Morphological Characteristics and Sediment Transport in an Engineered Tidal Freshwater Marsh System

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1.1 Scientific Abstract

Tidal freshwater marshes serve important ecological functions such as attenuating storm surges and protecting higher land from erosion. In the Anacostia watershed, marshes have been lost to urbanization and channelization, and are currently at risk to decreasing sediment supply and sea level rise. Marsh construction and restoration is part of the effort to combat these risks, and marsh response to sea level rise is a research area of increasing interest. Sediment accretion within tidal freshwater marshes must equal or outpace sea level rise for marshes to maintain elevation. Marsh channels distribute sediment throughout the marsh system and deposit it onto the elevated marsh platform. The morphology of the marsh system impacts the effectiveness of sediment transport through the channels. The goal of this study is to examine the relationship between marsh channel morphology and sediment transport in a constructed tidal freshwater marsh and to compare these characteristics to theoretical systems and local tidal freshwater marshes. The constructed tidal freshwater marsh is located off the Anacostia River in Hyattsville, Maryland. Field and air photograph measurements were used to estimate drainage density, channel width distribution, and hydraulic geometry. These morphological characteristics were used to calculate vertical distributions of suspended sediment concentration for each cross-section. The constructed marsh had a larger drainage density than natural Patuxent marshes. The cumulative channel length and relationship between inlet width and basin area was comparable to natural systems. However, the constructed marsh channels widened locally. This morphology suggests sediment is being deposited on the channel beds as opposed to on the marsh platform.

1.2 Plain Text Abstract

Sea level rise poses a risk to wetlands such as tidal freshwater marshes. For marshes to outpace sea level rise, they must accumulate sediment at a faster rate than sea level rise. For this to happen, sediment must travel through the channels and upwards onto the marsh platform. The size and shape of an individual channel within the marsh influences the amount of sediment moving through it. It also influences whether sediment is deposited onto the bottom of the channel, or if it is deposited on the elevated marsh platform. In natural marshes, channels get narrower as distance into the marsh increases. This allows for sediment to be transported from the inlet to the furthest parts of the marsh platform. Sediment transport and accumulation can be estimated using field and air photo measurements. The aim of this study is to evaluate the channel system of a constructed marsh and the relationship between channel morphology, sediment transport, and sediment deposition. The vertical distribution of suspended sediment was calculated for individual channels and used to determine the longitudinal distance of sediment transport for multiple grain sizes. The suspended sediment distributions suggest coarse grain sizes will be deposited on the channel beds, instead of onto the marsh platform.

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Cover Photo Description: Photo of the constructed marsh inlet, facing the Anacostia River.

2 Statement of Problem

Tidal freshwater marsh channels distribute mineral and organic sediment throughout the channel network to the marsh platform. The sediment flux throughout the marsh can be determined using the hydraulic geometry of channels within the network. Sea level rise in the Chesapeake Bay has accelerated to a rate of 4 to 10 millimeters per year and is exacerbated by regional subsidence (Ezer and Corlett, 2012). Tidal freshwater marsh response to sea level rise is an area of increasing interest. Rates of marsh sedimentation increase when sea level rises because the period of inundation increases (Friedrichs and Perry, 2001). However, annual accretion within the marsh must keep pace with the rate of sea level rise for marsh elevation to maintain equilibrium. The extent to which marshes are at risk is still being studied. Kirwan et al. (2016) found that previous models of annual marsh accretion overestimate marsh vulnerability to sea level rise. Longer periods of inundation caused by sea level rise led to increased sedimentation, vegetation growth, and organic matter accumulation and annual marsh accretion rates grew at a comparable rate to sea level. In the study, Kirwan et al. (2016) discuss other anthropogenic factors that impact marsh elevation such as reduced sediment supply and regional subsidence. Marsh elevation is defined as:

(1)

$$Marsh\ elevation = Sediment\ Accretion - (Subsidence + Sea\ Level\ Rise)$$

where sediment accretion includes mineral and organic sediment. Channel geometry and marsh morphology control the amount of sediment distributed throughout the marsh. In the 20th century, tidal wetlands in the Anacostia Estuary had largely been lost to channelization, urbanization, and agricultural land-use. Approximately 2,600 acres of wetlands within the Anacostia Estuary were destroyed between 1900 and 1960 (NCPC, 2008). As a result, the frequency and severity of floods caused by heavy rainfall increased. In recent years, wetlands have been created to restore the estuary to its previous condition. Since 1993, over 100 acres of wetlands have been restored or built in the Anacostia Estuary (NCPC, 2008). The focus of this research is to examine the geomorphic and hydraulic characteristics of the constructed Anacostia tidal freshwater marsh system to determine how these characteristics impact sedimentation throughout the marsh. The constructed marsh is in the Northwest sub-branch of the Anacostia Watershed (Figure 1).

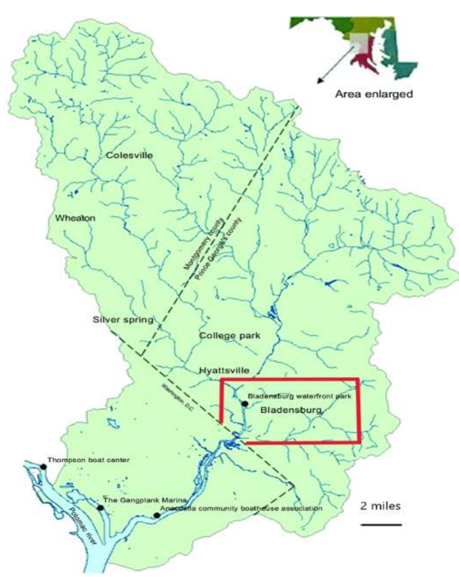

Figure 1: Map of the Anacostia Estuary (Murray et al., 2015) with the area of interest highlighted in red.

3 *Previous Work*

Sediment transport through tidal channels is driven by wind, river flow, and tides. The Anacostia Estuary experiences a semi-diurnal tidal cycle; there are two high tides and two low tides within a 24-hour period. The magnitude of the tidal force varies throughout the month depending on lunar position. Flood tide inundates tidal channels with sediment and sediment is delivered to the elevated marsh platform. Water surface decreases during ebb tide as flow moves out of the marsh (Friedrichs and Perry, 2001).

The geometry of the marsh inlet significantly impacts inflow and retention of sediment. As cross-sectional area of the inlet increases, a larger volume of water enters the system during flood tide (Lanzoni and Seminara, 2002). Over time, the morphology of flood-dominated tidal systems evolves towards an equilibrium state. Tidal bed profiles become more concave due to deposition as sediment flux is focused inland; the elevation of the system increases landward. The tidal system evolves towards a fixed length, which is determined by the geometry of the inlet.

The drainage density, D of a tidal freshwater marsh is defined as the total length of the channels, L, within the marsh divided by the basin area, A.

(2)

$$D = \sum L/A \qquad (m^{-1})$$

In tidal systems, drainage density is defined by the degree of channelization and the shape of the basin (Marani et al., 2003). Drainage density is used to examine how efficiently channels direct flow during flood and ebb tide. It is also used as a proxy for sedimentation characteristics within a tidal marsh. Marani et al. (2003) studied tidal marshes in the Venice Lagoon, Italy and found that basin area was a more important variable than tidal prism for marsh equilibrium states. The area of the marsh determined the final bed elevation and concavity. Vandenbruwaene and Temmerman (2012) found that constructed tidal marshes had a lower drainage density after four years compared to natural tidal marshes. The lower drainage density resulted in a high suspended sediment concentration in distal channels and rapid infilling as loose sediment piled up.

At-a-station hydraulic geometry

Channel width, depth, and velocity of a cross-section vary to maintain discharge. This is known as at-a-station hydraulic geometry. Discharge is defined as the volume of water moving through a cross sectional area over time. Leopold and Maddock (1953) described the relationship between width, depth, and velocity to discharge and introduced the concept of hydraulic geometry.

(3)

$$Q = w * d * v = constant \quad (m^3 \cdot s^{-1})$$

where Q is discharge, w is channel width, d is depth, and v is velocity. In natural tidal systems, the concentration of suspended sediment increases as discharge increases. This implies the system is inundated with up-river erosional sediment during rainfall and storm events (Leopold and Maddock, 1953).

Up-marsh hydraulic geometry relationships

At-a-station hydraulic geometry is used to describe geometric relationships throughout a channel network. As distance inland increases, channel width decreases. Mean depth and mean velocity vary slightly. Langbein (1963) interpreted this significant decrease in channel width as a necessity for velocity to be maintained and for sediment to be distributed through the entire system. In natural flood dominated systems, the relationship between channel width and distance inland can be characterized using this equation:

(4)

$$B = B_0\, exp\left(\frac{-x}{L_b}\right) \qquad (m)$$

where B is the width of the cross-section, B_0 is the width of the inlet, x is the longitudinal distance moving inland, and L_b is the convergent length or the total length of the marsh system (Lanzoni and Seminara, 2002). Lanzoni and Seminara developed a one-dimensional numerical model using this relationship and found it supported field observations in both Venice Lagoons and salt marshes.

Suspended Sediment Transport Theory

Flow through tidal channels vary based on interactions with channel boundaries. According to the Law of the Wall, mean velocity is a function of shear velocity and roughness height of the bed, and increases moving upwards at a logarithmic rate (Prandtl, 1952).

(5)

$$u = \frac{u_*}{k} \ln\left(\frac{z}{z_0}\right) \qquad \left(\frac{m}{s}\right)$$

where u is mean velocity, u_* is shear velocity, k is von Karman's constant, z is distance above the bed, and z_0 is roughness height. For tidal channels, bed roughness is the frictional force acting on tidal flow. Bed shear stress is the amount of force per unit area acting on the bed of the channel. Critical shear stress is the shear stress value required to entrain sediment. Shear velocity of flow changes based on turbulence and turbulence varies with depth. Shear velocity is defined as:

(6)

$$u* = \sqrt{gSH}$$

where g is acceleration due to gravity, S is water surface gradient, and H is flow depth. Larger clasts require a higher shear velocity to be transported so they fall out of suspension when flow regime decreases slightly. Finer grain sizes are likely to be deposited only during slack tide, when flow is not moving in either direction. Sediment concentration is defined as:

(7)

$$c = \frac{sediment\ volume}{water\ volume + sediment\ volume}$$

Rouse (1937) defined the Rouse number as the ratio of particle fall velocity to shear velocity. Particle fall velocity can be defined as:

(8)

$$v_s = (R_f)(\sqrt{RgD})$$

where R_f is particle Reynolds number, R is the specific gravity of the sediment, g is acceleration due to gravity, and D is grain size. Using the Rouse method, a vertical profile of suspended sediment concentration can be plotted. Grain sizes in suspension a certain height above the bed are likely to deposit onto the elevated marsh platform. Grain sizes concentrated near the bed are likely to deposit onto the channel bed, and infill the channel. A vertical suspended sediment profile was calculated for each of the measured cross-section locations. These distributions can be used to estimate the longitudinal distance of sediment transport for varying grain sizes.

Vegetated tidal channels

The presence of vegetation in natural tidal channels leads to higher flow resistance and, therefore, lower shear stress acting on the bed. This contributes to sediment accretion within the marsh. Statkiewicz (2014) found the presence of submerged aquatic vegetation within the channels increased hydraulic roughness and flow resistance for tidal freshwater marshes in the Patuxent Watershed. The presence of submerged vegetation decreases the channel area and funnels flow through the center of the channel. Vegetation catches sediment and temporarily increases sediment accumulation. However, during vegetation die-back, this sediment likely leaves the channels with the vegetation.

4 Hypotheses

Morphological Hypotheses:

- **I.** The constructed marsh has a lower drainage density compared to five natural freshwater tidal marshes in the Patuxent River.
- **II.** Channel width does not decrease exponentially as distance inland increases.
- **III.** The restored marsh channels do not have submerged vegetated platforms with a triangular shape.

Sedimentation Hypotheses:

- **IV.** Channel extent and depth limit the transport of sediment into the marsh.
- **V.** Sediment will be deposited on channel beds, particularly in locally widened sections of channel and in small channels with shallow depths.

Null Hypothesis: The constructed marsh network and channel characteristics are not significantly different from natural or theoretical marsh channel characteristics.

5 Study Site

The constructed tidal freshwater marsh is in the Anacostia River, Hyattsville MD (38°55’30” N and 76°56’17” W). Construction began in 2009 and was completed in 2010 (Figure 2). The eastern boundary of the marsh is constrained by a bike path and urban development.

Figure 2: Top: Google Earth air photo from 12/2008 of the marsh location before construction. The red outline has an area of 39,000 m2 and depicts the future location of the marsh. Bottom: Air photo from 1/2017 of the constructed marsh with the same red outline from the image on the top.

Figure 3: Map of Patuxent River Marshes. Google Earth air photo taken on 8/2010.

The constructed marsh was compared to natural tidal freshwater marshes along the Patuxent River, MD (Figure 3). Statkiewicz (2014) studied the annual cycle of sediment erosion and deposition within the marshes, and how this cycle is impacted by aquatic vegetation. Aquatic vegetation was separated into two categories: emergent species and submerged aquatic vegetation. The constructed Anacostia marsh has emergent vegetation, but the extent of submerged aquatic vegetation within the channels still needs to be studied.

6 *Methods and Data Analysis*

Cross-section measurements

On September 16 and October 1, 2023, Dr. Prestegaard and I collected cross- section measurements at 13 sites throughout the marsh system (Figure 4). At each channel, depth measurements were collected in 1-foot intervals across each channel transect using a tape measure and a survey rod. Each depth measurement includes the depth to the channel bed and the depth including soft sediment. To record the amount of soft sediment at the bottom of the bed, the survey rod was pushed into the sediment and the additional depth was recorded. The rod entered soft sediment with little resistance and abruptly stopped upon reaching the channel bed. Uncertainty for cross-section widths can be determined using a Google Earth measurement to calculate the percent error. The channel depth measurements were used to calculate the vertical distribution of suspended sediment concentration at each site. The measurements were used to quantify up-marsh hydraulic geometry relationships and to predict distance inland of sediment transport.

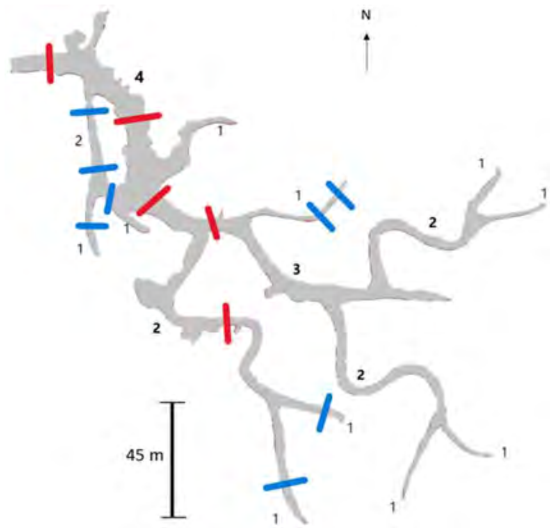

Figure 4: Drawing of cross-section measurement locations. The red lines represent measurements recorded on 9/16/2023. The blue lines represent measurements recorded on 10/01/2023. The lines are exaggerated and only represent location, not size of the cross-section.

Water surface level measurements

On September 16 2023, water surface level measurements were recorded at five sites throughout the marsh system. USGS-style staff gages were placed into the marsh platform at the edge of each channel site (Figure 5). Gage height was measured over a period of 4 hours as water level decreased during the ebbing tidal stage. Each measurement was recorded to the minute. The staff gages are marked in intervals of a hundredth of a foot. The gage height is measured to a thousandth of a foot with ± 0.01 ft error. Each measurement was converted to meters with an error of ± 0.003 meters.

Figure 5: Tidal stage measurement using a USGS staff gage.

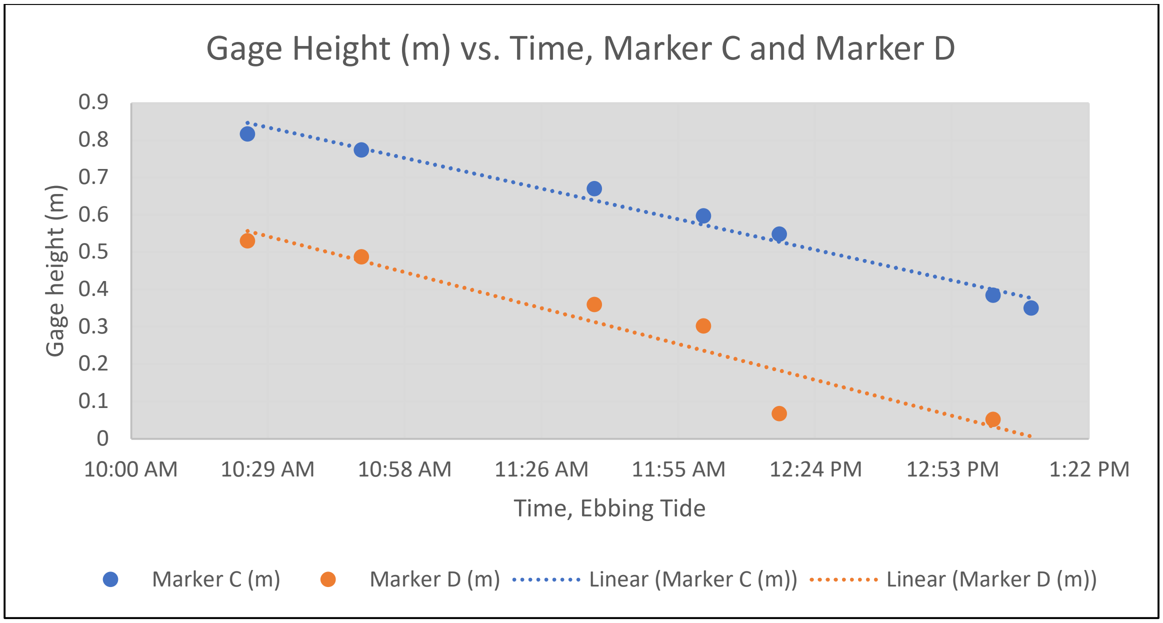

Figure 6: Raw gage height data plotted against time during ebb tide. To calculate water surface gradient, gage heights are standardized to an initial starting value. Each data point has an error of ± 0.003 meters.

The USGS provides gage height data measured at the Anacostia Park boat ramp on the Anacostia River. These data can be used to determine when high tide and outgoing tide measurements should be taken. On September 16, 2023 the first high tide was at 09:25 a.m. (U.S. Geological Survey, 2023, National Water Information System). As water surface level decreased, gage height was recorded. Gage height is plotted against time (Figure 6). Each marker is labeled in alphabetical order as distance from the inlet increases, with the inlet being A. These data were used to normalize cross-section measurements to the same high tide value for a particular day. Water surface level measurements were used to calculate gradient, S between two sites. Gradient is used to calculate shear stress. This was used to calculate the vertical distribution of suspended sediment concentration. The gradient calculations will also be compared to water surface levels and elevations in local marshes and in theoretical systems.

Google Earth Measurements

Air photos were used to measure morphological characteristics and to observe changes in morphology since marsh construction in 2009. The sum of channel lengths will be measured using Google Earth and a percent uncertainty will be applied. The basin area of the constructed marsh was also be measured using Google Earth. The relationship between these values is defined as drainage density and will be compared to the drainage densities of local Patuxent marshes (Statkiewicz, 2014). Longitudinal distance, x, has been measured using Google Earth and used to plot channel width distribution throughout the marsh system.

Vertical distribution of suspended sediment concentrations

The Rouse profile of suspended sediment concentration is constructed using a reference level bedform height of b = 0.1. The upwards profile, z, is calculated from a value of 2*b (Figure 7). The ratio of z and flow depth, H is plotted against the ratio of sediment concentration to near-bed sediment concentration. Flow depth, H is the maximum depth without mud measured for each cross-section.

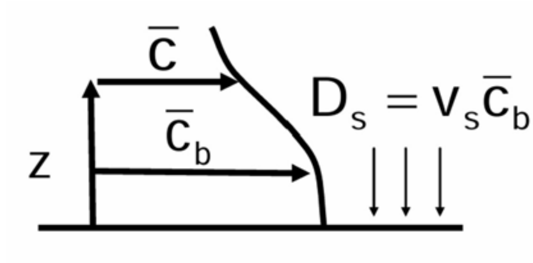

Figure 7: The standards used to plot a vertical profile of suspended sediment concentration (Parker, 2004).

7 *Presentation of Data and Discussion of Resuslts*

Drainage Density

Drainage density was calculated for the constructed Anacostia marsh and three natural Patuxent marshes by measuring the total channel lengths and basin areas using Google Earth air photographs. Contrary to the first hypothesis, the constructed Anacostia marsh has a higher drainage density compared to the natural Patuxent marshes. This suggests that the Anacostia marsh has a higher degree of channelization than the natural Patuxent marshes. Visual observations of the marsh support this; the Anacostia marsh has a higher ratio of channels to marsh platform than the Patuxent marshes. As basin area increases, the drainage density decreases exponentially.

Figure 9 plots total channel length against basin area for the constructed Anacostia marsh, in red, and three of the natural Patuxent marshes. The points from all four sites reasonably plot along the same line which suggests a positive correlation between total channel length and basin area. This suggests that marsh area is a key forcing that determines marsh formation and evolution. The lower total channel length and higher drainage density suggest the constructed Anacostia marsh has a more efficient channel network.

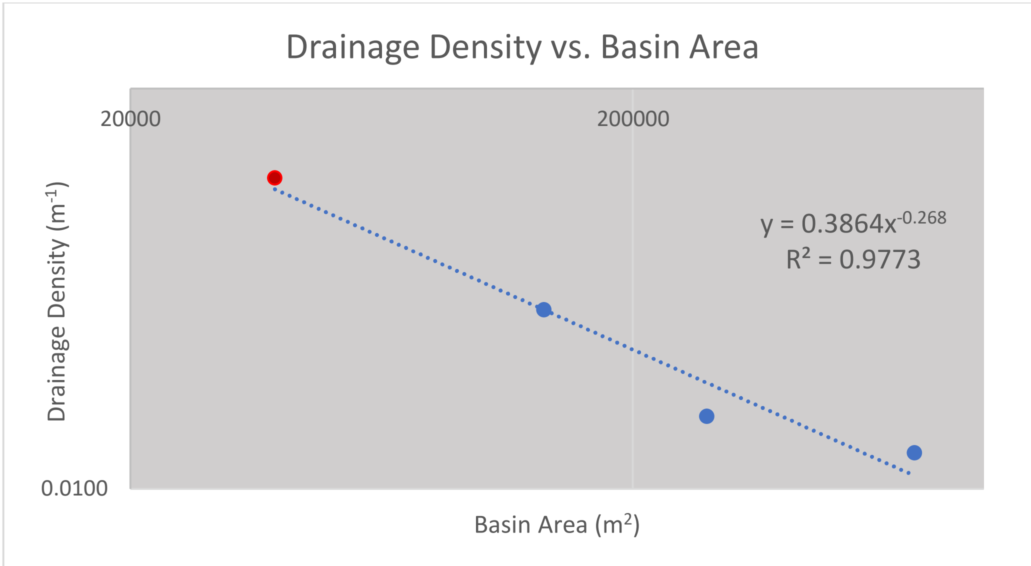

Figure 8: Drainage density vs. Basin area. The constructed Anacostia marsh is represented in red. The Patuxent marshes are in blue.

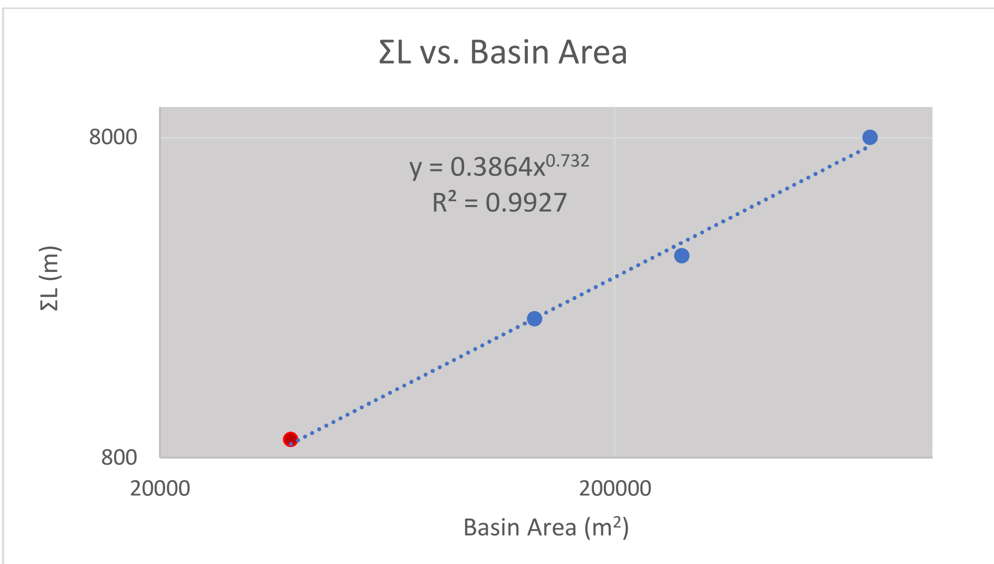

Figure 9: Total channel length vs. Basin area. The constructed Anacostia marsh is represented in red. The Patuxent marshes are in blue

Inlet width and depth determines the amount of flow and sediment that can enter and exit the marsh. The basin area of four constructed Anacostia marshes was plotted in red against inlet width. The basin area and inlet width of natural Patuxent marshes are represented in blue. The constructed Anacostia marshes tend to have narrower inlets than Patuxent marshes based on the basin area. One possible consequence of a narrow inlet is that the volume of water, and therefore the amount of sediment, entering the tidal marsh is limited.

Figure 10: Google Earth air photo showing four constructed Anacostia marshes.

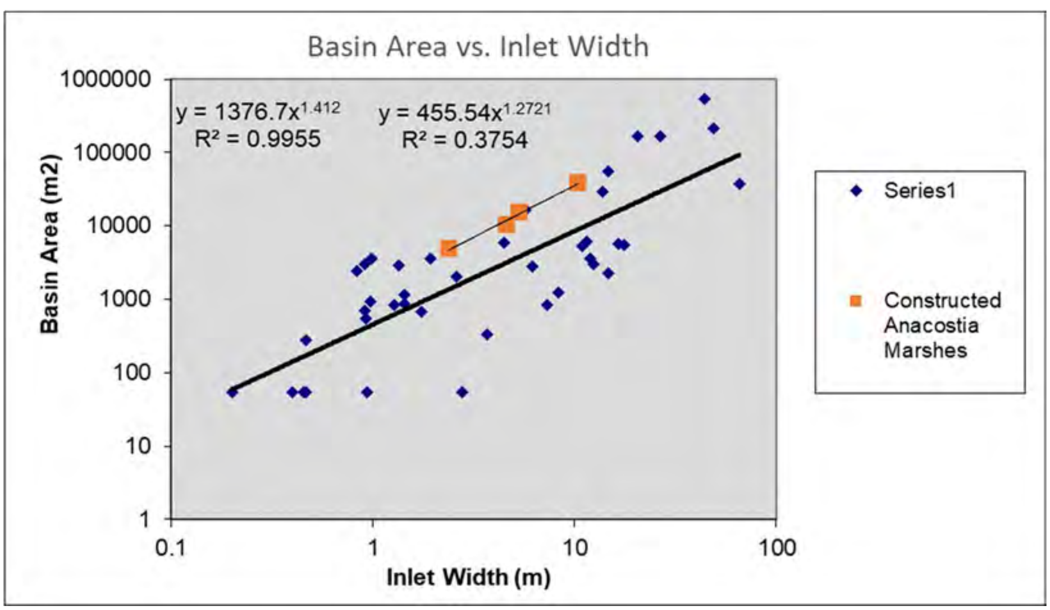

Figure 11: Basin area vs. inlet width for the four constructed Anacostia marshes (red) and natural Patuxent marshes (blue).

Width Distribution

Channel width measurements made in the field were compared to distance measurements made using air photos and the results are plotted. Distance inland is measured from the inlet. In the constructed marsh, channel width decreases as distance inland increases with a constant of proportionality of -0.003. Between 50 and 100 meters, two channels widen with distance and both channels are wider than the inlet. The theoretical channel width distribution yields a constant of proportionality of -0.004. Each theoretical channel width was determined using Equation 4. The rate of width decreases using the theoretical model is higher than the actual values.

Distance Inland, from Inlet (m)	Actual Channel width (m)	B_0 Theoretical Width (m)
0	10.40	10.40
31	3.96	8.93
52	11.60	8.27
54	5.79	8.21
74	3.05	7.63
82	3.96	7.41
86	14.00	7.31
110	6.34	6.69
142	4.57	5.96
146	1.37	5.87
147	4.40	5.85
200	3.96	4.82
219	4.27	4.50

Table 1: Table of measured channel widths and calculated theoretical channel widths.

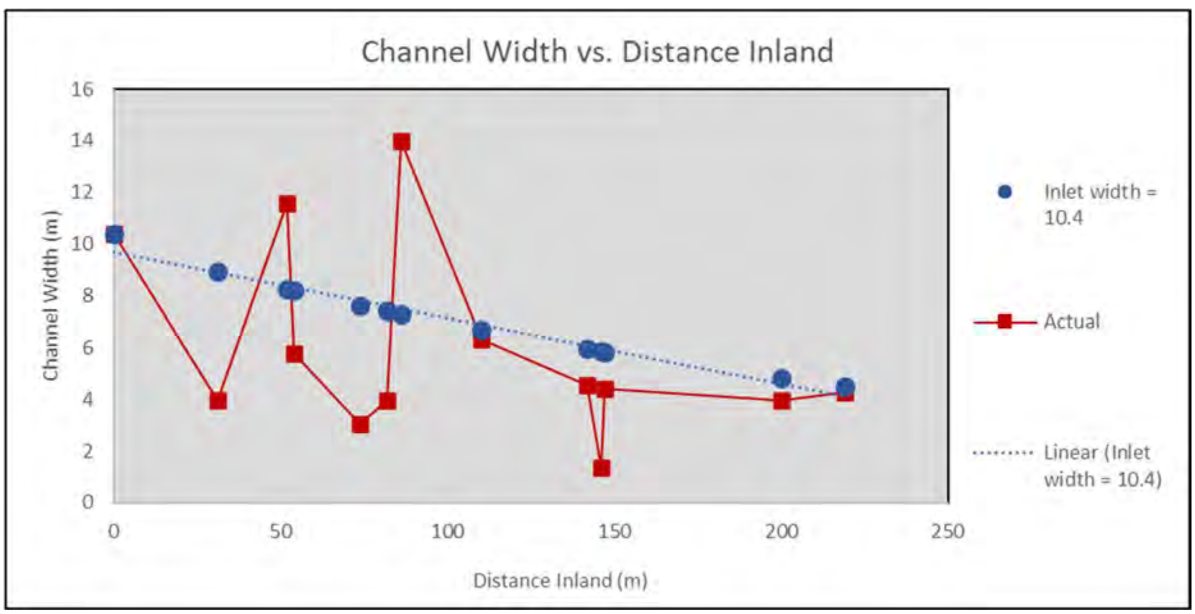

Figure 12: Channel width vs. distance inland. In red are the measured channel widths. The theoretical distribution is in blue.

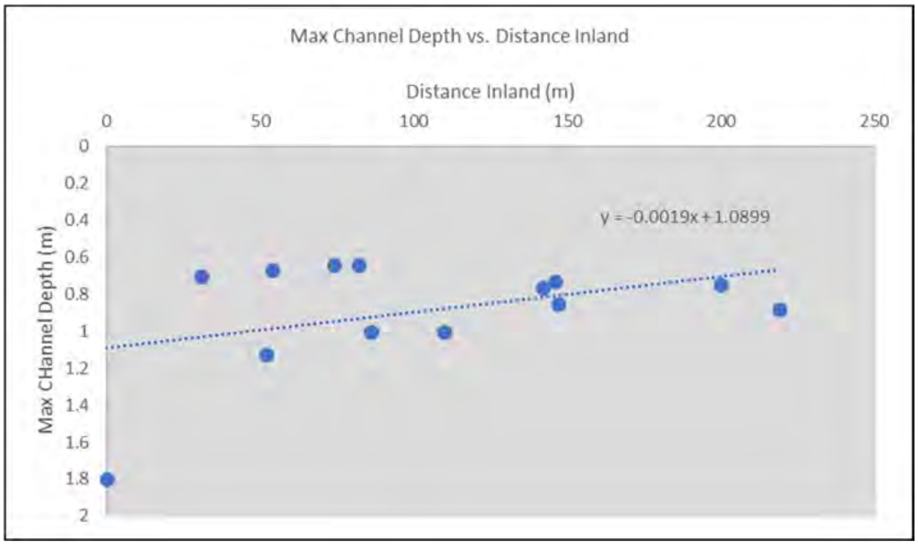

Figure 13 Maximum channel depth vs. distance inland.

Cross Section and Vegetated Platform

The hydraulic characteristics of the constructed marsh were compared to natural Patuxent marshes. Statkiewicz (2014) studied the impact of vegetation on inlet morphology and hydraulic characteristics. The constructed marsh channels diverge from the natural marshes, and this potentially impacts sediment transport. A Patuxent marsh inlet has a significant portion of submerged aquatic vegetation (Figure 8). This creates an incised triangular shape where flow is concentrated. The constructed Anacostia marsh inlet does not have submerged aquatic vegetation and has a parabolic shape (Figure 9).

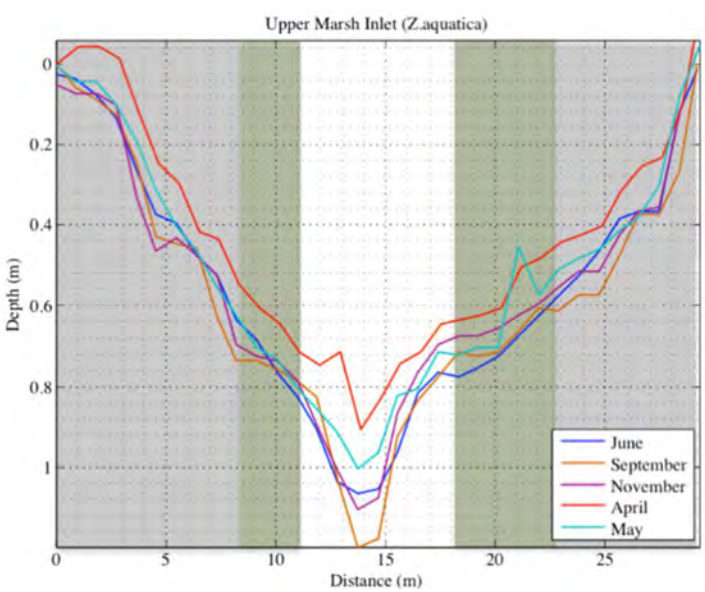

Figure 14: Cross-section of a natural Patuxent River marsh inlet (Statkiewicz, 2014). Each line represents the month of data collection. The green and gray shaded area represent submerged aquation vegetation.

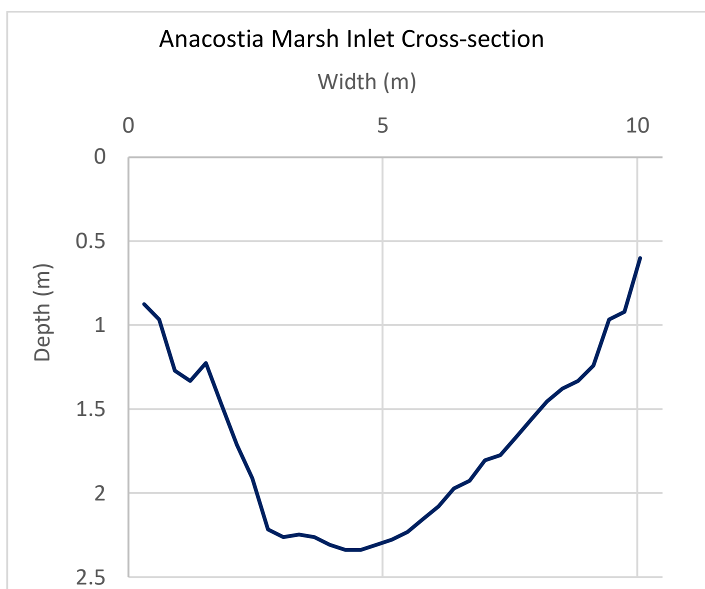

Figure 15 : Cross-section of the constructed marsh inlet.

Sedimentation

Water surface gradient between two sites was determined graphically. Marker C is the downstream gage located 86 meters inland. Marker D is the upstream gage located 110 meters inland. The raw gage height data from each site was normalized to the same starting value and the difference in gage height is recorded. The difference is used to calculate gradient:

(9)

$$S = (Gh_{up} - Gh_{down})/\Delta L$$

where Gh_{up} is the upstream gage height, Gh_{down} is the downstream gage height, and ΔL is the longitudinal distance between the two gages. Longitudinal distance was measured using Google Earth.

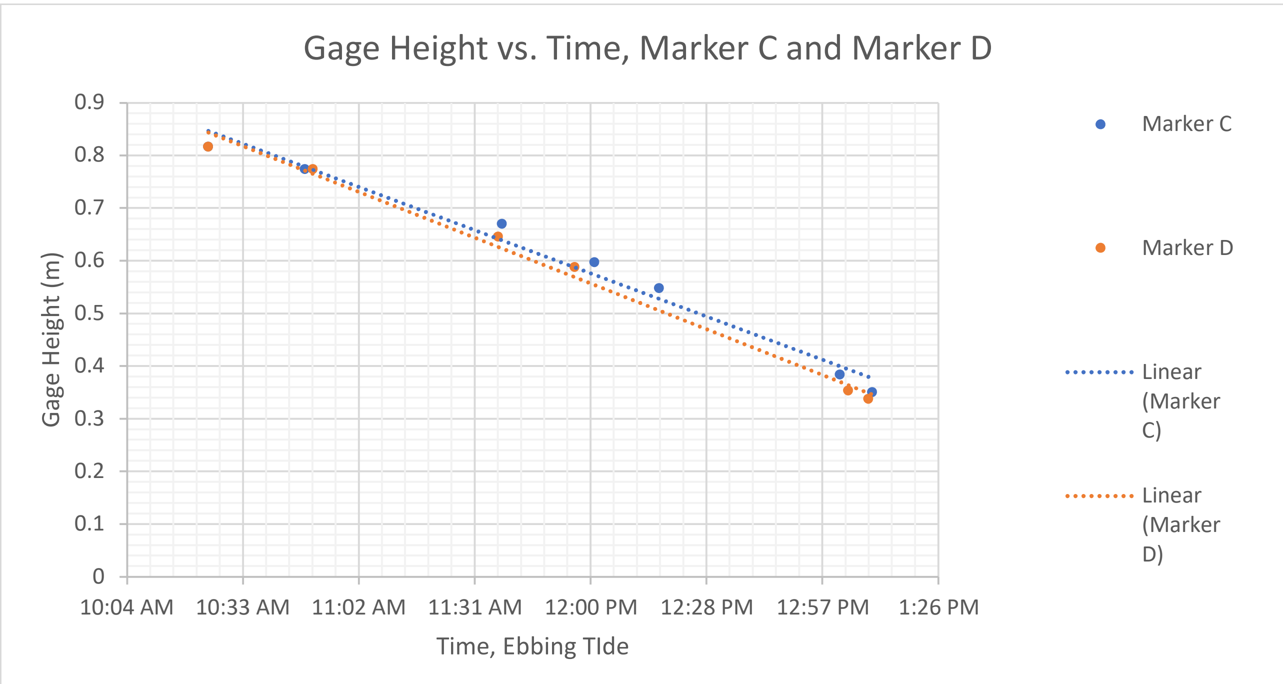

Figure 16: Normalized gage height data from Figure 6. The difference in gage height between the two sites increases with time during ebb tide.

The marsh water surface gradient is used to determine shear velocity and to calculate the vertical distribution of suspended sediment concentration for multiple grain sizes at each cross-section location. The Rouse-Vanoni profile of suspended sediment concentration was plotted for four sites in the marsh. The grain sizes range from fine clay (63 microns) to coarse sand (4 millimeters). The distributions suggest that a high concentration fine clay stays in suspension for the entire vertical profile and is likely to be deposited on the marsh platform. A low concentration of coarse sand stays in suspension below a value of z/H = 0.5. Coarser particles are only in suspension near the bed and are likely to deposit on the channel bed.

One interesting result from the Rouse-Vanoni profile of suspended sediment concentration is that channels C and D have the smallest maximum grain size that can be carried above

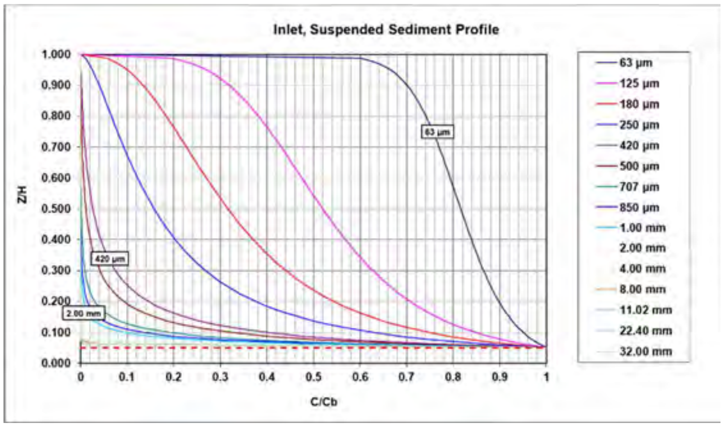

Figure 17: Vertical distribution of suspended sediment concentration by grain size for the inlet.

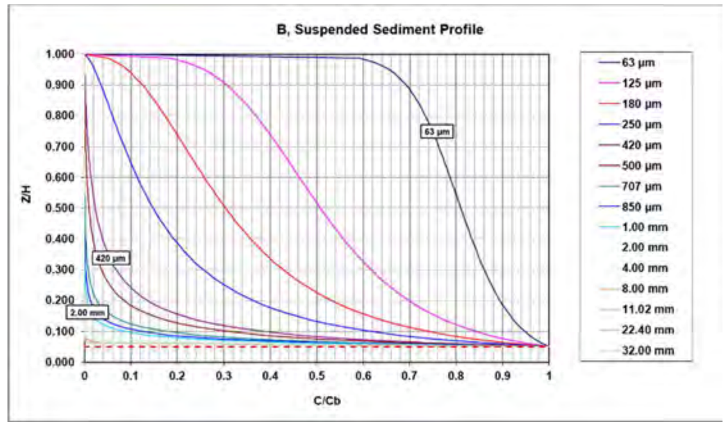

Figure 18: Vertical distribution of suspended sediment concentration by grain size for Marker B.

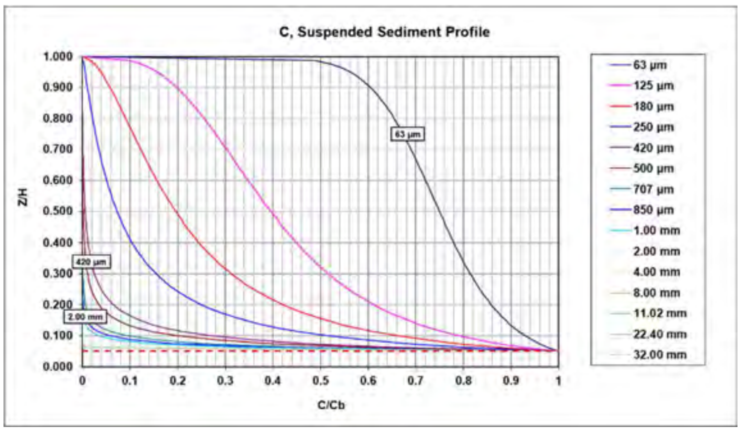

Figure 19: Vertical distribution of suspended sediment concentration by grain size for Marker C.

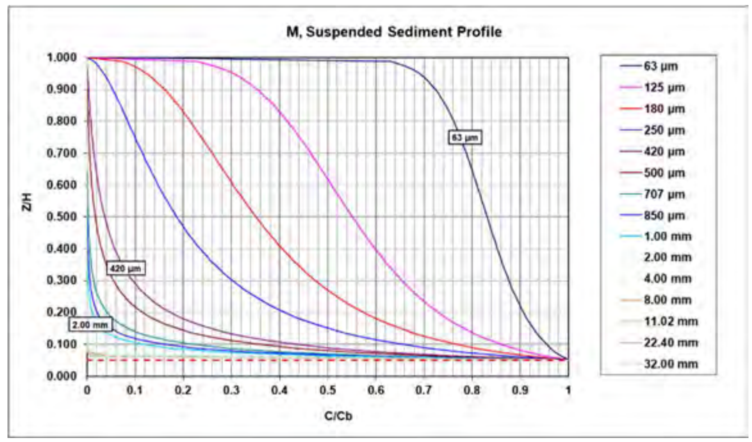

Figure 20: Vertical distribution of suspended sediment concentration by grain size for Marker M, which is the cross-section located the furthest inland.

the bed. Channel C is the widest channel and is 86 meters inland. The maximum grain size carried by channels C and D is 63 micrometers. This suggests that, during flood tide, coarse sand is carried 86 meters into the marsh system before falling out of suspension and accumulating at the bed of channel C. This is consistent with the hydraulic geometry. Upon reaching channel C, the cross-sectional area increases from 13.2 m^2 at channel B to 14.1 m^2. The width of the channel increases drastically and as a result, flow velocity through the channel must decrease for discharge to be maintained. While collecting cross-section data, Dr. Prestegaard and I observed sediment at the bottom of every channel. This is consistent with the Rouse profile results which suggest that coarse sand falls out of suspension.

	Distance Inland, from Inlet (m)	Max Grain size (micrometer)	Width (m)	Cross Section Area (m2)
Inlet	0	125	10.40	18.70
M	31	125	3.96	2.78
B	52	125	11.60	13.08
L	54	420	5.79	3.88
J	74	420	3.05	1.95
K	82	420	3.96	2.54
C	86	63	14.00	14.08
D	110	63	6.34	6.38
F	142	420	4.57	3.48
G	146	420	1.37	1.00
E	147	500	4.40	3.76
I	200	420	3.96	2.96
H	219	125	4.27	3.77

Table 2: Maximum grain size in suspension, width, and cross-section area for each measured channel.

	Distance Inland, from Inlet (m)	Max Grain size, z/H = 0.50	Width (m)	Cross Section Area (m2)
Inlet	0	1 mm	10.40	18.70
M	31	1 mm	3.96	2.78
B	52	1 mm	11.60	13.08
L	54	850 µm	5.79	3.88
J	74	850 µm	3.05	1.95
K	82	850 µm	3.96	2.54
C	86	707 µm	14.00	14.08
D	110	707 µm	6.34	6.38
F	142	1 mm	4.57	3.48
G	146	1 mm	1.37	1.00
E	147	1 mm	4.40	3.76
I	200	1 mm	3.96	2.96
H	219	1 mm	4.27	3.77

Table 3: Maximum grain size in suspension halfway up the channel, width, and cross-section area for each measured channel.

8 Conclusions and Broader Implications

Natural tidal channels are designed to transport water and sediment throughout the marsh system and onto the marsh platform, contributing to annual accretion. For sediment to be distributed through the entire system, channel width decreases inland while velocity and discharge are maintained (Langbein, 1963). Channel width in the constructed Anacostia marsh did not consistently decrease with distance inland. In the main channel, widths increased between 50 and 100 meters inland. This local widening causes coarse grains to fall out of suspension and fill the bottom of the channel. Over time, this will prevent sediment from reaching the furthest parts of the marsh and will contribute to a shallowing of the main channel. Field observations and data analysis support the hypothesis that sediment is deposited onto locally widened channels.

The local channel widening was reflected in the Rouse-Vanoni profiles of suspended sediment concentrations. Channels C and D are the only channels unable to suspend a grain size larger than 63 micrometers for the entire channel depth. Other than this, Rouse-Vanoni profiles did not show significant variation. Sand size sediment is only transported near the bed and is not deposited onto the marsh platform. The silt sized particles remain in suspension for the entire channel depth and are more likely to be deposited onto the marsh platform or trapped by vegetation.

The constructed Anacostia marsh had a larger drainage density compared to the natural Patuxent marshes. This suggests the marsh channels can efficiently direct flow and transport sediment. However, the width of the inlet and the local widening of channels could possibly hinder the ability of flow to enter the marsh and then travel through the entire system. This only partially supports hypothesis IV. Channel extent and degree of channelization are not a likely cause of limited sediment transport. The up-marsh hydraulic geometry is the most likely explanation.

While taking cross-section measurements, Dr. Prestegaard and I noticed the parabolic shape of the channels, specifically the inlet. Sedimentation data suggests that, despite the parabolic shape, the inlet is still effective in bringing water and sediment into the marsh system. The lack of a triangular vegetated platform could be a result of the marsh being relatively young, the type of vegetation within the marsh, or of water flowing over the marsh platform instead of incising the channel.

This marsh may be able to outpace sea level rise. However, the observed infilling and truncation of channels suggests the marsh is either overwhelmed with sediment, or unable to distribute it onto the marsh platform. This may convert the available accommodation space into realized accommodation space, leading to a decline in rate of sedimentation (Rogers, 2021). Models suggest that marshes on gently sloping land tend to expand in response to accelerated sea level rise (Kirwan et al., 2016). This migration allows the marsh to persist in response to sea level rise. However, the constructed Anacostia marsh is constrained by a bike path on the east boundary and surrounded by a very steep slope. This hinders the possibility of expansion or migration.

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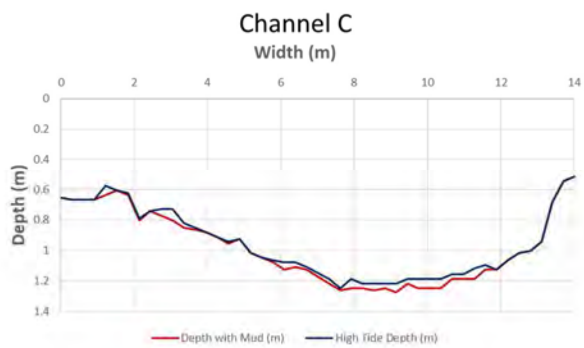
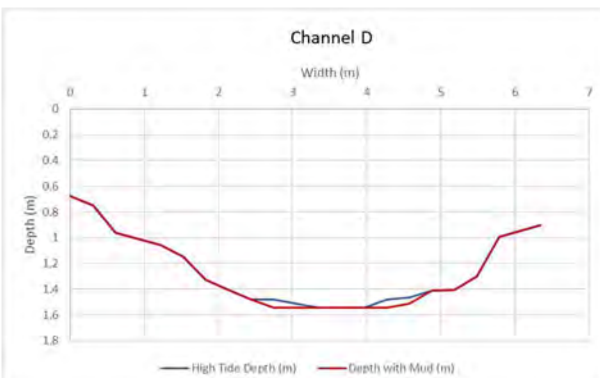
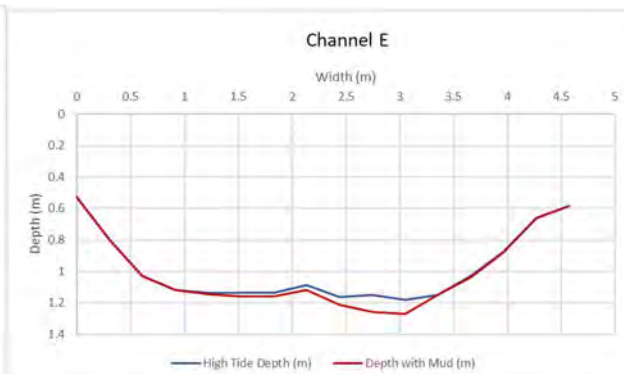
10 Appendix

Cross-sections – September 16, 2023







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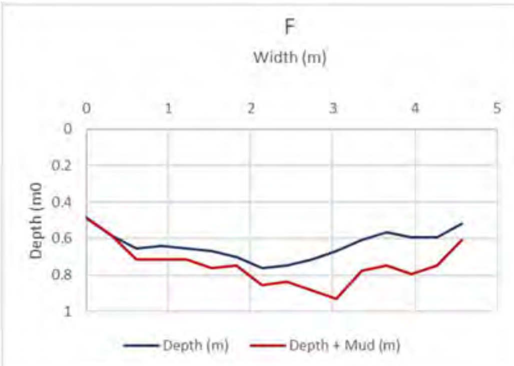
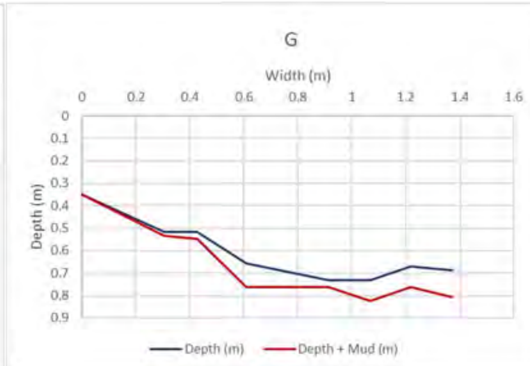
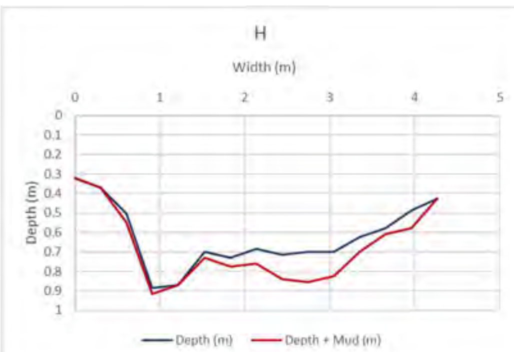
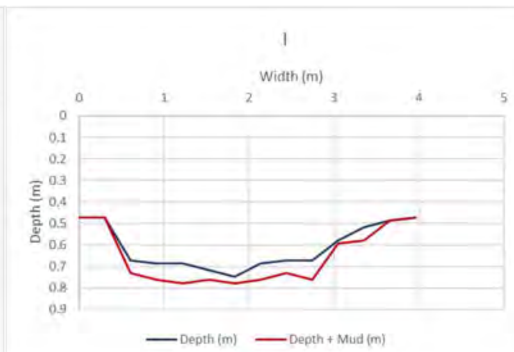
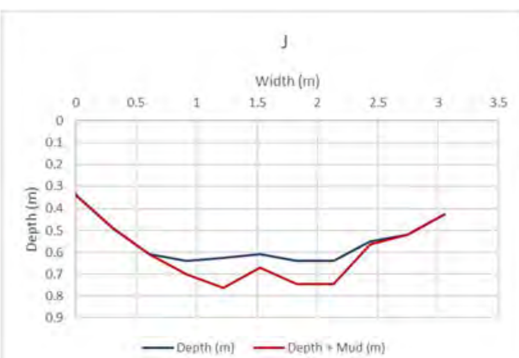
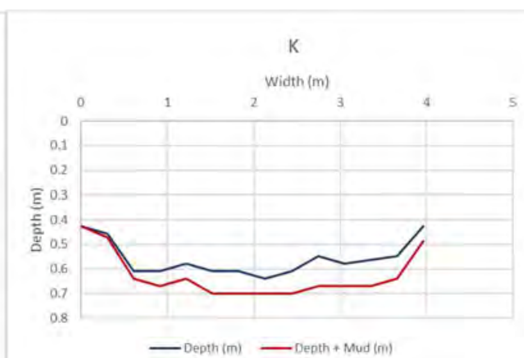


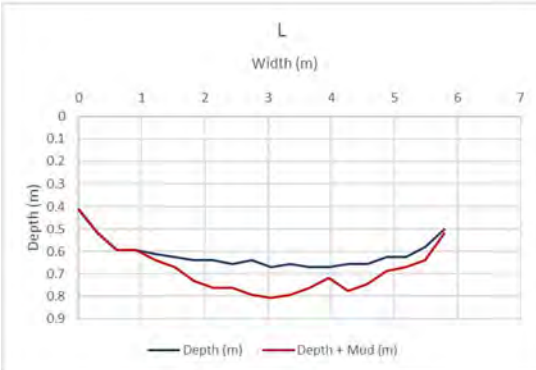


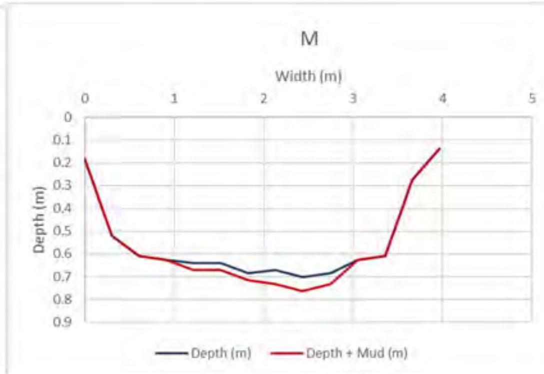




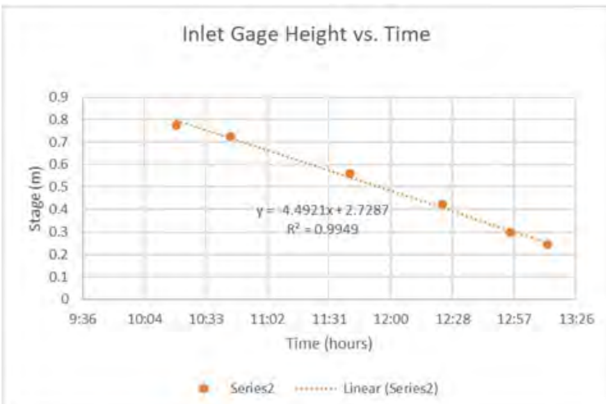


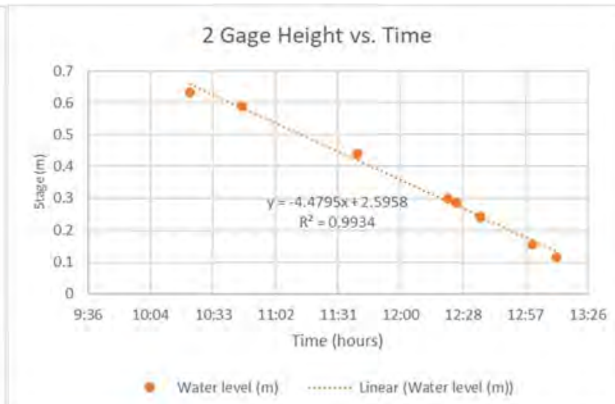



L
Width (m)
Depth (m)
Depth (m)
Depth + Mud (m)

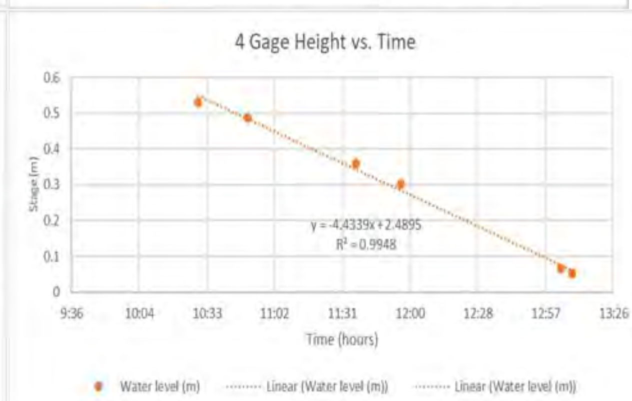

M
Width (m)
Depth (m)
Depth (m)
Depth + Mud (m)

Gage Height


Inlet Gage Height vs. Time
Stage (m)
y = -4.4921x + 2.7287
R² = 0.9949
Time (hours)
Series2
Linear (Series2)


2 Gage Height vs. Time
Stage (m)
y = -4.4795x + 2.5958
R² = 0.9934
Time (hours)
Water level (m)
Linear (Water level (m))


3 Gage Height vs. Time
Stage (m)
y = -4.1001x + 2.6264
R² = 0.98
Time (hours)
Water level (m)
Linear (Water level (m))
Linear (Water level (m))


4 Gage Height vs. Time
Stage (m)
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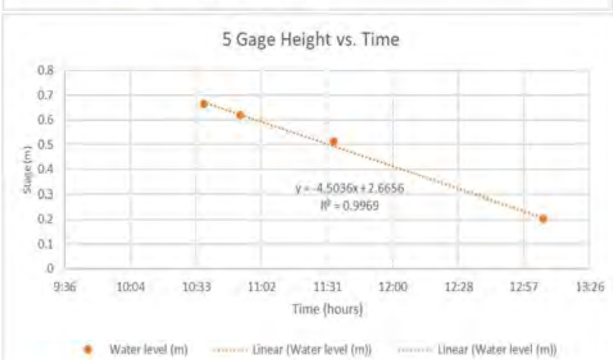
R² = 0.9948
Time (hours)
Water level (m)
Linear (Water level (m))
Linear (Water level (m))


5 Gage Height vs. Time
Stage (m)
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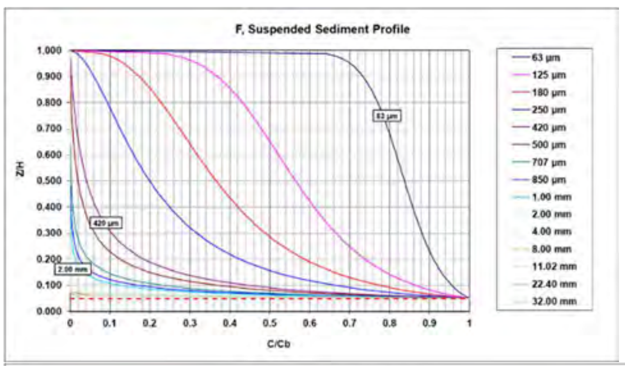
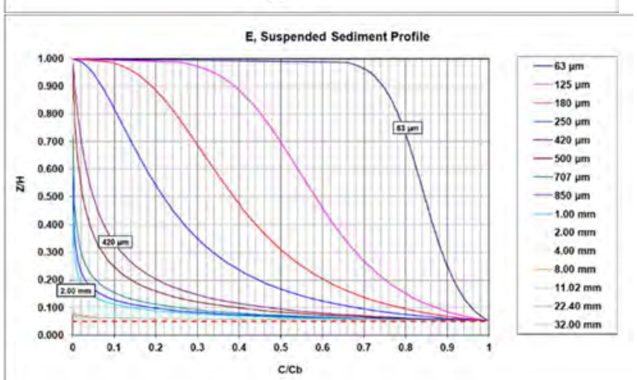
R² = 0.9969
Time (hours)
Water level (m)
Linear (Water level (m))
Linear (Water level (m))


F, Suspended Sediment Profile
Z/H
C/Cb
63 µm
125 µm
180 µm
250 µm
420 µm
500 µm
707 µm
850 µm
1.00 mm
2.00 mm
4.00 mm
8.00 mm
11.02 mm
22.40 mm
32.00 mm


E, Suspended Sediment Profile
Z/H
C/Cb
63 µm
125 µm
180 µm
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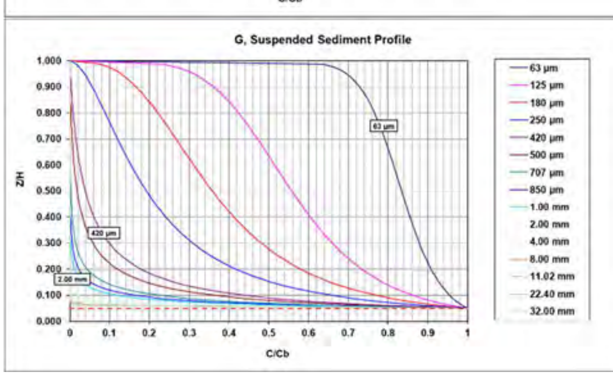
1.00 mm
2.00 mm
4.00 mm
8.00 mm
11.02 mm
22.40 mm
32.00 mm


G, Suspended Sediment Profile
Z/H
C/Cb
63 µm
125 µm
180 µm
250 µm
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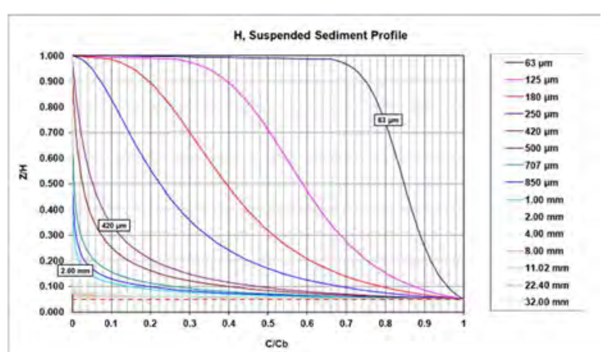
707 µm
850 µm
1.00 mm
2.00 mm
4.00 mm
8.00 mm
11.02 mm
22.40 mm
32.00 mm


H, Suspended Sediment Profile
Z/H
C/Cb
63 µm
125 µm
180 µm
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420 µm
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707 µm
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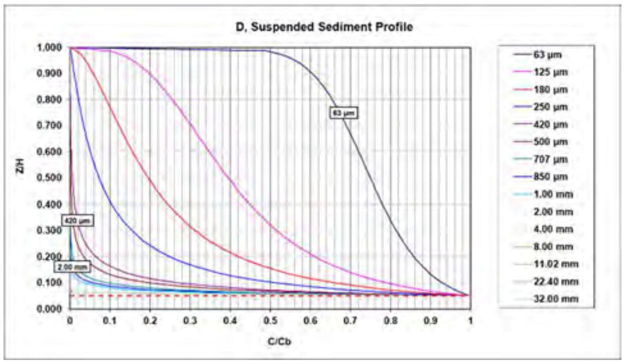
2.00 mm
4.00 mm
8.00 mm
11.02 mm
22.40 mm
32.00 mm


D, Suspended Sediment Profile
Z/H
C/Cb
63 µm
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63 µm
125 µm
180 µm
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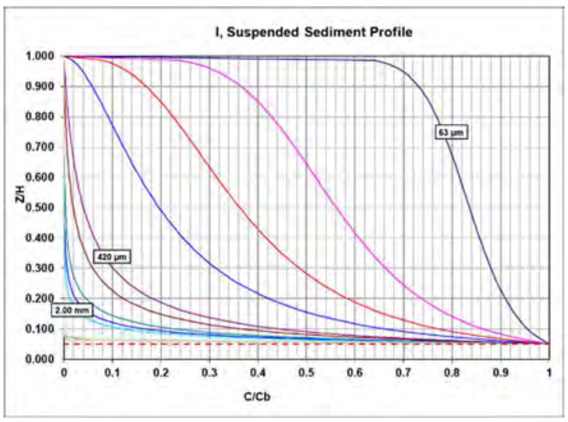
22.40 mm
32.00 mm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C/Cb
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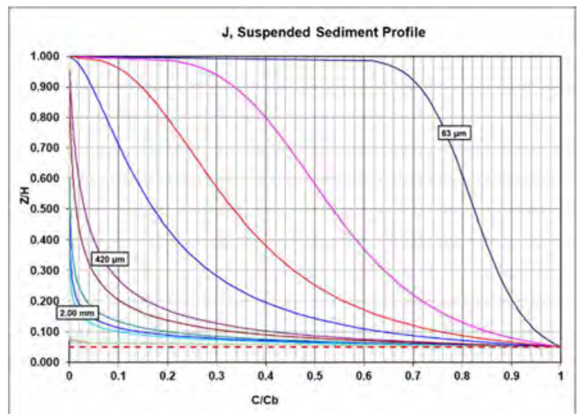
2.00 mm


J, Suspended Sediment Profile
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C/Cb
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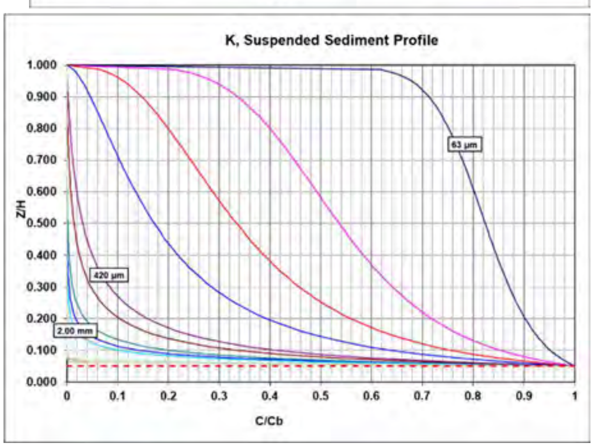
2.00 mm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C/Cb
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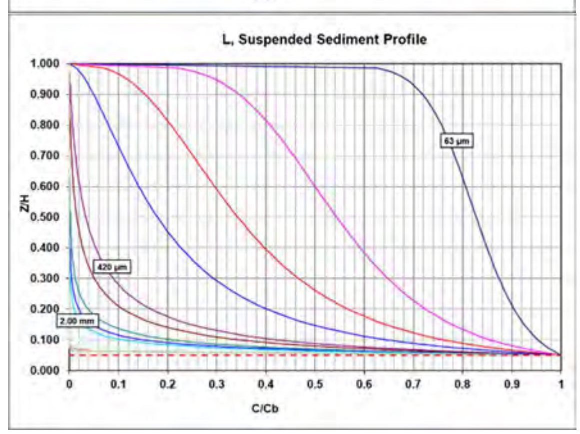
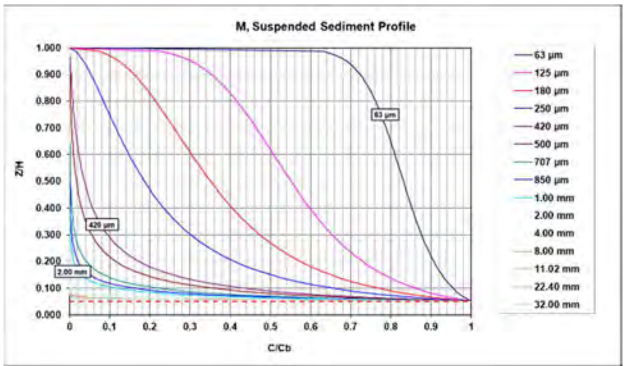
2.00 mm


L, Suspended Sediment Profile
Z/H
C/Cb
63 µm
420 µm
2.00 mm



Honor Pledge

I pledge on my honor that I have not given or received any unauthorized assistance on this assignment.

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Alana Dixon