



# Coastal Nuisance Flooding of the USNA Columbarium, College Creek, Annapolis, MD



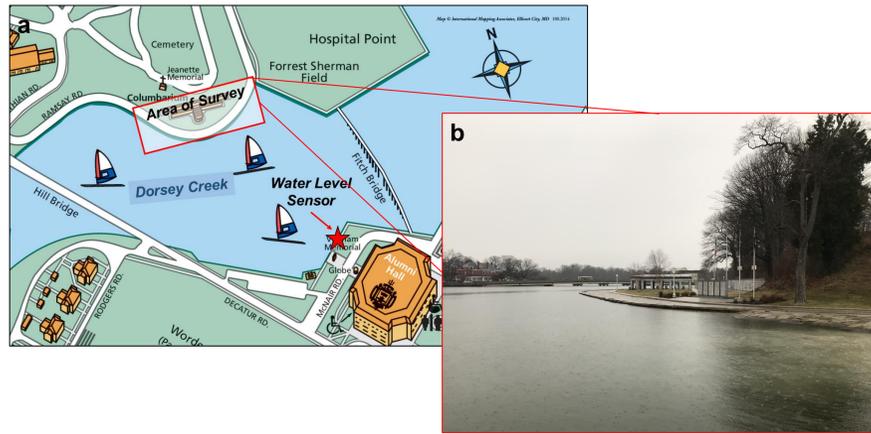
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Advisor(s): Dr. Joseph P. Smith, Instructor Andrew Keppel, Mr. Luis Rodriguez, and Instructor Alex Davies

## Abstract

The U.S. Naval Academy (USNA) Columbarium, Annapolis, MD is subject to coastal nuisance flooding. In this study, water levels were monitored in College Creek and landscape surveys were conducted to assess coastal nuisance flooding thresholds and quantify future inundation levels in order to provide data to help inform management decisions related to the site. The USNA Columbarium holds a special spot in the hearts of many and it is important to preserve this resting place for service members.

## Study Area and Methods



**Figure 1.** (a) Birds eye view map of the area of the U.S. Naval Academy (USNA) where the USNA Columbarium is located on Dorsey Creek (College Creek) and (b) a view of the Columbarium from Fitch Bridge after a rainstorm and high tide event in spring of 2019, showing minor flooding on Ramsay Road.



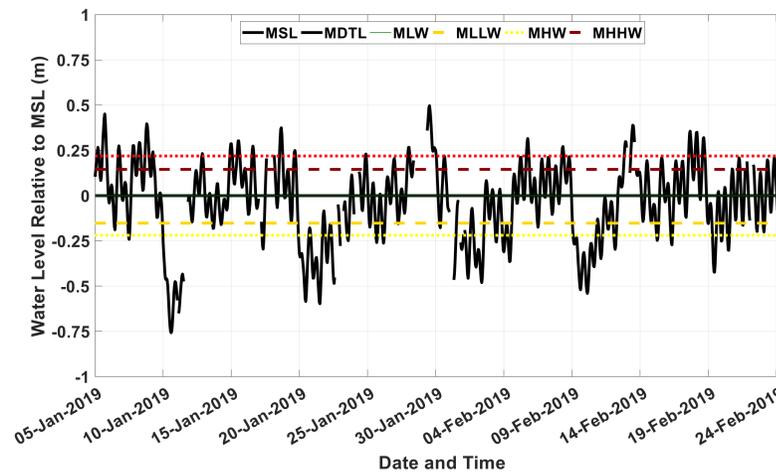
**Figure 2.** (a) MIDN 1/C Ally Warnimont deploying the Onset HOBO U20 Water Level Sensor in College Creek; (b) MIDN 1/C Lauren Greenberg checking the sensor and (c) Mr. Andrew Keppel and Mr. Luis Rodriguez conducting landscape surveys in 2018 using the TOPCON Total Station used in this study.

An Onset HOBO U20 Water Level Sensor (1 Hz) was deployed in College Creek at a reference height of ~ 1.7 m MSL from 05 January – 24 February 2019 (Fig. 1 and Fig. 2a & b). One minute pressures were averaged to each hour using a 60-minute moving average and converted to water levels (m) via the hydrostatic equation using atmospheric pressure and water column density from data measured at Node 1 of the USNA Severn River Watershed Observatory (SRWO) located at the Hendrix Oceanography Lab (HOL). A TOPCON Total Station (Fig. 2c) was used to survey the land elevation at the USNA Columbarium site. Survey data was referenced to horizontal and vertical location data collected with a handheld Trimble Geo-7X centimeter-grade GNSS (+/- 0.3-0.9 m) using WGS 84 datum and a web Mercator projection. Vertical data was referenced to Mean Sea Level (MSL). Geo-referenced elevation data was used to create an elevation grid using a kriging interpolation method and contoured at a 0.25 m smoothed interval using Surfer v.11 (Fig. 3).

**Figure 3.** Contoured elevation map of the land area of the USNA Columbarium referenced to Mean Sea Level (MSL). The red line is the main (reference) survey line for a landscape survey using a TOPCON Total Station. The white lines show each individual survey/slope line. Geo-location data from a handheld Trimble Geo-7X centimeter-grade GNSS was used to reference survey data to MSL and to add additional vertical data points for developing an elevation grid in Surfer v.11 using a kriging interpolation method.



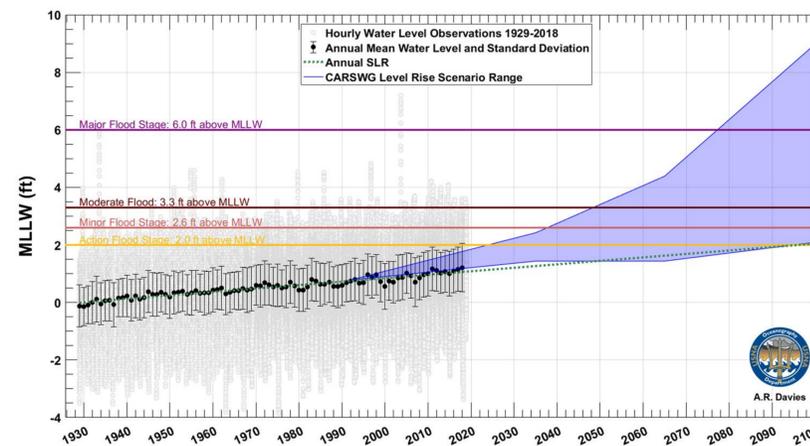
## Current Water Levels



**Figure 4.** Hourly water levels (m) relative to MSL in College Creek from 05 January – 24 February 2019 measured using an Onset HOBO U20 Water Level Sensor (1 Hz) deployed across from the USNA Columbarium (Fig. 1). Also shown are lines indicating Mean Sea Level (MSL), Mean Diurnal Tide Level (MDTL), Mean Low Water (MLW), Mean Lower-Low Water (MLLW), Mean High Water (MHW), and Mean Higher-High Water (MHHW) at the NOAA Annapolis tide gauge (ID 8575512; <https://tidesandcurrents.noaa.gov/datums.html?id=8575512>) in the Severn River, located at USNA HOL.

There were clear variations in water levels (m) in College Creek from 05 January – 24 February 2019 with some values well below MLLW and well above MHHW (Fig. 4). Looking at the mean elevation of the USNA Columbarium relative to College Creek water levels, there was no event that could lead to nuisance flooding during this study (Fig. 5a), however the high water level on 29 January 2019 came very close to the threshold for flooding of the lowest lying areas (Fig. 5b). A 0.3 m rise in mean sea level by 2035 is within the range of plausible scenarios for USNA and Annapolis (Fig. 6). Assuming this scenario and assuming no change in land elevation it can be seen that the high water level measured on 29 January 2019 will be at the threshold for nuisance flooding of the entire Columbarium area (Fig. 7a) leading to inundation of the lowest lying areas (Fig. 7b).

## Future Water Levels

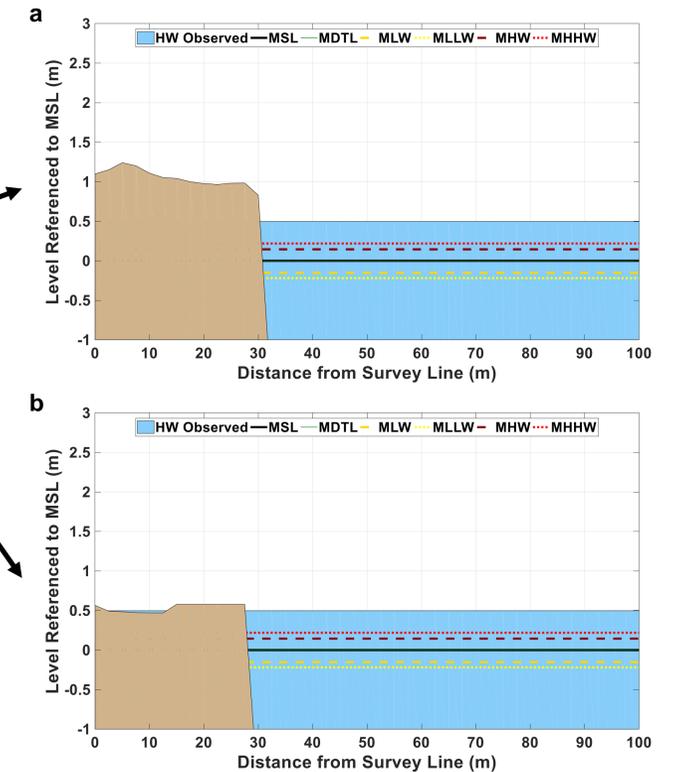


**Figure 6.** Annapolis, MD hourly (light grey) and annual mean (black dots with std. dev.) water levels MD from 1929 to 2018 showing a linear rise in sea level. Plausible future water level scenarios shown for 2035, 2065 and 2100 from the Coastal Assessment Regional Scenario Working Group (CARSWG; Hall et al., 2016).

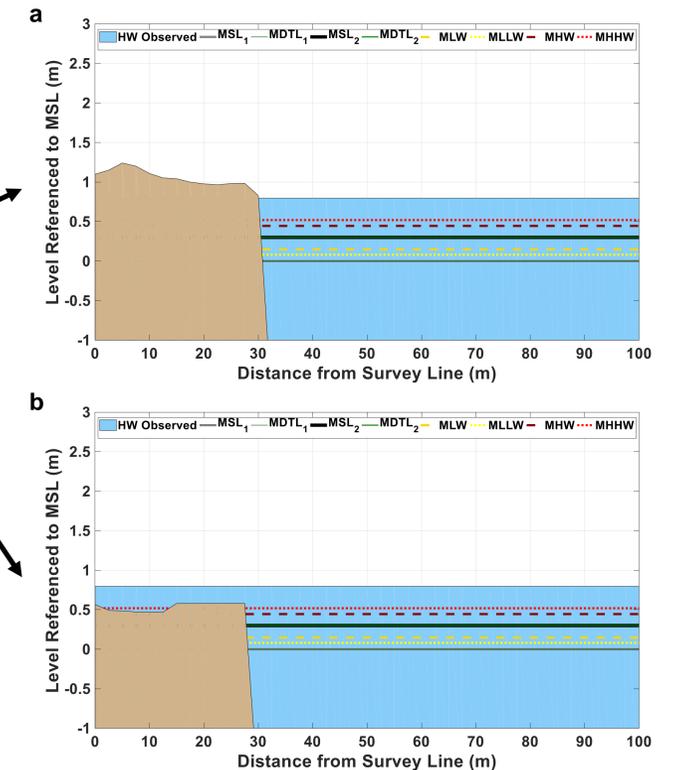
## Conclusions

- *The USNA Columbarium is currently susceptible to nuisance flooding events. Local sea level rise threatens to significantly increase the frequency of nuisance flooding events and the scale of inundation at the USNA Columbarium as soon as 2035*
- *Future sea level rise scenarios should be carefully considered when planning infrastructure improvements at USNA that include adaptations to protect this important ceremonial area*

**Acknowledgements:** This work was made possible by the generous gift of funding by the Volgenau family. Special thanks to MIDN 1/C George Davis for his help with recovering data from the Onset HOBO U20 Water Level Sensor.



**Figure 5.** Measured hourly water levels (m) relative to MSL from 05 January – 24 February 2019 plotted against (a) mean and (b) minimum Columbarium shoreline elevation vs. distance from survey reference line into College Creek (Fig. 1). Also shown are lines indicating current MSL, MDTL, MLW, MLLW, MHW, and MHHW.



**Figure 7.** Measured hourly water levels (m) relative to MSL from 05 January – 24 February 2019 with 0.3 m future sea level rise plotted against (a) mean and (b) minimum Columbarium shoreline elevation vs. distance from survey reference line into College Creek (Fig. 1). Also shown are lines indicating current MSL<sub>1</sub> and MDTL<sub>1</sub>, along with future MSL<sub>s</sub> and MDTL<sub>s</sub>, MLW, MLLW, MHW, and MHHW.