# Addressing Resilience in Project Development

U.S. Department of Transportation
**Federal Highway Administration**

## Living Shoreline along Coastal Roadways Exposed to Sea Level Rise

This study explores the use of a living shoreline to protect a coastal roadway from the effects of sea level rise and storm surge.[1]

### Site Context and Facility Overview

Shore Road is a low volume, two-lane coastal road that parallels the south shore of Mt. Sinai Harbor, a small coastal bay along the north shore of Long Island, New York. It is owned and managed by the Town of Brookhaven. The road provides public access to the water and several homes.

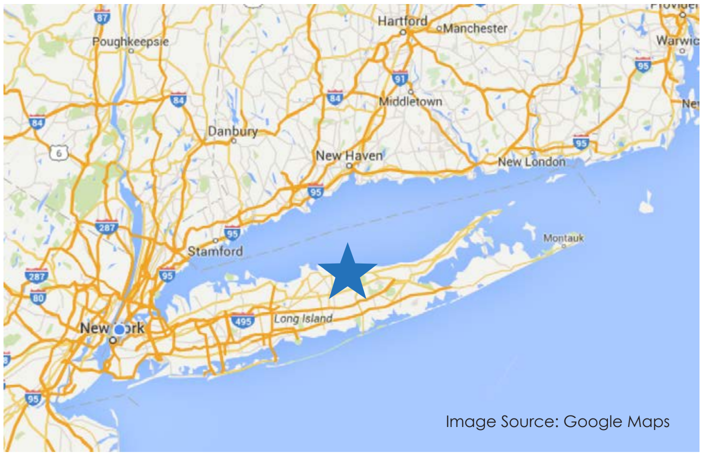


**Figure 1: Map showing the location of Shore Road.**

The road, which is only two feet above Mean Higher High Water (MHHW), has experienced erosion and embankment failure due to waves at high tides and is threatened by inundation due to sea level rise. Between the road and harbor there is little to no shoulder remaining, and the failing embankment is protected by a mixture of concrete debris (from the eroded roadway shoulder), small rocks, and large boulders that form short revetment/seawall segments.

### Environmental Stressors and Scenarios

Sea level rise is the primary stressor of concern. Sea level rise will:

- Increase the number of roads in the area that experience daily nuisance flooding.
- Increase the magnitude and extent of inundation from storms and increase exposure of the road and revetment to wave action.


**Figure 2: Shore Road (facing west) and existing revetment.**

Table 1 shows the relative sea level rise projections that the research team developed using the U.S. Army Corps of Engineers' (USACE) Sea-Level Change Curve Calculator[2] and corresponding adaptation guidance in EM 1165-2-212.[3]

[1] This snapshot summarizes one of nine engineering-informed adaptation studies conducted under the Transportation Engineering Approaches to Climate Resiliency (TEACR) Project. See https://www.fhwa.dot.gov/environment/sustainability/resilience/publications for more about this study and *Synthesis of Approaches for Addressing Resilience in Project Development.*

[2] USACE Sea-Level Change Curve Calculator (2015.46). Accessible at: http://www.corpsclimate.us/ccaceslcurves.cfm.

[3] USACE "Sea Level Change Considerations for Civil Works Programs."

| Sea Level Rise Scenario | Global Sea Level Rise, feet (meters) | Local Relative Sea Level Rise,* feet (meters) |
|---|---|---|
| Low | 0.66 (0.2) | 0.87 (0.26) |
| Intermediate | 1.64 (0.5) | 1.90 (0.58) |
| High | 4.92 (1.5) | 5.19 (1.58) |

**Table 1: Estimated sea level rise for the period 1992 to 2100.**
*Relative sea level rise accounts for local subsidence.

## Analytical Approach

### Overview

The research team determined the year when the roadway would first begin to experience annual, monthly, and daily flooding under the USACE low (historic rate) and USACE high (NRC III) sea level rise projections, with adjustments to reflect local variation. This was accomplished by creating water surface elevations combining local return period estimates for storm surge elevation and wave height extracted from the USACE Coastal Hazards System,[4] and the USACE projected sea level rise and extreme water level statistics. The roadway was considered inundated when the water surface elevations were greater than the edge of pavement elevation (i.e., about +6 feet MSL).

This analysis could be expanded to determine the year in which a specific depth of flooding over the roadway is achieved. Such evaluations are made when specific safety or threshold criteria are known (e.g., maximum depth of flooding for safe vehicle operation, pedestrian safety).

The research team also considered the potential for frequent wave damage to the shoulder. Wave damage was assumed to occur when the wave crest elevation was at or near the edge of pavement elevation at high tide. The USACE method for estimating fetch-limited (e.g., within a harbor) waves was used to evaluate wind-wave growth potential across Mt. Sinai Harbor.

### Results

As shown in Table 2, wave damage is projected to begin as soon as 2025, and monthly flooding due to tidal variability will begin around year 2060.

| Scenario | 1-yr Event Flooding | Monthly Flooding | Daily Flooding | Wave Damage |
|---|---|---|---|---|
| USACE Low | 2025 | 2270** | 2300** | 2080 |
| USACE High | 2015* | 2060 | 2065 | 2025 |

**Table 2: Estimated year of flooding and/or damage.**
*Indicates that asset currently floods.
**Years beyond 2100 are reported for comparison only and these values should be interpreted as "not by 2100."

## Adaptation Options

The research team considered three possible adaptation options: 1) protect the asset with traditional engineered structures, 2) protect the asset with nature-based methods like living shorelines, and 3) abandon the asset.

### Traditional Protection

Traditional protection approaches can increase resilience to current wave damage and delay flooding due to sea level rise. Figure 3 shows a traditional coastal protection option where the roadway and shoulder are protected by a sheetpile wall with concrete cap running along the roadway shoulder, and a sloping rock revetment installed atop geotextile fabric.

[4] USACE Coastal Hazards System. Accessible at: https://chs.erdc.dren.mil/default.aspx.

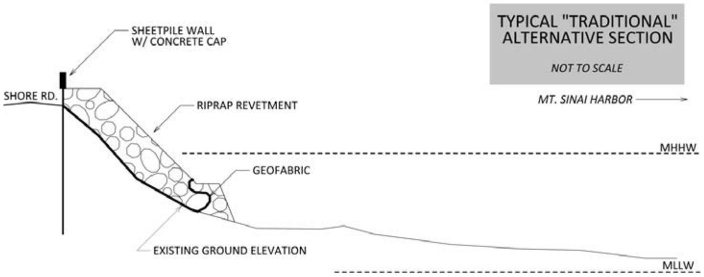


**Figure 3: Diagram of traditional roadway embankment armoring and flood protection.**

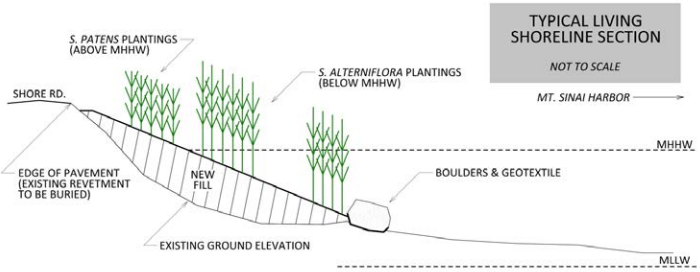


**Figure 4: Diagram of constructed marsh profile.**

A +1 ft. sheetpile wall and cap could potentially delay the onset of daily nuisance flooding by 15 years from 2065 to 2080 under the USACE high sea level rise scenario. That same level of protection could also prevent the road from flooding under a two-year return period storm event until about 2025.

This strategy would cost approximately $1.3 million and would not create intertidal habitat value.

## Living Shoreline Protection

A living shoreline would mimic the wave attenuation provided by local marshes in neighboring areas. However, the living shoreline itself does nothing to eliminate the potential for flooding when water levels are above the roadway elevation.

The living shoreline would use natural and organic materials that complement the natural shoreline characteristics while providing a suitable habitat for local species. Figure 4 shows large boulders placed along the toe (seaward edge) of the constructed marsh to retain new clean sand fill and reduce wave energy, as well as plantings of appropriate saltmarsh and saltmeadow cordgrass below and above the MHHW tidal datum, respectively.

Laboratory investigations[5] show that Spartina alterniflora (cordgrass) marshes are effective at reducing wave heights by as much as 90 percent over a horizontal distance of 30 feet (i.e., through the marsh). The proposed marsh would extend 70–100 feet into the harbor, so it should be very effective at reducing wave damage along the roadway shoulder. Additionally, some studies show that saltmarshes are at least keeping pace with the present-day rate of sea level rise in the Long Island Sound area,[6] so the living shoreline adaptation may continue to provide wave height attenuation and protection of the roadway shoulder as sea levels rise.

The estimated construction cost is $0.5 million, much less than the traditional protection.

## Abandon the Road

With increasing flooding events and roadway damage, the asset owner could abandon Shore Road by removing it from service or deeding it over to local property owners. However, there are related legal issues, which may prevent abandonment from being a realistic option for transportation organizations.

---

[5] USACE "Laboratory Studies of Wave Attenuation through Artificial and Real Vegetation."

[6] Orson, R.A.; Warren, R.S.; and Niering, W.A. "Interpreting Sea Level Rise and Rates of Vertical Marsh Accretion in a Southern New England Tidal Marsh."

## Recommended Course of Action

The preferred course of action is to initially use a living shoreline to protect Shore Road from wave action at high tide. This adaptation addresses the current vulnerability of Shore Road to wave damage at a relatively low cost while recognizing that the roadway, due to its existing elevation, may not be impacted by routine flooding for many years. Also, use of the living shoreline is likely to have positive impacts on habitat and water quality in the harbor and complements future wetlands restoration activities in the harbor planned by the asset owner.

## Lessons Learned

- Often, future sea level rise scenarios are used to project vulnerabilities or flood depths at specific planning horizons (e.g., 2050, 2100). That approach is appropriate and an important exercise for the design of new infrastructure. However, in this study focused on protecting existing infrastructure, the research team employed an alternate approach by projecting the timeframe when certain thresholds would be exceeded (e.g., when the asset will flood twice daily during high tide) under a range of different sea level rise and storm scenarios. So while a traditional approach would be to specify a timeframe and determine the vulnerability, in this assessment the vulnerability was specified first and then the timeframe in which it would occur was determined.
- For this assessment, existing sea level rise projections and frequency-based storm surge data from USACE and NOAA tide gauges provided suitable information. Using existing data can reduce assessment time and costs, and ensure consistency across projects.
- For Shore Road, the living shoreline approach was the lowest cost adaptation strategy, and it would successfully protect against the primary threat of erosion, thus extending the life of the roadway while providing natural habitat. The asset owner can also use an adaptive management approach by monitoring conditions and updates in sea level rise projections to determine when to install additional protection (e.g., a sheetpile wall and concrete cap between the roadway and constructed marsh). So even where living shorelines may not provide comprehensive protection in the long term, they can be used as cost-effective and environmentally appropriate measures that provide initial resilience until a more traditional, engineered structure is added for greater protection.
- Shore Road may have been in use since the late 17th century and has already experienced 1.5 feet of sea level rise. This may explain why the shoulder and embankment have been failing for a number of years. Stressors, such as sea level rise, are likely already reducing the functionality of some older transportation infrastructure, a situation that will worsen with time.

## For More Information

### Resources:

**Transportation Engineering Approaches to Climate Resiliency (TEACR) project website**
www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/teacr/index.cfm

**HEC 25 Volume 2: Assessing Extreme Events**
www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=192&id=158

### Contacts:

**Robert Hyman**
Sustainable Transportation & Resilience Team, FHWA
Robert.Hyman@dot.gov, 202-366-5843

**Robert Kafalenos**
Sustainable Transportation & Resilience Team, FHWA
Robert.Kafalenos@dot.gov, 202-366-2079

**Brian Beucler**
Hydraulics and Geotechnical Engineering Team, FHWA
Brian.Beucler@dot.gov, 202-366-4598

**Khalid Mohamed**
Hydraulics and Geotechnical Engineering Team, FHWA
Khalid.Mohamed@dot.gov, 202-366-0886