Urban Infrastructure Resilience Analysis
Norfolk, Virginia, and Hampton Roads

Sandia National Laboratories is actively investing in an Urban Resilience Program to improve urban infrastructure resilience.

Using a multidisciplinary, science-based approach, Sandia developed a suite of infrastructure models and resilience analysis capabilities to help federal and municipal organizations address challenges to critical infrastructure systems.

These capabilities are the result of fifteen years of Sandia experience developing and applying resilience solutions to complex systems and over $100 million in investments.

The objective is to leverage and improve these capabilities while developing new capabilities to help cities become more resilient.

Importance

A city is a complex system of dynamic, interdependent physical, behavioral, and functional subsystems. Seemingly insignificant events, such as flooding of a portion of a city and electric power assets, may result in cascading infrastructure failures affecting the entire city and the surrounding region.

Critical infrastructures are interconnected and interdependent—significant infrastructure disruptions in a given city may affect critical infrastructure operations across the United States.

Understanding a given urban area's baseline resilience is the first step in planning and implementing improvements. This requires a systematic analysis using advanced technical capabilities, such as attribute-based and performance-based methods, to answer such questions as:

- What makes the city's infrastructure more/less resilient to a given disruption?

- How resilient is the city's infrastructure?

Analysis findings help cities identify areas of greatest risk and highest consequence and prioritize decisions for improving urban infrastructure resilience.

Case Study: Norfolk, Virginia

The Norfolk, Virginia, area is home to Naval Station Norfolk, the world's largest naval station, Norfolk International Terminals, the United States' fifth busiest container port, and Lambert's Point, the world's largest coal transloading facility.

Collocation of these strategic and economic assets in one area presents significant risks from global climate change. Rising sea levels throughout Hampton Roads and increasingly destructive storms threaten to increase flooding in and around Norfolk.

Sandia is working with Norfolk and the city's partners from the Port of Virginia, the U.S. Navy, Dominion Power, and the 100RC Initiative to improve Norfolk's infrastructure resilience to better withstand, adapt to, and recover from potential flooding.

Sandia applied its Urban Resilience Analysis Process to:

- Identify critical city and infrastructure assets physically affected by flooding events.

- Characterize cascading impacts to infrastructure, city, and regional operations beyond the flooded region.

- Generate intuitive geospatial visualizations of affected areas for scenarios.

Flood Inundation Scenario Extents

- FEMA 100yr Flood
- FEMA 100yr Flood with 1.5 ft. of Sea Level Rise
- FEMA 100yr Flood with 3 ft. of Sea Level Rise
- Military Installation

- Quantify projected economic consequences.

- Perform analyses for 100-year flooding events under three potential sea-level-rise scenarios.

Key Findings

Economic impacts of 100-year flood in Hampton Roads with varying amounts of net-sea-level-rise (NSLR)			
	0 feet NSLR	1.5 feet NSLR	3 feet NSLR
Annual Direct Losses	$135 M	$182 M	$231 M
Annual Indirect Losses	$219 M	$296 M	$376 M
Total	$355 M	$479 M	$606 M

Analysis results of the three-net-sea-level-rise scenarios indicate that:

- Significant portions of the most developed regions in Norfolk are likely to experience increased flood depths.

- Lambert's Point is at significantly greater risk for loss of services as compared to Norfolk International Terminal and Naval Station Norfolk.
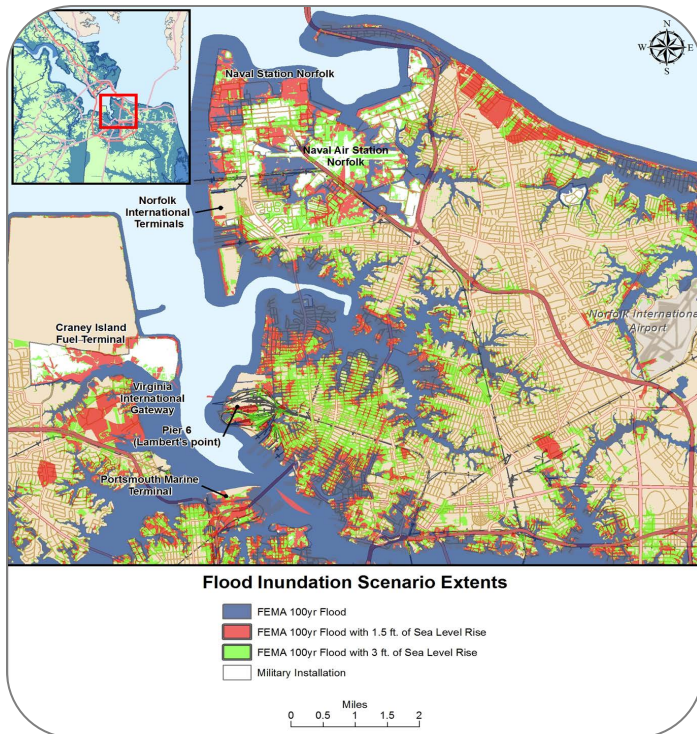
The risk to Lambert's Point can be partially mitigated by ensuring continued operation of critical electric power substations, telecommunication wire centers, transportation paths, and petroleum fuel storage locations.

Economic impacts from Norfolk flooding are likely to have local and global consequences. Total annual economic losses from a flood event under the three feet net-sea-level-rise scenario for Hampton Roads are almost double the projected losses from a flood event under the zero feet net-sea-level-rise scenario.

For more information, access the full report at: www.sandia.gov/cities or contact Rossitza Homan at: rhoman@sandia.gov