a contour map of ϕ_{est} for the lower Severn River (**Fig. 8**).

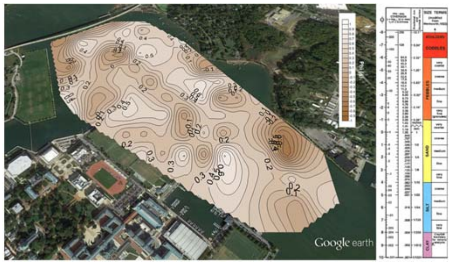

Figure 8. Google Earth layer of contoured ϕ_{est} for the lower Severn River developed by kriging. Estimated phi values range from 1 to -1 indicative of a mean grain size between coarse and very coarse sands (http://pubs.usgs.gov/of/2000/of00-358/text/chapter1.htm).

The contour map developed for the lower Severn River (**Fig. 8**) is a reasonable representation of relative grain size distribution. Results likely over-represent the gravel fraction resulting a larger mean grain size. Differences could result from limiting grain size analysis into just three size fractions. Errors were also introduced by assuming a flat bottom (**Fig. 3**) across the entire survey area (**Fig. 5A**). Future efforts should account for a non-flat bottom and use higher-resolution grain size data from advanced analytical methods like Laser Diffraction Particle Size Analysis.

Conclusions:

- ***The relationship between sediment grain size data from discrete samples and sidescan backscatter amplitude survey data yields a reasonable correlation that can used to develop sediment grain size contour maps.***
- ***Contour maps like those created in this study can potentially be used to develop simple, first-order models of sediment erodibility, transport, and geotechnical stability which can ultimately enhance Navy and Marine Corps operations in the littoral zone.***

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