Union of Concerned Scientists

FACT SHEET

The US Military on the Front Lines of Rising Seas

Exposure to Coastal Flooding at Marine Corps Base Camp Lejeune, North Carolina

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 Marine Corps Base Camp Lejeune found that in the second half of this century, in the absence of preventive measures, this installation 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 Marine Corps Base Camp Lejeune ("Camp Lejeune"), North Carolina, 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 around Camp Lejeune, seas are projected to rise between 3.7 and 6.1 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 Camp Lejeune. 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 with a more rapid rate of 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 Camp Lejeune could be exposed, assuming no new measures are taken to prevent or reduce flooding.[3] This analysis finds the following key results:

US Marine Corps

NATURAL DEFENSES AT RISK

The extensive mainland portion of Camp Lejeune has limited exposure to sea level rise this century compared to its barrier islands and the low-lying areas along the New River (shown here); these could face daily tidal flooding late this century. The islands provide storm surge protection for the mainland. Though not modeled here, their inundation could affect storm surge exposure of the mainland portion of the camp.

TIDAL FLOODING AND LAND LOSS

- **Certain areas face daily high tide flooding**. Today, tidal flooding within Camp Lejeune affects low-lying locations, mainly wetlands, eight times per year on average. In the highest scenario, flood-prone areas within the camp are underwater nearly 90 percent of the time by 2100.
- **Flooding during extreme high tides will become more extensive**. In the highest scenario, higher water levels caused by extreme tides flood roadways roughly eight times per year by later in this century.
- **Loss of protective barrier islands is possible**. By 2070, in the highest scenario, Camp Lejeune's barrier islands could flood with most high tides and be underwater 35 percent of the time.

STORM SURGE

- **Sea level rise exposes previously unaffected areas of Camp Lejeune to storm surge flooding**. By 2100 in the intermediate scenario, the area in Camp Lejeune exposed to a Category 1 storm surge flooding increases by about 4,000 acres (or 3 percent of the camp); in the highest scenario, it increases by about 7,000 acres (or 5 percent of the camp).
- **Sea level rise exposes Camp Lejeune to deeper, more severe flooding**. In general, over time, the area inundated by 10 feet or more of seawater during storm surges will increase. In an end-of-century worst-case scenario involving a Category 4 storm, six feet of sea level rise in the highest scenario could more than double the area exposed to flooding 20 or more feet deep—from 7 to roughly 20 percent of the camp.

Base Information

Camp Lejeune is located along the New River near Jacksonville, North Carolina. The camp includes several barrier islands that provide a buffer between the Atlantic Ocean and the mainland.

> ***In 1996, Hurricane Bertha hit Camp Lejeune with winds of up to 108 miles per hour and caused an eight-foot storm surge, leading to $250 to $270 million in damage.***

Camp Lejeune

Branch:	Marines
Established:	1941
Size (Acres):	139,070
Active Duty:	45,622
Family Members:	52,853
Civilian:	5,857
Retirees and Family Members:	27,120

SOURCE: DOD 2016.

Camp Lejeune's mission is to train and maintain combat-ready forces. The majority of the active duty forces at Camp Lejeune are Marines, but the Navy, Army, Air Force, and Coast Guard also have a presence at the installation (USMC n.d.). The camp, which includes amphibious assault training facilities and live fire ranges, is supported by six additional facilities, including Marine Corps Air Station New River (USMC n.d.).

Camp Lejeune is an integral part of both the community and the economy of Onslow County. Including salaries, construction, services, and other expenditures, the annual economic contribution of the camp to the state and surrounding region is over $4 billion (USMC 2013).

Historic Exposure to Storm Surge and Flood Hazards

Since 1842, 104 hurricanes or tropical storms have passed within a 75-mile radius of Onslow County (NOAA n.d.). Of the hurricanes, 16 were direct hits in Onslow County and 24 crossed portions of the county, resulting in approximately $611 million in property damage and $56 million in crop damage (in 2014 dollars) (Onslow County 2015).

In 1996, Hurricane Bertha hit Camp Lejeune with winds of up to 108 miles per hour and caused an eight-foot storm surge, leading to $250 to $270 million in damage (NWS n.d). That same year, Hurricane Fran, a Category 3 storm, also made landfall, followed in 1998 by Category 3 Hurricane Bonnie and, in 1999, Category 2 Hurricane Floyd (Evans et al. 2014). These and subsequent hurricanes caused storm surge and changes to the Onslow Bay Barrier system, the series of barrier islands that protect portions of Camp Lejeune and the New River Estuary (Evans et al. 2014).

While Camp Lejeune's infrastructure is for the most part located on high ground, some infrastructure and training grounds are located in low-lying areas, including the barrier islands (Evans et al. 2014).

Future (Projected) Exposure to Storm Surge and Flood Hazards

The intermediate scenario projects that Camp Lejeune will experience 3.7 feet of sea level rise and the highest scenario projects 6.1 feet of rise by 2100. This rise will lead to increased exposure to different types of flooding.

> ***In both the intermediate and highest scenarios, extreme-tide flooding inundates additional areas, including roadways, by 2070.***

TABLE 1. MCBC Lejeune: Projected Sea Level Rise (Feet) in Two Scenarios

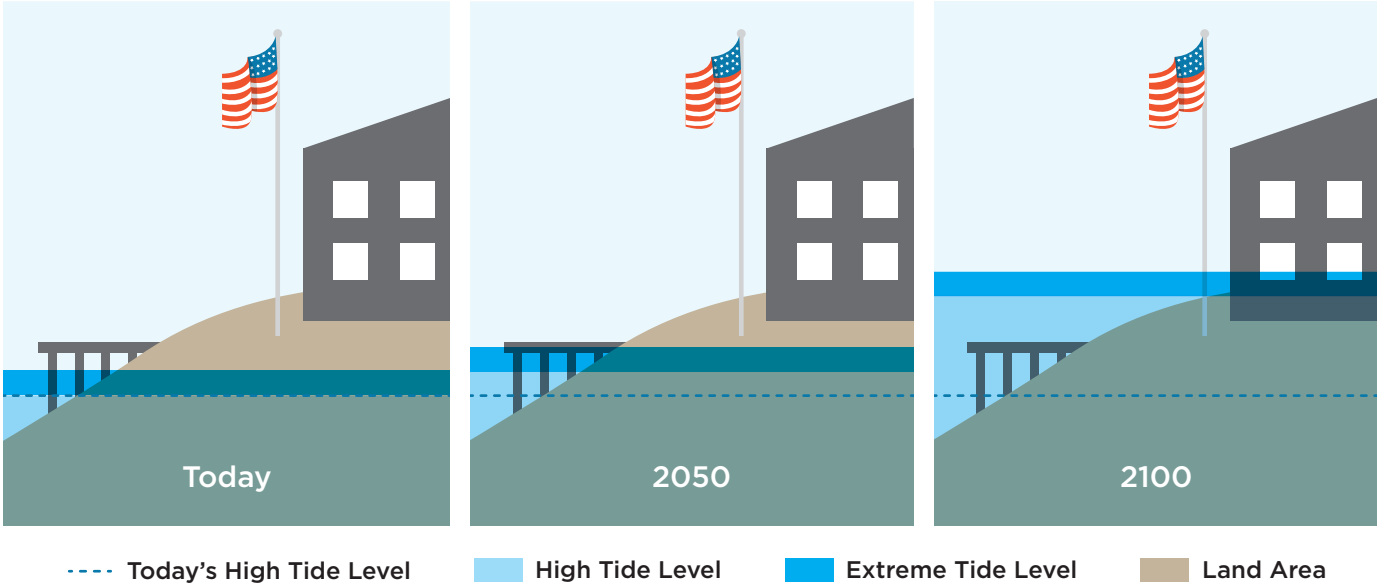
Year	Intermediate	Highest
2050	1.0	1.6
2070	1.9	3.1
2100	3.7	6.1

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).

TIDAL FLOODING AND LAND LOSS

The vast majority of Camp Lejeune's area is unaffected by tidal flooding today. However, low-lying areas in the region, including on its barrier islands and ocean-facing and river shorelines, experience flooding during extra-high tides about eight times per year on average. As sea level rises, extreme-tide flooding—that which reaches beyond the daily high tide mark—is expected to become more extensive and frequent. In both the intermediate and highest scenarios, extreme-tide flooding inundates additional areas, including roadways, by 2070.

FIGURE 1. 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. Current and Future Tidal Flooding Frequency around Camp Lejeune

	Intermediate		Highest	
Year	Events per Year	% of Year	Events per Year	% of Year
2012	8 ± 7	0	8 ± 7	0
2050	118 ± 21	3	289 ± 23	8
2070	392 ± 27	12	667 ± 12	35
2100	687 ± 12	45	280 ± 21	89

As flood conditions begin to span multiple high tide cycles, the number of distinct flood events gradually drops while their duration increases. Installations such as Camp Lejeune will be affected by this flooding depending on the presence of low-lying, flood-prone land on-site. 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.

By 2050, flood-prone areas in this region could experience between 120 and 290 floods per year, approximately, depending on the scenario. In the highest scenario, flood-prone areas throughout the region, notably barrier islands and areas around tidal rivers, experience flooding with nearly each of the two daily high tides and are underwater 35 percent of the time by 2070.

Whereas a Category 4 storm today exposes less than 10 percent of the installation to flooding 20 or more feet deep, that percentage rises to about 20 percent in the worst case.

In the intermediate scenario, flood-prone areas are inundated close to twice daily by 2100. In the highest scenario, during the last quarter of this century, flood events in this area begin to span many high tide cycles. As a result, the number of individual flood events decreases but their duration increases, until it is essentially constant and the land that was once above the high tide mark, including much of the camp's barrier island, is permanently inundated.

THE CHANGING THREAT OF HURRICANES

Category 1 hurricanes are the most likely type to affect this area.[4] Over time, sea level rise exposes a greater portion of Camp Lejeune to inundation resulting from Category 1 storms. Both today and in the future, the areas most affected by storm surge from a Category 1 hurricane are the installation's barrier islands, its ocean-facing coast, and its river shorelines. A Category 1 storm today exposes 22 percent of the camp's area to flooding from storm surge. In the intermediate scenario, nearly 4,000 additional acres are exposed to flooding such that 25 percent of the installation is exposed by 2100. In the highest scenario, 7,000 acres more than today (about 5 percent more area) are exposed. In both scenarios, the area flooded as a result of a Category 1 storm in 2100 is equivalent to or greater than the area flooded during a Category 2 storm today.

Sea level rise also increases the depth of flooding that Camp Lejeune can expect with major storms. Today, all flooding resulting from a Category 1 storm would be less than 10 feet deep. In 2100 in the intermediate scenario, about 5 percent of the installation experiences flooding 10 or more feet deep when hit by a Category 1 storm.

The worst-case scenario for the region in this analysis is a Category 4 storm hitting in 2100 in the highest scenario. Today, a Category 4 storm exposes 35 percent of Camp Lejeune to flooding. In the worst case, an additional 10,000 acres of the installation, or more than 40 percent total, is exposed to storm surge. Whereas a Category 4 storm today exposes less than 10 percent of the installation to flooding 20 or more feet deep, that percentage rises to about 20 percent in the worst case.

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

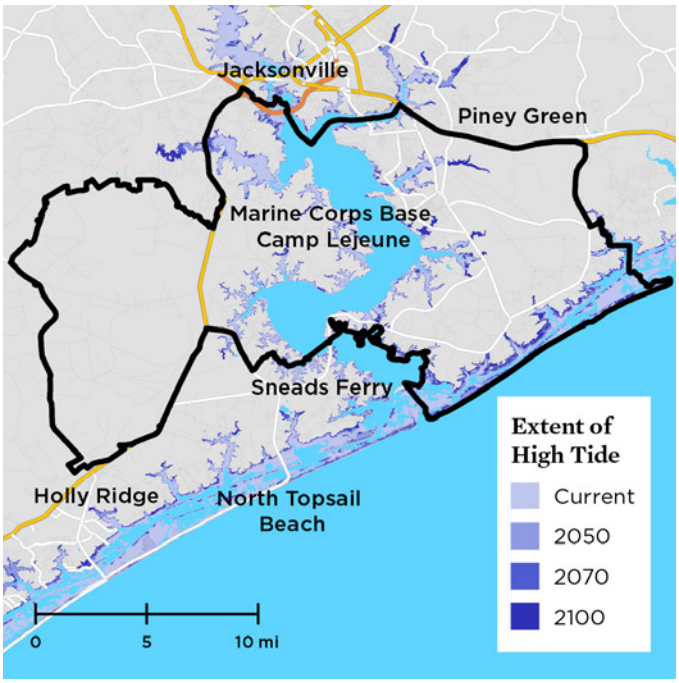
rise have emerged as key threats of the 21st century, and our military is beginning to respond (Hall et al. 2016; USACE 2015; DOD 2014).

Given the history of hurricanes and coastal storms in Onslow County, Camp Lejeune recognizes its vulnerability to coastal flooding and storm surge. The DOD modeled the potential impacts of storm surge and sea level rise on the barrier island system at Camp Lejeune, which will help the installation plan for cost-effective mitigation measures (Evans et al. 2014). Onslow County recently developed a multihazard mitigation plan that addresses flood risk reduction measures, and the county is working closely with Camp Lejeune on a range of planning and response activities (Onslow County 2015).

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 Camp Lejeune, face all of these risks.

This analysis provides snapshots of potential future exposure to flooding at Camp Lejeune. For the camp 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; and allocate resources for preparedness projects, on- and off-site, many of which will stretch over decades.

FIGURE 2. Camp Lejeune Is Expected to Face Barrier Island Loss



The projected reach of future daily high tides, shown on the top, encompasses mainly the barrier islands and land around tidal rivers, as seen in the bottom image. The highest scenario is mapped here. Because barrier islands typically provide storm surge protection to mainland areas, their future inundation could have bearing on mainland exposure.

SOURCE: GOOGLE EARTH.

> ***The gap between the military's current sea level rise preparedness and the threats outlined by this analysis is large and growing.***

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 contacts at multiple installations. However, in some instances, 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 more common in the region and known to generate damaging storm surge. As SLOSH models only hurricanes, lesser storms, such as nor'easters, were not included in this analysis. Increases in surge extent and depth should be expected with these storms as well.*

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