High Water Levels Generated by Rivers, Tides and Storm Surges in the Anacostia River Upper Estuary

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Introduction

The purpose of this study is to evaluate the separate and combined effects of urbanization, storm surge and sea level rise on flood hazards along the Anacostia River. Morphological changes (river channelization and wetland removal) and hydrological changes (urbanization and climate) in the Anacostia watershed and estuary may have significantly impacted tidal propagation and natural channel adjustments. Understanding how these modifications result in hazardous conditions will be useful in preparing for future extreme events. High water levels generated by rivers, tides and storm surges in the Anacostia River will continue to rise, emphasizing the importance of understanding the root causes, such as urbanization, channelization and sea level rise.

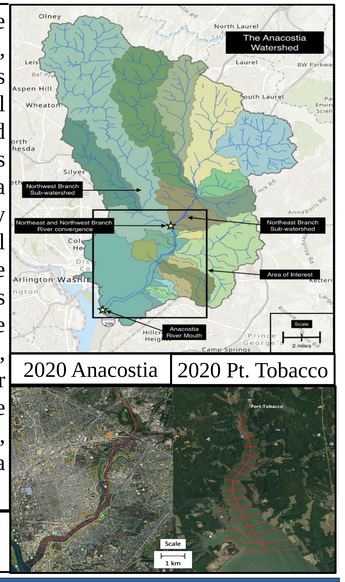


Fig. 1: a) The Anacostia Watershed b) Left: Anacostia Estuary; Right: Port Tobacco Est.

Hypotheses

1. The historical channel width distribution of the Anacostia River-Estuary system more closely matches theoretical values than present-day width distributions.
2. The water surface elevations on both ends of the Anacostia system have increased over time due to urbanization and climate change (sea level rise).
3. The water level data indicates that extreme high-water levels are more probable at the upstream end due to river flooding than at the river mouth due to high tides or storm surges.

Methods

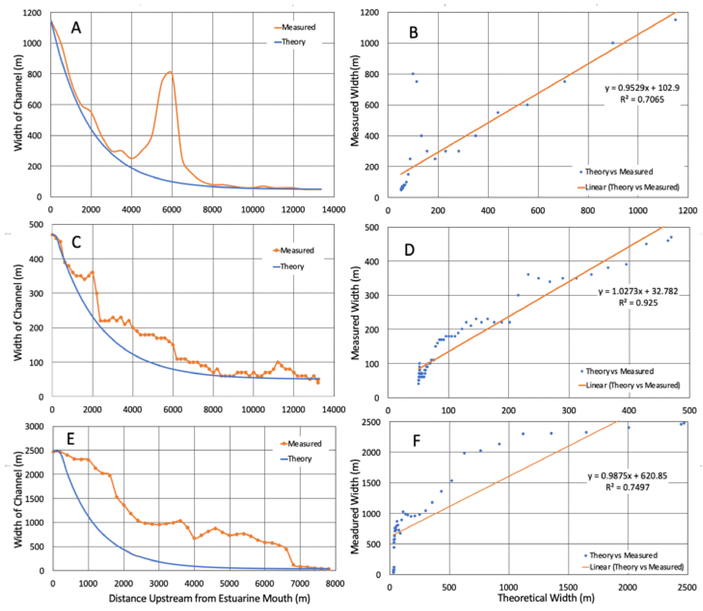
1. **Width Analyses -** I compared measured river-estuary widths to the Bolla Pittaluga et al. (2015) Equation, where B is Estuary width, B_u is stream width, B_0 is outlet estuary width, x is upstream distance, L_b is total estuary length.

$$B = B_u + (B_0 - B_u)\exp\left(-\frac{x}{L_b}\right)$$

2. **Annual Water Elevations** – The probability of water level elevations for river and tidal inputs for period October 2019 to October 2020 was analyzed to identify probability of extremes from both sources.
3. **Extreme Events WR 2020** – Water level (converted into elevation (NAVD88)) and specific conductance data for five extreme events were evaluated for dynamic responses during extreme events.

Results

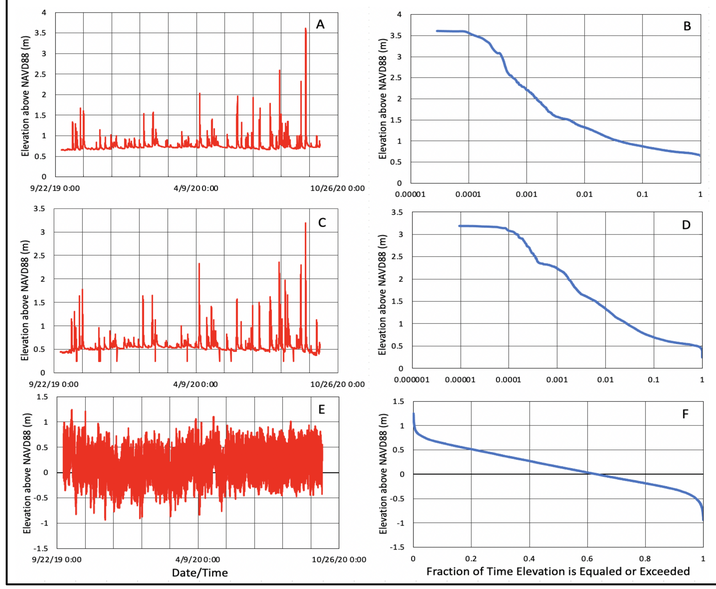
Estuarine Width - Measured vs. Theory:



Both the 1895 and 2020 estuary measured widths were similar to predicted widths. Port Tobacco Estuary shows the greatest differences due to infilling of the river mouth with sediment.

Fig. 2: A) 1895 Anacostia Map vs. Theory; B) 1895 Regressions, C) 2020 Anacostia Imagery vs. Theory; D) 2020 Regression, E) 2020 Port Tobacco Imagery vs. Theory, F) Port Tobacco Regression

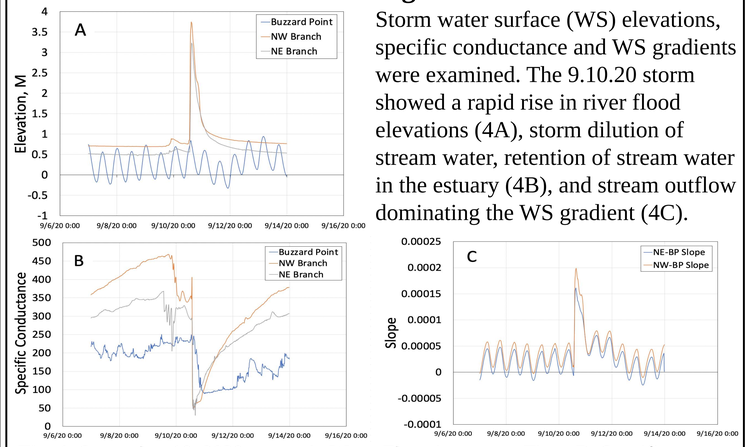
Annual Water Level Probabilities:



Maxima river water levels were higher (3.6 m, 3.2 m) than maximum tidal water levels (1.2m).

Fig. 3: Water surface elevation time series for: A) NW Branch Anacostia, C) NE Branch Anacostia, E) Estuary mouth at Buzzard Point. Water surface exceedance probabilities for: B) NW Branch, D) NE Branch, F) Buzzard Point

Water Surface Elevations During Extreme Storm Events:



Storm water surface (WS) elevations, specific conductance and WS gradients were examined. The 9.10.20 storm showed a rapid rise in river flood elevations (4A), storm dilution of stream water, retention of stream water in the estuary (4B), and stream outflow dominating the WS gradient (4C).

Fig. 4: September 10, 2020 storm: A: Water Elevation versus Time, B: Specific Conductance - dilution of river and estuarine water, C: Gradient data indicates outflows.

Long Term Trends: Regional sea level rise rates are 3.34±0.28 mm/year. Flood discharge is increasing at a rate of 1.7 m^3/s per year and increasing in variability. This raises extreme water levels at both ends of the system.

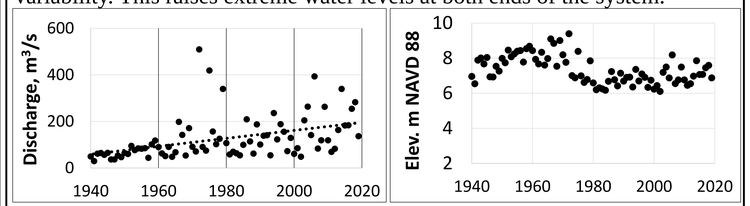


Fig. 5: Northwest Anacostia Annual Maximum Floods: Left - Discharge Trends, Right - Extreme Water Elevation Trends (Note: flood channel built in 1965).

Conclusions

1. The present-day Anacostia River channel is more consistent with the theoretical width distribution, than the historical Anacostia River channel.
2. Both river and tidal water elevations are increasing gradually over time because of the impacts of sea level rise and urbanization, and will most likely continue to increase.
3. The Anacostia Estuary water levels are primarily controlled by extreme precipitation events at the upstream river end of the system and the downstream river flow.

Acknowledgements

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