N.C. Division of Coastal Management
Assessment of 27 Marsh Sills in North Carolina

Final Report

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CAMA	Coastal Area Management Act
CRC	Coastal Resources Commission
NCCF	North Carolina Coastal Federation
NOAA	National Oceanic and Atmospheric Administration
DCM	North Carolina Division of Coastal Management
DMF	North Carolina Division of Marine Fisheries
DWQ	North Carolina Division of Water Quality
WRC	North Carolina Wildlife Resources Commission
NOAA	National Oceanic and Atmospheric Administration
UNC-IMS	University of North Carolina at Chapel Hill – Institute of Marine Sciences
USACE	United States Army Corps of Engineers

1.0 Project Introduction

1.1 Introduction

North Carolina has more than 9,000 miles of estuarine shoreline (DCM 2010). Most of these shorelines are eroding (Riggs and Ames 2003). The coastal region where these estuarine shorelines are located has also experienced rapid population growth over the past decade. The 20 coastal counties subject to the Coastal Area Management Act have seen on average a 13 percent increase in population from 2000 – 2009 (NCOSBM 2010). These two trends have combined to make estuarine shoreline stabilization an important coastal management issue.

The type of stabilization structure used and how many such structures are present have the potential to impact North Carolina's estuarine shorelines and the ecological benefits they provide. Natural shorelines capture nutrients and sediment from stormwater before it enters our estuarine systems. They also provide feeding and nursery habitat for a multitude of species and dampen wave energy along the shoreline. These ecosystem services are what help maintain the health of our estuaries. Shoreline stabilization often leads to a change in these ecosystem services. While a small change in these ecosystem services on a parcel by parcel basis may not seem significant, when you scale the effect to the watershed level, the collective impact due to all shoreline stabilization activity can be extremely significant.

Presently, bulkheads are the primary way in which estuarine shorelines are stabilized in N.C (DCM 2010). As understanding of ecosystem function has increased, new alternatives to bulkheads have emerged. These alternatives are designed to provide similar levels of shoreline stabilization while minimizing the reduction in ecosystem services compared to a bulkhead. The rock sill with marsh plantings, commonly referred to as a marsh sill (Figure 1), is one alternative that has been of particular interest to the N.C. Division of Coastal Management (DCM), the Coastal Resources Commission (CRC), and the N.C. General Assembly.

1.2 Marsh Sills Background

Marsh sills, for the purpose of this project, are shore parallel structures made up of two critical elements: 1) an offshore low relief mound made of rock or oyster shell called a sill; and 2) an intertidal area between the offshore sill and the upland containing emergent marsh vegetation. Fill is sometimes used landward of the rocks/oysters to properly grade the area to the elevation required for marsh plant establishment and survival. The sill is typically designed with overlaps, gaps, or dropdowns to allow water, fish, and other nekton access to the marsh area. The overlap design provides an opening by splitting the offshore sill into two sections. In the area where the two sections meet, they overlap for a few feet in a parallel offset manner. The gap design provides an opening by splitting the offshore sill into two sections. In this design the two ends do not fully meet, leaving a gap in the offshore sill. The dropdown design provides access by periodically lowering the height of the offshore sill. Figure 1 shows pictures of three marsh sills with these design elements labeled.

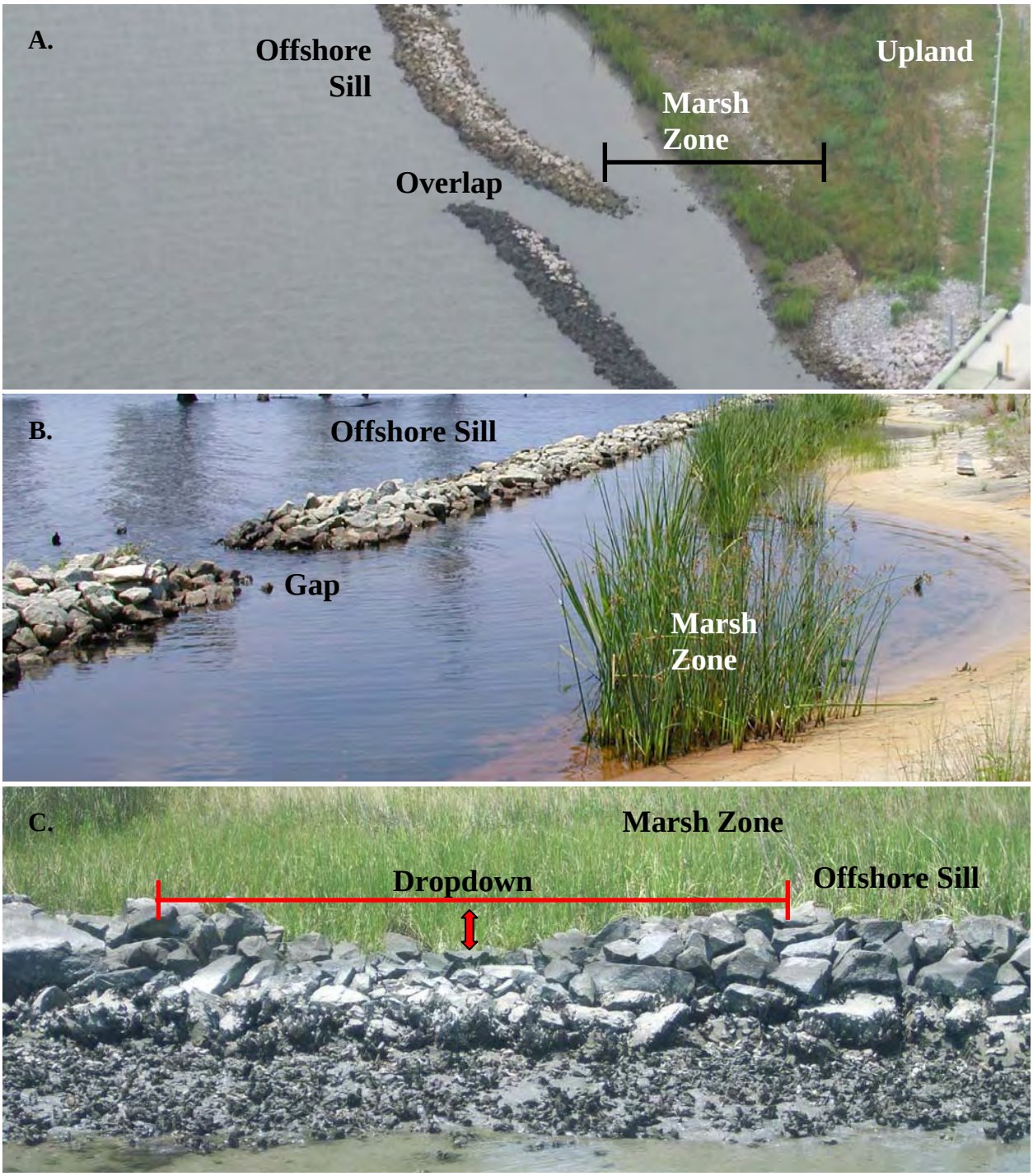

Figure 1: Labeled marsh sill design elements. Panel A depicts the overlap design, panel B the gap design, and panel C the dropdown design. The red lines and arrows in panel C show the vertical relief of the dropdown area.

Marsh sills are considered living shorelines. "Living shorelines" are defined as shoreline stabilization methods that employ as many natural habitat elements as appropriate for site conditions to protect shorelines from erosion (Erdle, et al. 2006). Because marsh sills include

natural shoreline features in their construction and maintain some of the natural shoreline habitats, they are considered by many as a better alternative to more traditional shoreline stabilization methods such as bulkheads. Marsh sills minimize shoreline erosion because the sill protects the marsh or allows marsh establishment. Once established, marsh absorbs wave energy, preventing it from reaching the upland (Rogers and Skrabal 2001).

Despite the benefits of marsh sills listed above, there are also a few concerns associated with them. During marsh sill construction, shallow subtidal and intertidal flats are converted into other habitat types, potentially reducing fish feeding habitat and submerged aquatic vegetation habitat. There is also concern that marsh sills may lead to the creation of new uplands, converting what was originally public trust areas into private land. Finally marsh sills, specifically the rock portions, have long lifetimes (50+ years). This has caused some to worry that if marsh sills do not perform as expected, it may be difficult to remove them.

Research efforts by many groups in many states are ongoing to assess the performance of marsh sills. In the interim, more than 30 marsh sill structures have been constructed in the state. Given the potential impact these structures may have (positive and negative), their long lifetime (50+ years), and their current use in N.C, the CRC requested that DCM assess how the existing marsh sills are performing.

1.3 Marsh Sill Permitting

The construction of a marsh sill requires permit authorization under the Coastal Area Management Act (CAMA). The type of permit required for a marsh sill is determined by the design of the proposed structure, the proposed location of the structure, and the potential for impacts to coastal resources that would result from the construction of the sill. If the design of the proposed sill structure entails minimal potential for adverse impacts, and if the design of the sill does not exceed certain specific use standards, a General Permit (Section 15A NCAC 07H.2700) may be issued for the proposed project. Most General Permits, which are an expedited form of a CAMA Major Permit, can be issued within a few days and require minimal agency coordination. However, due to complexities associated with sill projects, the sill General Permit involves several additional coordination steps, requires that the applicant coordinate directly with the DWQ and the USACE to ensure compliance with those regulatory programs, and thus likely will take longer to process than other general permits.

If a proposed sill project does not qualify for a CAMA General Permit, a CAMA Major Permit will be required. The CAMA Major Permit application, which requires that the applicant prepare a more formal permit application package, is coordinated with as many as 14 State and Federal review agencies. If no significant concerns are raised during this review, or if concerns are raised that can be addressed through design modifications, a CAMA Major Permit can be issued for the sill. The CAMA Major Permit review process typically takes an average of 75 to 90 days to complete.

1.4 Project Objectives

To meet the CRC mandate, DCM initiated a qualitative technical assessment of existing marsh sills. Sills were evaluated on two criteria: 1) Are the marsh sills performing their function as expected? and 2) What are the landowner and adjacent property owners' (where marsh sills are located) perceptions of the marsh sill shoreline stabilization option? Criterion one addressed the following questions:

- Has the marsh sill stabilized the shoreline of the property where it is installed?
- Has the marsh sill caused any unexpected erosion or other unanticipated problems or benefits?
- Based on the performance of the existing marsh sills, are the specific conditions outlined in 15A NCAC 7H .2705 of the marsh sill general permit appropriate?

Criterion two addressed the following questions:

- What are the feelings and perceptions of the landowner regarding the marsh sill stabilization technique where the marsh sills are currently installed?
- What are the feelings and perceptions of the property owners regarding the marsh sill stabilization technique adjacent to where the marsh sills currently are installed?

It should be noted that concurrent with this effort, many additional research efforts are currently being conducted to understand estuarine processes. Researchers from the University of North Carolina at Chapel Hill – Institute of Marine Science (UNC-IMS) are conducting an examination of the existing and planned marsh sills to quantify the biological and ecological impact of these structures through a study funded by the North Carolina Marine Resources Fund. Researchers from the North Carolina Coastal Reserve and National Estuarine Research Reserve, the National Oceanic and Atmospheric Administration (NOAA), Center for Coastal Fisheries and Habitat Research, UNC-IMS, and the University of North Carolina Wilmington are investigating the impacts of bulkheads on coastal fringing saltmarsh. DCM is working on a project to map all estuarine shorelines in terms of margin type (natural, bulkhead, marsh sill, riprap revetment, etc.). All these efforts together will provide qualitative and quantitative information regarding how marsh sills are performing in North Carolina and how they relate to the larger estuarine systems in general.

2.0 Methods

2.1 Field Visits

Questions associated with criterion one were assessed by visiting 27 marsh sills that have been installed in North Carolina through the CAMA major permit or marsh sill general permit process (Figure 2). These sites were identified by a review of the DCM permit database (Bendell 2010). A full description and photograph of each site is included in Appendix 8.1. Table 1 includes general characterizations for each visited marsh sill site.

Figure 2: Locations of marsh sills visited during the study. Marsh sill locations are marked by red dots. Note that some points represent more than one marsh sill.

At each marsh sill visited, representatives from the agencies and organizations listed in Table 2 visually evaluated the condition of the marsh sill structure, the property where the sill is located, and the adjacent properties. Qualitative evaluations were conducted through the use of a field data sheet containing a list of questions designed to assess marsh sills in four areas: navigation, rock and fill; erosion control and impacts; wetlands habitats and tidal flow; and other (Appendix 8.1). The site visits were conducted during June, July and August 2010. The site visits typically occurred at low tide so that more of the structure could be observed; however a few sites were also visited at high tide to ensure no major discrepancies in observer responses occurred due to differences in the tide state. Permission was obtained from all property owners to access the marsh sills.

Table 1: Characteristics of Visited Marsh Sills.

Site	Permit #	Permit Type	County	Waterbody	Year Permitted	Mound Material	Length (ft)
1	42-00-03	Major	Carteret	Core Sound	6-2000	Rock	90
2	39-01	Major	Carteret	Gallant's Channel	4-2001	Rock	315
3	13-02	Major	Carteret	Gallant's Channel	1-2002	Rock	300
4	42-00-05	Major	Carteret	Bogue Sound	2-2002	Rock	400
5	42-00-06	Major	Carteret	Bogue Sound	5-2002	Rock	450
6	42-00-08	Major	Carteret	Straights	3-2004	Rock	410
7	42-00-10	Major	Carteret	North River	7-2004	Rock	456
8	20-05	Major	Carteret	Oyster Creek	2-2005	Rock	258
9	45794C	General	Carteret	Straights	7-2006	Rock	95
10	142-06	Major	Carteret	Newport River	8-2006	Rock	230
11* and 12*	48144C 48145C 50129C 50168C 50130C	General	Carteret	Back Sound	3-2007 3-2007 2-2008 2-2008 2-2009	Rock	105 99 (204*) 52 12 106 (170*)
13	131-07	Major	Carteret	North River	8-2007	Rock	282
14	49808C	General	Carteret	Back Sound	2-2008	Rock	180
15	15-08	Major	Carteret	North River	2-2008	Rock	~1000
16	42-00-09	Major	Chowan	Chowan River	5-2004	Rock	450
17	42-00-04	Major	Craven	Neuse River	8-2000	Rock	176
18	36-09	Major	Dare	Roanoke Sound	3-2009	Oyster Bags	425
19	46565B	General	Hyde	Pamlico Sound	10-2006	Rock	225
20	42-00-02	Major	Onslow	White Oak River	6-2000	Rock	285
21	28-05 Rock	Major	Onslow	Stump Sound	2-2005	Rock	550
22	28-05 Oyster	Major	Onslow	Stump Sound	2-2005	Oyster Bag	150
23	47575D	General	Onslow	Chadwick Bay	5-2007	Broken Cement	100
24	47-09	Major	Onslow	White Oak River	4-2009	Oyster Bags	400
25	50-03	Major	Pamlico	Neuse River	4-2003	Rock	653
26	42-00-11	Major	Onslow	Stump Sound	10-2005	Rock	62
27	42-00-07	Major	Tyrrell	Albemarle Sound	1-2003	Rock	424
* these were all permitted separately, but were constructed as indicated into two structures.							

Table 2: Participating organizations.

U.S. Army Corps of Engineers	N.C. Division of Coastal Management
N.C. Division of Marine Fisheries	N.C. Division of Water Quality
N.C. Coastal Federation	N.C. Wildlife Resources Commission
University of North Carolina at Chapel Hill	NOAA-National Marine Fisheries Service
N.C. Sea Grant	NOAA-National Ocean Service

Information from each organization's field datasheets were compiled by DCM staff into one summary sheet for each marsh sill project that contains the comments of all the representatives that visited that site. These summary sheets are included as Appendix 8.1 of this report. The results of the closed-ended questions from the summary sheets were tabulated into an excel spreadsheet. Closed-ended questions are defined as ones with specific yes or no answers. Open-ended questions are defined as those which did not have a specific yes or no answer. These

questions provided an open space in which respondents could write in whatever response they thought suitable.

The participating representatives from the U.S. Army Corps of Engineers (USACE) were not able to provide DCM with their field datasheets due to internal agency considerations. However, USACE personnel did visit the marsh sills with the rest of the assessment team and provided DCM with a summary letter of the USACE comments and concerns. In addition to their field datasheets, the following agencies/organizations provided DCM with summary letters: the N.C. Division of Marine Fisheries (DMF); the N.C. Division of Water Quality (DWQ); the N.C. Wildlife Resources Commission (WRC); and the N.C. Coastal Federation. These letters are included in this report as Appendix 8.2.

2.2 Property Owner Surveys:

Questions associated with criterion two were assessed through the use of property owner and adjacent property owner surveys. Surveys were provided to all owners of the properties visited as part of this project. Surveys were also provided to the property owners immediately adjacent to the visited properties. The surveys were designed to assess the feelings and perceptions of both the property and adjacent property owners regarding the use of marsh sills. Surveys were administered through several methods including, in person, via email, via U.S. mail, and via the online survey provider surveymonkey.com. Returned surveys were compiled and analyzed for common themes. The returned surveys, with identifiable information removed, are included as Appendix 8.3.

3.0 Results:

The tabulated results from the field assessment team's responses to closed-ended questions are provided in Table 3. The numbers presented are the percentage for each response after pooling the data from the 27 visited marsh sills. These numbers do not represent the percentage of sill sites visited as there were multiple answers for each question at each site. The answers to the open-ended questions of the field datasheet (questions 3, 5, 7, 8, 10, 12, 18, 20, 22, 23, 33, 35, 36, 40, 41, 42, 45, and 48) were too lengthy to include in the text of this section. These data are located in Appendix 8.1 within the summary datasheets for each visited project. Responses from both the open and closed-ended questions were used to develop the project findings.

DCM had a 90 percent response rate for the homeowner surveys, and a 47 percent response rate for the adjacent property owner surveys. Tables 4 and 5 provide the responses to these two surveys respectively. The "provided responses to other" column for both Tables 4 and 5 represent all responses received for each question. Additional open-ended written comments were also provided by most survey respondents. These responses were too lengthy to include in this section. These data are located in Appendix 8.3 under question 9 for the property owner survey, and question 10 for the adjacent property owner survey.

Table 3: Tabulated field team responses for all visited marsh sills.

	Question	Yes	No	Unsure	N/A
1	Based upon the placement of the structure and your observations, has navigation of the adjacent waterbody been impacted by this structure?	1%	93%	5%	
2	Do you think the overall benefit of the marsh created outweighs the initial impacts/changes due to the placement of rock on shallow water habitats?	64%	5%	31%	
4	Does the overall benefit of the marsh created outweigh the initial impacts/changes from the fill used to create proper grade and depths?	34%	4%	29%	34%
6	Is the grade behind the sill still gently sloping?	78%	9%	13%	
9	Is there evidence of erosion on this property?	26%	61%	13%	
11	Is erosion occurring on the adjacent properties?	31%	46%	23%	
13	Is there a distinct shoreline offset between this property and the adjacent properties?	37%	50%	13%	
14	Has the sill created new uplands behind it?	16%	64%	20%	
15	Was the placement of the sill appropriate?	61%	15%	24%	
		Too far	**Too close**	**Other**	
16	If you answered "No", please check the appropriate box.	12%	81%	7%	
		Yes	**No**	**Unsure**	
17	Are other non-erosional impacts (positive and negative) observable on this property due to the installation of the sill?	38%	24%	38%	
19	Are other non-erosional impacts (positive and negative) observable on the adjacent properties due to the installation of the sill?	2%	48%	50%	
21	Is the structure damaged in any way?	3%	89%	8%	
24	Are both high and low marsh plant species present?	80%	14%	7%	
		Dense	**Patchy**	**Other**	
25	Does the marsh behind the sill appear continuous and dense, or patchy?	73%	19%	8%	
		Yes	**No**	**Unsure**	
26	Has there been any noticeable sediment accumulation landward of the sill?	41%	26%	32%	
27	Are upland species colonizing the area behind the sill?	37%	44%	19%	
28	Is there evidence that the upper marsh area is mowed?	6%	91%	3%	
29	Has the marsh grown waterward completely against the sill?	63%	33%	3%	
		Landward	**Waterward**	**Neither**	**Unsure**
30	Is SAV present landward or waterward of the sill?	1%	40%	29%	30%
		Yes	**No**	**Unsure**	
31	Are oysters present on or around the sill?	75%	19%	6%	
32	Is macroalgae present on or around the sill?	57%	25%	18%	
34	Is there evidence of water passage through the sill and the ability for fish ingress and egress?	66%	22%	12%	
37	Is there a noticeable wrack line landward of the sill?	58%	34%	8%	
38	Is there noticeable trash in and around the sill area?	22%	76%	2%	
39	Are there any noticeable issues with the water quality?	6%	77%	17%	
43	Do you think this sill is functioning as intended?	83%	2%	15%	
44	Do you think a different structure would have performed/functioned better in this location?	17%	45%	38%	
46	Overall, do you think the wetland creation portion of the project has been successful?	75%	5%	20%	
47	Do you think this structure will continue to function into the future given expected sea level rise?	51%	10%	40%	

Table 4: Tabulated property owner survey responses.

Question		Response	Provided Responses to Other
1	Did you install the marsh sill or was it present when you bought your property?	• 89%, Yes, I installed sill. • 11%, No, it was already present.	
2	What two factors most influenced your decision to install a marsh sill?	• 5%, Cost • 29%, Maintain the environmental integrity of my property. • 43%, Protect my property from future erosion. • 0%, Having a structure like my neighbor's. • 10%, Wanted something besides a bulkhead. • 7%, Aesthetics. • 7%, Other.	• Put marsh sill in because neighbor put one in and felt I had to follow suite as a defense to protect my property from erosion. • Hopefully enhancing water quality. • Marsh sill put in because was a requirement placed on our CAMA major permit application by National Marine Fisheries.
3	Did the presence of the marsh sill impact your decision to buy this property?	• 5%, Increased my desire (to buy). • 5%, Decreased my desire (to buy). • 90% N/A, I installed the sill.	
4	Are you happy with the performance of the marsh sill?	• 95%, Yes. • 5%, No.	
5	Has your marsh sill had any impacts to your property?	• 84%, Increased my marsh. • 0%, Decreased my marsh. • 11%, Had no impacts. • 5%, Caused erosion. • 16%, Caused accretion. • 11%, Degraded my viewscape. • 32%, Enhanced my viewscape. • 26%, Other. Overall: • 86%, positive responses • 14%, negative responses	• Trash collection (behind sill). • Hopefully will cause accretion. • Caused some erosion by beach, marsh area essentially unchanged since installation. • Provided additional habitat for wildlife. • Halted erosion.
6	Has your marsh sill ever had to be repaired? If so, how?	• 11%, Yes. • 89%, No.	• 50% of marsh had to be replanted in second year. • Lost vegetation in Veteran's Day storm of 2010.
7	Do you think your marsh sill has had any impacts (good and bad) on your neighbor's property? If yes, what were they?	• 58%, Good impact. • 0%, Bad impact. • 42%, No impact.	• Increased their marsh grass. • Made their bulkhead look awful. • Increase of neighbor's marsh and visual aesthetics. • Enabled neighbor's added fill to remain in place and not wash away. Helped protect their shoreline. • Fisheries enhancement. • Maintained neighbor's beach area…added some sand. • Reduced neighbor's erosion. • Slowed neighbor's erosion. • Helped to slow neighbor's erosion. • Convinced neighbor to install sill.

Table 5: Tabulated adjacent property owner survey responses.

Question		Response	Provided Responses to Other
1	Was your neighbor's marsh sill present when you bought your property?	• 27%, Yes. • 73%, No.	
2	Did the presence of your neighbor's marsh sill impact your decision to buy your property?	• 0%, Increased my desire (to buy). • 7%, Decreased my desire (to buy). • 20%, Had no impact on my decision. • 73% N/A, it was installed after I purchased my property.	
3	Has your neighbor's marsh sill had any impacts to your property?	• 20%, Increased my marsh. • 13%, Decreased my marsh. • 13%, Had no impacts. • 33%, Caused erosion. • 20%, Caused accretion. • 27%, Degraded my viewscape. • 20%, Enhanced my viewscape. • 47%, Other. • Overall 45% positive responses. 55% negative responses.	• Preserved bulkhead as good buffer, I have a bulkhead too. • Nice to look at from water. • No access to beachfront to the west of my property. • Washed sand out. Marsh use to be real tall but now is short. • Caused boat ramp on my property to collapse. Clogged drainage pipe from road. Decreased water access by causing beach area to erode. • Added sand. • A bulkhead would be more attractive. • Dramatically changed my shoreline. • Increased my marsh.
4	In your opinion, has your neighbor's marsh sill done its job? If no, Why?	• 73%, Yes. • 27%, No.	• Project was a failure. • Yes, for them. Caused more impact (erosion) on my beach. • Dramatically changed my shoreline.
5 and 6	Do you currently have a shoreline protection structure on your property? If yes, which kind	• 53%, Yes. • 47%, No.	• 3 responses of riprap revetment. • 1 response of marsh sill. • 2 responses of groin. • 5 responses of bulkhead.
7	Would you consider installing a marsh sill in the future on your property?	• 53%, Yes. • 47%, No.	• Caused horrible consequences for my property. • *Expletive* no.
8	What two factors most influenced your answer to question 7?	• 47%, Maintain the environmental integrity of my property. • 47%, Protect my property from future erosion. • 13%, Ease of permitting. • 13%, Cost of installation. • 13%, Having a structure like my neighbors. • 40%, Aesthetics. • 47%, Other.	• Success of other neighbor's sills. • Hurricane damage. • I want the property and water left as is. • Ruined sea grasses/clam beds, clogged wetlands. Permit system is very poor and allows failures to be installed. • Having natural beach areas. • Having a nice sand beach to walk on. These things are awfully ugly and create walking hazards and severely limit access to water. • Prohibits usage of natural shoreline.

4.0 Findings

- **4.1 Marsh sills were not found by the field team to present a hazard to navigation.**

This finding is based on answers to question 1 of the field data sheet (Table 3) and the agency letter from DMF. Ninety-three percent of the respondents said that navigation was not impacted by the sills that were visited as part of this project. Out of 214 total responses, only three times did a field team member consider the marsh sill to have an impact to navigation. One field team member thought that project 142-06 impacted navigation. Another thought that project 15-08 impacted navigation. Finally, one thought project 42-00-05 impacted navigation, but noted in a comment that this was only in regard to getting kayaks in and out of the water. The agency letter from DMF states: "DMF did not observe any of the sills causing any problems related to navigation…" (Appendix 8.2).

- **4.2 Marsh sills were observed to provide erosion protection to the property upon which they were installed.**

This finding is based on the responses of the field team to questions 9, 21, and 43 of the field datasheet (Table 3), the agency letter from DMF, and the responses of the property owners to property owner survey questions 4, 5, and 6 (Table 4). The field team noted 61 percent of the time that erosion was not occurring on the properties protected by marsh sills. Of the remaining responses, 13 percent of the time the field team was unsure and 25 percent of the time evidence of erosion was observable (Table 3, question 9). However, this does not imply that erosion was actively occurring at seven (25% of 27) of the visited marsh sills. One limitation of this study was that it did not account for the temporal difference between when the marsh sills were installed. Some of the visited marsh sills were more than ten years old, while others were recently constructed. The field team was only afforded a one-time snapshot view of the marsh sills. As such, it was not possible for the field team to assess when the observed erosion evidence actually occurred. There was only one site where the field team unanimously agreed that evidence of erosion existed, at project 47-09, the Jones Island marsh sill site in Onslow County. This marsh sill is newly constructed and sits in front of a pre-existing high bank bluff (Figure 3). It was the presence and condition of this bluff that the field team noted as evidence of erosion (Appendix 8.1, page 120, question 10).

The team observed that 89 percent of the time the marsh sills that were visited were not damaged (Table 3, question 21). This suggests that erosion was not actively occurring on most of the visited marsh sills. If erosion was actively occurring, it seems likely the marsh sill would show some damage, especially in the marsh area (*e.g.*, scoured marsh). The field team response to question 43 also supports the finding that marsh sills were preventing erosion. The field team found that the marsh sills were functioning as designed 83 percent of the time. If active erosion was occurring at the visited properties this result would most likely be lower. The agency letter from DMF supports this finding as well. In their letter, DMF states that "at all sites, the sills appeared to be preventing erosion of the upland property…" and "Overall, the sills appeared to be functioning well in controlling erosion…" (Appendix 8.2).

Figure 3: Eroding high bank bluff with marsh plantings in front at Jones Island, Onslow County.

The property owners' survey data corroborate the field team findings. Ninety-five percent of the property owners were happy with the performance of their marsh sills (Table 4, question 4). Question 2 of the property owners' survey demonstrated that protection from erosion was the most important issue for property owners in deciding to utilize a marsh sill. Thus, one may conclude that if erosion was actively occurring, the property owners would not be happy with the performance of their marsh sills. Of the property owners surveyed, only one reported erosion that he attributed to his marsh sill (Table 4, questions 4 and 5). This individual went on to say in his open-ended comments that he was happy with the marsh sill and thought it was doing its job appropriately (Appendix 8.3). The property owners' survey data show that no repair was required to date at 89 percent of the visited marsh sills (Table 4, question 6). Eighty-four percent of the property owners reported an increase in their marsh coverage (Table 4, question 5). If erosion was actively occurring, it is not likely that marsh coverage would increase, or that the marsh sills would not have needed repairs. The viewpoints of the property owners relative to this issue are extremely valuable because the current property owners installed the marsh sill at 89 percent of the sites visited (Table 4, question 1). Thus, the property owners have observed the entire history of the sill from pre-construction conditions through post-construction performance, and are able to comment on erosion issues associated with the sill.

- **4.3 Marsh sills were often built in combination with other structures.**

This finding is based on visual observation from the field visits. Of the 27 visited marsh sills, 12 of them (44 percent) were built in front of or attached to another type of shoreline stabilization. Most commonly observed were marsh sills built in front of bulkheads, or in combination with groins. Figure 4 shows examples of several marsh sills built in combination with other stabilization structures. The interaction of several shoreline stabilization structures operating synergistically is a much more complex situation compared to a marsh sill by itself. The design process and potentially the permitting for marsh sills must account for the potential interaction between two or more shoreline stabilization methods utilized at the same place and time.

- **4.4 Marsh sills that utilized the gap or overlap design were observed to provide better water, fish, and other nekton access to the area behind the sill compared to ones utilizing the dropdown design.**

This finding is supported by the responses provided by the field team to question 34 (Table 3), and the open-ended questions 35 and 36 (Appendix 8.1). The agency letters from DMF and DWQ also document this finding. In general the field team responses indicated 66 percent of the time that water and fish ingress/egress was occurring at the visited marsh sills (Table 3, question 34). This finding is a little misleading as in several instances the field team commented that while water and fish ingress/egress was occurring, it needed to be improved (see Appendix 8.1, pages 67, 105, and 128, question 35 and 36 for examples). The dropdowns at many of the visited marsh sills were often found filled in with rocks that toppled down from the adjacent higher areas of the sill, partially blocked with oysters and/or retained sediment (Appendix 8.1). The agency letters from DMF and DWQ also address this finding. The DMF letter noted that “Dropdowns are more likely to trap fish, as well as sediment, behind the sill when the water level lowers. In addition, we observed oysters growing on the dropdowns which further obstructs water flow”. The DWQ letter also noted that, “In instances where the step-down (dropdown) was at or close to the elevation of the surrounding bottom, oysters would grow and fill the void and would come close to closing off the gap and impede the water flow.” The sills that utilized a gap or overlap design did not have this problem. At these locations, the field team often reported very good water and fish access (see Appendix 8.1, pages 42 and 122, question 35). The agency letters from DMF and DWQ support this finding as well. In their letter, DMF stated that, “DMF believes that a break in the sill will usually provide more fish access than dropdowns...”. In their letter, DWQ stated that, “During the site visits, this Office noted that the sill structures that had overlaps instead of drop downs functioned better.” (Appendix 8.2)

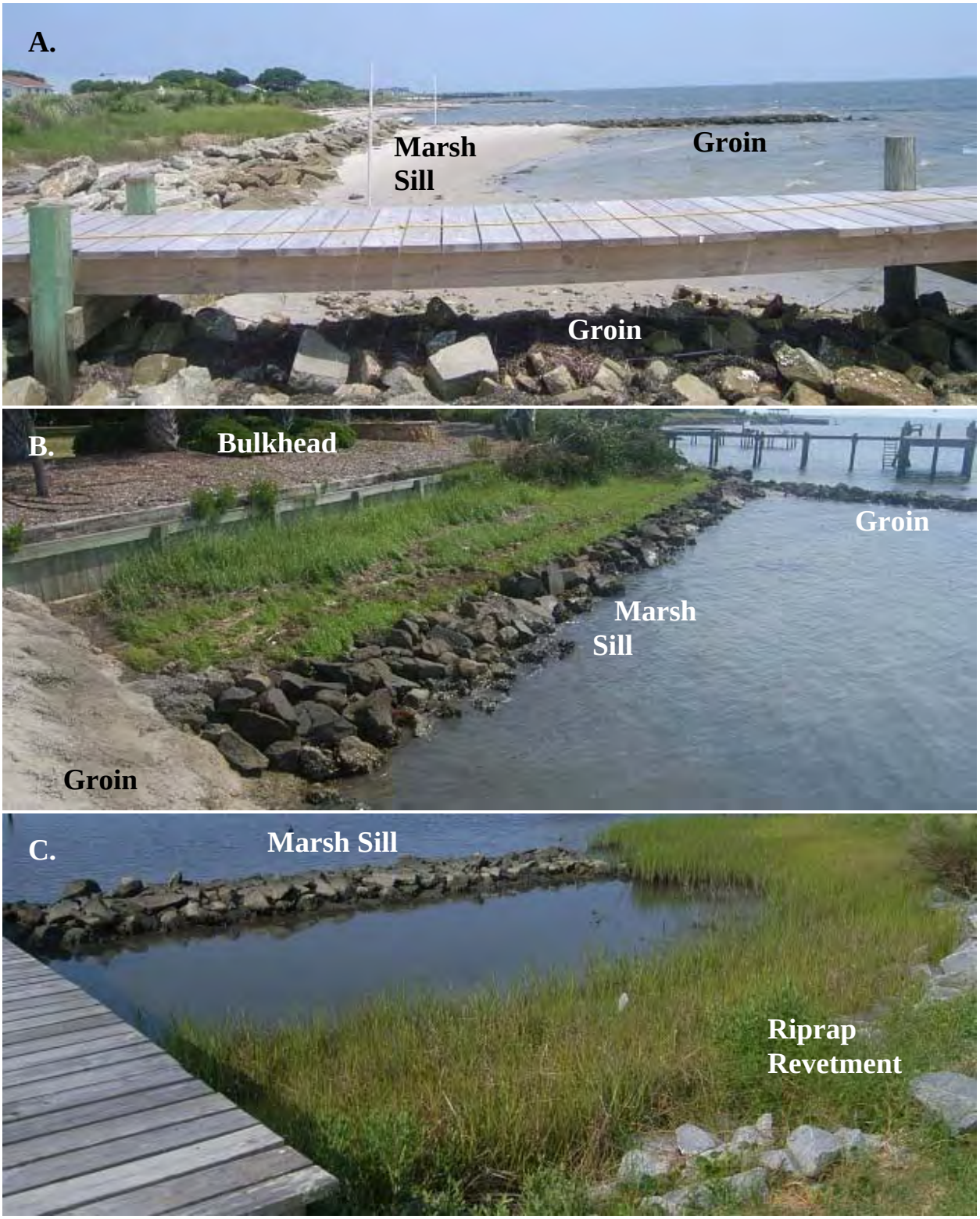

Figure 4: Marsh sills built in combination with other stabilization structures. Panel A: marsh sill and groins; Panel B: marsh sill and groins in front of a bulkhead; Panel C: marsh sill built in front of a riprap revetment.

- **4.5 It was unclear whether marsh sills cause erosional impacts on adjacent property.**

This finding is supported by responses provided by the field team to question 11 (Table 3); the open-ended question 12 of the field datasheet (Appendix 8.1); the agency letter from DMF (Appendix 8.2); the responses of the property owners to survey question 7 (Table 4); and the responses of the adjacent property owners to survey question 3 (Table 5). Question 11 from Table 3 explicitly asked the field team to assess whether erosion was occurring on adjacent properties. There was no agreement among the responses. The field team reported "yes" 31 percent of the time, reported "no" 46 percent of the time, and was "unsure" for the remaining 23 percent. As noted above, the field team was only afforded a one-time snapshot view of the condition of the adjacent properties. As such, it was not possible for the field team to assess when the observed erosion evidence actually occurred. Consequently, the field team was not able to defensibly conclude that the erosion was caused by the installation of the marsh sill. In fact there was not a single site where all field team members unanimously concluded that evidence of erosion was present on a neighboring property. DMF concluded in their agency letter that, "No sill-associated erosion problems were observed at adjacent properties." (Appendix 8.2)

There were two site visits (permit 42-00-07 and permit 46565B) where all but one team member noted evidence of erosion on the adjacent property. In both cases, the field team member that did not agree with the others marked "unsure" on their questionnaire (Appendix 8.1 Page 137 and 93, Question 11). For the case of permit 42-00-07, the adjacent property contained a natural swamp forest with remnants of dead trees on the edge (Figure 5).

Figure 5: Adjacent property to marsh sill project 42-00-07.

It was the presence of these dead trees that most of the team members cited as the evidence of erosion (Appendix 8.1, page 137, question 12). This type of shoreline margin is a natural feature of the Albemarle Sound and was not caused due to the installation of the marsh sill.

Several different areas of erosion on the adjacent properties were noted by the field team at site 46565B (Appendix 8.1, page 93, question 12). However, the field team was unsure if the erosion was being caused by the marsh sill or the two groins present at the site, as most of the erosion seemed to be occurring near where the marsh sill joined with the groins (Figure 6).

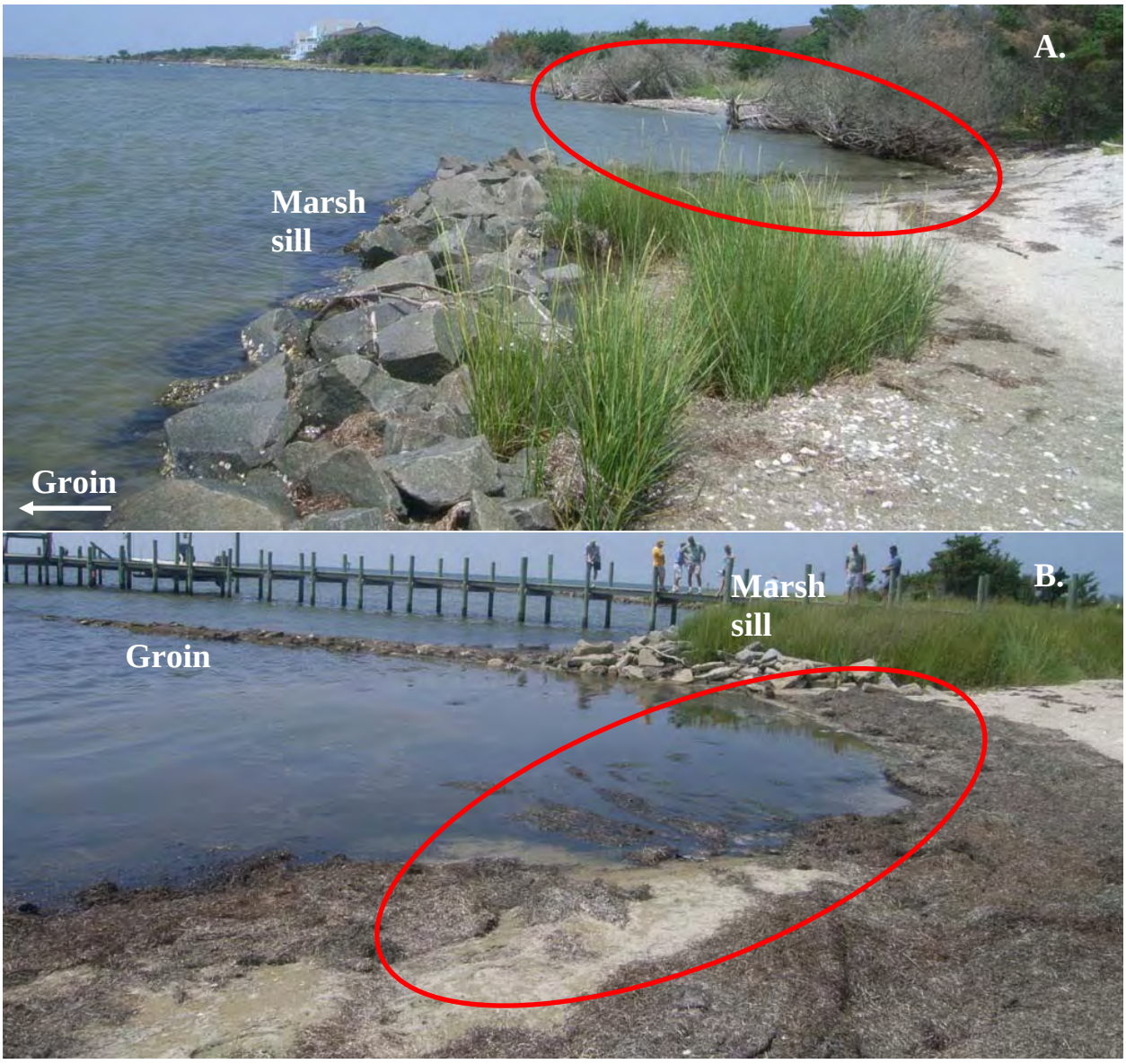

Figure 6: Erosion on adjacent properties of project 46565B. Panel A shows a picture of the adjacent property to the north taken from the junction of the marsh sill and one of the two groins. The groin extends off picture to the left as indicated by the arrow. Panel B is taken from the adjoining property to the south and shows where the other groin joins the marsh sill. The red circles on both panels show the areas of erosion.

The property owners unanimously reported in their survey that they did not consider their marsh sill was causing any detrimental impacts (including erosion) to their neighbors' properties (Table 4, question 7). In fact the property owners either thought their marsh sill had no impact to their neighbors' property (42%) or had beneficial impacts (58%) (Table 4, question 7).

The response of the adjacent property owners was not as easy to interpret. In question 3 of Table 5, which asked respondents to describe the impact their neighbor's marsh sill has had on their property, 45 percent of the responses were positive and 55 percent were negative. Of the negative responses, 34 percent directly cited erosional impacts. It is clear that some of the adjacent property owners sampled as part of this study believe that their property is experiencing erosion due to the presence of their neighbor's marsh sill. Seventy-three percent of the adjacent property owners that responded stated they owned their property before their neighbor's marsh sill was installed (Table 5, question 1). As such, they have been able to observe how their property has changed or not changed after their neighbor's marsh sill was installed. However, this historical perspective should be viewed with caution as direct cause and effect can not be solely based on observational evidence.

- **4.6 After completion of the field aspects of this project, the resource agencies still prefer to review and comment on marsh sill permits on a case-by-case basis.**

This finding is supported by the agency letters from USACE, WRC, DWQ, and DMF. The overriding theme of the letters is that marsh sills are site specific structures that require case-by-case review by the resource agencies. To fully appreciate this theme, it is necessary to read the agency letters in their entirety (Appendix 8.2). The following excerpts from the agency letters validate this finding.

The USACE letter states:

> "In our 2004 letter (enclosed), we identified 13 issues that require extensive review and which preclude the Corps from developing a more expedited permit process to authorize these projects. Those concerns have not been alleviated. The Corps continues to be concerned that it would not be in the best interest of the public to expedite the processing of a Department of the Army permit for activities that may individually and cumulatively result in significant impacts to the human environment."

WRC states in their letter:

> "Although the NCWRC believes the use of marsh sills to stabilize shorelines can protect or even enhance habitat opportunities, we also strongly believe the success of these structures is very site specific."; "The coast of North Carolina is vastly variable. A design in one location may not serve well in another."; and, "Marsh sills and their success are very site specific and require adequate review by resource agencies to evaluate the design, the impacts, and the area where the sill is proposed."

DWQ states in their letter:

> "This Office feels that each tidal regime and coastline needs to be evaluated as a case-by case situation."; "The sill evaluation project allowed this Office to

recognize that sills should be very site specific and still needs to be evaluated on a case-by-case basis by the agencies."; and, "It was noted during the sill evaluation project that successful sill construction is site/shoreline specific."

DMF states in their letter:

"From our observations the, amount of erosive energy and substrate type at a site had a large effect on the success of marsh sills in providing habitat.", "Decisions about trade-offs should be made on a case-by-case basis and based on the location, resources in the areas, and habitat threats in that location.", and, "The DMF requests that the DCM continues to utilize the input of resource agency personnel to site and design shoreline stabilization structures."

- **4.7 The mound material used in the marsh sills is often colonized with oysters.**

This finding is supported by the field team responses to question 31 (Table 3), and the agency letter from the DMF (Appendix 8.2). Oysters were observed on the sill by the field team 75 percent of the time (Table 3, question 31). DMF notes in their agency letter that: "Sills may be promoting oyster growth by providing substrate. Oysters were found growing on 20 of the 25 sills observed and those without oysters were located in low salinities (two sills) or located with minimal exposure to water(three sills)."

- **4.8 The marsh sills visited supported marsh grass and do not appear to be creating new uplands.**

This finding is supported by the field team responses to questions 14, 24, 25, and 46 (Table 3) and the agency letter from DMF. The field team noted 73 percent of the time that the marsh appeared dense and healthy (Table 3, question 25). Furthermore 80 percent of the field team responses documented both high and low marsh species were present behind the sill (Table 3, question 24). Both of these findings indicate that the elevations behind the sills are appropriate and supportive of marsh growth. Seventy-five percent of the field team responses indicated that the created wetland portions of the visited marsh sills were successful (Table 3, question 46). The older a marsh sill, the longer period of time it has had to trap sediment and potentially gain elevation. Looking at two of the oldest marsh sills visited - project 42-00-03 (~10 years old), and 42-00-02 (~10 years old) - both were found to still support high and low marsh species (Appendix 8.1, pages 5 and 99, question 24). Even at these oldest marsh sills, the majority of the field team noted no evidence of upland creation (Appendix 8.1, pages 4 and 98, question 14). Question 14 of the field datasheet specifically asked if the marsh sill had created new uplands. The field team reported 61 percent of the time that the marsh sills had not created new uplands (Table 3). In their agency letter DMF also concluded that, "Looking at 25 sills constructed over a nine year period, the intertidal zone behind the sills did not increase in elevation to a point that supported upland vegetation and did not scour to a point that did not allow marsh vegetation to grow." (Appendix 8.2)

- **4.9 Marsh sills were observed to be free from damage.**

The marsh sills visited by the field team were generally found to be free from damage. The field team noted no marsh sill damage in 89 percent of their responses (Table 3, question 21). The most common observed damages were drop downs that had started to fill in (see Section 4.4) and portions of the rocks that had settled and/or lost height due to shifting. The marsh sill owners also reported very few problems with the structures. Two reported some rock settling and two reported the need for replanting of marsh plants. Outside of these isolated incidents, 89 percent of the property owners reported that their marsh sill has never had to be repaired (including replanting) (Table 4, question 6). Marsh sills that are the oldest have more potential to show signs of damage. Looking at two of the oldest marsh sills visited - project 42-00-02 and 42-00-03 (both ~10 years old) - neither was found to be damaged during the field visits (Appendix 8.1, pages 4 and 98, question 21).

- **4.10 No marsh sill related impacts to water quality were observed.**

This finding is supported by the field team responses to question 39 (Table 3) and the open-ended responses to question 40 (Appendix 8.1). The field team noted no issues with water quality 77 percent of the time. Only six percent of the time did the field team note an issue with water quality. In all of these cases, the issue noted was related to stormwater runoff potential from the adjacent upland or via a pre-existing stormwater ditch or pipe (see Appendix 8.1, pages 17, 33, 57, 63, 78, 83, 100, and 122, question 40). These potentials would be the same regardless of what type of shoreline stabilization was installed on the property. The oyster growth noted in section 4.7 and the marsh noted in section 4.8 may eventually lead to increased water quality around marsh sills due to the increased filtering capacity provided by these elements. It should be noted that none of the marsh sills visited as part of this project were in the construction phase. During construction the potential for water quality impacts is much greater because of the disturbance associated with the marsh sill installation.

5.0 Specific conditions of the marsh sill general permit

The final aspect of this project was to examine the specific conditions of the marsh sill general permit. A list of the specific conditions is included in this report as Appendix 8.4. The specific conditions of the marsh sill general permit were classified into two categories: those that are common with other CAMA general permits; and those that are unique to the marsh sill general permit. Specific conditions (b), (e), (g), (h), (m), (n), (p), (q), (r), (s), (t), (u), (v), (y), and (z) are common conditions that exist in other CAMA general permits, and so will not be examined as part of this study. The remaining specific conditions (a), (c), (d), (f), (i), (j), (k), (l), (o,) (w), (x), (aa), (bb), and (cc) are unique to the marsh sill general permit. These can be further classified into those that detail design criteria [(a), (c), (d), (f), (i), (j), (k), (l), (o), (w)] and those that address other agency coordination [(i), (aa), (bb), and (cc)]. Note that one specific condition (i) appears in both the design criteria list and the other agency coordination list as it details specific design criteria but also states that deviations from the design criteria are allowable following coordination with DMF. The findings of this technical assessment provided no conclusive evidence that the marsh sill general permit unique specific conditions are unnecessary. However, the findings do provide some guidance on potential modifications to some of the specific conditions.

Specific condition (a) outlines the usable materials for the construction of the sill structure. Currently, it lists riprap or stone as the only allowable materials. Given the finding that oysters are colonizing the sills in most areas, and the fact that a few of the visited marsh sills successfully used oyster shell as the mound material, the list of usable materials should be evaluated to consider the addition of oyster shell.

Specific condition (i) describes the specifications for the use of dropdowns and openings. This assessment observed that the marsh sills that utilized the gap or overlap design were functioning better than the ones that utilized the dropdown design (see 4.4). Thus, it seems this specific condition could be modified to suggest or require gaps or overlaps be used instead of dropdowns.

The specific conditions that deal with other agency coordination, (i), (aa), (bb), and (cc), are the ones that make the marsh sill general permit more like a CAMA major permit as compared to the other CAMA general permits. These are also the specific conditions that make installing a marsh sill require more cost and processing time compared to the other shoreline stabilization options (bulkheads, riprap revetments, etc.) as often the coordination with the other agencies leads to additional state and federal permits. This study did not evaluate the need for specific condition (bb) which requires that DCM consult with the Department of Administration's State Property Office to determine whether or not an easement for the proposed marsh sill is required. The necessity of specific condition (i) and (aa) (coordination with DMF) and specific condition (cc) (coordination with DWQ, and USACE) were validated by the agency letters received as part of this project (Appendix 8.2). In each case, USACE, DMF, DWQ, and even though there is not a specific condition that requires it, the WRC, all state that they want to continue to review marsh sill permits on a case-by-case basis (see 4.6). Given this finding, specific conditions (i), (aa), and (cc) are still necessary.

6.0 Summarized List of Findings

- Marsh sills were not found by the field team to present a hazard to navigation.
- Marsh sills were observed to provide erosion protection to the property upon which they were installed.
- Marsh sills were often built in combination with other structures.
- Marsh sills that utilized the gap or overlap design were observed to provide better water, fish, and other nekton access to the area behind the sill compared to ones utilizing the dropdown design.
- It was unclear whether marsh sills cause erosional impacts on adjacent property.
- After completion of the field aspects of this project, the resource agencies still prefer to review and comment on marsh sill permits on a case by case basis.
- The mound material used in the marsh sills are often colonized with oysters.
- The marsh sills visited supported marsh grass and do not appear to be creating new uplands.
- Marsh sills were observed to be free from damage.
- No marsh sill related impacts to water quality were observed.

7.0 References

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