

# Mid-Currituck Bridge Submerged Aquatic Vegetation Mitigation Plan

3 February 2020



**Prepared for:**

Rummel Klepper & Kahl  
8601 Six Forks Road  
Forum 1 Suite 700  
Raleigh, North Carolina 27615



**Prepared by:**

CSA Ocean Sciences Inc.  
8502 SW Kansas Avenue  
Stuart, Florida 34997



# Mid-Currituck Bridge Submerged Aquatic Vegetation Mitigation Plan

DOCUMENT NO. CSA-RKANDK-FL-20-81045-3418-05-REP-01-FIN

Version	Date	Description	Prepared by:	Reviewed by:	Approved by:
01	04/30/19	Revised	E. Hodel	M. Fonseca	E. Hodel
02	08/20/19	Final draft to client	M. Fonseca	E. Hodel Client	E. Hodel
Fin	02/03/2020	Final	E. Hodel	M. Fonseca Client	E. Hodel

The electronic PDF version of this document is the Controlled Master Copy at all times. A printed copy is considered to be uncontrolled and it is the holder's responsibility to ensure that they have the current version. Controlled copies are available upon request from the Document Production Department.

## Contents

	Page
List of Tables .....	iv
List of Figures .....	iv
<b>Background</b> .....	<b>1</b>
<b>Construction and In Water Work Moratorium</b> .....	<b>9</b>
<b>Impacts Summary</b> .....	<b>9</b>
Shading Tool Prediction .....	10
<b>Proposed Mitigation and Monitoring Plan</b> .....	<b>13</b>
Potential Mitigation Options .....	14
ONSHORE ALTERNATIVES .....	15
OFFSITE AND OFFSHORE ALTERNATIVES .....	16
Option 2: Offshore wavebreaks near landing sites for erosion control and marsh enhancement .....	16
Option 3: Modification of SAV landscape on eastern end of bridge corridor via offshore wavebreaks .....	16
Option 4: Filling of dredge holes near existing SAV habitat .....	17
Option 5: Restoration or enhancement of SAV habitat and/or erosion reduction around marsh islands .....	17
<b>Monitoring and Reporting</b> .....	<b>18</b>
<b>Literature Cited</b> .....	<b>18</b>

## List of Tables

Table		Page
1	Estimations of SAV acreage affected by various gradations of shading predicted by the shading tool for the month of June within the east end of the Mid-Currituck Bridge alignment .....	13
2	Estimations of SAV acreage affected by various gradations of shading predicted by the shading tool for the month of June within the west end of the Mid-Currituck Bridge alignment .....	13

## List of Figures

Figure		Page
1	North Carolina Department of Transportation selected alternative; final selected alignment for the Mid-Currituck Bridge in Currituck County, North Carolina .....	2
2	Previous submerged aquatic vegetation (SAV) distribution data in Currituck Sound in 2003 from Elizabeth City State University (ECSU) and in 2006 and 2012 from the Albemarle-Pamlico National Estuary Program (APNEP) for the NCDOT-funded SAVE Currituck Study .....	2
3	Comprehensive bathymetry data for Currituck Sound compiled for the NCDOT-funded SAVE Currituck Study .....	3
4	Results from the Wave Exposure Model (WEMo) analysis in Currituck Sound for the NCDOT-funded SAVE Currituck Study showing representative wave energy (RWE) zones.....	4
5a	Corolla (east) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in May and October 2018 .....	5
5b	Mainland (west) end of the proposed Mid-Currituck Bridge alignment showing lack of submerged aquatic vegetation (SAV) cover in May and October 2018.....	6
6a	Corolla (east) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in October 2018 and previous years.....	7
6b	Mainland (west) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in October 2018 and previous years.....	8
7a	East end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover and various gradations of shading predicted by the shading tool for the months of June and October .....	11
7b	West end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover and various gradations of shading predicted by the shading tool for June and October .....	12
8	Schematic of a living shoreline that includes a sill feature .....	16

## Background

A new bridge from the mainland to Corolla on the Outer Banks in Currituck County, North Carolina is proposed for construction by the North Carolina Department of Transportation (NCDOT). Construction of the new Mid-Currituck Bridge will impact submerged aquatic vegetation (SAV) resources that exist within the proposed bridge footprint (Selected Alternative, NCDOT) (**Figure 1**). The exact acreage of SAV that will require mitigation as a result of impacts is unknown at this time. Additionally, SAV may be secondarily impacted by shading from the bridge structure over water (Reevaluation of Final EIS 2019; existing SAV shaded at 3.5 acres [ac]; and potential SAV shaded at 8.8 ac) and therefore potentially require some degree of mitigation (these shading estimates may be refined with utilization of a shading model recently delivered to NCDOT; CSA 2019). This document describes the proposed options for mitigating potential impacts from both direct (e.g., bridge piling, temporary construction bridge) and indirect (e.g., shading) sources to SAV.

SAV in Currituck Sound have been studied for several decades (Davis and Brinson, 1990; Luczkovich, 2010; CZR, 2011) and status and distribution have been examined since the early 1980s (Davis and Carey, 1981; Davis and Brinson, 1983; Carter and Rybicki, 1994). More recently, surveys performed by Elizabeth City State University (2003) and the Albemarle-Pamlico National Estuary Program (2006 and 2012) have shown an increase in total SAV acreage throughout Currituck Sound from 2003 to 2012 (Corbett et al., 2018) (**Figure 2**). Another study by (Atkins 2013) collected some additional habitat information as part of an effort to identify potential mitigation sites. Additionally, the Submerged Aquatic Vegetation Evaluation in Currituck Sound (SAVE Currituck) Study, being funded by NCDOT, is in its third and final year. This study aims to develop a comprehensive understanding of the dominant drivers of SAV distribution in the oligohaline waters of Currituck Sound, by collecting and synthesizing recent bathymetry, wind, wave, sediment, and SAV percent cover data (**Figures 2, 3, 4**). These environmental data, particularly those provided in the recent SAV Currituck study, including the advanced wave energy modeling, extends the initial analysis done by Atkins (2013) to a more comprehensive spatial extent and provides updated knowledge to inform mitigation opportunities associated with the Mid-Currituck Bridge construction.

The distribution of SAV habitat falling specifically within the Mid-Currituck Bridge alignment has also recently been examined by review of previous data along with recently-collected side-scan imaging sonar data from May and October 2018 (RK&K, 2018) (**Figures 5a, 5b, 6a, 6b**). The proposed bridge landing area on the east end (Corolla, on the Outer Banks) has SAV habitat forming nearly continuous cover from the shoreline westward into the Sound, a distance of approximately 914 m (3,000 ft) (**Figures 5a, 6a**). Proceeding west towards the mainland, the bridge alignment crosses an area of deeper water where SAV is absent. At the western landing site on the mainland in Currituck County (**Figures 5b, 6b**), no SAV was observed in May or October 2018, although small SAV patches along the shoreline have been observed in previous years, indicating a spatially and temporally variable SAV resource in this area.

A total of seven SAV taxa have been identified in Currituck Sound from the SAVE Currituck Study (Corbett et al., 2018). Taxa consist of one species of a euryhaline seagrass (*Ruppia maritima*), four species of freshwater aquatic plants (*Myriophyllum spicatum*, *Najas guadalupensis*, *Potamogeton perfoliatus*, and *Vallisneria americana*), and two freshwater algae taxa (both of the genus *Chara*). It is important to note that one of the SAV species is invasive, the Eurasian watermilfoil (*Myriophyllum spicatum*) and mitigation for impact to this species is not recommended. This species has been observed frequently throughout the study area close to shore.

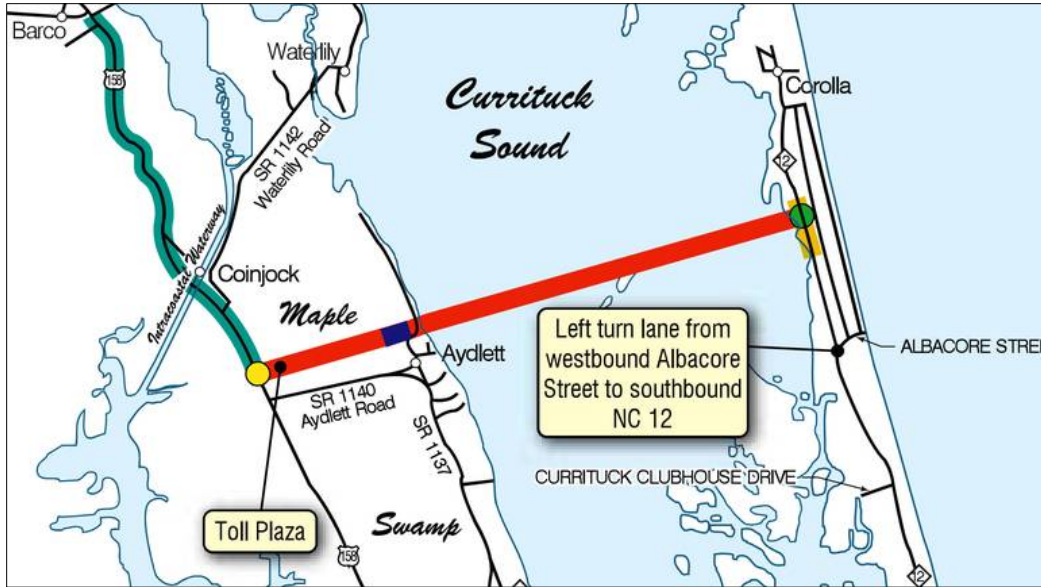


Figure 1. North Carolina Department of Transportation selected alternative; final selected alignment for the Mid-Currituck Bridge in Currituck County, North Carolina.

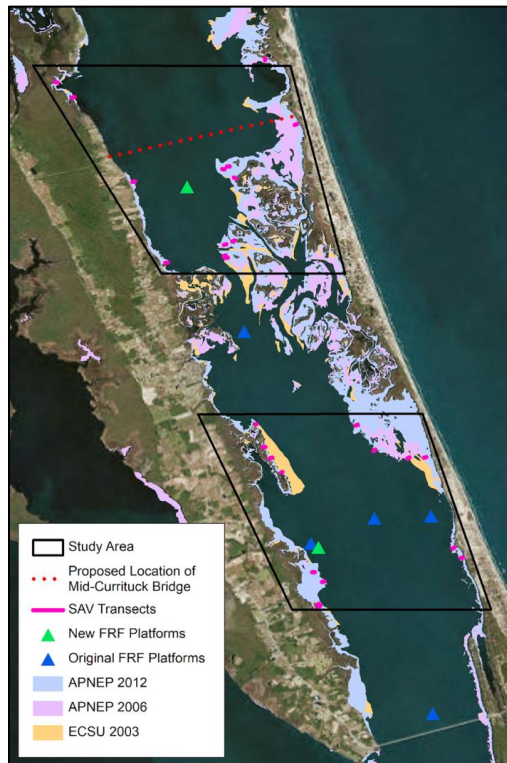


Figure 2. Previous submerged aquatic vegetation (SAV) distribution data in Currituck Sound in 2003 from Elizabeth City State University (ECSU) and in 2006 and 2012 from the Albemarle-Pamlico National Estuary Program (APNEP) for the NCDOT-funded SAVE Currituck Study. Water quality data is also being collected for the SAVE Currituck Study by the U.S. Army Corps of Engineers Field Research Facility (FRF). Map provided by D.R. Corbett, East Carolina University.

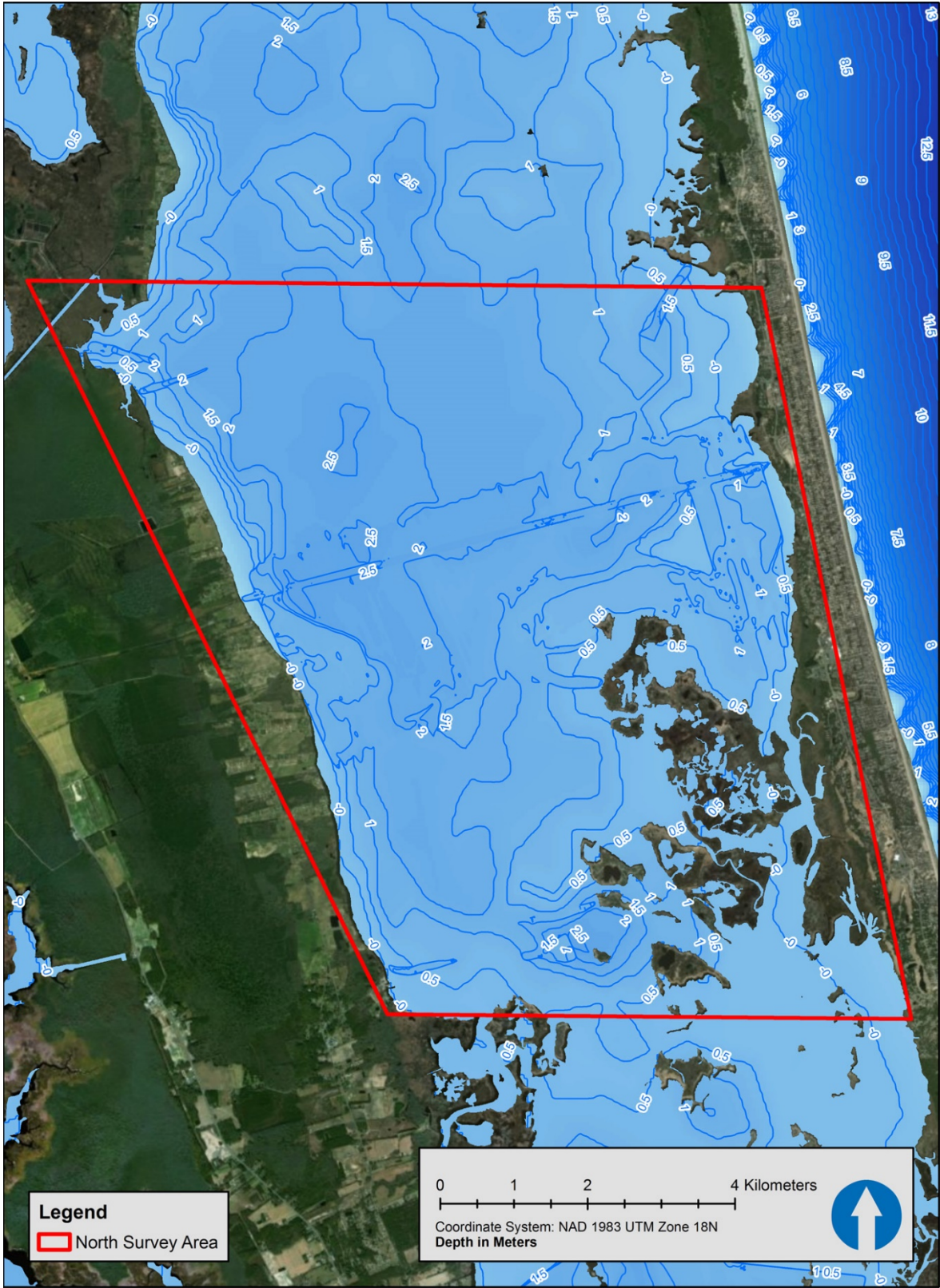


Figure 3. Comprehensive bathymetry data for Currituck Sound compiled for the NCDOT-funded SAVE Currituck Study. Map provided by CSA Ocean Sciences Inc.

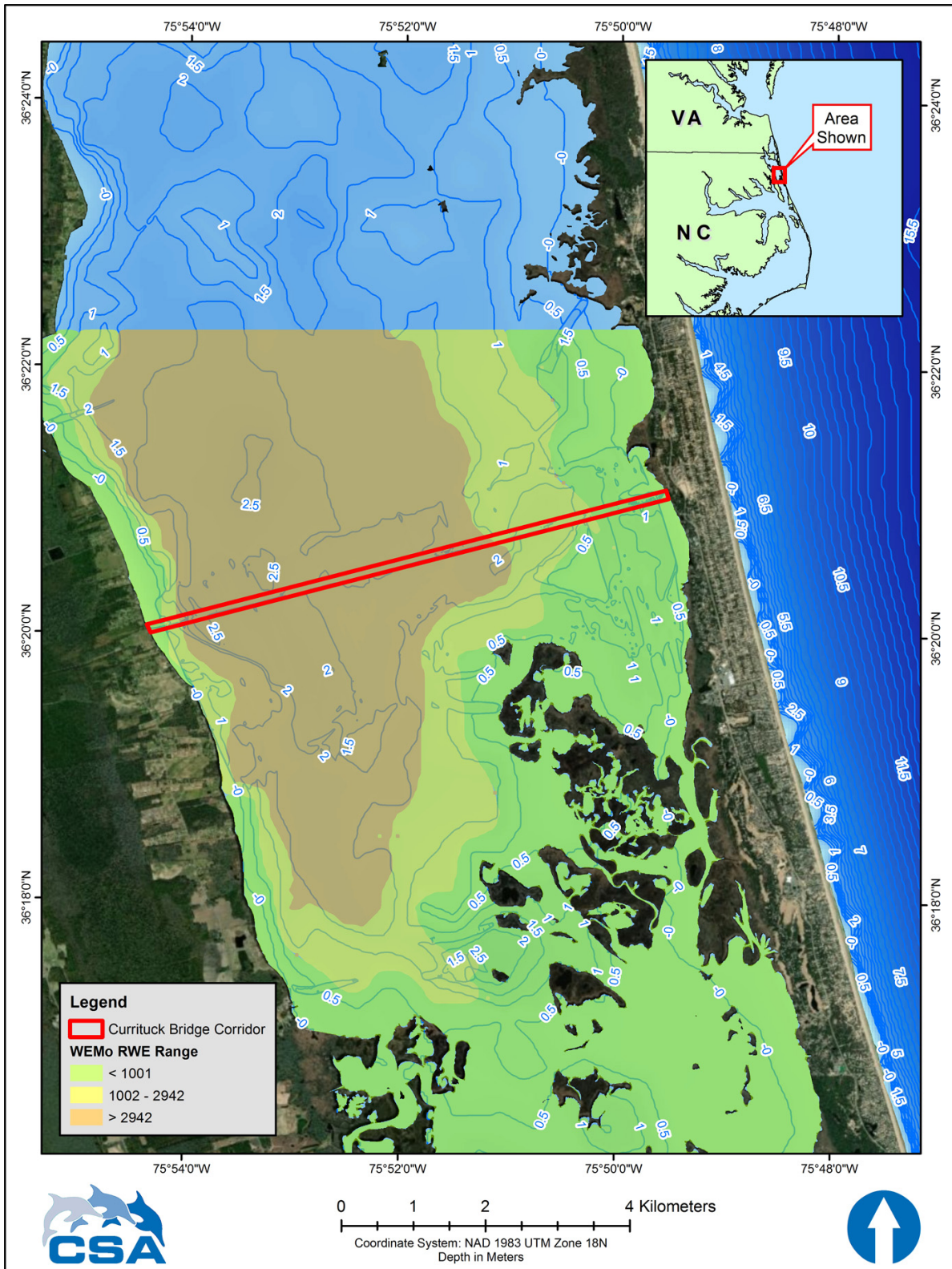


Figure 4. Results from the Wave Exposure Model (WEMo) analysis in Currituck Sound for the NCDOT-funded SAVE Currituck Study showing representative wave energy (RWE) zones. Map provided by CSA Ocean Sciences Inc.



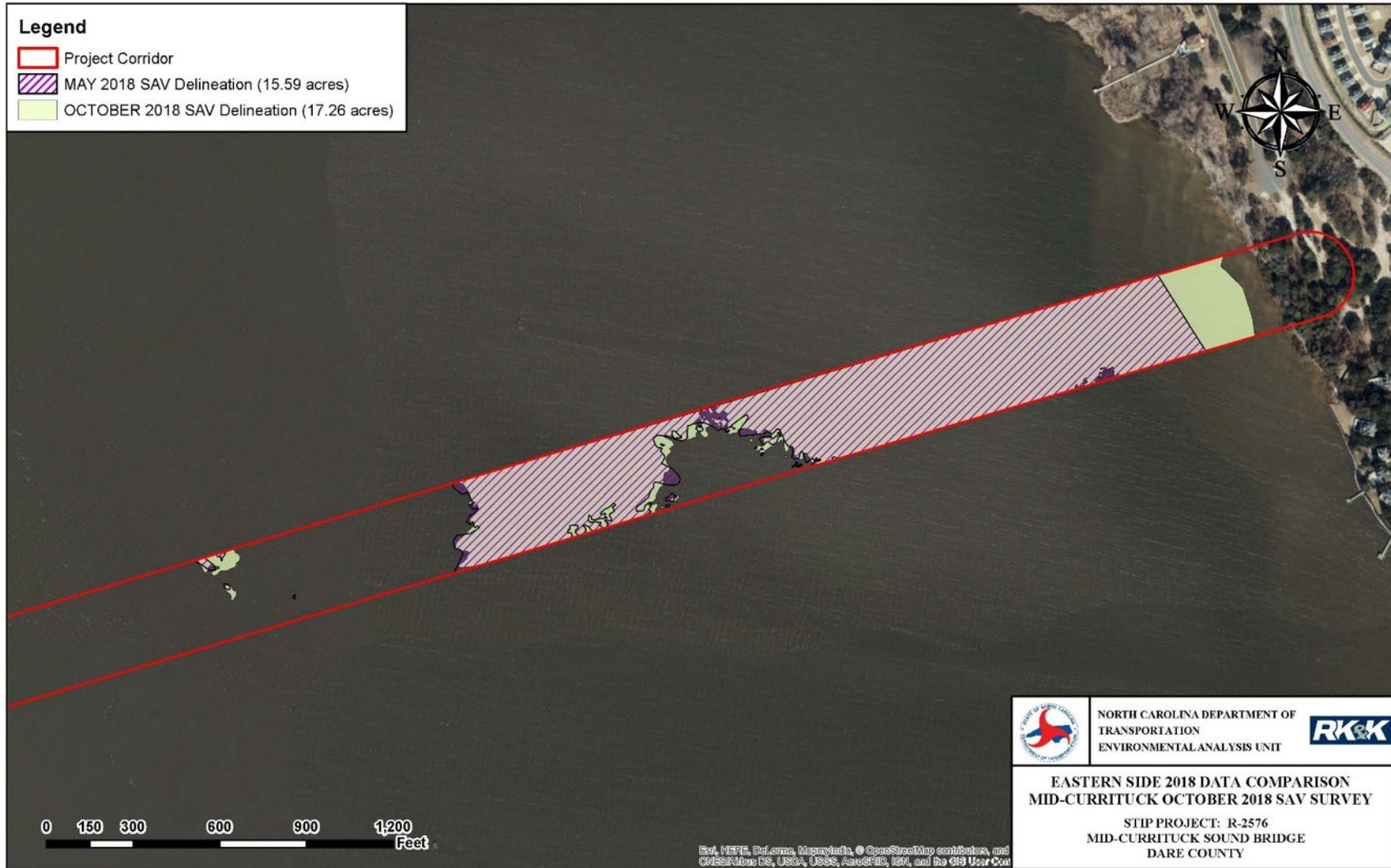


Figure 5a. Corolla (east) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in May and October 2018.



Figure 5b. Mainland (west) end of the proposed Mid-Currituck Bridge alignment showing lack of submerged aquatic vegetation (SAV) cover in May and October 2018.

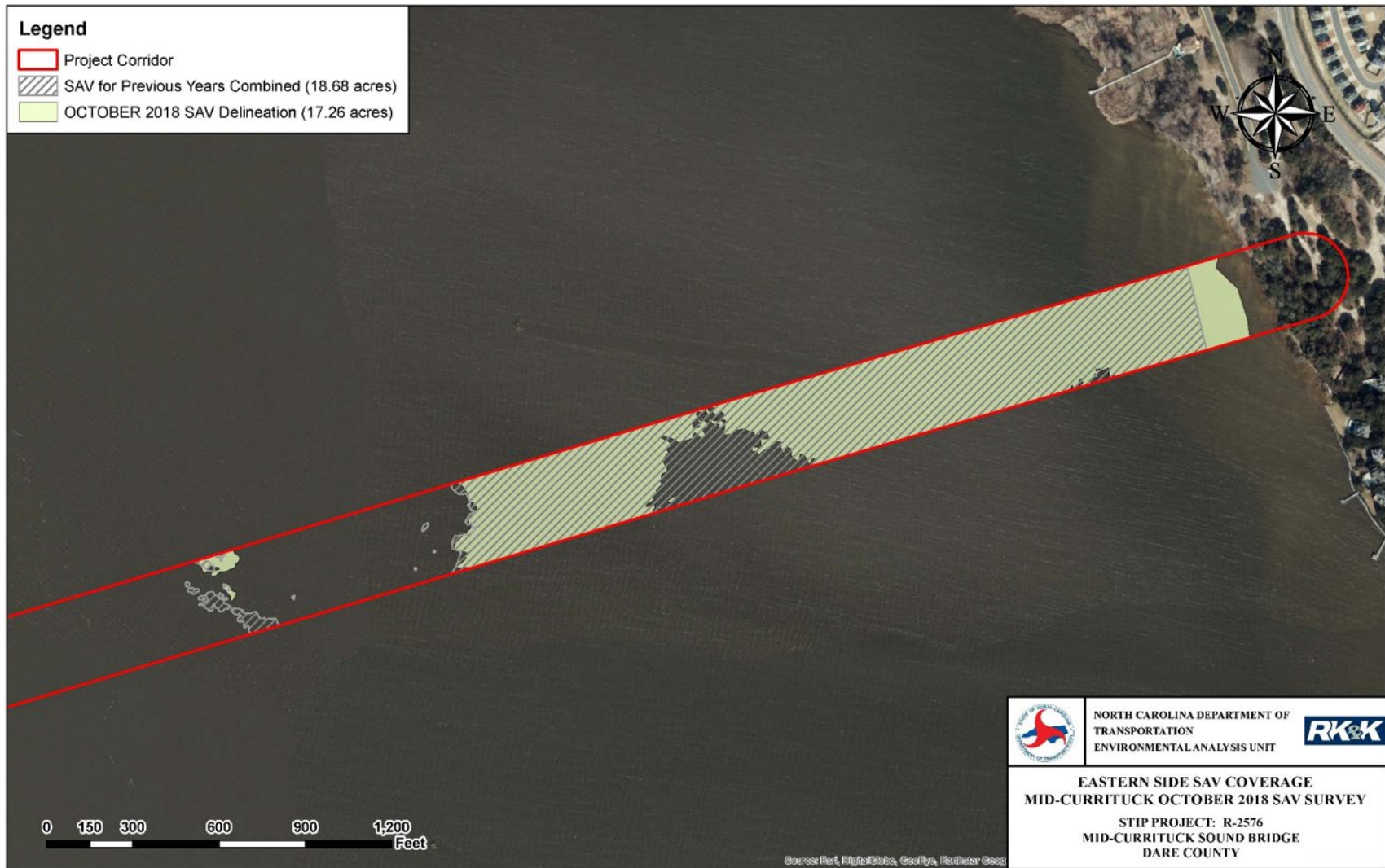


Figure 6a. Corolla (east) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in October 2018 and previous years.

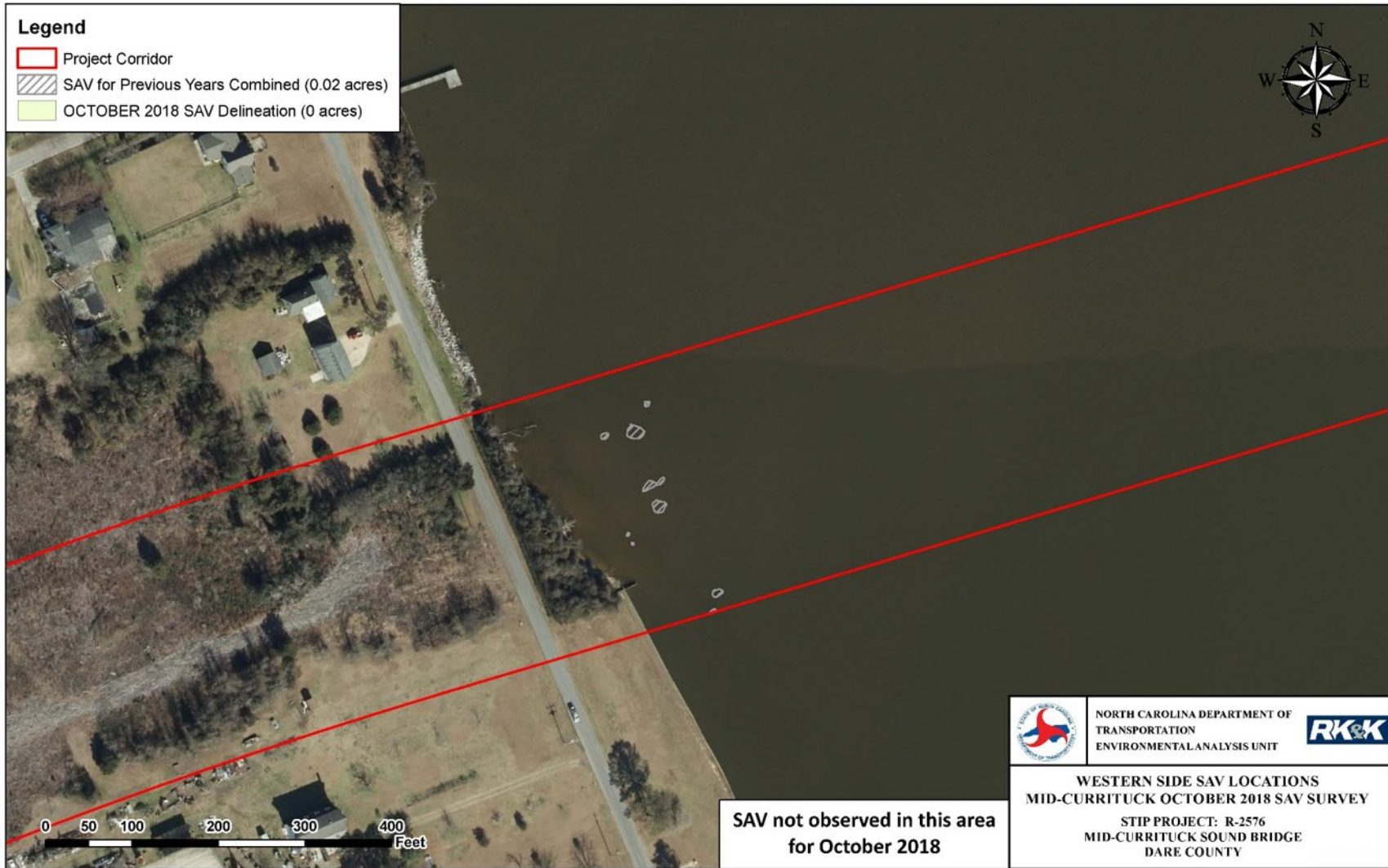


Figure 6b. Mainland (west) end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover in October 2018 and previous years.

## Construction and In Water Work Moratorium

Permanent and temporary piles will be vibrated and/or driven into the bottom with the use of silt curtains to contain any disturbed sediments where needed. To minimize construction impacts to the maximum extent practicable to SAV by in-water work, the NCDOT will follow the following protocols to protect SAV habitat (including existing beds). These methods were presented in Section 6.5 of the March 2019 Record of Decision.

- There will be no dredging in any part of Currituck Sound.
- There will be no in-water work in SAV habitat (including existing beds) during a moratorium period from February 15 to September 30. In-water work consists of bottom disturbing activities like temporary trestle pile placement and removal and driving of permanent piles. Working above the water, including barge operations (non-bottom disturbing), installation and removal of temporary trestle beams and decking, and installation of Mid-Currituck Bridge pile caps, beams, and decking, will occur up to 365 days a year at the discretion of NCDOT.
- Use of an open (i.e., beams only to support a crane) temporary construction trestle to minimize shading impacts to the maximum extent practicable while the trestle is on place. Marine industry standard pans will be placed under construction equipment operating on the open trestle to capture any accidental spills of oil and lubricants.
- SAV habitat that meets North Carolina Marine Fisheries Commission's (NCMFC's) criteria (including dense SAV beds) has been documented from the eastern side of the sound. In this area of the sound, NCDOT will install temporary piling and temporary open work trestle for approximately 4,500 linear feet and will, outside of the moratorium dates, drive piles for both the permanent bridge and the temporary trestle within SAV habitat (including existing beds). Based on the limited presence and sparse coverage of SAV found only along the shoreline in the western portion of Currituck Sound, an open trestle will not be necessary on this side of the sound.
- Turbidity curtains will be used during pile installation (permanent and temporary bridges) and pile removal (temporary bridge). Turbidity curtains will capture any silt from migrating outside the curtain perimeter. These are common and proven turbidity control techniques. Pile installation will be performed both by vibratory and impact hammers, with no jetting of piles.
- Minimization of potential impacts to potential SAV habitat (areas of the sound 6 feet deep or less and have a suitable substrate) will be accomplished through no dredging anywhere in Currituck Sound, by pile installation using both vibratory and impact hammers, with no jetting of piles, and the use of turbidity curtains during pile installation when necessary.

## Impacts Summary

SAV surveys have been conducted by NCDOT in the project area since 2015. SAV coverage has ranged from 13.17 acres in 2017 to 17.26 acres in 2018. The survey area extended 175 feet on either side of the proposed bridge center line for a total of a 350 feet wide area to account for any possible temporary bridge impacts. Given the selected Alternative (**Figure 1**) the proposed bridge structure will permanently impact up to 0.15 acres of SAV within the piling footprint. Total existing and historic (since 2015) seagrass coverage that could potentially require mitigation in the proposed bridge footprint is 4.05 acres. The Record of Decision (ROD) indicates that potential SAV habitat (water depths  $\leq 6$  feet) that

could be impacted is 8.7 acres. However, recent and ongoing research and surveys indicate that due to the water clarity and light attenuation in Currituck Sound, no SAV has been found to grow in water more than 3 feet deep.

### Shading Tool Prediction

To better understand the shading influence of transportation structures on SAV, an interactive shading tool was developed. This modeling tool allows users to input the structural geometry (e.g., height, width) over an open water structure to derive a geographically and temporally accurate projection of shading produced by that structure. The amount of light reduced by shading and the percentage of time that a given area of habitat is shaded along with ambient water column attenuation may then be related to any changes in SAV abundance (e.g., biomass, cover).

The tool utilizes the solar angle for a given geographic location, day of the year, and time of day to cast a shadow from a selected structure on the surrounding environment. The shading tool was applied to the selected Alternative for the proposed Mid-Currituck Bridge structure at two different times of year, June and October, to account for seasonal differences in solar angle and extent of SAV habitat. Results from the shading tool for the eastern and western banks of the bridge corridor are displayed in **Figures 7a** and **7b**, respectively, and show various gradations of shading (percent time in shade) within the corridor footprint. The shading tool bins the percent time in shade into five strata: 0 to 20%, 20 to 40%, 40 to 60%, 60 to 80%, and 80 to 100%.

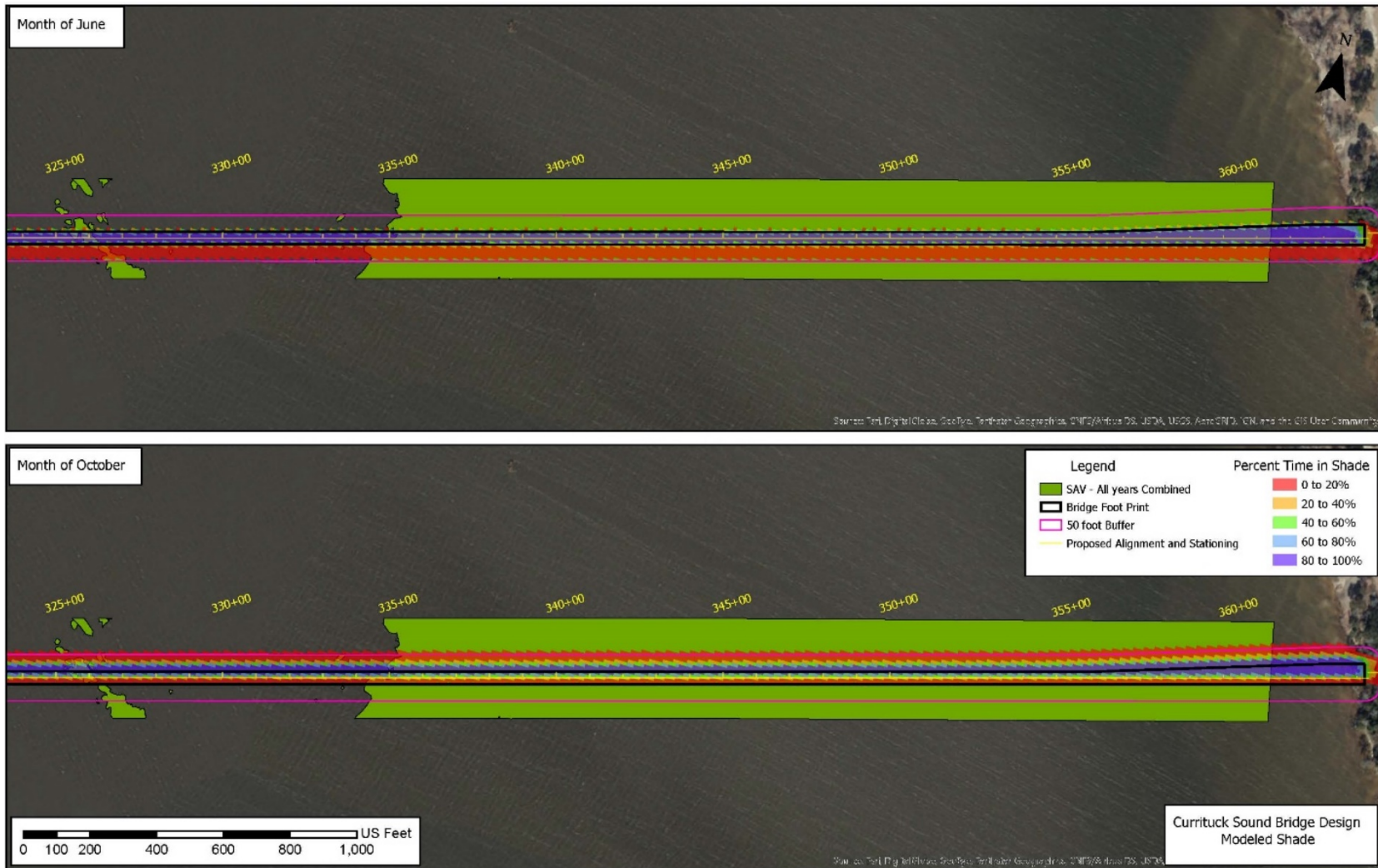


Figure 7a. East end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover and various gradations of shading predicted by the shading tool for the months of June and October. (Please zoom in on electronic version to better view legend).

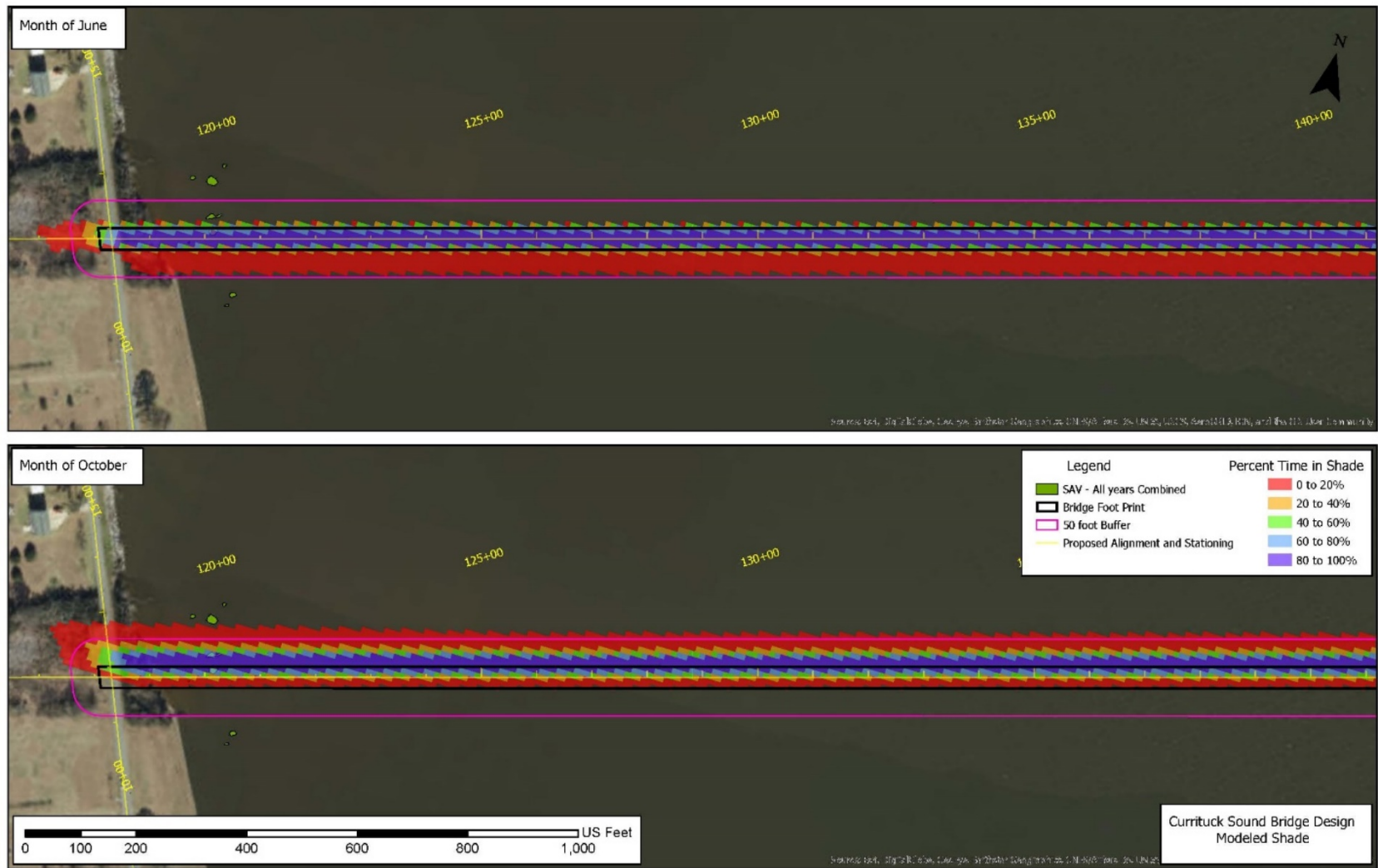


Figure 7b. West end of the proposed Mid-Currituck Bridge alignment showing submerged aquatic vegetation (SAV) cover and various gradations of shading predicted by the shading tool for June and October. (Please zoom in on electronic version to better view legend).



Estimations of acreage of SAV within the alignment corridor affected by varying percent time in shade was calculated by the shading tool for the eastern side in June (**Table 1**) and October (**Table 2**). (The western side of the corridor contains very little SAV and therefore calculations of this nature were not performed). In June, approximately 2.31 acres of SAV within the eastern corridor (40.5% of total) are estimated to be shaded from 0 to 20% of the time, while 1.70 acres (29.9% of total) will be shaded 80 to 100% of the time. The remaining SAV in the area, approximately 1.69 acres (29.6% of total), will be shaded from 20 to 80% of the time (**Table 1**). In October, results were similar, with the highest acreage of SAV (2.38 acres, 40.6% of total) falling within the least amount of time in shade (0 to 20%), followed by 1.57 acres (26.7% of total) falling within the greatest amount of time in shade (80 to 100%), and the remainder (1.91 acres, 32.7% of total) falling within 20 to 80% time in shade (**Table 2**). Results from the shading tool will be ground-truthed with field-based monitoring, which will include photosynthetic active radiation (PAR) measurements at the water’s surface and SAV abundance and density estimations for each of the five shading strata.

Table 1. Estimations of SAV acreage affected by various gradations of shading predicted by the shading tool for the month of June within the east end of the Mid-Currituck Bridge alignment.

Percent Time in Shade	Acre	Square Feet	Percent of Total
0 to 20 %	2.31	100,655	40.5
20 to 40%	0.63	27,226	11.0
40 to 60%	0.44	19,260	7.7
60 to 80%	0.62	27,162	10.9
80 to 100%	1.70	74,241	29.9
<b>Totals</b>	<b>5.71</b>	<b>248,544</b>	<b>100.0</b>

Table 2. Estimations of SAV acreage affected by various gradations of shading predicted by the shading tool for the month of June within the west end of the Mid-Currituck Bridge alignment.

Percent Time in Shade	Acre	Square Feet	Percent of Total
0 to 20 %	2.38	103,769	40.6
20 to 40%	0.70	30,566	12.0
40 to 60%	0.48	21,100	8.3
60 to 80%	0.73	31,687	12.4
80 to 100%	1.57	68,331	26.7
<b>Totals</b>	<b>5.86</b>	<b>255,454</b>	<b>100.0</b>

## Proposed Mitigation and Monitoring Plan

Mitigation for direct impacts (e.g., bridge piling, temporary construction bridge) and indirect impacts (e.g., shading) to SAV will be performed if warranted, to the extent necessary as determined from pre- and post-construction SAV monitoring surveys in comparison to local reference baseline. Unlike marine SAV communities, the SAV communities in the Currituck appear to be more spatially and temporally dynamic. This inherent variability will ultimately influence overall mitigation levels and monitoring strategy in order to discriminate natural variability from potential bridge impacts. Recent studies of Currituck Sound overall supported by NCDOT and directed surveys of the bridge corridor provide a useful pre-construction portrait of the SAV resources and their inherent variability in the area.

The NCDOT will monitor temporary construction impacts and shading impacts from the permanent bridge during construction and for 5 years post construction. Any shading impacts to SAV that are determined by the NEPA/404 Project Team to be permanent impacts shall be mitigated at a 1:1 ratio, using the best science available at the end of the 5-year post construction monitoring period.

## Potential Mitigation Options

Several mitigation options have been developed and are designated as either at, or offshore from the shoreline. In the first two options living shoreline alternatives are proposed, one at the shore and the other offshore. The transition in choice from at or offshore forms of living shoreline alternatives is generally governed by exposure of the site to wave energy. Living shorelines placed at the shoreline provide stabilization through the addition of natural structural materials to absorb wave energy, reducing erosion of the shoreline, thereby reducing sediment input to the Sound and restoring shoreline marsh areas. However, protection located at the shoreline itself is limited to the mid-range of wave energy conditions. Very low wave energy environments without shoreline erosion may not require living shoreline amendments whereas highly exposed shorelines can have wave energy that may exceed the structural limits of the typically, less structurally robust shoreline protection methods. When higher wave energy is experienced at a shoreline, inclusion of structure located offshore of the shoreline may be appropriate (Miller et al. 2015). However, offshore structures may also be complimented by living shoreline amendments at the shoreline itself (Fear and Bendell 2011). The cut-off for when at the shoreline vs. off the shoreline mitigative alternatives should be employed in North Carolina is not yet quantitatively determined (but see Miller et al. 2015) and represents a potential information gap.

One of the focal areas of the SAVE Currituck Study has been the potential influence of wave exposure on SAV using a Wave Exposure Model (WEMo) (Malhotra and Fonseca 2010). In that study wave height and energy maps of the Currituck, including that of the bridge alignment that have already been developed and provide a source of guidance in mitigation site selection. However, those wave height and energy maps are developed using mean sea level bathymetry. Wind-driven shifts in water levels are a regular feature of Currituck Sound and the Pamlico Sound in general (pers. obs.). A wind event that generated high wave energy superimposed over a generally elevated water level would allow for comparatively unimpeded transmission of wave energy to the shoreline. Thus, the wave height and energy maps available should be treated as a nominal condition and, though a substantial improvement over the fetch estimations provided previously (Atkins 2013), are not necessarily fully representative of wave energy that could reach a shoreline under all water level conditions. However, the WEMo program offers the ability to uniformly raise or lower water level across a given bathymetric data layer, allowing simulation of changes in wave energy distribution as the result of fluctuations in water level, although this was not part of the SAVE Currituck analysis.

A third option included for consideration is to utilize the WEMo results from the SAVE Currituck Study to expand on the initial analysis provided by Atkins (2013) to determine if wavebreak structures could be used to enhance or restore SAV habitat around the marsh island areas. In this mitigation scenario the modification of wave energy in SAV or marsh habitat to cause a shift to more unit area cover of SAV or marsh with less temporal variability (vis a vis the Bonner Bridge wavebreak structure; CSA 2018 and living shoreline concepts for North Carolina marshes in general [e.g., Broome et al., 1992, Currin et al., 2010]). Finally, an alternative for reclaiming excavated seafloor to SAV habitat is considered. This alternative is patterned after options regularly utilized in other southeastern states as a seagrass mitigation alternative.

In coordination with regulatory agencies, finalization of any option will be further informed by subsequent surveys of physical conditions and SAV distribution at the mitigation site. Wave exposure on SAV using the aforementioned wave height and energy maps of the Currituck, including that of the

bridge alignment will be consulted along with any subsequently generated survey data to inform the most appropriate alternative for a given site.

## ONSHORE ALTERNATIVES

### *Option 1: Living shorelines at bridge landings for erosion control and marsh enhancement*

**Description:** Various materials including sand, rock, fabricated concrete, fence, coconut fiber logs, marsh plants and/or other SAV, can be utilized for living shorelines placed at the shoreline itself. Reduced wave energy along the shoreline as a result of this wave interception provided by living shoreline materials also reduces shoreline erosion, facilitates sediment accretion and marsh growth, adding to the stability of the shoreline. Additionally, living shorelines provide ecological services by providing habitat, predation refuges and nursery areas for aquatic animals and plants, in addition to improving water quality through enhanced nutrient and sediment reduction (Gittman et al., 2016; National Oceanic and Atmospheric Administration [NOAA] Habitat Blueprint, no date; North Carolina Department of Environmental Quality [NCDEQ], no date). Estuarine shoreline erosion of swampforests and marshes on the western side of Currituck Sound as well as back-barrier island shoreline erosion of marshes on the eastern side of the sound has been a critical issue for several decades (Benner et al., 1982; Riggs, 2001) and is of concern for NCDOT at landing sites of the proposed Mid-Currituck Bridge (T. Stanton, 2019, pers. comm., NCDOT).

**Methodology:** Living shorelines will be installed at the shoreline along selected portions of the shoreline on either side of the bridge landing sites where erosion of existing riparian vegetation is observed, and wave energy is moderate. Construction of living shorelines may require specialized machinery in order to effectively place heavier material such as rock, coconut fiber logs, or sandbags along the edge of the shoreline or several meters from the shoreline underwater, to create a sill feature (**Figure 8**).

A comprehensive synthesis report evaluating 27 marsh sill projects in eastern North Carolina found them to be effective at combating shoreline erosion (Fear and Bendell, 2011). Native species of marsh grasses (*Spartina* spp.) will be obtained from local plant nurseries and planted along the shoreline or in the intertidal area between the sill and emergent marsh along shore.

However, this option will only be appropriate for non-high wave energy areas. According to the Currituck WEMo data (**Figure 4**), wave energy is in the low category along the shoreline at both landing sites (<1001 joules/meter<sup>2</sup>); however on the western side there is a gradient to high wave energy within approximately 0.5 km from shore (again, recalling that the WEMo model data represent nominal water level conditions; slight elevation of water levels could allow substantially increased wave transmission to the shoreline) and therefore living shorelines at the shoreline itself may be less appropriate at the western versus the eastern landing site.

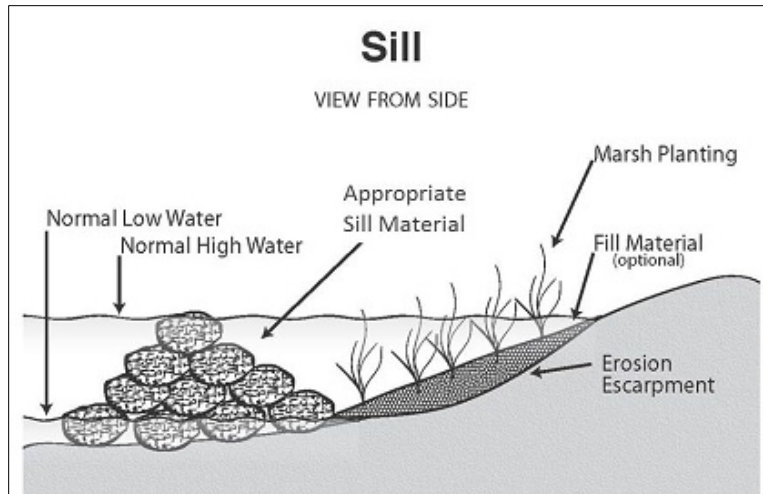


Figure 8. Schematic of a living shoreline that includes a sill feature. Drawing by North Carolina Department of Environmental Quality, no date.

## OFFSITE AND OFFSHORE ALTERNATIVES

### Option 2: Offshore wavebreaks near landing sites for erosion control and marsh enhancement

**Description:** In higher wave energy areas, wavebreaks located offshore of the shoreline may be more effective at reducing wave energy in order to protect the actual shoreline. These structures may also facilitate shoreward sediment accretion, adding to expansion and stabilization of the shorelines versus other alternatives such as living shorelines at the shoreline itself (NOAA, no date). Engineering considerations including material, shape, location, size, seafloor slope, and water depth of the wavebreaks will be informed by physical data including wind and wave energy forecasts as well as local bathymetry and sediment characteristics. Verification of the suitability of areas just offshore landing sites to receive wavebreaks will require detailed physical surveys; however, existing WEMo results and sediment data from the SAVE Currituck Study will be consulted initially to help inform suitability of this option at any selected site.

**Methodology:** Wavebreaks may be constructed of modular artificial reef units or rock material. Design and planning of wavebreaks will be performed by professional engineers, while construction will be performed by a local contractor with engineering oversight. Heavy equipment such as excavators and barges will likely be utilized during construction. Native marsh plantings (*Spartina* spp.) may be added following construction to vegetate the shoreline shoreward of the wavebreak, depending on the shoreline morphology and presence of suitable substrate.

### Option 3: Modification of SAV landscape on eastern end of bridge corridor via offshore wavebreaks

**Description:** The eastern side of Currituck Sound supports extensive SAV beds (**Figure 2**) however the distribution and density of SAV has been spatially and temporally dynamic, likely as a result of the life history of these plant communities and aperiodic extreme wind events and waves. Consistent with the approach used at the Bonner Bridge wavebreak project, here it is proposed to enhance natural SAV distribution and cause a shift to enhance SAV recruitment for a more extensive and permanent cover (decrease patchiness and variability in cover over time) thereby providing a net increase in SAV cover.

*Methodology:* SAV colonization or expansion from nearby existing beds would be facilitated by use of stone sills or modular fabricated units (e.g., Bonner Bridge wavebreak structures) to create wavebreaks arranged in a chevron pattern normal to the direction(s) of the predominant wave energy in areas adjacent to SAV beds but on unvegetated seafloor. Structures would be high enough to provide wind wave (and any vessel wake) reduction based on the tidal frame at the site. The length of each wavebreak will be determined based on the acreage of SAV required for mitigation based on experience generalized from CSA (2018) regarding the amount of SAV generated per linear foot of wavebreak.

#### Option 4: Filling of dredge holes near existing SAV habitat

*Description:* If anthropogenically created holes or depressions in the seafloor exist (as a result of dredging, dock removal, or other activities) near extant SAV habitat in Currituck Sound, these holes will be filled and brought to the grade of the surrounding, natural seafloor. Water depth, and thus light penetration is likely a strong factor influencing SAV distribution in Currituck Sound. SAV distribution data collected to date for the SAVE Currituck Study found 99% of all SAV surveyed to date to occur in water depths less than 1.9 m, and 80% in water depths less than 1 m (Corbett et al., 2018). Therefore, if suitable mitigation sites of this nature exist, areas deeper than 1.9 m could be filled and brought to grade of the surrounding seafloor providing habitat for natural colonization from existing, surrounding SAV beds, thus providing new SAV acreage. For example, there exists an area south of the eastern terminus of the proposed bridge alignment, where the marsh is eroding toward NC 12, that would be an appropriate candidate to assess for this mitigation option.

*Methodology:* Bathymetric data (SAVE Currituck Study) and local knowledge (e.g., NCDENR, ECU investigators, USACE) for Currituck Sound will be consulted to investigate potential sites with man-made depressions in the seafloor with water depths greater than 1.9 m that also occur near extant SAV habitat. If depressions of this nature exist, after permitting they will be filled with suitable fill and brought to grade. Depending on the size of the site, fill can be provided using techniques perfected in restoration of vessel groundings elsewhere. Deep depressions may require mechanical placement of fill. For shallower depressions in shallow water, biodegradable sandbags will be delivered to the site via barge and placed using machinery or a combination of wading and snorkeling depending on the size and water depth of the site. Sand would be sourced from upland locations and biodegradable bags and/or tubes will be filled with sand while on land. Sediment elevation of the filled area would be confirmed for consistency with adjacent seafloor standard survey methods.

#### Option 5: Restoration or enhancement of SAV habitat and/or erosion reduction around marsh islands

*Description:* Building off of the concept in the Atkins (2013) report, locations in Currituck Sound where shoreline erosion has resulted in marsh and/or SAV loss would be targeted for erosion control intervention and potentially SAV and/or marsh plantings as a mitigation strategy.

*Methodology:* The WEMo model data from the SAVE Currituck Study would be used to stratify shoreline and SAV habitats into areas of high, medium, and low wave energy based on the frequency distribution of the model raster file. This model would be re-run at other overall water depths to account for storm conditions that could deliver wave energy to new areas. Additionally, shoreline and SAV change analysis using historical aerial imagery would be performed for the high wave energy strata from the wave modeling. For shorelines, the method would follow that of Cowart et. al. (2010) who developed a process using North Carolina marsh shorelines. SAV change may be more difficult to ascertain given the issues involved with using remote imagery to detect SAV in Currituck Sound, but this would be

attempted. The areas found to have the highest shoreline and/or SAV loss would be considered for application of mitigation measures as described in Options 1-3 .

## Monitoring and Reporting

Monitoring and reporting will be described in subsequent documentation following selection and approval of mitigation options by NCDOT and the relevant permitting authorities. The final scale of any selected mitigation option will be determined in coordination with NCDOT and the agencies following review of results of the SAVE Currituck Sound study and a multiple year post construction monitoring effort.

## Literature Cited

- Atkins, 2013. Mid-Currituck Bridge STIP NO. R-2576 Compensatory Mitigation Plans for Submerged Aquatic Vegetation Currituck County, NC; Phase I: Environmental Mitigation Field Work
- Benner CS, Knutson PL, Brochu RA, Hurme AK. 1982. Vegetative erosion control in an oligohaline environment Currituck Sound, North Carolina. *Wetlands* 2:105-117.
- Broome SW, Rogers SM, Seneca ED. 1992. Shoreline erosion control using marsh vegetation and low-cost structures. *UNC-SG-92-12*.
- Carter V, Rybicki NB. 1994. Invasions and Declines of Submersed Macrophytes in the Tidal Potomac River and Estuary, the Currituck Sound-Back Bay System, and the Pamlico River Estuary. *Lake and Reservoir Management* 10(1):39-48.
- Corbett DR, Walsh JP, Biarrieta N, Mason L, Paris P, Wadman H, Dickhudt H, Fonseca MS, Hodel E. 2018. Submerged Aquatic Vegetation Evaluation in Currituck Sound (SAVE Currituck Sound). Presentation prepared for NCDOT, December 2018.
- Cowart L, Walsh JP, Corbett DR. 2010. Analyzing estuarine shoreline change: a case study of Cedar Island, North Carolina. *Journal of Coastal Research* 26(5):817-830.
- CSA Ocean Sciences Inc. 2018. B-2500 Bonner Bridge Seagrass Mitigation Site Y2 Annual Survey Report. July 2018. 67p.
- CSA Ocean Sciences Inc. 2019. CSA Ocean Sciences Inc. (CSA). 2019. Shadow toolbox user manual. ST\_01\_ver02. Submitted to Rummel, Klepper and Kahl, Raleigh, North Carolina. Junly 2019. CSA Document number CSA-RKK-NCDOT-FL-19-80763-3289-06-REP-01-FIN.
- Currin, CA, Chappell WS, Deaton, A. 2010, Developing alternative shoreline armoring strategies: The living shoreline approach in North Carolina, *in* Shipman H, Dethier MN, Gelfenbaum G, Fresh KL, Dinicola RS. eds., 2010, Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 91-102.
- Davis GJ, Brinson MM. 1983. Trends in Submersed Macrophyte Communities of the Currituck Sound: 1909-1979. *Journal of Aquatic Plant Management* 21:83-87.
- Davis GJ, Brinson MM. 1990. A Survey of Submersed Aquatic Vegetation of the Currituck Sound and the Western Albemarle-Pamlico Estuarine System. Albemarle-Pamlico Estuarine Study, United States Environmental Protection Agency and North Carolina Department of Environment, Health, and Natural Resources. Project No. 89-10.

- Davis GJ, Carey DF. 1981. Trends in Submersed Macrophyte Communities of the Currituck Sound: 1977-1979. *Journal of Aquatic Plant Management* 19:3-8.
- Fear JF, Bendell B. 2011. N.C. Division of Coastal Management Assessment of 27 Marsh Sills in North Carolina, Final Report. 21 pp.
- Gittman RK, Peterson CH, Currin CA, Fodrie FJ, Piehler MF, Bruno JF. 2016. Living shorelines can enhance the nursery role of threatened estuarine habitats. *Ecological Applications* 26: 249– 263
- Luczkovich JJ. 2010. Survey of the Submerged Aquatic Vegetation in the Proposed Alignment for the Mid-Currituck Bridge. A report to the North Carolina Turnpike Authority.
- Malhotra A, Fonseca MS. 2010. WEMo (Wave Exposure Model): Formulation, Procedures and Validation. NOAA Technical Memorandum NOS NCCOS #65. 28 pp.  
[https://cdn.coastalscience.noaa.gov/page-attachments/products/WEMo/WEMo\\_V4\\_manual.pdf](https://cdn.coastalscience.noaa.gov/page-attachments/products/WEMo/WEMo_V4_manual.pdf)
- Miller JK, Rella A, Williams A, Sproule E. 2015. Living Shoreline Engineering Guidelines. New Jersey Department of Environmental Protection. SIO-DL-14-9-2942.  
<https://www.conservationgateway.org/ConservationPractices/Marine/crr/library/Documents/Living%20Shorelines%20Engineering%20Guidelines.pdf>.
- National Oceanic and Atmospheric Administration (NOAA), no date. Habitat Blueprint, Living Shorelines.  
<https://www.habitatblueprint.noaa.gov/living-shorelines/>.
- North Carolina Department of Environmental Quality (NCDEQ), no date. University of North Carolina Living Shoreline Studies. <https://deq.nc.gov/about/divisions/coastal-management/coastal-management-estuarine-shorelines/stabilization/living-shoreline-research/unc-studies>.
- Reevaluation of Final Environmental Impact Statement. 2019. Mid-Currituck Bridge Study, Federal-Aid Project Number: BRSTP-000S (494) WBS Element: 34470.1.TA1 STIP No. R-2576. March 6, 2019. <https://www.ncdot.gov/projects/mid-currituck-bridge/Documents/final-reevaluation-feis.pdf>
- Riggs SR. 2001. Shoreline Erosion in North Carolina Estuaries. The Soundfront Series. North Carolina Sea Grant. [https://ncseagrant.ncsu.edu/ncseagrant\\_docs/products/2000s/soundfront-series\\_erosion/soundfrontseries\\_erosion3.pdf](https://ncseagrant.ncsu.edu/ncseagrant_docs/products/2000s/soundfront-series_erosion/soundfrontseries_erosion3.pdf).
- RK&K. 2018. R-2576 - Proposed Mid-Currituck Sound Bridge - Submerged Aquatic Vegetation Survey Findings Report for October 2018. Letter Report. 9 p.