Union of Concerned Scientists

FACT SHEET

The US Military on the Front Lines of Rising Seas

Exposure to Coastal Flooding at the US Naval Academy (USNA), Maryland

HIGHLIGHTS

With seas rising at an accelerating rate, coastal military installations are increasingly exposed to storm surge and tidal flooding. The Union of Concerned Scientists (UCS) conducted analyses of this changing exposure for 18 installations along the East and Gulf coasts. Analysis for the US Naval Academy (USNA) found that in the second half of this century, in the absence of preventive measures, the academy can expect more frequent and extensive tidal flooding, loss of currently utilized land, and substantial increases in the extent and severity of storm-driven flooding to which it is exposed.

The US Armed Forces depend on safe and functional bases, such as the USNA, Annapolis, Maryland, to carry out their stated mission: to provide the military forces needed to deter war and to protect the security of the country. A roughly three-foot increase in sea level would threaten 128 coastal Department of Defense (DOD) installations in the United States and the livelihoods of the people—both military personnel and civilians—who depend on them (NAS 2011). In the area of the USNA, seas are projected to rise between 4.0 and 6.4 feet by the end of this century.

To enable decision makers to better understand the sea level rise threat, and where and when it could become acute, UCS has performed a new analysis of 18 East and Gulf Coast military installations, including the USNA. These sites were selected for their strategic importance to the armed forces, for their potential exposure to the effects of sea level rise, and because they represent coastal installations nationwide in terms of size, geographic distribution, and service branch.

UCS projected exposure to coastal flooding in the years 2050, 2070, and 2100 using the National Climate Assessment's midrange or "intermediate-high" scenario (referred to here as "intermediate") and, in light of the low tolerance for risk in some of the military's decisions, a "highest" scenario based on a more rapid rate of

US Navy

THE INLAND MARCH OF HIGH TIDE

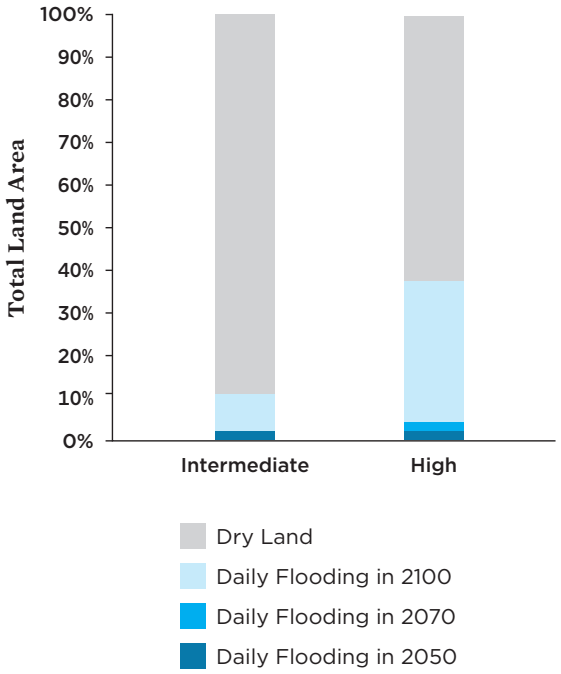
The USNA, one of five service academies in the country, trains students who go on to become officers in the Navy and the Marine Corps. Annapolis, the academy's location, is one of the East Coast cities that has seen a marked increase in the frequency of tidal flooding—on average, Annapolis now experiences roughly 50 floods a year. By 2050, the academy's flood-prone areas can expect to be underwater hundreds of times each year.

increase (Parris et al. 2012).[1] We modeled tidal flooding, permanent inundation, and storm surge from hurricanes.[2] The results below outline potential future flooding to which the academy could be exposed, assuming no new measures are taken to prevent or reduce flooding.[3] This analysis finds the following key results:

TIDAL FLOODING, PERMANENT INUNDATION, AND LAND LOSS

- **Flooding during extreme high tides will become more extensive.** Today, the Annapolis waterfront, including parts of the academy, is affected by flooding during extra-high tides roughly 50 times per year. In the highest scenario, almost 15 percent of the academy is flooded with this same frequency by 2070.
- **Certain locations could flood with each high tide.** The intermediate scenario shows the USNA experiencing roughly 400 tidal flooding events per year—on average, more than one per day—by 2050. By 2070, flood conditions begin to span several high tide cycles and flood-prone areas are underwater 85 percent of the time.
- **Sea level rise could claim currently utilized areas.** In both scenarios, currently flood-prone areas are underwater nearly constantly by 2070. In the intermediate scenario, with four feet of sea level rise, roughly 10 percent of the academy's land area is part of the tidal zone (flooding daily) by 2100. In the highest scenario, which projects 6.4 feet of rise, the area that floods with daily tides climbs above 35 percent by 2100.

FIGURE 1. The USNA May Experience Significant Land Loss



As high tide reaches farther inland, significant land loss is possible at the USNA, particularly if the highest scenario proves true. Unlike some of the other installations analyzed, where inundation may affect undeveloped areas most heavily, the academy consists almost entirely of developed, utilized land.

STORM SURGE

- **Sea level rise exposes previously unaffected areas to storm surge.** In both the intermediate and highest scenarios, sea level rise increases the area exposed to flooding from Category 1 storms by nearly 30 percent by 2100.
- **Sea level rise exposes the academy to deeper, more severe flooding.** Today, most storm surge flooding from Category 2 storms is less than five feet deep. By 2100 in the intermediate scenario, Category 2 storms expose one-third of the academy to surge flooding five to 10 feet deep.

Base Information

The USNA is located in Annapolis, Maryland, where the Severn River joins the Chesapeake Bay. It is situated within an East Coast sea level rise hot spot, where natural subsidence, low-lying topography, and changing ocean circulation patterns contribute to above-average rise (Sallenger, Doran, and Howd 2012). One of five service academies in the country, the USNA trains students who ultimately become officers in the Navy and the marine corps (DOD 2016).

US Naval Academy

Branch:	Navy
Established:	1845
Size (Acres):	338
Midshipmen:	4,400
Faculty:	580

SOURCE: DOD 2016.

Historic Exposure to Storm Surge and Flood Hazards

Since 1876, 15 hurricanes have passed within 150 nautical miles of the academy (NOAA n.d.). Hurricanes are relatively rare in the Chesapeake Bay area; the Navy has estimated that

there is a 20 percent chance of a tropical cyclone and a 3 percent chance of a hurricane passing within 75 nautical miles of Annapolis in any given year (Kato, Handlers, and Brand 2000). However, storm surge from Hurricane Isabel, a Category 1 storm passing nearby in 2003, caused unprecedented flooding that rendered half of the academy's classroom unusable (NOAA 2004).

To mitigate damage from coastal flooding, the USNA has installed five seawalls (Marine Technologies n.d.).

Future (Projected) Exposure to Storm Surge and Flood Hazards

SEA LEVEL RISE

The intermediate scenario projects that the USNA will experience 4 feet of sea level rise and the highest scenario projects nearly 6.5 feet of rise by 2100. This rise will drive the high tide line inland and lead to increased exposure to different types of coastal flooding.

TIDAL FLOODING AND LAND LOSS

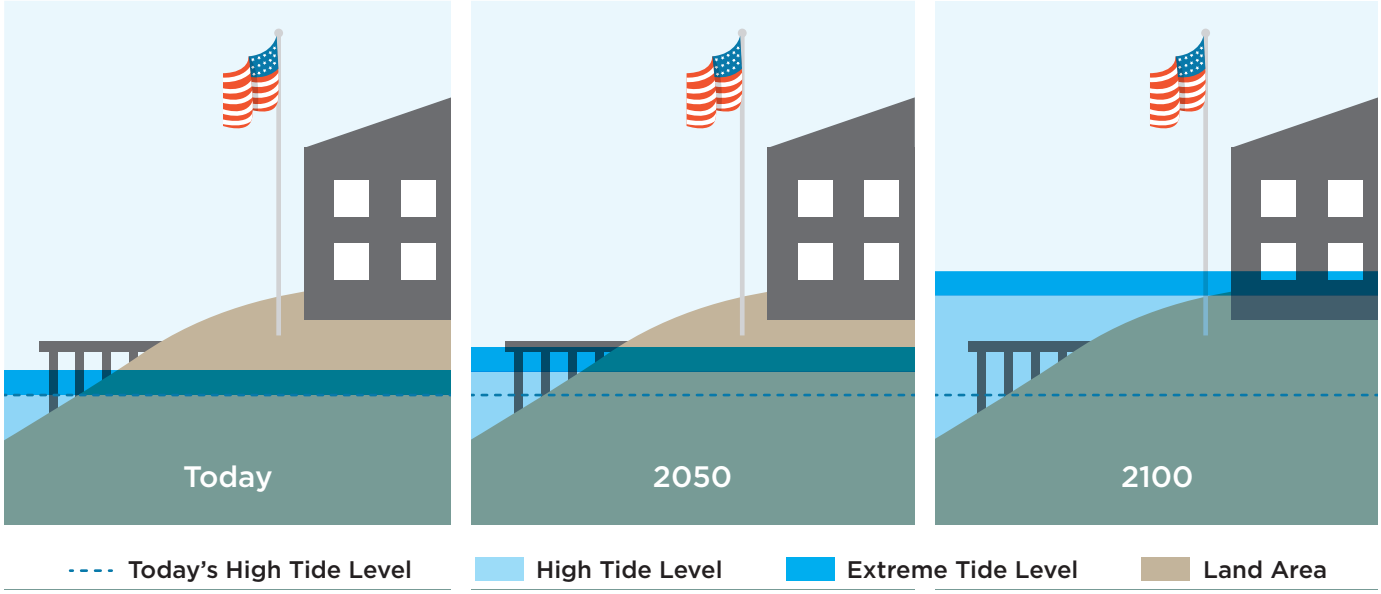
Currently, the Annapolis waterfront and parts of the academy experience flooding during extra-high tides associated with a full or new moon roughly 50 times per year. The intermediate scenario projects that, by 2050, areas currently affected by occasional tidal flooding will experience about 400 tidal floods per year—in other words, they would flood daily on average. This land can thus become unusable within the next 35 years.

TABLE 1. USNA Projected Sea Level Rise (Feet) in Two Scenarios

Year	Intermediate	Highest
2050	1.2	1.8
2070	2.1	3.3
2100	4.0	6.4

In the intermediate scenario, ice sheet loss increases gradually in the coming decades; in the highest scenario, more rapid loss of ice sheets occurs. The latter scenario is included in this analysis to help inform decisions involving an especially low tolerance for risk. Moreover, recent studies suggest that ice sheet loss is accelerating and that future dynamics and instability could contribute significantly to sea level rise this century (DeConto and Pollard 2016; Trusel et al. 2015; Chen et al. 2013; Rignot et al. 2011). Values shown are local projections that include unique regional dynamics such as land subsidence (see www.ucsusa.org/MilitarySeasRising).

FIGURE 2. How Sea Level Rise Causes Tidal Flooding and Land Loss



As sea level rises, local flood conditions can happen more often, to a greater extent, and for longer time periods when extreme tides occur. And the daily high tide line can eventually begin to encompass new areas, shifting presently utilized land to the tidal zone. In this analysis, land inundated by at least one high tide each day is considered a loss. This is a conservative metric: in reality, far less frequent flooding would likely lead to land being considered unusable.

TABLE 2. Annapolis Area Tidal Flooding Frequency

	Intermediate		Highest	
Year	Events per Year	% of Year	Events per Year	% of Year
2012	50 ± 13	1	50 ± 13	1
2050	403 ± 34	42	291 ± 15	74
2070	177 ± 22	85	12 ± 5	97
2100	2 ± 2	98	1 ± 1	100

Projected sea level rise will lead to constant or near-constant flooding around USNA. Shown here are flood events in low-lying, flood-prone areas projected by the intermediate and highest scenarios. Events per year are reported as the average over a five-year period with one standard deviation. Percent of year is reported simply as the average over a five-year period. As flood conditions begin to span multiple high tide cycles, the number of distinct flood events gradually drops toward one, while the duration of flooding increases until it is constant.

As sea level rises, flooding that occurs during high tide lasts longer. In Annapolis, the difference between high and low tide is small enough that flood conditions are expected to eventually exist even at low tide. By 2050 in the highest scenario, the number of individual flood events will increase but also, and more significantly, the duration of flood conditions in low-lying areas will increase. By 2070, that flooding is essentially constant and the land in question is permanently inundated. Both scenarios project that the academy can expect flood-prone areas to be nearly constantly under water by 2070. Given the highest scenario's projection of 6.4 feet of sea level rise by the end of the century, roughly 40 percent of the academy's land area would flood daily.

THE CHANGING THREAT OF HURRICANES

Category 1 hurricanes are the most likely type to affect the USNA.[4] Today, a Category 1 hurricane exposes roughly 20 percent of the academy's area to storm surge flooding. In 2070 in both scenarios, the area inundated by a Category 1 storm is equivalent to the area inundated by a Category 2 storm today. And in 2100 in both scenarios, a Category 1 storm exposes an additional 30 percent of academy area to storm surge.

Sea level rise also increases the depth of flooding the academy can expect with major storms. Category 1 storms today cause relatively shallow flooding at the academy: most is five feet or less deep. In the highest scenario, however, more than half the flooding resulting from a Category 1 storm in 2100 is five to 10 feet deep.

For the mid-Atlantic region, the worst-case scenario considered in this analysis is a Category 4 storm occurring in the highest scenario in 2100. Today, a Category 4 storm exposes 50 percent of the academy to flooding, and more than 40 percent of the base could be covered by flood waters greater than five feet deep. By 2100 in the highest scenario, a Category 4 storm exposes almost 60 percent of the academy to flooding. Almost half of its area could experience flooding 10 or more feet deep, and roughly 20 percent would see depths of 20 or more feet.

> ***Given the highest scenario, roughly 40 percent of the academy's land area would flood daily.***

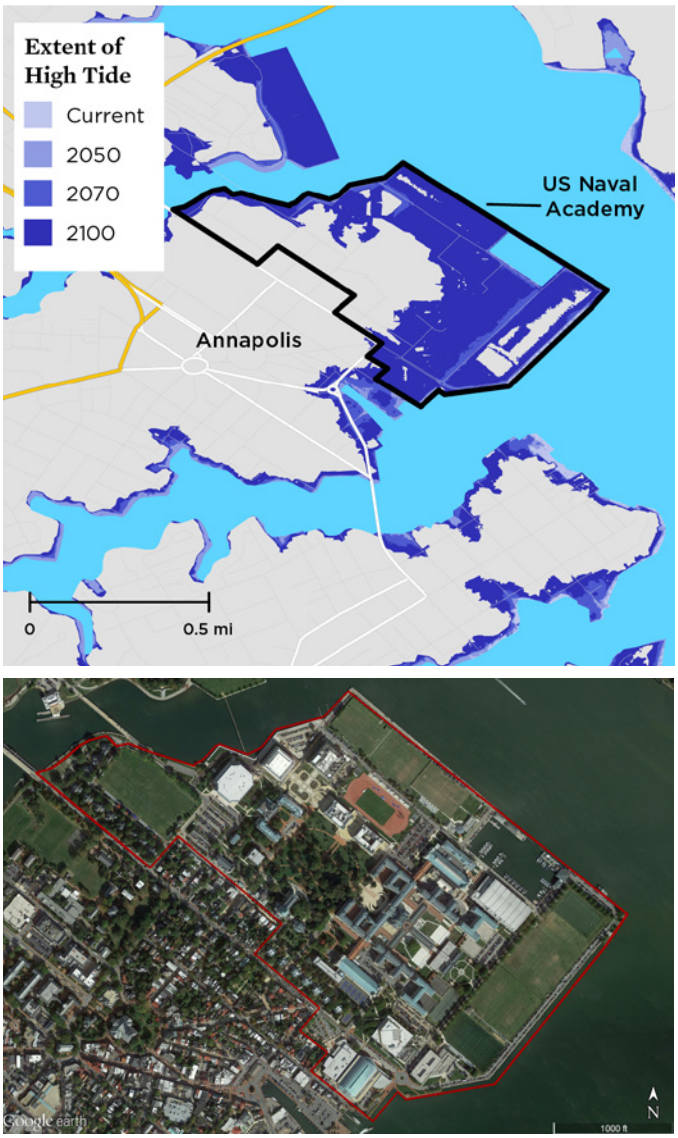
Mobilizing on the Front Lines of Sea Level Rise

A vital trait of our nation's military is its ability to adapt in response to external threats. Climate change and sea level rise have emerged as key threats of the 21st century, and our military is beginning to respond (Hall et al. 2016; USACE 2015; DOD 2014). Recognizing the threat of increased flooding, the USNA has multiple flood hazard mitigation measures in place and in process. Academy staff have been repairing its seawalls and installing necessary backflow preventers within its storm water system. Door dams designed to protect academic buildings and other structures from flooding have also

been installed (Kenson 2016). The USNA is currently working on a flood mitigation design informed by the Army Corps of Engineers' analysis (Kenson 2016).

But here and across US coastal installations there is still far to go: the gap between the military's current sea level rise preparedness and the threats outlined by this analysis is large and growing. Low-lying federal land inundated by rising seas, daily high-tide flooding of more elevated land and infrastructure, and destructive storm surges—most of the installations analyzed, including the Academy, face all of these risks.

FIGURE 3. The USNA Is Expected to Lose Currently Utilized Land



The projected reach of future daily high tides, shown in the top panel, covers currently utilized land at the academy, shown on the bottom. The highest scenario is mapped here.

SOURCE: GOOGLE EARTH.

This analysis provides snapshots of potential future exposure to flooding at the USNA. For the academy to take action on the front line of sea level rise, however, it will need more detailed analysis and resources to implement solutions. Congress and the DOD should, for example, support the development and distribution of high-resolution hurricane and coastal flooding models; adequately fund data monitoring systems such as our nation's tide gauge network; allocate human, financial, and data resources to planning efforts and to detailed mapping that includes future conditions; support planning partnerships with surrounding communities; and allocate resources for preparedness projects, on- and off-site, many of which will stretch over decades.

Military bases and personnel protect the country from external threats. With rising seas, they find themselves on an unanticipated front line. Our defense leadership has a special responsibility to protect the sites that hundreds of thousands of Americans depend on for their livelihoods and millions depend on for national security.

ENDNOTES

1 *The intermediate sea level rise scenario assumes ice sheet loss that increases over time, while the highest scenario assumes rapid loss of ice sheets. The latter scenario is particularly useful for decisions involving an especially low tolerance for risk. These results are a small subset of the full analysis. For more information, the technical appendix, and downloadable maps, see www.ucsusa.org/MilitarySeasRising.*

2 *UCS analyzed storm surge depth and exposure extent for each base using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model, developed by the National Oceanic and Atmospheric Administration (NOAA), for storm events ranging in severity from Category 1 to Category 4, in addition to tidal floods. Both storm surge and flooding during extra-high tides can be significantly exacerbated by rainfall and wave action, neither of which we included in this study.*

3 *This analysis involved consultation with the USNA. However, preventive measures may be planned or in place that are not reflected in the analysis; these could affect the degree of current and future flooding.*

4 *Nor'easters are common in the region and generate damaging storm surge. As SLOSH models only hurricanes, we did not include lesser storms, such as nor'easters, in this analysis. Increases in surge extent and depth should be expected with these storms as well.*

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FIND THE FULL ANALYSIS AND METHODOLOGY ONLINE: www.ucsusa.org/MilitarySeasRising

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