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**PLANNING FOR SHORELINE RETREAT IN
MATUNUCK: THE RELEVANCE OF COASTAL
GEOLOGIC PROCESSES AND CLIMATE CHANGE**

**BY
SHANNON HULST**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS
IN
MARINE AFFAIRS**

UNIVERSITY OF RHODE ISLAND

2012

MASTER OF ARTS IN MARINE AFFAIRS
OF
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2012

ABSTRACT

Property owners and town officials in South Kingstown, Rhode Island are seeking means to protect private property and a local road from coastal erosion. Matunuck Beach Road is the only means of egress for nearly five-hundred homes in the village of Matunuck, and there is a public water main running underneath. There are millions of dollars worth of private structures that are also in danger from erosion. The political factors at play in this case are the desire to preserve private investments, the interest in keeping thriving businesses open, the protection of infrastructure, and the maintenance of community character. In addition to these anthropocentric factors, there are the coastal management challenges of maintaining a healthy and dynamic shoreline, preventing damage to neighboring coastal properties, and appropriately preparing for a future with a different climate and sea level.

This study uses mental models analysis to determine the extent to which research subjects understand the coastal processes and aspects of climate change relevant to the Matunuck coastline, and to determine the extent to which this understanding has informed what subjects identify as the most viable solution. In other words, subjects' understanding of the science is measured and then compared with their chosen erosion solution. Property rights beliefs, the most common of the political factors mentioned above, are considered as well. The research subjects in this study are key players in the planning process, specifically private property and business owners in Matunuck, South Kingstown Town Council members, South Kingstown government officials, and Coastal Resources Management Council members.

The results of the thesis show that subjects have low levels of comprehensiveness when comparing subject models to an expert model, and there are a few concepts that subjects commonly brought up that fall outside of the expert model. There is no relationship between mental model comprehensiveness scores and what management options subjects believe are best; in other words, how much a subject knows about the natural science is unrelated to what they think should be done to address the problem of shoreline retreat. Finally, while comprehensiveness cannot explain management choices for each subject, subjects' beliefs about property rights and the shore (whether coastal armoring should be a private property right) can help to explain subjects' management choices.

ACKNOWLEDGMENTS

First I would like to thank my major professor, Robert Thompson, for his help and guidance throughout this project, and for challenging me to work harder and produce a better result. I would also like to thank my committee members, Richard Burroughs and Jon Boothroyd, for their time and input. I would like to thank Tiffany Smythe for providing an example and ample guidance. Thanks to Bryan Oakley for his time and input ensuring that my geology is as accurate as possible. I would like to thank my family for their support throughout the duration of this project. Finally, thank you to Mike for his love, support, and encouragement every day.

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CHAPTER 1

INTRODUCTION

It is not feasible, desirable nor appropriate to attempt to “stabilize” or fight the natural cyclical patterns of the sand placement and dune/beach shape and profile of the constantly changing...beach shoreline. As evidenced by local efforts in the past, this system will continue to be dynamic, and will cause hardship for those who structurally position themselves within this changing landscape.

-Coastal Resources Management Council, Salt Pond Special Area Management Plan, p.6

If short term measures to mitigate erosive forces are not permitted while a longer term solution is determined and implemented, a true public safety crisis will result, the effects of which would extend well beyond this stretch of shoreline. The loss of Matunuck Beach Road resulting from a lack of cooperation and regulatory inflexibility would be a tragedy for the Village, Town, and State of Rhode Island.

-Town of South Kingstown, Resolution submitted January 27, 2011

The preceding quotations illustrate the opposing positions on the issue of how best to address shoreline retreat along Matunuck Beach Road in South Kingstown, Rhode Island. As frequently occurs with coastal zone management, it is difficult to reconcile natural dynamic processes with the desires of human societies. However, coastal zone management agencies, such as Rhode Island’s Coastal Resources Management Council, are charged with finding ways to overcome this challenge and reconcile the two.

Typically coastal managers oppose the stabilization of the shoreline or development that impedes the dynamic processes of the shoreline because they understand that stabilization generates new problems, such as eliminating the beach seaward of these structures, and creates a false sense of security for those located

behind these structures. Particularly in the face of climate change, nature has the ability to destroy anything that humans create and is nearly guaranteed to cause significant damage to structures built along the shoreline at least once per century. In order to minimize loss of human life and suffering, economic losses, damage to infrastructure and development, and costs of post-disaster recovery, coastal managers usually attempt to keep development out of hazardous locations. Towns and private citizens, however, advocate building in these areas because they minimize the danger that encompasses coastal locations and justify development with the high tax revenues and pleasure of living on the coast, and fight to protect their properties when they are in danger from the ocean for these reasons. The same is true for the Matunuck area situation, with additional historic and community factors. Thus this case study can be applicable to the numerous other communities that face problems with shoreline retreat in New England and throughout the United States (Hapke et al. 2010) as they attempt to protect shoreline structures and reconcile private property rights and expectations, community character, coastal zone regulations, and natural processes (Pope 1997).

This research investigates the role of natural science mental models (individuals' thought processes regarding how the world works) in the decision-making process surrounding the Matunuck Beach Road area. The research questions for this case study are: (1) With regard to coastal geologic processes, how do subjects' mental models compare to the expert model in terms of comprehensiveness and variance? (2) With regard to the relevant aspects of climate change, how do subjects' mental models compare to the expert model in terms of comprehensiveness and

variance? (3) Can these mental models of coastal geologic processes and climate change be used to predict what management measures subjects choose as most reasonable? (4) If mental models cannot predict the management measures that subjects choose as most reasonable, what factors might predict these choices? The first two are preliminary questions, the third the primary research question, and the fourth a follow-up question.

The research hypotheses for this study, specifically the third research question, are: 1) If key players in Matunuck have inaccurate mental models concerning beach migration and erosion, and the hazards associated with climate change, they will be more likely to support the creation of an immobile hardening of the shoreline; 2) If key players in Matunuck have accurate mental models concerning beach migration and erosion, and the hazards associated with climate change, they will be less likely to support the creation of an immobile hardening of the shoreline; 3) The positions of key players on shoreline hardening are morally consistent with their mental models; if key players have complete mental models and still support an immobile hardening of the shoreline, then other factors are likely more important than coastal processes and climate change.

These hypotheses are grounded in two basic assumptions: (1) those with the most developed mental models regarding natural science will make decisions based on the expectation that major future shoreline change (in the form of advanced shoreline retreat, sea level rise and storms) will undermine or destroy existing structures, and therefore today's resources should not be spent on seemingly futile efforts to protect existing structures for another decade or two but rather in encouraging development

away from the coast where it will be in less danger; and (2) those with less developed mental models will make decisions based on the expectation that seemingly permanent structures, such as a seawall, will withstand most natural forces and protect existing structures for the foreseeable future (one or two decades). Subjects with limited mental models most likely do not have a sufficient understanding of shoreline movement and climate change to understand how drastically the coast is expected to change in the future, and therefore the actions suggested by those with more complete mental models (e.g. relocating structures or the road further inland) seem unreasonable.

This research investigates how well individuals involved in the decision-making process surrounding the Matunuck situation understand the natural science of geologic processes and climate change that are imperative to this location (being the cause of the existing problems and generating a need for planning for the future), and the extent to which this understanding influences what solutions individuals deem most reasonable for Matunuck. The purpose of the research is to understand the mental models of stakeholders in order to better understand how they view and make sense of the issue and where potential shortcomings in knowledge are, in order to work towards finding ways in which opposing groups may be able to better communicate to reach more agreeable solutions.

CHAPTER 2

BACKGROUND ON MATUNUCK

Figure 1: Location of Matunuck Beach in South Kingstown, RI

The beach community of Matunuck, located in the Town of South Kingstown on the southern shore of Rhode Island, has existed as a residential and summer vacation haven for decades. It serves primarily as a tourist attraction, with numerous summer rental cottages, public access to surfing, fishing, kayaking, paddle boarding, windsurfing, kite boarding, and the beach.¹ Matunuck has a handful of businesses, the two most significant for the purposes of this study being popular restaurant/bars that are frequented by community members, tourists, and the local college population alike. These two businesses provide seventy-five full-time equivalent jobs between the two of them, and are thus considered by the town a “significant source of

¹ See South Kingstown Town Council Joint Work Session with CRMC, 2011, p. 23.

Source: Author's collection and <http://www.southkingstown.househunt.com>

Figure 2: Homes on Matunuck Beach and a cottage in Mary Carpenter's Beach Meadow

employment” and “an important part of the local economy”.² The Matunuck community offers a unique blend of lower- and middle-class beach cottages and trailers, million dollar homes, nightlife, ocean views and access, and a little bit of beach (see Figure 2). Thanks to Mary Carpenter's Beach Meadow and the Matunuck Trailer Association, many out-of-state residents and Rhode Island residents whose permanent homes are inland and who may fall into a lower income bracket have spent many summers in Matunuck, and thus have a particular fondness for the area.

As of September 26, 2011, the total assessed value of the properties in Matunuck (east of the Matunuck Trailer Association) was \$141,883,600, with \$2,059,057.36 in tax revenue to the town.³ This tax revenue is a significant source of income for the town, particularly in that a number of these property owners are seasonal and do not use town resources for much of the year. The coastal location drastically increases the value of these homes, but also the vulnerability. A memo released in early 2011 by the South Kingstown Tax Assessor indicated that tax abatements would be awarded to Mary Carpenter because of the loss of land as a result

² See South Kingstown Planning Department. (2011). *Planning Department Memo March 23, 2011*, 2.

³ Values acquired from personal communication Jean-Paul Bouchard, South Kingstown Tax Assessor.

of erosion and its consequently diminished utility (Tiernan 2011). This, perhaps, is a sign of things to come for the eroding community and the town's consequently eroding tax base. In public meetings regarding the future of Matunuck Beach Road and the adjacent structures that are threatened by erosion, many residents and South Kingstown government officials have expressed their interest in preserving Matunuck for its natural beauty as well as historic and cultural value, not to mention all of the people and homes that currently exist there and would have to be relocated if the access road and public water were lost to erosion, as well as the tax revenue these properties provide for the town. It is clear that many people, including residents, property owners, and visitors, have a particular attachment to the place and would like to see it preserved in its current state for future generations. Some of those people are interested in preservation based solely on sentimental value; others have monetary and public safety investment interests.

The Problem in Detail

The beach along Matunuck Beach Road in South Kingstown, Rhode Island has been undergoing substantial erosion, with total losses from 1939 to 2006 being between 145 and 200 feet. The years 1978 to 1997 demonstrated an increase in the landward movement of the high tide line, which has further accelerated since 1998.⁴ According to most personal accounts and town meeting discussions, the erosion has been a notable problem for the past fifteen years, with the Patriot's Day storm being

⁴ See South Kingstown Planning Department 2010, p.5 for data.

particularly damaging.⁵ In 2010, nor'easters in late winter removed even more sand so that many structures along Matunuck Beach Road were reported as being within feet of the ocean and sustained damage; in some cases high tide brought waters that engulfed the pilings on which structures were supported (Kuffner and Lord 2010). For some structures, the base of their pilings are now consistently under water with each high tide regardless of wave height. During the fall of 2011, Matunuck residents had begun to erect protective structures in front of their shorefront properties without permits from CRMC because CRMC would not grant them the required permits, and because they judged that their structures would be in danger of being undermined or collapsing with the potential erosion caused by the next storm. In January 2011, the Town of South Kingstown submitted a resolution to the Governor's office in order to bring attention to the problem, and in attempt to prompt some leniency from the Coastal Resources Management Council (CRMC). The resolution was submitted after a series of violation notices had been issued from CRMC to the Matunuck residents taking measures to protect their properties without permits (Town of South Kingstown 2011). In a memo released by CRMC February 25, 2011, it was noted that "violations for unauthorized shoreline structures will be held in abeyance until the Town works out a course of action" (Rhode Island Coastal Resources Management Council 2/25/2011, p.4). (Although the legality of this act seems questionable, according to the CRMC Management Procedures, "[t]he Executive Director may, based on the impact to coastal resources, hardship on an applicant, and the cost of Council resources

⁵ For details of comments, see South Kingstown Town Council Joint Work Session with CRMC, March 29, 2011.

Source: <http://gis.cdm.com/website/southkingstownri/parcels/MapView.htm>

Figure 3: Map of Matunuck*, including parcel numbers, for the area in question

*Note: Aerial photography from 2008. The beach has eroded significantly since.

associated with enforcement and staff review, adjust the administrative fees.”⁶) During the spring of 2011, the portion of Matunuck Beach Road directly west of the Ocean Mist Restaurant and Bar and adjacent to 883 Matunuck Beach Road, an empty lot owned by Mary Carpenter (parcel 92-3:1 in Figure 3), was approximately fifteen feet from the edge of the sand.⁷ After tropical storm Irene in September of 2011, there were approximately three feet of sand scarp left seaward of the road at that location. While the ocean itself remained about twenty feet seaward of the road, there was an approximately six-foot drop to the stable sand (see Figure 4). This required the use of jersey barriers to block off a portion of the road, and a few of those barriers were undermined during the storm (Cotter 2011). The area from 855 Matunuck Beach Road to 933 Matunuck Beach Road (parcels 92-2:47 to 92-3:9 in Figure 3) is the section of

⁶ For more detail and quotation, see Rhode Island Coastal Resources Management Council, (2011). *Rhode Island Coastal Resources Management Council Management Procedures*, 10.

⁷ For further discussion, see Rhode Island Coastal Resources Management Council, May 4, 2011).

Matunuck Beach Road most in danger. The two parcels on either end of this stretch of road, both owned by Mary Carpenter, have some sort of structural shoreline protection measure on them; a rock bulkhead with a rip-rap toe stands along the property at 855

Source: Author's collection

Figure 4: Eroded scarp along parcels 92-2:47 and 92-3:1

Matunuck Beach Road (parcel 92-2:47) with some rubble remaining from failing rip-rap along 883 Matunuck Beach Road, and a concrete bulkhead exists at 933 Matunuck Beach Road. These two structures were installed as they are in the early 1980s (there had been some sort of structure in those locations for a number of years prior to this), though it is unclear whether they were permitted (J. Freedman, personal communication, February 6, 2012). Regardless of their legality, they stand today as clear markers of both ends of the area that has experienced the most significant erosion damage.

Concerns of the Town of South Kingstown

Since tropical storm Irene in September of 2011, the road was approximately three feet away from the edge of a six-foot drop-off adjacent to 883 Matunuck Beach Road (parcel 92-3:1 in Figure 3). With inevitable continued erosion and no new structural shoreline protection, these remaining three feet would be eroded and the sediment underneath the road would begin to be pulled out to sea. With the erosion of

the sediment underneath the road, the stability of the road would be compromised and it would likely collapse in this location, in addition to being regularly severely flooded by storms. This has become the primary concern of the town for two reasons: 1) there is a public water main running under the road which, if it were compromised by the collapse of the road or erosion of the land underneath it, would leave multiple communities without fresh water; and 2) that road provides the only vehicular access to 240 homes and businesses east of this location (beginning at the Ocean Mist; including structures on Matunuck Beach Road, Prospect Road, Peninsula Road, Ocean Avenue, and Ninigret Avenue). If the road became impassable, not only could residents and visitors not get in or out of the community, but emergency response vehicles would be unable to reach anyone in those 240 homes beyond the hypothetical breach in the road. For these reasons and the impending breach of the road, Matunuck Beach Road and the South Shore Water System Main were identified among the top priorities for the town in terms of vulnerability to natural hazards in the 2006 “Multi-Hazard Mitigation Strategy Plan – Strategies for Reducing Risk from Natural Hazards in South Kingstown, Rhode Island”. Should the road and the water main be compromised as a result of being undermined by the erosion of the remaining sand, there would be water access problems for Matunuck and surrounding communities as well as egress problems for the Matunuck community.

In order to avoid this public safety hazard, the Town of South Kingstown explored various mitigation options, taking funding procurement and federal and state permit acquisition into serious consideration as the most significant limiting factors.⁸ Ultimately in September 2011 the town sought permission from CRMC to erect a

⁸ For more detail, see South Kingstown Planning Department, 2010.

stabilizing structure that is intended to protect the road in the location that it was most in danger. The structure the town applied for was a steel sheet pile wall costing about a half a million dollars. If approved, it would be erected within the town's right-of-way along the road, adjacent to the empty lot located at 883 Matunuck Beach Road which has been experiencing the most significant erosion (parcel 92-3:1 in Figure 3). The wall would be driven thirty feet into the ground and extend for approximately two-hundred feet along the road. It would be adjacent to a few properties on the landward side, and allow for entrance and egress to those properties. In the event that privately-owned structures are lost to erosion and no longer offer protection to the road, the wall could be extended to provide this protection (S. Alfred, personal communication, September 1, 2011). No publicly funded structure can be erected seaward of the private properties because of CRMC regulations that restrict such construction; a wall in that location could only be constructed if there were a compelling public purpose, in which case an application could be submitted under the "Special Exceptions" section of the Coastal Resources Management Program. Without a solid argument for a valid public purpose for such a wall, the town did not pursue it and private property owners have been unable to pursue it on their own.⁹ While the town officials are concerned for the interests of the property owners, they have to focus their energies and funding on a solution that would protect the public road and utilities rather than private properties.

Concerns of the Property Owners

The primary interest of the private property owners is to protect their homes, businesses, and investments. Property owners have sentimental and economic interests

⁹ For further discussion, see Rhode Island Coastal Resources Management Council, June 24, 2011).

in protecting their properties. While property owners seem to accept that their properties cannot last forever in the face of the advancing ocean, they want to do what they can to prolong the functional lifetimes of their properties. In the words of Francis O'Brien, co-owner of Tara's, one of the Matunuck businesses, "it's been here a long time. It's got to last a little longer" (Kuffner and Lord 2010). Those that got most heavily involved in the debates over the issue with the Town of South Kingstown and CRMC fought for permission to take matters into their own hands in the best way they saw fit. Some, if not all, property owners have experimented with various "soft" solutions such as sandbags advocated by CRMC, but they claim that they do not work well enough to be worth the money (Mastruobono 2011; Alfred, Stephen April 28, 2011).¹⁰

Through fall 2011 there was no concerted effort from the property owners. However they individually (and sometimes collaboratively) investigated a range of property protection methods, including erecting some sort of seawall that would tie together the two existing revetment structures (located at 855 Matunuck Beach Road and 933 Matunuck Beach Road, respectively) and various experimental renourishment efforts such as a type of underwater groin system and polyethylene barriers that trap sand on their landward side. None of these methods had been applied in Matunuck as of this writing for various reasons, among them being a lack of agreement among property owners on the best course of action, cost of these methods, and a lack of permits from CRMC. In the cases of many property owners, cheaper and less permanent structural protection measures such as wooden walls and bulkheads were erected without the required CRMC permits, but property owners were not asked to

¹⁰ See also Rhode Island Coastal Resources Management Council, April 20, 2011.

remove them as a result of the agreement between the Town of South Kingston and CRMC to withhold enforcement for the duration of negotiations regarding Matunuck Beach Road.¹¹ Property owners sought to protect their properties and structures, either with or without formal permission from the CRMC and with or without the support of the town.

The two restaurant/bar businesses, the Ocean Mist Restaurant and Bar and Tara's Tipperary Tavern, have moved to the front line of the ongoing debate regarding the future of the community. Members of the Matunuck community and South Kingstown town government view the businesses as small economic drivers for the town, providing seventy-five jobs between the two of them, drawing tourists and locals to the area, and providing the town with tourism and tax revenue. The Ocean Mist, the business located furthest to the east, is in the most immediate danger of being compromised by the ocean. Although the owner of the Ocean Mist has taken many actions to protect the structure (both with and without the permission of CRMC), the sand continues to erode from underneath the structure, which is likely to cause a future breach in the road (see Figure 5). In addition, both the Ocean Mist and Tara's are well-known and loved by members of the community, and these community members have been able to exert some political influence over the situation. Finally, the owners of the two establishments have been particularly vocal and proactive in the debate regarding erosion in Matunuck and what is to come of their businesses.

¹¹ See Rhode Island Coastal Resources Management Council February 25, 2011.

Source: Author's collection

Figure 5: Sand loss under the Ocean Mist

Concerns of the Coastal Resources Management Council

The primary interest of the state agency, the Coastal Resources Management Council, is to uphold the duties assigned to the Council in the enabling legislation

to preserve, protect, develop, and where possible, restore the coastal resources of the state for this and succeeding generations through comprehensive and coordinated long range planning and management designed to produce the maximum benefit for society from these coastal resources; and that preservation and restoration of ecological systems shall be the primary guiding principle upon which environmental alteration of coastal resources will be measured, judged, and regulated (RIGL § 46-23-1 [a][2]).

CRMC is also particularly mindful of preserving lateral access along the shore for the public trust, as provided in the Rhode Island Constitution, Article I, Section 17: “the people shall continue to enjoy and freely exercise...the privileges of the shore, to which they have been heretofore entitled under the charter and usages of this state, including but not limited to...passage along the shore” (RIGL § 46-23-1 [a][1]). CRMC was fulfilling its constitutional and legislative duties by upholding those regulations and by suggesting those options most consistent with its regulations,

retreat or beach renourishment.¹² The Matunuck case has become a “test” case that will most likely set important precedents for how CRMC will deal with requests for coastal armoring in the future, and thus is of particular importance to CRMC.

The town of South Kingstown and some Matunuck residents sought exceptions to some of these regulations, more specifically Sections 130, 180, 200, and 300 of the Rhode Island Coastal Resources Management Program, known as the Red Book. The desired exceptions, which would allow for some sort of manmade protection structure, will be discussed in more detail below. Finally, in addition to upholding its regulations, CRMC reminded residents and the town that anything installed below the mean high water line would invoke federal jurisdiction, requiring approval from the United States Army Corps of Engineers, and that all requirements of the Rhode Island State Building Code must be met as well.¹³ Additional concerns of CRMC, including regulations and recommendations, will be addressed below.

The Process and Various Options

The first option explored by the town and CRMC was to classify the relevant section of Matunuck as “manmade shoreline”. This classification means that “natural shoreline features are no longer dominant...the presence of isolated seawalls, bulkheads, and similar structures does not constitute manmade shoreline” (Rhode Island Coastal Resources Management Program, Section 210.6). Thus CRMC decided that Matunuck “does not appear to meet the definition of a manmade shoreline in the Coastal Resources Management Program” (February 25, 2011; p.2). However, if this

¹² For recommendations, see Rhode Island Coastal Resources Management Council April 20, 2011; p.8.

¹³ For discussion, see Rhode Island Coastal Resources Management Council, April 20, 2011; p. 23.

classification were to be changed, CRMC recommends that the remaining section east of the proposed classification section from the Matunuck Business District beyond Deep Hole be classified as the “Matunuck Headland Coastal Natural Area” pursuant to RICRMP Section 210.4 (see Figure 6).¹⁴ This would preserve the remaining recreational uses and natural features for that area, but would allow structural shoreline protection measures to be erected in the Matunuck Business District (directly east of and adjacent to the proposed Natural Area). It would also be consistent with CRMC’s policy to balance multiple uses of an area but preserve environmental quality where possible, as well as fulfill CRMC’s duties under the Coastal Zone Management Act to manage coastal development in vulnerable

Source: http://www.crmc.ri.gov/guidesreports/Matunuck_Erosion_Report.pdf

Figure 6: Proposed Matunuck Headland Coastal Natural Area

¹⁴ For recommendations see Rhode Island Coastal Resources Management Council, April 20, 2011; p.10.

areas.¹⁵ Although not CRMC’s preferred choice for a policy recommendation, and indeed not recommended by the staff, this option is the “most palatable” (CRMC April 20, 2011; p. 10).¹⁶ On December 9, 2011, the Town of South Kingstown submitted a petition for this reclassification; as of this writing this petition was under administrative review with CRMC.

The next regulation brought into question was Section 200 of the Red Book, dealing with water type classification. The current classification for the entire south coast of Rhode Island is Type I, defined in part as “water areas that have retained natural habitat or maintain scenic values of unique or unusual significance, and water areas that are particularly unsuitable for structures due to their exposure to severe wave action, flooding, and erosion” (Rhode Island Coastal Resources Management Program, Section 200.1). Type II waters are “in areas with high scenic value that support low-intensity recreational and residential uses...” (Rhode Island Coastal Resources Management Program, Section 200.1). Shoreline protection structures, such as those being proposed by the town and property owners, “are prohibited on coastal features adjacent to Type I waters unless the area is classified as a manmade shoreline...” (CRMC February 25, 2011; p.2). These are, however, allowed adjacent to Type II waters (CRMC February 25, 2011; p.2).

The final regulations addressed by the Town and CRMC were Section 130, Special Exceptions, and Section 180, Emergency Assents. Under a Special Exception, the town would apply for an Exception from CRMC in order to erect a shoreline protection structure along with public access in tidal waters (CRMC February 25,

¹⁵ For further discussion, see Rhode Island Coastal Resources Management Council April 20, 2011; p.11.

¹⁶ See also South Kingstown Town Council Joint Work Session with CRMC, May 31, 2011.

2011). Under Section 130, the proposed activity must serve “a compelling public purpose which provides benefits to the public as a whole as opposed to individual or private interests”, and must be “associated with public infrastructure” or “an activity that provides access to the shore for broad segments of the public”, among other things. A series of stipulations would be applied to any structure permitted under Section 130.

Finally, the Town could apply for a pre-emergency assent for the steel sheet pile wall that they hope to install along the road right-of-way, and if the pre-emergency application were approved the Town would be able to immediately construct the wall “if erosion threatens the road and water line” (CRMC February 25, 2011). Provided the erosion situation reaches an emergency state before a pre-emergency assent is issued, the town could also apply for an Emergency Assent under Section 180 of the Red Book. An Emergency Assent can be issued when there is imminent peril, when conditions cause, among others, an “immediate threat to public health and safety”, which would be relevant if the road were to be undermined (Rhode Island Coastal Resources Management Program, Section 180).¹⁷ As of June 2011, CRMC Marine Infrastructure Coordinator and South Kingstown staff were working together to prepare an Emergency Assent for the 200 feet of Matunuck Beach Road in the most immediate danger.¹⁸

In a report released April 20, 2011, CRMC issued four formal recommendations:

1. The Town of South Kingstown should coordinate with the Towns of Charlestown, Narragansett, Westerly, North Kingstown and the CRMC on

¹⁷ See also Rhode Island Coastal Resources Management Council, June 24, 2011.

¹⁸ See Rhode Island Coastal Resources Management Council, June 24, 2011.

maintenance dredging and using the sediment for beach replenishment in the Matunuck Business District.

2. The Town of South Kingstown should work with Economic Development Corporation to look at opportunities for relocating the businesses threatened by erosion.

3. The Town of South Kingstown should develop a plan with assistance from the RI Department of Transportation to relocate Matunuck Beach Road farther inland.

4. The Town of South Kingstown should develop a post-storm debris removal and restoration plan.

These recommendations were not well-received within the town for various reasons.

With regard to moving the road and the water main underneath it, which would get both public utilities out of harm's way, the town claims that this is impractical as a result of cost, existing conditions, and topography, among other reasons.¹⁹ With regard to the recommendation of relocating the private structures to a safe inland site, most of those individuals do not own parcels of land further inland. In addition, the property owners do not want to relocate, because they purchased those properties for their location, and with regard to the businesses, it is the location that the owners credit with much of their success (Alfred, April 28, 2011). The town could, however, legally purchase those properties and force the property owners to relocate elsewhere using eminent domain. Beach renourishment has been deemed simply too expensive and not permanent enough for the cost, though it is unclear whether a concerted effort amongst the towns was ever investigated or pursued.²⁰ The only recommendation which was acceptable to the town, developing a debris removal and restoration plan, had already been fulfilled by the Town according to the Town Manager.²¹

¹⁹ For further details, see Rhode Island Coastal Resources Management Council, June 24, 2011; Boardman, 2011; and Alfred April 28, 2011.

²⁰ For more detail, see Rhode Island Coastal Resources Management Council June 24, 2011; and South Kingstown Town Council Joint Work Session with CRMC, May 31, 2011.

²¹ See South Kingstown Town Council Joint Work Session with CRMC, May 31, 2011, p.30.

In June 2011, CRMC released an Inter-Office Memo as a follow-up to the joint meeting held between CRMC and the Town of South Kingstown on May 31, 2011.

The memo offers “the Council may want to consider designating the shoreline segment...as an area for use of ‘experimental shoreline protection’ methods” (p.2). This is what many property owners and town officials were calling for, and a few property owners have ideas lined up for experimental methods that they would like to try, and are willing to contribute to financially.²² Such a designation, however, must be approved by the Council; a staff suggestion does not suffice. As of this writing, no substantial progress has been made on establishing such a designation.

The relationship between the Council and the other stakeholders, primarily the town and private property owners, is shaky at best. In January 2010, in response to numerous violations issued by CRMC to property owners along Matunuck Beach Road, the South Kingstown Town Council submitted a Resolution to the town’s congressional delegation and Governor Lincoln Chafee, requesting

that the CRMC take a flexible approach in the application of its rules and regulations, [and] review program policies applicable to this vicinity to determine if such are consistent with the actual conditions present and work with the owners of the ocean front properties in their efforts to combat the severe coastal erosion...(Town of South Kingstown, January 27, 2011).

The town and property owners are seeking leniency from CRMC that CRMC is not willing to agree to, nor necessarily able to agree to within the limitations of its enabling legislation and regulations. According to the enabling legislation, “preservation and restoration of ecological systems shall be the primary guiding principle upon which environmental alteration of coastal resources will be measured,

²² See South Kingstown Planning Department March 23, 2011.

judged, and regulated.” (RIGL § 46-23-1[2]). However, given the limited scope of the area in question in Matunuck, and what many Matunuck residents and local politicians see as inconsistencies between the Council’s existing classifications and reality (mainly, that Matunuck is classified as a “coastal headland, bluff, or cliff” pursuant to Section 210.4 of the Red Book, but perhaps should be considered a “manmade shoreline” pursuant to Section 210.6 given the developed nature of that small section of shoreline), there appears to be some room for CRMC to review its designations and ensure that they are accurate. CRMC would be acting within its legal limitations if it investigated a designation change, but would need to ensure that it fulfilled the enabling legislation mentioned above. The Council has been attempting to uphold the duties charged in the enabling legislation, while considering the realities of Matunuck.

In April of 2011, CRMC announced that it would grant temporary permits to property owners to build wooden bulkheads as means of protection. The structures would be approved for twelve months, with the option of a six-month extension (it is interesting to note, however, that in the section of the Rhode Island State Building Code regarding temporary structures, which was included as an appendix to the CRMC Staff Report, a temporary structure is allowed only for “a period of less than 180 days” [ASCE 24-05, Section G901]). In addition, the structures had to comply with a series of stipulations regarding materials and their potential impact on the beach and neighboring properties.²³ As of this writing, however, no applications had been submitted for such structures either because property owners had already erected similar (but unpermitted) protection structures, because applying for a permit would

²³ For more information see Rhode Island Coastal Resources Management Council, April 20, 2011; p.25.

still be time consuming and the stipulations were restrictive, because the temporary hold on violation notices agreed to between CRMC and the Town of South Kingstown made unpermitted structures possible to erect without punishment, or because they wanted something more permanent to be permitted (Alfred, April 28, 2011; p.1). While permit applications continue to be submitted for various protection methods by both the town and private property owners to CRMC, the two sides seem to have come to a stalemate. In the meantime, there are mumblings of pending lawsuits and continued erection of unpermitted structures by private property owners that, if they function as anticipated, provide protection to their individual properties and to the public road and water main landward of them, but may damage the beach environment.

Conclusion

The problem is the same as so many other land-use problems: everyone is looking out for their own interests or looking to fulfill their particular duty (statutory or otherwise), but those interests and duties are conflicting. Of those that are most heavily involved in the debate, the residents are looking to protect their coastal investments, business owners are looking to protect their investments and their livelihoods, local government officials are seeking to protect the public safety of those that live, work, and visit the area by ensuring that the road and associated utilities remain in tact, and the state coastal management agency is fulfilling its statutory duty to protect the state's coastal resources by enforcing its regulations. Other actors that have gotten involved include Save The Bay, whose primary concerns were with public

access and the legality of the actions of CRMC in offering permits, as well as Surfrider Foundation, which wanted to ensure public access, the preservation of the natural shoreface, and to uphold current coastal zone regulations.²⁴ The various parties continue to seek their own interests as expected, and the impasse continues while property owners continue to erect their own structural protection measures and the town seeks permission to install a steel sheet pile wall along the public right-of-way.

²⁴ For more detail and testimony, see South Kingstown Town Council Joint Work Session with CRMC, May 31, 2011.

CHAPTER 3

SHORELINE RETREAT: THE SCIENCE

Shoreline retreat is an umbrella term that encompasses the various causes of a retreating shoreline that will be discussed in this chapter. “Erosion” is typically the word used to describe shoreline retreat, but as will be explained below, a shoreline can change from various causes, and “erosion” is not appropriate to describe all of them. Specifically, “erosion” refers to the removal of sediment from a beachface, whereas “beach migration” refers to the inland migration of the beach as a whole. Both processes can happen simultaneously, but are distinct causes of shoreline retreat. This distinction is important because this research is investigating an understanding of the natural sciences, which includes the concepts behind proper terminology. The mental model that the average person utilizes to conceptualize the loss of sediment (and beach volume) might differ markedly from what geologists consider is actually occurring. Below is a general discussion of the various factors that can lead to the movement of sediment and shoreline change, followed by a discussion of shoreline retreat in Matunuck.

Background: Shoreline Change and Sediment Transport

Longshore transport, rip currents, winds, waves, tide cycles and currents and sea level rise play a role in beach morphology and shoreline retreat in both calm weather and storm conditions (Lacey and Peck 1998; p.1256). The sediment budget and energy budget, which deal respectively with “the amount and sources of available material” and the “amount of energy coming into the system”, are part of the system

that encompasses sediment movement (Boothroyd, Klinger, and Galagan 1998; p.A5-4). The energy budget has more to do with storm events, but is also relevant in the form of currents that transport sand downdrift. Over time sediment is transported in a consistent longshore transport pattern parallel to the shoreline, taking with it sand from one beach and depositing it on another or transferring it offshore to a deepwater sink (Pinet, 2009; p.1255). There are sediment sources and sinks that supply or trap sediment respectively, either contributing to or removing sediment from the system.

Storms are the primary agents in causing shoreline retreat (Boothroyd, Klinger, and Galagan, 1998, p.A5-18; Lacey and Peck, 1998, p.1256.). As determined by Hayes and Boothroyd (1969), the factors controlling the role of storms as geologic agents are size and intensity of the storm, speed of the storm movement, tidal phase, the path of the storm with respect to the beach, and the time interval between storms (Hayes and Boothroyd, 1969, p.31). The size and intensity determine the amount of energy in the storm as well as the duration of storm weather in the beach environment. The energy in the storm comes from wind, waves and storm surge, all of which interact with the shore causing erosion. The speed of the storm also contributes to duration; a slow moving storm, such as extratropical storms common in the winter months, may persist over multiple tidal cycles. This allows successive high tides to combine with a prolonged storm surge and cause more erosion. Although tropical storms tend to transport sediment at a faster rate, the longer duration of extratropical storms typically results in much higher volumes of sediment transport than tropical storms (Zitello, 2002, p.51-52). The tidal phase, whether high or low, spring or neap, contribute to the erosive damage as well; the higher the tide, the more erosion there is.

The track of the storm with respect to the shoreline is important, because this determines the angle from which the wind approaches the land, resulting in different levels of damage from wind as well as waves generated by the wind. A tropical storm that passes to the west is typically most detrimental to Rhode Island, because in this case the strongest winds on the right side of the storm directly hit the south shore, bringing with them high energy, waves, and storm surge (Boothroyd, 2008, p.5). Extratropical nor'easters (also known as sou'easters) can be particularly erosive along the south shore, because winds coming from the south and southeast, which are common with extratropicals, directly attack that coastline that is exposed to the open ocean and has a very large fetch (the area over which wind blows to generate waves) (CRMC, 1999, p.14). This can generate large, powerful waves, because wave size is determined by a combination of the strength of the wind, the duration of that wind, and the length of the fetch. Extratropical storms are particularly damaging as a result of their extended duration.

Finally, the time interval between storms is critical for erosion because beaches typically regain sediment when given enough time in fair weather summer months resulting from "the formation and landward movement of sediment in offshore bars that weld themselves to the beach face" (CRMC, 199, p. 13,20; Hayes and Boothroyd 1969). If multiple high-energy systems follow one after another with minimal time in between, there will likely not be enough time for sand to accrete and for the beach to regain sediment, and therefore the bluff will erode further and further inland, with each storm starting to erode the land at the point the previous storm stopped (Hayes and Boothroyd, 1969, p.31-34).

Another factor contributing to shoreline retreat is beach migration (O'Connell, 2010, p.70). Beaches naturally migrate landward over time as a result of wind, waves, tides, storms, and most importantly, in response to increases in sea level (Lacey and Peck, 1998). Overwash fans composed of sediment deposited high on the beach during storms help the beach to grow and migrate inland over time, provided they are left undisturbed. Along a developed beach, structures stand as barriers to this movement of the sand (see Figure 7) (Nordstrom, 2000). The buildings, revetments, and bulkheads can also act as sediment traps, which keep the sediment (that was there when the structures was erected) behind them and out of the coastal system. The structures also alter wave and wind patterns, which consequently affect depositional patterns of sand by acting as barriers, forcing sediment seaward of where it should naturally be deposited (Nordstrom, 2000). When the sand does succeed in moving inland as a result of storms, it is often removed by humans when it is deposited in roads, parking lots, and yards (Boothroyd, Klinger and Galagan, 1998, p.A5-21). These depositions are overwash fans that humans feel the need to remove because they cause an imposition—it's harder to drive and to park in sand—and because people tend to see sand as belonging on the beach rather than in the parking lot. This is the problem with attempting to make a dynamic system static: most people do not realize that the beach should eventually be where the parking lot is located. The action of removing sand from where nature deposited it impedes the natural functioning of the system, and restricts the landward migration of the beach. When beach migration is noticeable in front of shoreline structures, it is often perceived as erosion because it is consistent with the traditional understanding of erosion: that sand is disappearing from the beach

where people expect to see it (Thurman and Trujillo, 2004). However, this is a misconception, because were there no structural barriers, the beach would have simply moved. In the words of Jon Boothroyd, Ph.D., Rhode Island State Geologist, “there will always be a beach, it will just be in another place” (Boothroyd, 2008, p.4). Next is a discussion of sediment movement specific to the Matunuck Beach Road area.

Source: Bush et al. 2004. "The Fortified Coast: Living with Coastal Engineering"

Source: Google Maps, Shannon Hulst

Figure 7: Beach migration blocked by hard structure (Aerial of riprap revetment at Matunuck Trailer Association)

Shoreline Retreat in Matunuck

As discussed above, erosion is caused by the interaction of natural processes (primarily storms) and the coastline, as well as interaction of these processes with manmade structures. Matunuck is no exception. Beach migration is at work in Matunuck, as the glacial sediment forming the headland “have continued to erode, and the barrier spits and coastal lagoons have moved landward and upward, all by the force of storm waves and storm surges controlled by the level of the sea at the time of the storm” (CRMC, 1999, p.2). Overwash fans can be clearly seen in two locations in Matunuck where there are no structures impeding sediment deposition (see Figure 8). Storm events “are responsible for the vast majority of erosion to [the Matunuck Headland]” (South Kingstown Planning Department, April 2010, p.3).

Source: <http://gis.cdm.com/website/southkingstownri/parcels/MapView.htm>, Shannon Hulst
Figure 8: Overwash fans in Matunuck

Matunuck faces south and is “subjected to high energy coastal erosion processes, including storm surge and large waves during tropical and extra-tropical storms (i.e. hurricanes and nor’easters)” (CRMC, April 20, 2011, p.12). Because of this south-facing characteristic, it “receives direct onslaught from high energy events that shape the shoreline” (CRMC, April 20, 2011, p.12). These events include extra-tropical

nor'easters typically occurring between late fall and early spring, as well as tropical storms in the late summer and early fall.²⁵

With the exception of a hurricane, extra-tropical storms tend to cause the most erosion damage because of their extended duration, which allows storm surge to build up and persist over multiple tidal cycles (Davis and Dolan, 1993). When there are offshore winds, these transport sediment away from the shore (Davis and Dolan, 1993). The wave period in nor'easters tends to be shorter as well, allowing the waves to constantly pound the beach and remove larger amounts of sediment (Davis and Dolan, 1993). A hurricane that tracks to the west will bring the most energy and therefore damage to Rhode Island (Boothroyd, Klinger, and Galagan, 1998, p.A5-5). A nor'easter will bring south to southeast winds directly onshore, and the extra-tropical storm will have a long duration, causing the most damage to the south shore.

The energy in these storms displayed through wind, waves, and storm surge erodes beaches, dunes, and bluffs. The most significant erosion comes from the waves during the storm surge, because the elevated water level (resulting from wind, low pressure, and sometimes spring tides) allows wave action to reach the supratidal bluffs that in fair-weather conditions are out of reach of the waves. The most damage occurs to the Matunuck area when an extra-tropical storm with southeast winds passes, or when the path of a tropical storm passes to the west over Connecticut. These result in maximum onshore winds that bring a higher storm surge, which allows the water to reach an even greater land area and cause even more erosion (South Kingstown Planning Department, April 2010, p.4). According to the Matunuck Coastal Area Report developed by the South Kingstown Planning Department, data collected by the

²⁵ For more discussion see South Kingstown Planning Department, April 2010, p.3.

town suggest “that a greater frequency of storms with on-shore winds that produce a storm-surge has been occurring since 1998” because aerial photographs of South Kingstown Town Beach since that date show an accelerated movement of the high tide line when compared to earlier aerials (South Kingstown Planning Department, April 2010, p.5). These storms have resulted in more damage to Matunuck since that year.

The sediment eroded during storm events is transported either offshore or downdrift. This is largely toward East Matunuck State Beach and Point Judith,²⁶ but there is a small inconsistency in the direction of transport in the Matunuck area. Research has shown that near Browning Beach and Cards Pond, the littoral movement is in fact from east to west (McMaster, R. 1960). If this is correct, then the sand cell for Matunuck does not include sediment coming from Green Hill, which could otherwise be a sizable sediment source. Between Cards pond and Matunuck there is no sediment available for the beach. The transport direction changes hourly, with wind, tidal, rip, and surface and near-bottom current variations, sometimes transporting more sediment east and sometimes more west.²⁷ The net longshore transport is in the eastward direction in response to southwest winds (Oakley et al., 2009; Klinger 1996, p.53). However, some tidal currents and storm energy may transport the sediment westward, into “low lying headland areas and offshore” (CRMC, April 20, 2011, p. 12; Klinger, 1996, p.53). When sediment is transported offshore, some is deposited beyond the return depth where another storm could access it to return to the beach.²⁸ One study shows that between 1995 and 1997, storminess increased and volume of the

²⁶ For more discussion, see Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p.8,13.

²⁷ For more discussion see Beale 1975, p. 29-35.

²⁸ See Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p.3.

active berm decreased because sediment was eroded by storms and transported to the lower shoreface. “As storminess continued, fair-weather processes were not able to transport the sediment onshore. Instead it was transported further offshore by the action of combined flows, possibly beyond the return depth” (Zitello, 2002, p.93). (This is consistent with anecdotal evidence of the beginning of the advanced erosion in Matunuck.) By one estimate, this return depth is about twelve meters below mean low water; any sediment deposited at a greater depth than this cannot be returned to the intertidal beach by natural forces (Oakley et. al. 2009; Klinger, 1996, p.63). In the Charlestown area, the remaining sediment is in a sheet several hundred meters wide adjacent to the coast that continues to interact with the shoreline (Klinger, 1996, p.23).²⁹

The Matunuck Beach area is a headland made up of glacial sediments, with both dry and intertidal sand beaches fronting it (see Figure 9). The glacial sediments are highly susceptible to erosion. This eroding bluff provides a major source of sediment for the beach, except where manmade structures have locked the sediment behind them.³⁰ Just east of the Matunuck Business District, toward Deep Hole, there are thick washover fan deposits that extend inland and host dunes formed by wind blown sand (see Figure 8) (CRMC, April 20, 2011, p.13). There is a cobble terrace in front of this area on the upper shoreface extending several hundred feet offshore, a surf break which “dissipates some wave energy before reaching the shoreline”, resulting in lower erosion rates and shoreline changes than the Matunuck Business

²⁹ See also Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p.7,13.

³⁰ See Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p. 8.

District (CRMC, April 20, 2011, p.13). The Matunuck Business District is also seeing higher rates of erosion as a result of the two hard structures on either end, which act in the same way as the hard structures that will be described below: essentially, the riprap revetment and the concrete bulkead are redirecting energy to the adjacent properties, causing them to erode faster. Both walls are also locking sediment behind them, removing that sediment from the sediment budget and interrupting the landward migration of the shoreline.

Erosion and accretion rates have varied over time in Matunuck. The CRMC Shoreline Change maps, created by Rachel Hehre and Jon Boothroyd, Ph.D., demonstrate the overall average erosion rates (see Figure 9) (Boothroyd and Hehre, 2007). With the construction of the Harbor of Refuge in the early twentieth century, “during and after construction severe erosion had taken place at Matunuck Point”, and “offshore contours show a slight regression westward of Matunuck Point and severe regression eastward of Matunuck Point” (Beale, 1975, p.7). Onshore, the westward regression appears to have intensified. While it seems possible that the Harbor of Refuge, together with the Charlestown Breachway, have taken enough sediment out of circulation to cause significant erosion to the surrounding beaches, this has not been verified and has even been rebuked by local experts.³¹ (Given that the dominant longshore transport direction is west to east, the idea that the Harbor of Refuge could

³¹ For discussions of sediment transport in Rhode Island’s coastal lagoons, see Boothroyd, J.C., Friedrich, N.E., and McGinn, S.R. (1985). “Geology of microtidal coastal lagoons: Rhode Island” and Friedrich, N.E. (1982). *Depositional environments and sediment transport patterns, Point Judith-Potter Pond complex, Rhode Island*.

RHODE ISLAND SOUTH SHORE:

Matunuck Headland, South Kingstown

SHORELINE CHANGE 1939-2004

Rachel E. Hahre and Jon C. Boothroyd

EXPLANATION

DIGITAL SHORELINE ANALYSIS	SHORELINE VECTORY LINES	SHORELINE CHANGE	DREDGE MATERIAL PLACEMENT SITE
DSAS Transect	1939	End Point Distance	December 2006
Baseline	2004	End Point Rate	March 2007

DRAFT: Sep 03, 2007

Source: http://www.crmc.ri.gov/maps/shorechange/South-Kingstown_Matunuck-Headland.pdf

Figure 9: Matunuck Shoreline Change Map (excerpt)

have removed sediment from the system that would otherwise have ended up on Matunuck is unsupportable.) Photographs taken since 1999 demonstrate that the Matunuck bluff has eroded approximately 20 feet in that time, and the presence of structures built on top of the bluff has made this landward migration all the more evident (CRMC, April 20, 2011, p. 17). It should be noted, however, that the berm and beachface have also undergone substantial erosion, which anecdotally has drawn as much attention as the bluff eroding underneath the existing structures. The shoreline change maps demonstrate that since 1939, the mean high water line has migrated landward distances of 89.4' at the Matunuck Beach Trailer Association (though presumably the number would be higher if the riprap had not been installed), 101.9' at Mary Carpenter's Beach, and 50.1' at Tara's Tipperary Tavern (Boothroyd and Hehre, 2007).³²

Proposed Ideas for Matunuck and their Interactions with the Natural System

Various ideas for dealing with erosion in Matunuck have been proposed formally and informally, and a few have been approved by CRMC. These include both traditional "hard" and "soft" solutions, defined by the materials they are respectively constructed from and the subsequent impacts on the shoreline once installed, as well as a few uncategorized solutions. "Hard" solutions are typically substantial manmade shoreline protection structures, expected to be relatively permanent on a decadal scale, the purpose of which is protecting the landward property. Hard solutions generally cause significant damage to the surrounding coastal environment, including both the

³² For measurements, see South Kingstown Planning Department, April 2010, p. 4.

beaches in front of and adjacent to the structure (see Figure 7 for aerial image of the riprap revetment at the Matunuck Trailer Association that has eliminated the beach in front of it and cause scouring either end). “Soft” solutions are temporary (they usually need to be replaced at least each season, but often need repair after each large storm) and can be the act of beach replenishment or physical structures typically made of biodegradable materials. Soft solutions have the primary purpose of protecting structures in low-energy storms without causing much damage to the surrounding beach, returning sand to the beach, and/or breaking up in high-energy events in a way that poses no danger to surrounding structures, the environment, or people. Both types of protection are relatively costly, and neither is long-lasting without periodic maintenance, in that a significant storm could destroy the hardiest of manmade structures including those falling under “hard” structures.

“Hard” structures, or shoreline protection structures, serve the purpose of protecting the property behind (landward of) them. They are generally quite effective for this purpose, as long as they remain above the mean high water level and storm surges, and are appropriately constructed so as to withstand continual erosion, wave energy, and storm forces. Hard structures are often identified as the best option by those seeking to protect waterfront property, because they tend to be the most effective and are expected to last at least a few decades. However, these structures provide a false sense of security and encourage development behind them, leading property owners to believe they are safe from the ocean and discouraging them from taking other precautionary measures. In addition, they require continuous maintenance, and

negatively interact with local sediment movement, cause more erosion, and create further problems for adjacent properties.

Hard structures “by design deflect wave energy, causing erosion around the sides of the structure and scouring immediately seaward of the structure” (see Figure 10) (CRMC, April 20, 2011, p.19). These structures cause scouring directly in front of themselves as a result of the energy deflection of a wave. When a wave approaches the beach, it naturally ebbs and flows up and down the shoreface, and diffuses energy as it moves inland. It takes with it sediment that is suspended in the water, and as it moves up the beach it deposits that sediment on the upper beachface. In storm events, when storm surge makes the waves reach further inland, the sediment is deposited higher on the beach face and in overwash fans, which helps the upper beachface to increase in volume and the beach as a whole system to slowly migrate inland (this is the beach migration discussed earlier). Such overwash fans and sediment deposition are evident directly west of the Matunuck Trailer Association and east of the Deep Hole parking lot between Matunuck and East Matunuck beaches (see Figure 8). However, when the wave encounters a structure such as a seawall before it is able to naturally diffuse its energy, that energy must be deflected somewhere. Much of that energy is deflected downward, which pounds the sand directly seaward of the structure, suspending those sediment particles in the water and allowing them to be pulled out to sea with the retreating wave (CRMC, April 20, 2011, p.19). Over time, the slope of the beach in the nearshore zone begins to steepen, which in turn causes waves to move faster, build up, and become higher with more energy (Pinet, 2009, p.242-243; Bush, 2004, p.82). This results in more energy being deflected from the wall, meaning not only more

Source: CRMC Staff Report 4/20/11,
http://www.crmc.ri.gov/guidesreports/Matunuck_Erosion_Report.pdf

Figure 10: Shoreline protection structure causing beach loss

scouring at the base of the wall, but also the structural integrity could be compromised by the higher energy levels constantly assaulting it, and the base of the wall could begin to fail if not driven deep enough into the ground. The ends of the structures and adjacent shoreline are also vulnerable to enhanced erosion, as a result of the shape and location of the structure, angle of wave approach and refraction, and wave height and period (O'Connell, 2010, p.70; Bush, 2004, p. 73). Erosion also appears to occur in front of and to the sides of the structure as a result of beach migration, which is the gradual landward movement of the beach in response to the rise in sea level, discussed above (O'Connell, 2010, p.72). Hard structures, including shoreline protection structures and buildings, hamper this migration and artificially hold the dynamic beach in a static position, except where the beach continues to migrate around the ends.

During a storm surge which is higher than the structure itself, the water will overtop the structure and still cause damage to the buildings behind it, if those buildings are close enough (CRMC, April 20, 2011, p.19). It can also create pressure behind a wall or bulkhead, or remove soil from behind a revetment's soil barrier

leading to failure. This situation essentially defeats the purpose of the structure and can cause more sand to be deposited behind the structure, thus removing it from the longshore transport system and depriving the downdrift beaches of that sand (CRMC, April 20, 2011, p.8).

Downdrift beaches are also deprived of their sediment by shoreline protection structures because these structures block the longshore system from accessing the bluff behind them, thus reducing input to the sediment budget by blocking access to the primary source of sediment replenishment in Matunuck.³³ Eroding bluffs and sediment in the nearshore face are the primary sources of sediment for the beaches along the southern Rhode Island coast (CRMC, April 20, 2011, p.8). The sand deposits off of Matunuck have been moved too far offshore beyond the return depth to allow for natural processes to return a significant amount of this sediment to the beachface.

The proposed options for Matunuck Beach Road that would fall under this “hard” category are a riprap seawall, a steel sheet pile wall (once the bluff seaward of its location is eroded and the wall is exposed, it will effectively become a “hard structure”), a seawall, and the temporary wooden bulkheads; the last of which has been approved by CRMC. Each of these will interact with the natural environment in different ways, and some will have less of an impact than others. For example, a riprap revetment constructed properly will have less of a problem of frontal scouring and will be less susceptible to regular wave energy because water can infiltrate the spaces between rocks. But such walls will not allow landward deposition of sediment, trap

³³ See Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p. 8.

sediment behind them, ultimately lose beach seaward of them, can be relatively easily damaged during a high-energy storm event leaving boulders strewn across the beach, and require a lot of maintenance. The final problem that comes with these structures is that, particularly in the case of the wooden bulkheads, if they are broken up by wave energy they may become projectiles and cause damage to surrounding structures when carried by the energy of the storm (CRMC, April 20, 2011, p.5).

“Soft” options include sandbags, burritos, and beach replenishment. The purpose of soft solutions is to work with the natural environment as much as possible, but still provide protection to landward properties. A sandbag is a small, approximately square-foot bag, often made of burlap, which is filled with sand. These are stacked in various configurations in order to create a wall of sandbags that will ideally stop the waves from reaching the property behind the sandbags. Burritos are much larger sacs, approximately one-hundred feet long, three feet high, and four feet wide, filled with sand and wrapped up like a burrito. They have a much larger mass than sandbags, allowing them to withstand higher wave energy. They are typically made of biodegradable geotextiles. Finally, beach replenishment is the act of putting large amounts of sand on the beach, either by trucking and dumping it, pumping it through pipes from a nearby source, or moving sand with a barge and dumping it offshore so that fair summer weather can move the sand to the beach. Inevitably the sediment will always be lost from the desired beach location to erosion or beach migration, and thus replenishment must be continual. Still, when maintained, beach replenishment keeps the beach in a relatively static position while also maintaining some width, and this static position and width are ideal for most uses of the beach.

Sandbags and burritos do not permanently lock sediment behind them because they can easily be removed. However, when maintained, they do lock sediment behind them and actually cause scouring seaward of them in the same manner that hard structures cause scouring, because once the sand inside of them is wet they get very hard. They function by absorbing wave energy, but lose their functionality in average annual storm events. Particularly strong waves can damage sandbags and burritos, and can move them if the wave energy is strong enough, thus eliminating their protective value. However, if they are damaged or moved by a storm, unlike “hard” structures, they do not pose a threat to neighboring properties and do not damage the marine environment because the sand is introduced into the normal system and the sac is made of biodegradable materials. However, if they were damaged in one storm, they have to be replaced before the next storm. This happens frequently. In addition, in the event of a strong storm, they will not be as effective as a seawall in stopping the wave energy from reaching the structures that they are protecting. Burritos are similar to sand bags and function in much the same way, but are more resilient in storms as a result of their mass.

Beach replenishment does not disrupt sediment transportation, provided the replenished sediment is compatible with the natural sediment. Beach replenishment adds sediment to the beach, but comes with its own host of problems. It is an ongoing process; as the sediment is carried downdrift it must be replaced. Without the natural sources of sediment, which the beach replenishment is replacing, the beach replenishment must be continually carried out in order to maintain the beach. Every time a load of non-native sand is dumped on a beach, all wildlife is buried and the

beach must be repopulated. There are believed to be significant sediment deposits offshore in deep waters that would be suitable for beach replenishment, but extracting that sand and getting it onshore would be very expensive.³⁴ It can also introduce problems such as non-native sediment which changes the appearance and composition of the beach and affects the longevity of that sediment's lifetime on that beach. Dredging sediment also may cause environmental damage at the dredge site by disturbing local habitats. Dredged sediment may also be full of waste. This was the case when beach replenishment was attempted for Matunuck Beach and the surrounding beaches from December of 2006 to March of 2007: the sediment had been dredged from the Harbor of Refuge, and contained a significant amount of debris. Most notably, the beach was littered with lobster bands. This and other debris deterred some members of the community from supporting this option a second time.

A final category of options cannot be classified under "hard" or "soft". These include experimental options, relocation of Matunuck Beach Road, and retreat. The experimental options that have been proposed include gabion baskets, Holmberg Stabilizers, and Sandsavers. The gabion baskets, which have been used for storm attenuation in Florida, are steel-wire mesh cages that are lined with geotextile fabric, filled with rocks or sand and attached or piled to form a wall (Bush, 2004, p.70). They are intended to be similar to riprap or a sandbag (but stronger and heavier, making them less likely to break up). They are intended to protect the landward structures. The metal mesh tends to rust and erode, eventually resulting in debris on the beach unless the remains are removed (Bush, 2004, p.70). These have not been tested in Matunuck,

³⁴ For discussion, see Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011, p. 7.

and it is difficult to say how they will withstand the conditions specific to Rhode Island's south shore.

The Holmberg Stabilizers are essentially underwater groins created out of geotextiles and filled with concrete. The intent is that the stabilizers will cause waves to slow down and deposit their sediments, leading to accretion rather than erosion (Holmberg, 2010). However, in order for this to work, there must be a sediment source updrift from the retreating beach – for Matunuck, very little sediment is reaching the beach from this direction. There is also no evidence that these Stabilizers would not work the same way as groins do in Rhode Island waters (causing accretion on one side but erosion on the other). According to the Holmberg Technologies website, a number of independent researchers have attested to the success of this system in Florida and Michigan, but the reports themselves are not readily available (Holmberg, 2010).

Finally, the Sandsavers are similar to jersey barriers in that they are large, heavy, concrete modules. They have holes in them to allow water and sediments to pass through, and the idea is that the structures will break up wave energy and encourage the water to deposit its sediment load landward of the structures (The Granger Plastics Company, 2009). However, it is likely that these will act like a seawall and cause scouring just below them, and worse, will keep less sediment from reaching the upper beachface in the first place. With less sediment reaching the beach, what little sediment might be trapped on the landward side of these structures will not be enough to significantly increase the volume of sand, not to mention the width of the beach. The product website offers a few reports attesting to the success of the Sandsavers, but none that use the most recent technology (it has changed over time),

and most reports are from the 1970s with one from 1995. The locations claiming success were in Louisiana, Hawaii, New Jersey, and Canada (all different coastal environments than Rhode Island), and no recent reports have been published for the success of these systems (The Granger Plastics Company, 2009).

None of these experimental options have been tested in the Rhode Island south shore environment, and therefore it is difficult to say if they will have the intended effect or if there will be adverse affects. While they may address erosion caused by storms, they do not address beach migration and therefore cannot protect structures against it. However, given that storms are the most significant factor in causing shoreline retreat, this may be irrelevant. These systems, primarily the last two, have not been sufficiently publicly reviewed by coastal professionals to determine what their true effects on the coastal environment would be.

Finally, the last two options that have been proposed in the Matunuck case are moving Matunuck Beach Road and retreat. Moving Matunuck Beach Road would get it out of harm's way where it is currently threatened, but could develop other issues in its new location such as interfering with wetlands or still being threatened by encroaching seas. However, it would have no negative impacts on the coastal system in terms of sediment problems, and would likely encourage the natural landward migration by allowing the beach to continue landward and not be impeded by structures, meaning that perceived erosion would diminish. Town officials concur that moving the road is out of the question, however, primarily because of logistical challenges.³⁵ The final suggestion is retreat, which would be the gradual abandonment

³⁵ For discussion, see Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011.

of the area altogether. Town officials, property owners, and business owners oppose this option for economic, cultural, and sentimental reasons.³⁶ Retreat would allow the beach to return to its natural state as the structures were either removed or destroyed by storms, and as the sand was allowed to migrate inland and the beach allowed to expand. This would also allow for sea level rise as climate change makes itself more evident, as there would be no one threatened by the increased sea levels. However, as was discussed later, despite its positive impacts on the coastal environment, retreat is not a politically viable option.

Conclusion

Shoreline retreat (what most people recognize as “erosion”) is caused by various factors, primarily storm activity and beach migration. Erosion and beach migration are a natural part of the coastal system, and would scarcely be a problem if not for the human development along retreating shorelines. This development impedes the regular migration of sediment resulting in the appearance of erosion, and can exacerbate erosion when hard structures are installed. There is no doubt that the amount of sediment on Matunuck Beach has diminished over time, and the basic causes are well understood by coastal scientists and managers. A number of solutions have been presented to deal with the shoreline retreat in Matunuck, which interact with the coastal system in various ways, some exacerbating erosion, some potentially reversing erosion, and some having no impact. The next question that must be addressed is the impact of climate change: what effects will climate change have on

³⁶ For discussion, see Joint Work Session of the Town Council of the Town of South Kingstown and the Coastal Resources Management Council, May 31, 2011.

the Rhode Island coast and on erosion in general, and how will those affect the erosion prevention or shoreline protection methods that should be seen as most ideal? These questions, along with climate change in general, will be addressed in the next chapter.

CHAPTER 4

COASTAL CLIMATE CHANGE: THE SCIENCE AND WHY IT MATTERS

With increases in sea level and storminess, Rhode Island's shorelines will change significantly, potentially becoming less attractive and less accessible. Barrier beaches in particular, on the south shore, will be especially vulnerable to increased erosion and landward migration as sea level rises. Increased storminess will result in increased storm overwash, breaching of barrier beaches, and damage to shoreline real estate and development on beaches and lagoon shores. (CRMC, 2010, p.49)

Background: The Science

Climate change is defined by the International Panel on Climate Change (IPCC) as:

a change in the state of the climate that can be identified...by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (2011, p.2).

Many scholars agree that it is likely made worse by human influence (see Titus et al., 1991; Frumhoff et al. 2007; and Mann and Kump, 2009). The term “climate change” is preferred by this author over the term “global warming”, because the changes in climate produced by the overall warming of the planet are predicted to produce various types of changes, such as shifts in weather patterns, drought, precipitation, and average temperature – including cooling in some regions. “Global warming” is often misinterpreted by those who do not have a complete understanding of the climatic shifts that the earth is undergoing, allowing skeptics to use a particularly cold or snowy winter as evidence against the “global warming”. However, those weather changes likely reinforce the fact that the climate is changing, including shifts in normal weather patterns with higher winter precipitation amounts predicted for the

northeast region of the United States (Frumhoff et al., 2007).

The earth has always undergone changes in climate over geologic timescales without human influence, but the rapid increase in global population and the even more rapid increase in the use of fossil fuels within the last one- to two-hundred years have caused a significant change in the use of the planet and its resources. In addition, with the increase in population has come an increase in development and an astronomical expansion in the societies, infrastructure, and economies, especially along the coast, that will be affected by the changes in climate and the consequences of those changes. Regardless of the cause of climate change, it is undeniable that there are shifts occurring in the climatic patterns around which modern society was developed, and those changes pose significant challenges to the normal functioning of modern society moving into the future.

The most widely discussed cause of climate change is the large amount of fossil fuel use. This contributes to an increase in atmospheric concentrations of carbon dioxide in excess of what would be released without input from humans. Carbon dioxide is a greenhouse gas, which together with other greenhouse gases such as methane and nitrous oxide, is acting to raise the average temperature of the lower atmosphere (Titus et al., 1991; Frumhoff et al., 2007; and Mann and Kump 2009). Because these gases act in a similar way to the glass in a greenhouse, the earth is experiencing a similar effect as plants inside a greenhouse – the gases are trapping the heat from the sun’s rays inside the atmosphere, keeping more heat in and letting less heat out than would occur with lower concentrations of greenhouse gases (Mann and Kump, 2009, 22-27). The amount of carbon dioxide in the atmosphere “has risen from

a preindustrial level of 280 parts per million (ppm) to 385 ppm in 2005, the highest it has been in 650,000 years” (CRMC, 2010, p.16; IPCC, 2007; Allison et al., 2009). In addition to the greenhouse effect, changes in land use that affect absorption and energy-exchange properties, such as the clearing of tropical rainforests that act as carbon sinks, have also contributed to the changes in climate (Mann and Kump, 2009, p.19). These processes and others are causing changes in the natural systems that society has become accustomed to, including in Rhode Island (Freedman, 2010; Frumhoff et al., 2007 [both]).

A summary of the changes that will be seen in each northeast state as a result of climate change was compiled by the Northeast Climate Impacts Assessment Synthesis Team and published by the Union of Concerned Scientists in 2007 (Frumhoff et al.). The report for Rhode Island shows that “spring is arriving earlier, summers are growing hotter, and winters are becoming warmer and less snowy” (Frumhoff et al., 2007, p.1). Temperatures have increased 1.5°F in the northeast since 1900, and are projected to rise 4°F to 12°F above historic levels in winter and 3°F to 14°F in summer by late in the twenty-first century (Frumhoff et al., 2007, p.1). In Providence, the National Weather Service data report an increase in the annual mean temperature between 1905 and 2006 of 18.74 °F (CRMC, 2010, p.8). In the northeast, sea surface temperatures are expected to increase by 4°F to 8°F by the end of the century (Frumhoff et al., 2007, p.12). Impacts on coastal communities are expected in the form of changes in fisheries, changes in agriculture, sea level rise, coastal flooding, and shoreline change and erosion (Frumhoff et al., 2007, p. 3). Some of these impacts will be discussed further below.

Interactions with the Northeast Coast: Sea Level Rise and Storms

The aspects of climate change that will have the most significant impact on the coast are sea level rise and tropical storms with higher intensity. These will increase flooding, property damage and land loss, and erosion (Frumhoff et al., 2007, p.15). Because of higher sea levels, regular flooding with spring tides will increase to a higher elevation. Also because of higher sea levels, storm surge will have more of an impact because the base mean high water level will be higher, allowing storm surge to reach even further inland and to apply greater force to those areas that were already subject to flooding. If tropical storms are more intense, the energy in them will likely bring higher storm surges, larger waves, and more flooding, not to mention increased damage from wind. Because the Northeast coast is densely populated, a significant amount of property, infrastructure, and economic activity will be affected by coastal climate change (Frumhoff et al., 2007, p.15).

The IPCC reports with high confidence that sea level rise will contribute to future extreme high water events along the coast, and that “locations currently experiencing adverse impacts [from sea level rise] such as coastal erosion and inundation will continue to do so in the future” (IPCC, 2011, p.12). Sea level varies all over the world in response to relative sea level rise, or the position of the sea in relation to the continental crust, which is affected by tectonic shifts and various geologic factors. For Rhode Island, relative sea level is important with regard to crustal rebound from glaciation: during the last ice age when glaciers covered the northeast, the continent sank into the earth’s mantle from the added weight of ice, then once the glaciers melted, rose up again without the added weight, and is now relaxing

again back into the crust. In places where this land subsidence is occurring, such as Rhode Island, sea level is rising faster than in places where the continents are stable or rising. This localized rise in relation to continental uplift or subsidence is known as isostatic sea level rise. Eustatic sea level rise is the second type of rise, which is the better-known melting of land-based glaciers that add water to the ocean (sea-based glaciers do not add any additional water), and the thermal expansion of ocean water as it warms (Boothroyd, 2008, p.5; Mann and Kump, 2009, NAS 2008). Eustatic sea level rise is ultimately caused by increased atmospheric temperature (Mann and Kump, 2009).

As of 2007, global sea level rise predictions were between 0.5 and 1.2 meters by 2100, with most predictions falling between 0.8 and 0.9 meters, or between 2.6 and 3 feet (Mann and Kump, 2009, p.98). As of 2008, sea level rise in Rhode Island was at a rate of 0.13 inches per year (Boothroyd, 2008). According to data extrapolated from the Newport tide gauge, sea level rose 25.8 centimeters, or 10.2 inches in the century from 1908 to 2008 (CRMC, 2010, p.10). There is evidence that in southern New England, sea level is “rising faster than the global average because the land is gradually subsiding” (Frumhoff et al., 2007, p.16; CRMC, 2010, p.10). Recent predictions for Rhode Island suggest two to five feet of sea level rise by 2100, which is recognized as being potentially too conservative.³⁷ Sea level rise will have numerous impacts on the Rhode Island coast, including “erosion, flooding, and loss of coastal habitat, beaches, and private and public land and infrastructure utility with offshore uses”, and “will reduce the effectiveness and decrease the life of existing

³⁷ See Rhode Island Coastal Resources Management Council, 2009. *Rhode Island Coastal Resources Management Program: Section 145*.

coastal structures such as seawalls and revetments, docks, roads, and bridges” (CRMC, 2010, p.10). For the purposes of this research, the most important impacts are the increase in erosion and flooding, and the reduced life of seawalls, revetments, roads and bridges, some of which is already evident in Matunuck.

The second major impact of climate change is an increase in extreme weather, specifically the intensification of tropical storms and hurricanes as ocean temperatures rise (Mann and Kump, 2009, p.56). There is scientific uncertainty surrounding whether climate change will in fact result in increases in tropical storm intensity (Mendelsohn et al., 2012). However, many scientists support the conclusion that climate change is likely to cause an increase in tropical cyclone intensity (IPCC, 2011, p. 5,11; CRMC, 2010, p.11). The energy in a tropical storm is directly dependent on water temperature; such storms can only form over warm water and they intensify as the water underneath them gets warmer (Archer, 2009, p.48). Thus warmer water could increase the destructive potential of tropical storms (Mann and Kump, 2009, p.56).

With an increase in intensity, it is probable that major storms such as the 100-year storm will have a higher likelihood of occurring every year and will consequently bring higher economic losses (IPCC, 2011, p.13; CRMC, 2010, p. 12). These may become 50-year storms, and the 50-year storms could become 10-year storms, etc, and with that increased likelihood of intense storms would come an increase in associated damage; approximately 30% more by one estimate (Bender et al., 2010). One prediction states that if the 1938 hurricane, a 100-year storm, were to hit Long Island and New England again today, it would likely cause about \$20 billion in insured

property damage (not to mention uninsured) (Frumhoff et al., 2007, p.18). In addition, accounting for three feet of sea level rise, the same size storm would produce a surge almost sixteen feet above the mean higher high water in Providence (Boothroyd, 2008, p.8). Evidence shows that there has been a global poleward shift in the storm tracks of extra-tropical storms, but there is disagreement about whether they have or will become more or less frequent (IPCC, 2011, p. 5,11; Frumhoff et al., 2007, p.30,31). Of concern to this research, “storms and associated storm surge cause damage to seawalls and revetments, docks, roads, [and] bridges...Storms can also...affect sediment movement, altering beaches and coastal habitats as well as needs for dredging” (CRMC, 2010, p.12).

Impacts on Coastal Properties: Shoreline Retreat and Flooding

Most importantly for this study, climate change is likely to accelerate erosion and beach migration and to alter and expand flooding patterns (Hehre, 2007). These are a cause for concern because erosion and beach migration lead to the undermining of the ground on which many structures were built, resulting in continuous futile efforts to maintain the structure followed by the ultimate destruction of the structure as it collapses into the sea, unless the structure has been relocated inland. Changes in flooding patterns mean that larger areas will be flooded and previously flooded areas will be flooded more regularly, resulting in increased flood damage to homes, more frequent disruption of infrastructure, and increasing costs to communities and governments.

There is already evidence that current increases in erosion may be related to

sea level rise and changes in climate (Hapke et al., 2010, p.52; Hehre, 2007; Lacey and Peck, 1998). In Rhode Island, “the effect of any amount of sea level rise will be an increased rate of coastal erosion as waves will break higher on bluffs and dunes along the south shore for any given storm intensity” (Boothroyd and Klinger, 1998, p. A5-9). Sea level rise will decrease the amount of dry sand and allow storm waves to access higher elevations, making it the most significant long-term driver of erosion (Lacey and Peck, 1998; CRMC, 1999). Sea level rise will also accelerate beach migration, because beach migration is the beach’s natural response to sea level rise. However, as a result of structures behind the beach, it will not be able to successfully migrate in many locations and the dry beach will consequently grow smaller in size. Sea level rise and storm events will work together, producing higher storm surges (Frumhoff et al., 2007, 1998). With higher storm surges, “because of the erosive impact of waves (especially storm waves), the extent of shoreline retreat and wetland loss is projected to be many times greater than the loss of land caused by the rise in sea level itself” (Frumhoff et al., 2007, p.15).

Storms cause severe erosion and coastal flooding, and are largely responsible for the enhanced beach loss experienced in Matunuck (South Kingston Planning Department 2010). As stated by Jon Boothroyd, Ph.D., “the severity of frontal erosion is dependent on storm size and frequency; the depth and inland penetration of storm-surge overwash is dependent on storm size and path of the storm with respect to the shoreline. An elevated mean higher high water level due to future storms is dependent on all of the above factors plus the rate of sea level rise” (Boothroyd, 2008, p.3). If climate change brings either increased storminess or storm intensity, erosion will

increase because it is the waves and storm surge from these coastal storms that cause the most drastic sediment loss in the shortest amount of time (Boothroyd, 2008, p.4; CRMC, 1999; Dolan, Lins, and Hayden, 1988; and McMaster 1961-1996 in Lacey and Peck, 1998). Increased storm frequency and intensity will increase the extremity and regularity of erosion and beach migration events. More often, significant swaths of beach may be lost in single storm events (Haddad and Pilkey, 1998). Changes in storms that are likely to come with climate change could greatly accelerate changes along the beachfront which put existing structures in ever-increasing danger. As more erosion occurs, topography is reshaped and the location and extent of flooding from sea level rise and storm surge will have to be re-evaluated (Frumhoff et al., 2007, p.28).

A second combined impact of sea level rise and intense storms will be increased coastal flooding, as discussed above. Nor'easters, which typically generate a powerful and damaging storm surge without an influence from climate change, have recently been striking New England more frequently and with greater intensity as a result of what seems to be a northward shift in storm tracks (Frumhoff et al., 2007, p.31; Bromirski, 2007; and Eichler and Higgins, 2006). Compounded by sea level rise, these storm surges could be devastating. If any storm, tropical or extra-tropical, were to hit at high tide, the combination of tide, higher sea levels, and storm surge would create a level of flooding rarely, if ever, seen in the past. One impact of this flooding is the increase in both intensity and elevation predicted for major weather events, such as the 100-year flood. Estimates show that by the end of the century, most Northeast locations can expect an average increase of 2 to 2.5 feet in the Base Flood Elevation of

the 100-year flood. The 100-year flood may become the 50-, 10-, or 5-year flood: every year or two in Boston, every nine to twenty-one years in Woods Hole, MA, and every seventeen to thirty-two years in New London, CT (Frumhoff et al., 2007, p.19).³⁸ In other words, a major flooding event of such magnitude as is currently recognized as having a 1% chance of occurring every year will now occur with the frequency presented above for each location. These are drastic increases in the probability of occurrence of such a flood. Clearly, this indicates that new Base Flood Elevations will have to be recalculated (a problem in and of its own given current shortcomings in the Federal Emergency Management Agency's flood mapping system), flood maps will have to be redrawn, insurance premiums will have to change to reflect the enhanced risk, and structures located in areas of frequent inundation will either have to be significantly updated and floodproofed or removed, and their users would need to relocate.

The rate of future shoreline change in the face of sea level rise and climate change is unknown. While there have been various models generated to predict shoreline change rates, such as the commonly used Bruun rule, they have all had shortcomings such as technical limitations in topographic data, reliance on potentially inaccurate assumptions, and an inability to take into account dynamic processes (Gutierrez et al., 2011, p.2). A model was recently released by Gutierrez et al., however, that promises higher accuracy using a Bayesian network to account for geomorphic setting, coastal slope, tidal range, wave height, and relative sea level rise in order to calculate the rate of shoreline change (2011). While calculating the

³⁸ It is unclear what the source of this data is; the document discusses work done by Northeast Climate Impact Assessment researchers but does not provide references to a primary document.

shoreline change rate for Matunuck using this method is beyond the scope of this study, making such calculations would provide a clearer vision of what to expect in the future in terms of shoreline change rates. This would help decision-makers and private property owners be better prepared for the likely changes by making decisions now to incorporate these future probabilities.

Importance of Preparing for Climate Change along the Coast

Based on the evidence presented above, the effects of climate change must be considered when planning for future coastal hazard mitigation. There is an extremely high likelihood of a large increase in what the IPCC deems *exposure*: “the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets, in places that could be adversely affected” (2011, p.2). This is particularly relevant to coastal areas that have experienced a boom in development with the increase in population. The more there is in hazardous locations, the more there is at risk (Mendelsohn et al., 2012). With sea level rise and increased storm intensity, structures built along the coast will become increasingly more susceptible to the ocean, and it will become increasingly difficult to protect them. This will put people, livelihoods, infrastructure, and cultural and social assets in danger from the hazards discussed above, as well as many others (Mendelsohn et al., 2012). Without viable protection, property owners and communities in affected areas will likely seek compensation from the National Flood Insurance Program (NFIP) and federal disaster assistance, which in recent years have regularly exceeded their financial capacities (the NFIP has borrowed approximately \$17.8 billion since Hurricane Katrina in 2005,

and as of April 2011 owed the U.S. Treasury the same amount) (GAO, 2011, p.48). According to a Government Accountability Office report, it is unlikely that the Federal Emergency Management Agency, under which disaster assistance and the NFIP operate, will ever have the ability to repay this debt (Williams Brown, 2010, p.8). With the continual need for borrowing from the U.S. Treasury, these actions deepen the nation's debt and put more of a burden on taxpayers nationwide (GAO, 2011, p.49). Therefore, it would be prudent now for local governments to take action to minimize the amount of property, buildings, and infrastructure that will be damaged in the future by encouraging inland retreat where possible and discouraging actions that prolong the lifespan of structures in immediate danger along the coastline. The literature surrounding preparation for climate-induced and natural hazards has become quite extensive, indicating a wide-spread acknowledgement of the need to plan for climate change (for example, see Climate Change Adaptation Working Group 2009, Frumhoff et al., National Oceanic and Atmospheric Administration 2010, Coastal Services Center 2010, and Adger 2010).

The heart of the matter in this case is the question of what should be done in Matunuck in the face of erosion. As most stakeholders involved argue that retreat is not an option, they must turn to methods of shoreline protection. When considering such coastal engineering structures, it is critical that climate change be taken into account. "Seawalls and other stabilizing structures may slow erosion and land loss, but as sea levels rise, so will the costs and environmental impacts of such intervention" (Frumhoff et al., 2007, p.27). With sea level rise, such structures are more likely to be overtopped in storms. Although they slow erosion of the land behind the structures,

they accelerate seaward erosion. This accelerated seaward erosion may undermine the structures (Titus et al., 1991, p.8). Increased intensity of storms will put more pressure on the structures, increasing the chances that they will be damaged or destroyed. If a seawall is expected to last fifty years under today's "normal" conditions, it is important to consider how much that anticipated lifetime could be reduced by the effects of climate change and how quickly these anticipated changes will manifest themselves (i.e. how soon will today's 50-year storm, which would destroy that wall, become the 10-year storm).

In addition, protective structures will become less effective as sea levels rise and they are subject to the energy of more intense storms. The Salt Pond Special Area Management Plan offers a warning: "...buildings now protected by coastal engineering structures will [be] subject to increased wave attack as the protection structures are overtopped by smaller and smaller storms...it would be prudent to be aware of the impact of sea level rise" (CRMC, 1999, Ch.4 p.15). Given the potential shortcomings of shoreline protection structures in the face of climate change, the value of any new structures should be carefully considered before money, time, and effort are expended for a structure with a continually decreasing lifespan. In short, it will become increasingly more difficult for humans to hold back the sea. As coastal managers have concluded, hardening the shoreline may not be the best option, but it seems to be the most favored by coastal property owners.

In addition to the problems posed by shoreline protection measures, climate change could have a significant impact on the economic value of the beach. Not only will buildings behind coastal engineering structures be in danger from changes in

climate, but the beaches in front of them will continue to disappear as sea levels rise and the beach attempts to migrate (see Figure 7 in the *Shoreline Retreat* chapter). With structures in the way of beach migration, the beach in some areas could be lost altogether, which could lead to a significant loss in tourism dollars.

As the mean sea level rises and moves farther inland, there could be also challenges to property rights, especially where there are questions between public and private land. More specifically, questions will arise as to who rightfully owns submerged property (property formerly above sea level and formerly clearly privately owned), or property that has become sandy beach as a result of migration in a location that was formerly fastland inland of the beach. These property rights challenges will interfere with the public trust as well as public access. If the beach is lost and the inland neighbors are granted the right to exclude others from their property that was previously well above the mean high water line, public access points could disappear.

Finally, property values could decrease as property becomes more vulnerable, indicating a weakened investment on the part of the property owners and a loss of revenue for communities (CRMC, 2010, p. 50). The combination of private property litigation, loss of beach and consequently of tourism and its associated tax revenue, and loss of property values will all have a negative impact on Rhode Island's public trust lands and economy (CRMC, 2010, p.50). Therefore it would be wise to take action now to minimize these negative impacts in the future.

It is clear that most of society continues to operate under the false assumption that the ocean and the climate are stable entities (Frumhoff et al., 2007, p.19). In Rhode Island, the coastal areas threatened by storm surge are relatively small, but hold

a disproportionate amount of the population (CRMC, 1999, p.4). With so many people on the coast, it is not possible to simply relocate. In addition, many users of the coast are unconvinced of the reality of climate change as a result of the scientific uncertainty that accompanies it. Thus coastal managers are faced with the challenge of reconciling climate change, the dynamic coast, and development. Rhode Island's Coastal Resources Management Council is seeking to pursue smart coastal management decisions in order to minimize future damage: "With advanced planning, the harm and costs associated with [the] potential impacts [of climate change] can be reduced and may be avoided" (CRMC, 2010, p.6). However, taking such action is rarely simple. Homes, critical infrastructure, livelihoods, and ways of life are rooted in the existing coastal development, and can not only be prohibitively expensive to move but may interfere with property rights, sentimental value, and politics from a society that developed within what was mistakenly believed to be a static shoreline and stable climate.

CHAPTER 5

METHODS

The purpose of this research is to identify the mental conceptualizations of research subjects regarding the natural science behind the causes of shoreline retreat and the ways in which climate change could affect the problem in the future; the extent to which that knowledge informs the choices made by each individual regarding what solution he or she deems most appropriate for addressing shoreline retreat in Matunuck; and where the mental models do not inform solution choices what other factors contribute to those decisions. In other words, the research answers the research questions by establishing whether the completeness of the mental models influences the types of protection measures that key players deem reasonable; whether they view shore armoring as the best solution or favor a more dynamic option such as the landward relocation of endangered buildings and infrastructure. The research will also determine if mental models support the management approach that key players favor or if other factors, such as cost and protecting private properties, are more significant than the natural science of coastal processes and climate change. Data was collected through interviews with key players involved in the planning process surrounding the shoreline retreat problem in Matunuck.

Mental models analysis, a method that extracts subjects' mental conceptualizations about a specified topic to determine how fully the subject understands that topic (which will be described in detail below), was used to answer the research questions. This was done by using the data to identify any shortcomings

in subjects' understandings of the causes of shoreline retreat and the impacts of climate change, and to evaluate if these shortcomings can explain a subject's preference for certain solutions.

The basic hypothesis is that if subjects have inaccurate or incomplete mental models, they will be more likely to choose “hard” solutions or structural protection measures that will interfere with coastal processes, exacerbate erosion in adjacent locations, and will not withstand the impacts of climate change well. Simply put, they will have mental models that do not adequately account for the effects of climate change over time, for the inevitable changes that will occur along the shoreline due to sea level rise and storms. Because their mental models do not include change over time, fixed coastal armoring seems like a reasonable solution. Subjects with incomplete mental models will choose such solutions because in the short term these will protect the shorefront property, and subjects do not understand the shortcomings of these structures. On the other hand, subjects with more complete and accurate mental models of coastal processes and climate change will opt for “soft” solutions or solutions that do not negatively interfere with coastal processes, and will be more effective in the face of climate change and inevitable shoreline change. Subjects will choose such solutions because they understand the causes of shoreline retreat and the shortcomings of hard structures in relation to erosion, particularly in light of likely impacts of climate change.

If the research results disprove the hypotheses, it will likely be because other factors, such as private property rights and expectations, economics, protecting infrastructure, and preserving community character are more important to respondents

than working with the dynamic coast and climate change. These other factors are not included in the mental models analysis as part of the “expert” model, but awareness of them allows the researcher to gain a comprehensive understanding of all factors involved in the planning process, and where the impacts of coastal processes and climate change fall among all of the values relevant to key players in Matunuck. These factors and their role in the decision-making process will be further discussed further in the Analysis and Discussion sections.

Mental Models

A mental model is an internal representation of the outside world which assists individuals in understanding and interacting with that external reality through a reasoning mechanism existing within the working memory (Jones et al., 2011, 46, 47).³⁹ The mental models approach is based on work done by Kenneth Craik in 1943, and furthered by Johnson-Laird in 1983. Craik proposed that people use small-scale models in their minds to understand how the world works, to reason, and to anticipate (Craik, 1952). Johnson-Laird expanded this theory into “the idea that humans construct mental models of the world, and they do so by employing tacit mental processes” (Johnson-Laird, 1983, p.x). Mental models form the basis of reasoning, decision-making, and behavior (Jones et al., 2011, p.46). They are constructed by each individual based on that individual’s personal experiences, perceptions, and existing understandings of the external world, and provide the structure for filtering and storing new information (Jones et al., 2011, p.46). Often, if new information is not consistent

³⁹See also Craik, K. J. W. (1952; first ed. 1943). *The Nature of Explanation*. New York: Cambridge University Press.

with an individual's existing mental model, it will be ignored and excluded from the mental model (Jones et al., 2011, p. 50, 51; Abel et al., 1998, p.84). As a result of cognitive limitations, it is not possible nor desirable for every detail found in reality to be represented by a mental model, meaning that all mental models are limited to some extent (Jones et al., 2011, p.50). Mental models are dynamic, however, and can develop to incorporate new information and new relationships through new experiences and learning (Jones et al., 2011, p.50; Abel et al., 1998, p.78). In the natural resource management field, mental models are used "because of the need to understand stakeholders' constructions of how the system functions and what values might be brought to bear on actual practices" (Du Toit et al., 2011, p. 22).

Mental models in the context of this research are used in part in the "process aspects" investigated by Abel et al. (1998, p.79). These "process aspects" look at the processes of shoreline retreat and climate change, at what is causing the shoreline retreat in Matunuck, how different shoreline protection methods can improve or worsen the shoreline retreat, and how climate change can affect the shoreline retreat problem and the existing structures that the town and property owners are seeking to protect. The mental models of research subjects, which combine their experiences, personal research, and formal education, will be compared against an "expert model", the details of which are discussed below. In so doing, inconsistencies and inaccuracies will be identified, and new ideas not represented in the expert model will be addressed. This will allow for the integration of local knowledge with formal theory, which can be a valuable combination when managing a local resource (Abel et al., 1998, p.79). Abel et al. argue that merging the unique models of users, managers, and

experts “can enrich the separate models, enhance communication among the groups, and improve the management” (1998, p.79).

Relevant to the potential next steps of this research, it will be helpful to understand the mental models of those involved in the Matunuck case so that communication can be enhanced and the area can be more collaboratively managed. It is important for mental models to be accurate and complete (based on the expert model) for successful decision-making, and effective communication typically results from commonalities in mental models. In this research, mental models will be used generally for the following purposes, based on different natural resource management uses: “to explore similarities and differences between stakeholders’ understanding of an issue to improve communication between stakeholders” (used by Abel et al.); “to integrate different perspectives, including expert and local, to improve overall understanding of a system” (used by Ozesmi and Ozesmi 2004); and “to identify and overcome stakeholders’ knowledge limitations and misconceptions associated with a given resource” (used by Morgan et al. 2002).

In Matunuck, residents, municipal officials, and state coastal management agents must work together to reach the best decision for Matunuck. If all stakeholders had common or at least more compatible mental models in which many of the same basic concepts were understood and accepted, communication would be easier. Differences in the understanding of a system can hinder communication and cooperation between stakeholders, which consequently impedes management efforts (Abel et al., 1998, p.79). “To encourage people with contrasting views to work together, it is necessary to identify and support a shared understanding among relevant

stakeholders and to enhance the collective decision making process” (Jones et al., 2011, p.48.). This research will help to identify where mental models fall short, are inconsistent, or are incompatible, which will suggest that further education in those areas could enhance both successful decision-making and effective communication (Du Toit et al., 2011, p.25). Where the mental model is expanded to include factors other than coastal processes and climate change, it becomes evident which factors are most important to stakeholders and therefore what could be further impeding communication. The base of these ideas is the theory that addressing inadequacies and inconsistencies (in comparison to the expert model) in mental models can improve the functionality of the system overall (Jones et al., 2011, p.50). Improving mental models through education would require that such educational methods and the information provided be presented in a way that is compatible with individuals’ current mental models (Morgan et al., 2002).

The Expert Model

The “expert model” is the knowledge base against which all subject mental models will be compared, represented by Figure 12. This comparison will demonstrate the extent to which subjects accurately understand the coastal processes and climate change hazards relevant to Matunuck, based on the method used by Morgan et al. (2002). The expert model is a representation of all knowledge necessary to firmly understand the scientific processes of shoreline retreat and climate change in Matunuck, and the impact that hard structures have on erosion and beach migration.

The expert model was created by the researcher based on the available literature, using geology and climate change texts as well as publications by local experts. The information comprising the expert model is laid out in detail in the preceding chapters *Shoreline Retreat* and *Climate Change*. There are three primary

Figure 11: Basic expert model

tenets of the expert model; shoreline retreat, climate change, and the impact of hard structures on shoreline change. This last concept is included as a primary aspect of the mental model because hard structures have a significant impact on the erosion of the surrounding beaches, and because many of the management options

discussed by subjects for Matunuck include hard structures that would alter the characteristics of the surrounding beach and exacerbate erosion. The node “impacts of hard structures” and its sub-nodes could be incorporated into the “shoreline retreat” umbrella, but were given their own distinction because of the number of sub-nodes necessary for the expert model. Figure 11 represents the expert model in its most basic form: only the major nodes and sub-nodes are represented. These represent the most basic interactions and processes within the system, from which all others proceed in further detail. This model is intended to allow the reader to see the basic structure of

the expert model without the complicated interactions displayed in the full model. The full model, represented by Figure 12, is displayed below.

In Figures 11 and 12, color is used to bring some clarity to the complicated models. The primary concepts are represented by different colors in the model itself: “shoreline retreat” nodes and sub-nodes are red, “climate change” are yellow, and “impacts of hard structures” are blue. Arrows connecting nodes and sub-nodes, representing relationships between concepts, are in corresponding colors, for example, if two “shoreline retreat” sub-nodes are connected, the arrow is red. If two primary concepts overlap, however, the arrow color is the hybrid of the two primaries: an arrow connecting a “climate change” and “shoreline retreat” node is orange, between “climate change” and “impacts of hard structures” is green, and between “shoreline retreat” and “impacts of hard structures” is purple. The use of color is intended to bring order to an otherwise complicated visual, and to allow the reader to better understand the interconnected nature of the concepts in the expert model.

The sub-nodes, or supporting nodes, of shoreline retreat, climate change, and impacts of hard structures were developed by summarizing the information in the *Shoreline Retreat* and *Climate Change* chapters. As discussed below section, some sub-nodes in the model are very specific in order to enhance accuracy. Simply recognizing a concept does not necessarily indicate whether the subject accurately understands the relation of the concept to shoreline retreat in Matunuck, and therefore in some cases it was necessary to add more detail. The expert model as represented by Figure 12 will be used as the basis for comparison throughout the analysis.

Selection of Research Subjects

Research subjects were selected from the pool of individuals involved in the erosion mitigation planning process through public and private meetings. These individuals came from various backgrounds, and included South Kingstown Town Council members, South Kingstown municipal officials, council members of the Rhode Island Coastal Resources Management Council (CRMC), and property owners along Matunuck Beach Road.

Research subjects were initially contacted if they had spoken during public town meetings regarding the subject, indicating that they were particularly concerned about the Matunuck case and were interested in influencing the policy decisions by interjecting their understandings of the problems and solutions. Although a few spoke at meetings, individuals from CRMC staff were not contacted because the expert model, discussed above, was developed in-part based on reports developed by the staff, so comparing staff mental models to an “expert” model created by them could have resulted in skewed and superfluous data. In addition, because of resource constraints, it was not possible to contact and interview every individual involved in the planning process. CRMC council members were contacted if they had spoken or were present at meetings. Property owners were initially contacted based on whether they spoke at a meeting, and then a few more were added in a snowball sample when individuals who had been interviewed suggested other neighbors to speak with and supplied contact information or physically introduced the researcher to new interview subjects. These new interview subjects were suggested because they had expressed their concern for and interest in the situation within their community, but had been

unable or unwilling to voice those opinions in the setting of a public meeting.

Ultimately fifteen individuals participated in the research, including three CRMC council members, four Town Council members, two municipal staff members, and six private property and business owners.

Interviews

The data for this research was gathered through interviews conducted with individuals involved in the planning process to protect structures and the public road along Matunuck Beach from shoreline retreat. Before starting, interview scripts were reviewed with several colleagues, and necessary changes were made to make the script flow better and to maximize the neutral tone of the questions being asked. Interviews were conducted between August and October of 2011, once with each individual, at a location of his or her choosing (their home, place of employment, or a coffee shop). Interview durations ranged from approximately twenty minutes to two hours. All interviews were conducted in person, and all except for one were recorded (extensive notes were taken during the interview where permission was not granted for recording).

Interviewees were asked questions in the manner of the mental models approach developed by Morgan et al. in relation to risk analysis (Morgan et al., 2002). Mental models interviews begin by using open-ended, non-leading questions to allow the researcher to gain an understanding of the knowledge and perceptions of the respondent. If initial questions are not open-ended and broad, the interviewer risks influencing the interviewee's thinking about what is or is not important and worthy of

discussion. Thus, the interviewer is able to learn what the interviewee thinks is most important. This allows the interviewer to “find out what people know and what they need to know” (Morgan et al., 2002, p.24).

The questions in the mental models approach followed a “funnel design”: begin broad, and narrow the focus as the interview continues (Morgan et al., 2002, p.64). This allows the topic to be introduced generally (respondents’ perceptions of the situation), then allows the interviewer to guide respondents, if necessary, to the subjects being focused on (coastal processes and climate change), but only to tease out their understanding rather than introduce a completely new idea to their mental model (Morgan et al., 2002, p.65). Here the interviewer first uses general prompting questions and then, if needed, more specific prompting questions to address any part of the expert model that the subject did not discuss himself. Quite importantly, the researcher keeps track of which responses are prompted and which are not. In some cases the subject is able to expand upon these concepts once brought to his attention, in others the subject can offer no new information. Topics raised by the researcher in this part of the interview that the subject is able to discuss, indicating it is part of his mental model, “might be thought of as topics that are not part of people’s working knowledge but could readily be understood if brought to their attention” (Morgan et al., 2002, p.67). The intention is to extract as much information as possible about their mental model; to try to reach every concept that the subjects have knowledge about but not to introduce a new idea that was not previously in their model. In the *Analysis*, what was discussed by the subject without prompting from the researcher will be referred to as the “working model”, and the combination of the working model and the

prompted portions of the interview will be referred to as the “full” model, representing all of the information that the subject has access to but might not necessarily use.

Interviews began by asking the subject to explain to the researcher what was happening in the Matunuck area with respect to coastal structures. This allowed subjects to bring up coastal processes and climate change if these were relevant to their mental model of what the problem was. Further opening questions allowed the interviewer to gather information on what factors were important to the subject, such as private property rights, economics, and community character that were not part of the mental models of coastal processes and climate change. These will be addressed further in the *Discussion* section. During interviews, topics covered by the subject were kept track of by the interviewer on the interview guide in accordance with the Morgan et al. system. This allowed the interviewer to know what topics had been addressed and what needed to be brought up. As a result of the researcher’s familiarity with the instrument, this became relatively easy to do in a conversational manner, which helped put subjects at ease. Follow-up questions were used to clarify topics that subjects brought up, so as to allow the researcher to completely explore that aspect of the subject’s mental model.

It is possible that mental models interviews will be limited by the extent to which interpersonal factors, such as trust and honesty, affect the elicitation process between the researcher and the subject, and consequently the accuracy of the external representation (Jones et al., 2011, p.54). It is also challenging in the second part of the interview, when more direct questions about coastal processes and climate change are posed, to make the proper judgment call about what topics to address. Some subjects

clearly have no new information to add, and asking them further questions about topics that they are unable to address can undermine the trust between the researcher and the subject by making the subject feel unintelligent or annoyed, which can damage the rapport needed for the remainder of the interview (Morgan et al., 2002, p.67). As such, the researcher attempted to limit opportunities for undermining the interview atmosphere by making judgment calls about when to skip follow-up questions.

Data Preparation

All interviews were transcribed, coded, and analyzed. Given that the nature of the broad, open-ended questions used for this research is to elicit conversation, a lot of information gathered by the researcher during these conversations was not relevant and therefore not used for analysis. All recorded interviews were transcribed verbatim by the researcher using the recordings obtained during interviews. Transcriptions were usually completed manually using software associated with the recording device (Sony Digital Voice Editor 3) to play back the interviews and using Microsoft Word to transcribe them. Dragon Naturally Speaking (Nuance Communications) software, a voice recognition software that allowed the researcher to repeat the interview and have it automatically typed, was also used for about half the interviews.

After transcribing was complete, each interview was coded using NVivo 9 (QSR International), software used for qualitative data analysis. In accordance with the method suggested by Morgan et al., the coding scheme was developed based on the expert model (Morgan et al., 2002, p.79). Each individual concept in the expert model was assigned its own node, a word or phrase summarizing the concept and

serving as an umbrella code for references to that particular concept. For example, if a subject discussed sea level rise this discussion would be coded as the node “sea level rise”, or if a subject addressed nor’easters, it would be coded under the node “extra-tropical storms”. Each time a particular concept was mentioned by the interview subject, it was coded at the corresponding node (Morgan et al., 2002, p.79). Where necessary, concepts or phrases were coded at multiple nodes. Nodes were also created to keep track of which responses were prompted by very specific questions from the interviewer, as discussed above. A number of nodes emerged outside of the expert model, and these were given their own nodes as they arose. These will be discussed in the “variance” sections of the *Analysis and Discussion* chapter. Some interview questions that were asked were intentionally unrelated to the expert model, specifically introductory questions, and answers to these questions were given their own nodes as well. The majority of these nodes were relevant to the management options that subjects deemed most appropriate for addressing shoreline retreat in Matunuck, and the reasons that subjects chose those options. These nodes were compiled into groups of nodes (e.g. coastal geologic processes, climate change, management options, and factors affecting decision-making about management options) in order to be used to answer each of the four research questions.

Analysis

Initial analysis was conducted based on the comprehensiveness measure utilized by Smythe (2011, p.110). This method compares the number of concepts or nodes in the expert model that each subject addresses to the total number of concepts

or nodes in the expert model, and establishes a percentage. Analysis began by creating queries in NVivo using the matrix query tool. A collection of nodes that corresponded to the expert model were gathered as a “set” or “collection”, and then run through the query to compare all subjects’ to the expert nodes. This query showed how many times, if at all, each subject mentioned each node in the expert model (whether prompted or unprompted). The query was exported to Microsoft Excel, where the number of times each subject mentioned a node was converted to the number one, indicating simply whether or not the subject addressed the node. For example, if a subject mentioned sea level rise three times, the 3 that would have shown up in the initial query would have been converted to 1. Once every cell held either a 1 or 0, indicating either presence or absence of nodes for each subject, sums were calculated for each subject, then divided by the total number of expert model nodes, which was fifty-four (see Appendix B). This provided a percentage for each subject, which was the percent of the expert model represented by each subjects’ individual model. A second query was run and percentages calculated following the same process to determine what percentage of each subject’s mental model was prompted; in other words, how much of what was discussed was discussed only because the researcher brought it up. Most of the data were compiled by affiliation (CRMC, Town Council, municipal staff, and property/business owners) to enable comparison across those associations in order to produce more meaningful results. This process was followed to provide the analysis for research questions 1 and 2.

A second method of analysis was used to answer questions 1 and 2 deemed “variance”, which addressed how the mental models of the research subjects differed

from the expert model. The purpose of discussing variance was so that the researcher could identify not only what concepts were missing from mental models (addressed by the comprehensiveness measure) but also those that fell outside of the expert model. These variance concepts represent how subjects are making sense of the situation without having the expert knowledge, and also show how they may be justifying their actions based on what they know.

Variance was addressed qualitatively rather than quantitatively by identifying the concepts that subjects discussed during interviews that were related to the natural science of shoreline retreat and climate change but fell outside of the expert model. These concepts typically were misunderstandings that were contrary to the expert model, ideas about the causes of shoreline retreat that had not been sufficiently studied to be supported or refuted by the expert model, and theories that have been debated enough that they could not be included in the expert model. The number of subjects within each affiliation (CRMC, property/business owners, municipal staff, and Town Council) that addressed each variance concept was tallied to identify which concepts were addressed most commonly by research subjects. Knowing this allows the researcher to identify concepts outside of the expert model that need to be addressed to correct subjects' models and ensure accurate understandings of all components of the expert model. Understanding the entirety of mental models – both what is accurate and inaccurate – is necessary for any attempts at future education to be most effective, so that those gaps and misunderstandings can be addressed (Thompson, 2004, p. 145).

To answer research question 3, the management options that each subject supported (elicited during interviews) were compiled through another matrix coding

query in NVivo combined with Microsoft Excel. Management options or solutions were categorized into four ordinal categories. Category 1 represents solutions that are intended to benefit the natural beach by causing no alteration of coastal processes (and in fact restoring natural processes by removing existing barriers) and accommodating climate change by moving endangered structures out of harms way. The solutions that fall into this category are elevation, retreat, moving the road, and removing the existing walls. Category 2 represents management options that are intended to protect shoreward structures by putting sand back on the beach and with minimal impact to the surrounding environment; these cause a minor, temporary alteration of coastal processes and accommodate climate change through their temporary nature. Options that fall into this category are beach replenishment, burritos and sandbags, and planting dune grass. Category 3 is designated solely to experimental mechanisms (in this case “Sandsavers” and “Undercurrent Stabilizers”) that are likely to cause a moderate alteration of coastal processes and could accommodate climate change. These mechanisms would most likely actually cause the same amount of damage as structures in the next category, but interview subjects expected them to cause less damage because their advertised purpose is to return sand to the beach. Because the intent of this categorization system is to compare subjects’ mental models to the solutions that they chose, the solutions will be kept consistent with subjects’ expectations (and thus the reasons why they opted for those solutions in the first place – they thought experimentals would cause less damage than a seawall). Finally, Category 4 encompasses solutions that are intended to be permanent in order to protect property. These cause a major alteration of coastal processes and do not accommodate

climate change. The solutions that fall into this category are a breakwater, riprap, a seawall, and a steel sheet pile wall (this would ultimately become a seawall, but would not begin as one – see *Matunuck* and *Shoreline Retreat* chapters for further discussion). The category determinations discussed above were made using the information in the *Shoreline Retreat* and *Climate Change* chapters.

Each research subject was given a score of 1 to 4 based on the management options each subject chose and how many times he or she mentioned each option. Most subjects suggested multiple management options, but generally preferred one or two over the rest – thus the number of times an option was mentioned was important (the more frequently it was discussed, the more the subject preferred that option). The score itself was important to the analysis because it simplified subjects' solution choices: a single number and classification scheme (that encompassed all of each subjects' choices) allowed for comparison between subjects with various combinations of solution choices.

The score was calculated through a somewhat complicated algebraic equation intended to create an ordinal scale that captured the difference in management options as discussed above: management options categorized as a 1 were intended to have a different value than those categorized as a 4 to show distinctions between the various levels of management options. The score was calculated by *multiplying* the value of each category (1 through 4) by the total number of times a subject addressed management options in each category (again, 1 through 4), *summing* the products for each of the four categories, then *dividing* that sum by the total number of times the subject discussed management options, regardless of category. For example, if a

subject discussed beach replenishment 4 times (a category 2 solution), experimental mechanisms 3 times (a category 3 solution), and a seawall 7 times (a category 4 solution), the solution score was calculated as follows:

$$X = [(1*0) + (2*4) + (3*3) + (4*7)] / (4+3+7) = 3.21$$

This calculation gave a score between 1 and 4, intended to correspond to the ordinal categorization system of 1 through 4. The lower the value of the score, the more the subject supported solutions falling into the lower categories: solutions that would require minimal to no alteration of the coastal environment, would adapt to climate change, and would offer very little protection to private properties. The higher the value of the score, the more the subject supported solutions falling into the higher categories: solutions that alter the coastal environment, may not be adaptable to climate change, and offer property protection. All of the preceding information was compiled and summarized in a table, which is displayed in Table 3 in the Appendix and further discussed in the *Analysis* chapter. Finally, a regression was run to test for statistical significance and any correlation between the two variables.

Finally, a process similar to that used for questions 1 and 2 was followed for research question 4, without the percentage calculations. Using NVivo, the relevant nodes (those identified by subjects as factors influencing their decisions regarding the solutions they chose) were compiled in a “set” and entered into a matrix coding query comparing this set to each interview subject. The final result displays the percent of times each factor was discussed by subjects in each affiliation. This data is displayed in Table 7 in the Appendix. One factor, private property rights, emerged as the most significant factor. To simplify analysis, this factor alone was compared with mental

model comprehensiveness and management scores to demonstrate any relationships. A one-way Analysis of Variance with a Tukey post hoc test was run between private property data and management scores, as well as between property scores and mental model comprehensiveness.

CHAPTER 6

ANALYSIS AND DISCUSSION

Research Questions 1 and 2

The first two research questions explored subjects' mental models in relation to the expert model, and were investigated together. The first research question posed for this study was: (1) With regard to *coastal geologic processes*, how do subjects' mental models compare to the expert model in terms of comprehensiveness and variance? The second research question was: (2) With regard to the relevant aspects of *climate change*, how do subjects' mental models compare to the expert model in terms of comprehensiveness and variance? As discussed in the *Methodology* chapter, the "comprehensiveness" of mental models is measured using the method developed by Smythe (2011, p.99) whereby each subject's mental model is compared to an "expert" model and calculated as a percentage of the number of concepts in the expert model that the subject correctly addresses. "Variance" occurs when the interviewees mental models contain processes and explanations that are absent from the expert model. Geologic processes and climate change mental models will first be addressed separately, then will be combined into one expert model and considered as one unit for the majority of the research. Ultimately it was more accurate to create a single expert model representing both systems rather than two distinct models because they are related to one another and these relationships are crucial to the complete understanding of the two systems as they relate to this case study. The codebook and all subject models can be found in Appendix B.

Geologic Processes Mental Models

The expert model for geologic processes can be seen in Figure 14. When addressed on the basis of subjects' affiliations (CRMC appointed council members, South Kingstown municipal staff, Matunuck property/business owners, or South Kingstown Town Council), average full mental model comprehensiveness ranges from 29% for CRMC appointed council members to 42% for property/business owners.⁴⁰ Working model comprehensiveness ranges from 26% for CRMC appointed council members to 35% for property/business owners. While all subjects are far from having comprehensive working models, this presents interesting findings: CRMC appointees collectively have the least complete understanding of geologic processes, while property/business owners have the most complete. This is of particular interest because the appointed members of CRMC might be expected to have the most comprehensive mental models as they are statutorily charged with making decisions regarding the coastal resources of the state.⁴¹ The lack of knowledge exhibited by the appointed council members, if made public, has the ability to undermine the credibility of CRMC staff.

Variance in mental models regarding geologic processes arose through eight concepts.⁴² The most common was the idea that the shoreline retreat is caused by the Harbor of Refuge and the Charlestown Breachway taking sediment out of the system and therefore starving Matunuck (mentioned by eleven subjects) (see Figure 14). For example: "...you can see the Harbor of Refuge is shoaled up with sand. My thinking

⁴⁰ See Table 1 in the Appendix for complete data.

⁴¹ It is important to note that CRMC staff members were not included in this study as research subjects. As they are experts in the content area and as evidenced by the Staff Report released April 2011, their mental models are substantially more complete than the interview subjects who serve on the Council.

⁴² See Table 5 in the Appendix for complete data table.

is, had you not built those two jetties...would that sand not have migrated down the beach? That's the local peoples' opinion." This misconception has to do with the dominant direction of longshore transport, which was another concept identified in the variations of subjects' models. Though the Harbor of Refuge caused disturbances when it was constructed, the notion that it is depriving Matunuck of sediment is inconsistent with the expert model because the direction of longshore transport is primarily west to east (except a small cell west of the Harbor), meaning that sediment from east of the Harbor would not have reached Matunuck regardless of whether the breakwaters had been built (see *Shoreline Retreat* chapter). This misunderstanding is shared by all of the most-involved community participants.

Figure 13: Location of Harbor of Refuge and Charlestown Breachway
Source: Google Maps, Shannon Hulst

The Charlestown Breachway, however, is west of Matunuck, and could be taking sediment out of the system. This was not addressed in the expert literature, however, and therefore was not included in the expert model, but could be useful to

integrate. Some subjects commented on the responsibility of the Army Corps of Engineers or CRMC (different subjects had different ideas as to who was responsible) to dredge the Breachway and replenish the downdrift beaches with the dredged sediment. However, no subjects blamed the whole of the problem on the Breachway, nor suggested that CRMC or the Army Corps should be responsible for fixing the shoreline retreat that has occurred in Matunuck. The idea that the Charlestown Breachway is removing sediment from the longshore system is not unreasonable and may be worth investigating. This lends tentative support to a claim made by a number of interview subjects; that those living in Matunuck that observe the beach on a daily basis may know more about some aspects of shoreline retreat in the area than the experts, because the experts have yet to be able to study every possibility.

Other examples of variance are the result of subjects' observations, and subjects will believe what they see rather than what they may be told if the two are inconsistent: "recipients of information tend to accept that which confirms their [existing mental] constructs, and shed the rest" (Abel et al., 1998, p.78). In other words, people tend to stick to what they understand and what fits with their existing models and observations, while discounting all other information (Jones et al., 2011; Morgan et al., 2002). For example, five subjects expressed observing sand movement east to west rather than west to east as the experts say (see *Shoreline Retreat* chapter): "I know CRMC has an opposing argument to this, they say sand accretes from west to east...but I've witnessed the sand move west" (property/business owner). There is a small cell near Matunuck in which sediment does in fact move in this direction, but the overall longshore transport along the south coast of Rhode Island is west to east.

However, because subjects can see the one cell moving in the opposite direction, they do not believe the west-east movement is primary. Unless there is an explanation that is consistent with their observations, subjects will disregard contrary information. Likewise, they are much less likely to accept something if they do not observe it themselves: “if we do not directly see the effects...we are much less likely to believe that the [effects] are occurring when we are told about it” (Thompson, 2004, p.144).

Figure 14: Geologic Processes Expert Model

Climate Change Mental Models

The climate change expert model can be found in Figure 15.⁴³ The average comprehensiveness scores demonstrate that property/business owners have the lowest full model comprehensiveness scores for climate change at 42%, while CRMC appointed council members have the highest at 63%. In working model comprehensiveness, CRMC appointed council members retain the highest average score with 50%. This is more consistent with what might be expected (decision-makers might be expected to have more complete mental models than others). This suggests that CRMC appointed Councilmembers are more aware of climate change. This is likely the result, at least in part, of the adoption of a recent CRMC regulation addressing climate change for which the Council members were briefed by the staff on the basics of climate change and its implications along the Rhode Island Coast (Coastal Resources Management Program, Section 145).

Given this information, however, it might be expected that appointed CRMC council members would have had even more comprehensive climate change mental models than an average of 63%. A few possible explanations for this: within the last year, the Council has changed membership, so new members may not have been briefed on the climate change information, the climate change information did not fit into their existing mental models because the appointed Council members are not required to have a background in the field of coastal management, and some members may have disregarded what they were told because of their personal beliefs about the reality of climate change (Center for Research on Environmental Decisions, 2009, step

⁴³ See Table 2 in the Appendix for complete data table.

1). Other research subjects (property/business owners, municipal staff, and Town Council members) would have to have sought climate change information on their own, or absorbed whatever information they learned in passing, making their lower results unsurprising.

Turning to variance⁴⁴, three concepts arose as part of subjects' models that fell outside of the expert model: erosion is not related to climate change, climate change is a long term problem, and climate change is not important for Matunuck with regard to the current problem. The latter two can be combined, because although they were identified in different ways they ultimately reach the same conclusion: climate change is not something that needs to be addressed now and therefore is not relevant to the existing problem. These concepts were brought up by eight and five subjects, respectively. Some examples: "I won't say [climate change] is irrelevant, I'll say it's of less consequence than most people would think, than most scientists would put on it" (CRMC appointed council member); "The only thing about that is that I'm not going to have to worry about it" (property/business owner); and "They're trying to blame the erosion on sea level rise, but that's ninety years away, so it's irrelevant right now" (property/business owner).

Variation of concepts from the expert model was distributed almost exclusively among CRMC appointed council members and property/business owners. Two-thirds of CRMC research subjects suggested that climate change is too long term to consider, and one-third stated that climate change is irrelevant for the current case. These seem to contradict the regulatory duties of the CRMC to consider climate

⁴⁴ See Table 5 in the Appendix for complete data table.

change in the decisions that they make.⁴⁵ Property/business owners had a high level of variance from the reference climate change model; all but one said that climate change is long term, and two thirds said it is irrelevant for Matunuck. If property/business owners were to accept and plan for climate change in Matunuck on a shorter timescale, their costs for addressing shoreline retreat would increase and the range of options that they deemed acceptable would become quite limited, or no options would be deemed acceptable.

Overall, eight subjects believed that the effects of climate change are too far in the future to be considered for the purposes of today's planning. This indicates that the timeframe of these subjects' mental models is very limited; they do not believe that they are already experiencing climate change, and their models only encompass a few decades (many only consider the length of time they expect to live). Their models are not broad enough to encompass some important parts of the climate change expert model: it is true that some aspects of climate change will not be experienced until many decades into the future, but in sixty to ninety years (to use one subject's timeframe) climate will not suddenly drastically change: it is a graduated change over time, the effects of which are already manifesting themselves. Inevitable change over time is not being accounted for in these subjects' mental models.

“[There exists] a tendency for people to construct perceptions of likelihood based on the mental availability of instances” (Meyer, 2006, p158-159). In other words, people tend to think about the future hazards they face in terms of what they can comprehend based on experience, which is not inclusive of future circumstances (Meyer, 2006). With regard to climate change, there is minimal recent data to allow

⁴⁵ See Coastal Resources Management Program, Section 145: Climate Change and Sea Level Rise.

subjects to even begin to construct these perceptions of likelihood, and no existing effects of climate change have had any drastic impact on these research subjects. Research subjects who commented that climate change is irrelevant for Matunuck are exhibiting this human tendency to ignore future circumstances. For example, "...sea level rise is 60 or 90 years away, so that should not be in the picture...it has nothing to do with [this problem]" (property/business owner).

Part of the inability or unwillingness to consider future circumstances is caused by the uncertainty associated with climate change, which leads people to discount it: "It's of less importance than most scientists would make it. If there is to be climate change over the next 100 years, I'll be the first to tell you what the effects are" (CRMC appointed council member). Another part is the inability to plan for the future (more than the next one or two decades) because of the way that people tend to learn, i.e. their learning biases.

Two learning and information processing biases (as discussed by Meyer, 2006) are particularly relevant here: a tendency to see the future as a simple extrapolation of the present, and a tendency to overly discount the value of ambiguous future rewards compared to short-term costs (or the reverse, a tendency to overly discount the cost of future problems compared to immediate rewards). The first tendency applies here because subjects simply cannot grasp what climate change means for Matunuck, and therefore they see the future as an extrapolation of the present – they are aware that there will likely be changes, but with the uncertainty of those changes, they cannot imagine anything much different from the present: "sea level has been rising for 1000 years. Is an inch going to make a difference?...I don't thin sea level rise will have an

impact on [the seawall I want to build or on my property]” (property/business owner). They also cannot comprehend the need to adapt their current lifestyles to these potential unknown future changes.

With the second tendency, property owners and municipal officials see the drastic steps that would be guaranteed to accommodate climate change (such as moving the road and waterfront structures inland) as having far too many short-term costs to be beneficial in the future, particularly when the future dangers are not clear. The more difficult the future is to imagine, such as unknown climate change impacts, “the more short-term decisions tend to be anchored toward those that make the most sense in the present” (Meyer, 2006, p.162). Here, it makes sense in the present for people to protect their homes, businesses, roads, and water lines because that seems feasible, and the future dangers are too abstract to incorporate into planning. Consequently, people tend to focus on the immediate situation rather than plan for change, which is evidenced by the variance in climate change mental models presented above.

Figure 15: Climate Change Expert Model

Complete Expert Model: Geologic Processes and Climate Change Combined

The “complete” expert model is the combined *geologic processes* and *climate change* expert models. This “complete” model will be used for the remainder of the analysis, because the relationships between the two models above are imperative for a true understanding of the two systems for the purposes of this case study. The complete expert model was shown in Figure 12 in the *Methods* chapter. Table 4 in the Appendix displays working and full comprehensiveness scores and percent prompted for each subject.⁴⁶

⁴⁶ See Table 3 in the Appendix for comprehensiveness scores by affiliation (CRMC appointed Council members, South Kingstown Town Council, South Kingstown town government, and private property/business owners).

Table 4 shows that full model comprehensiveness for the “complete” combined ranged from 20% (subject M3) to 56% (subject M10), and working models ranged from 15% (M13) to 48% (M4). Full models were notably more comprehensive than working models by as much as 11% (indicated by percent prompted), suggesting that the information that subjects actually work with conceptually in making decisions is quite limited. Given that the highest full model comprehensiveness score was 56%, it is fair to say that no subject had a very comprehensive mental model. This does not necessarily mean that subjects do not have enough information to make good decisions, but it is unlikely. The concepts that were missed most commonly (those addressed by less than four subjects), which indicate those concepts most poorly understood by subjects as a whole, are highlighted below in Figure 16.

The concepts that emerged indicating variance are shown in Table 5 in the Appendix and Figure 16. Variance offers insight into how subjects make sense of the causes behind the shoreline retreat that they observe in Matunuck, and consequently perhaps how they justify certain actions. For example, someone who supports the installation of a seawall may prefer to believe that a seawall will not cause erosion for neighboring properties, as two subjects commented. Variance also helps to give a more complete understanding of subjects’ mental models, because they demonstrate where subjects have entirely different understandings that fall outside of or contradict the expert model. While some of these concepts are simply incorrect according to accepted science (such as erosion being unrelated to climate change), not all are necessarily wrong. Some of these ideas have simply not been studied in great detail or there is disagreement in the scientific community about the validity of these concepts.

Research Question 3

The third research question is as follows: Can these mental models of coastal geologic processes and climate change be used to explain why subjects choose the management measures they see as most reasonable? This question will be answered by comparing subjects' mental models to the erosion management options that each subject identified during their interview in response to the question "what do you think should be done in Matunuck?" The hypotheses for this question are: 1) If key players in Matunuck have inaccurate mental models concerning beach migration and erosion, and the hazards associated with climate change, they will be more likely to support the creation of an immobile hardening of the shoreline; 2) If key players in Matunuck have accurate mental models concerning beach migration and erosion, and the hazards associated with climate change, they will be less likely to support the creation of an immobile hardening of the shoreline; 3) The positions of key players on shoreline hardening are morally consistent with their mental models; if key players have complete mental models and still support an immobile hardening of the shoreline, then other factors are more important than coastal processes and climate change. This section will show that the first two hypotheses are incorrect, suggesting that the final hypothesis is correct which will be addressed in the final research question. Table 7 displays management option scores (as discussed in the *Methods* chapter), management option choices, and comprehensiveness for both working models and full models, organized by affiliation.⁴⁷

⁴⁷ To see the comparison of individual comprehensiveness and management option scores, see Table 6 in the Appendix.

When comparing working model comprehensiveness and management scores, the first two hypotheses discussed above are not verified. In other words, subjects with higher comprehensiveness scores do not necessarily have lower management scores, as they should if the hypotheses were to hold true. Rather, most management scores fall between or equal to 3 and 4, regardless of comprehensiveness. Subjects are, of course, assuming that the options they choose will have the effect that they expect. (This links back into deficiency of mental models – subjects may advocate a seawall if they do not know that it adversely impacts the surrounding beach, but may opt for another solution when provided with this knowledge.)

Interestingly, the only subject who scored a perfect 1 for a management score (which happens to represent ideal coastal management tactics), was also the subject who had the lowest comprehensiveness score. This is the opposite of what would result if subjects' mental models fully explained their solution choices: the subject with the most deficient mental model would be expected to choose the solution that is least compatible with natural processes, an immobile hardening of the shoreline (which would be a management score of 4), but in fact chose the most compatible (management score of 1). This example, along with the rest of the data, indicate that management choices cannot be explained by mental model comprehensiveness. A regression analysis demonstrated no statistical significance for a correlation between the two, perhaps because of the small sample size and/or low scores for comprehensiveness.

	Working Model Comprehensiveness	Full Model Comprehensiveness	Management Option Score
CRMC	30%	35%	0.91
Municipal Staff	31%	35%	4.00
Property/Business Owners	35%	42%	3.12
Town Council	28%	41%	3.00

Table 7: Average comprehensiveness and management option scores by affiliation

Instead of choosing management options corresponding to mental model comprehensiveness, it appears that subjects chose options that were consistent with their affiliation (CRMC, municipal staff, property/business owners or town council) regardless of their mental model comprehensiveness. This may be explained through a type of collective mental model, known as cultural models. These are “imaginative structures that people use to evaluate experiences, interpret observations, make judgments, resolve problems, and make classifications” (Thompson, 2004, p.145). In this instance, there are different cultural models for different affiliations – generally speaking, CRMC appointed council members follow one cultural model consistent with their statutory duties to preserve coastal resources for the general public, and property/business owners, municipal staff, and Town Council members follow a different cultural model that puts the expected rights of the local citizens ahead of the health of the public beach; “through the sovereignty model we conceptualize the connection between property, personal control, security, and privacy” (Thompson, 2007, p.215). CRMC appointed council members, at least in their duties as council members, adhere to the ecological model, in which “land and water are interconnected by ecological processes...which creates obligations to neighbors, the larger

community, future generations, and other living organisms” (Thompson, 2007, p.224). Property and business owners, municipal staff, and Town Council members tend to follow the sovereignty model, which gives property owners uncontrolled dominion over their property (Thompson, 2007, p.215), which in this case can be private or municipal property. These two models directly conflict over the armoring of the shoreline. The difference in these cultural models is the root of differences in management option choices.

CRMC appointed council members as a whole chose lower score options that allow natural processes to continue unrestricted to the greatest extent possible, consistent with the ecological cultural model. They advocated most strongly for options like retreat and moving the road that fall into Category 1, but also made concessions for burritos and sandbags from Category 2 and experimental mechanisms from Category 3 which they thought would provide some protection to structures in their current locations but minimize damage to the surrounding environment. For example, one appointed council member said, “I’m sympathetic to proposals that would allow us to experiment with modifying the shape of the coastline using softer structures...to learn more about those technologies because we will need them in other parts of the Rhode Island coastline”. While CRMC appointed members may have deficient mental models regarding the reasons that certain management options are ideal from the point of view of the CRMC, they understand which options are legal and within those which are ideal from the state coastal management agency’s perspective. Therefore they chose options that are consistent with this information.

Municipal staff chose an option guaranteed to protect the road: a steel sheet pile wall for which they had already applied to CRMC for a permit. This is more consistent with the sovereignty cultural model, where the property in question is publicly owned by the town (so under this model the town has the unrestricted right to protect it). The primary interest of the staff was to protect the property of the town (the road and water main) for the sake of the public. Staff members had invested time in researching and weighing the various options, and determined that the steel sheet pile wall would have the greatest success in protecting the public property at risk while minimizing negative consequences to neighboring properties (this incorporates the ecological model to a small extent). Municipal staff members were consistent in choosing this management option.

Property/business owners opted for solutions that would protect their property (consistent with the sovereignty model) but left some room for retaining a sandy beach for their personal enjoyment and the enjoyment of the public (a step toward the ecological model). After all, the large expanse of beach that existed when property owners purchased their homes was attractive to them, and they are aware of the CRMC regulations that limit hard structures. Most property/business owners advocated for a seawall, but also offered some less permanent alternatives such as experimental mechanisms and beach replenishment that they believed would still offer some protection to their homes but would also perhaps preserve the beach. For example, “I just think if the system exists that in fact would restore the beach to a more natural state, isn’t that a better alternative to a seawall?” Property and business

owners are trying to act within the confines of the law and to preserve the beach if possible, but still have a primary goal of protecting their own properties.

Finally, Town Council members wanted to support their municipal staff, their property and business owners, and to please the CRMC to the greatest extent possible. As the decision-making body for the town, they have many parties to please: they have a duty to all residents of the Matunuck area to maintain the road and public water main that services the area, and they also feel an obligation to the waterfront residents that are in danger of losing their homes and businesses and have been looking to the Council for help for years. Therefore they act largely through the sovereignty model that protects the property of their citizens and of the town. While they have a duty to act lawfully under the regulations of CRMC, and wish to act in a way that will maximize benefits to all residents of the State of Rhode Island (which in this case would be actions consistent with the ecological model), their primary concern is the residents of South Kingstown and Matunuck. Therefore they chose options like a steel sheet pile wall, seawall, or experimental mechanisms that are likely to provide benefits to those local residents even at the expense of the residents of the State as a whole. This becomes “a case of the town capturing part of the value of a resource that belongs to the entire public” (Thompson, 2006, *109), where the town is looking to obtain the economic benefit from an area and protect its own citizens at the expense of the statewide public, putting the sovereignty model above the ecological model when it should not be.

Research Question 4

The fourth and final research question is: If mental models cannot explain the management measures that subjects choose as most reasonable, what factors might explain these choices? It is clear from the results of the preceding research question that the comprehensiveness of subjects' mental models cannot be used to explain the mitigation measures that subjects chose. Rather, as discussed above, subjects tended to choose options that were consistent with the collective personal interests of those in the groups that they were affiliated with. There were other factors that were relevant to these decisions, however, which reflect the cultural models discussed above. These various factors are presented in Table 8 in the Appendix, but only the most common will be discussed here.

The most important factor in choosing a management option for subjects overall was protecting private property (preserving this property in its existing location). This was brought up by fourteen out of the fifteen research subjects as being an important factor in choosing the best management option. This has become the heart of the issue; whether property owners should have the right to protect their private coastal properties, and if so, what form that protection should assume (this is where the sovereignty and ecological cultural models discussed above tend to clash). During interviews, subjects were asked the following question: "Should structural shoreline protection be a property right? In other words, do you think that by owning coastal property a person should have the right to erect a structure like a seawall to protect their property?" Subjects' answers to this question are summarized in the

tables below, which compare their answers to their mental model comprehensiveness and to their management scores.

Table 9 in the Appendix compares answers to the private property rights question to mental model comprehensiveness. The table is arranged in order of ascending comprehensiveness scores. This arrangement shows that there is no relationship between mental model comprehensiveness and private property rights beliefs. This is confirmed in a statistical Analysis of Variance (ANOVA) test; there is no significant difference in the mean comprehensiveness score for each group of property rights beliefs. In other words, in this set of research subjects, whether someone believes structural shoreline protection should be a property right or not has little or nothing to do with how well they understand coastal geologic processes or climate change. However, because these results are not statistically significant, it cannot be assumed that they are representative of the larger population.

Table 10 below compares private property rights to management scores. It is organized in order of ascending management scores. These results demonstrate that there is a relationship between private property rights beliefs and management scores, or what subjects believe should be done in the area. Specifically, subjects who believe structural shoreline protection *should* be a property right tended to have a higher management score, which corresponds to structural protection such as a seawall. Subjects who believe structural shoreline protection should *not* be a property right tended to have lower management scores, corresponding to more natural options that minimize human influence. These results are statistically significant in an ANOVA test, indicating that they are representative of a larger population. A post hoc test

(F=5.321) indicates that there is a statistically significant ($p < 0.05$) mean difference in management scores of 1.88 between those that answered “yes” and those that answered “no”. (Subjects are acknowledged as having answered yes or no regardless of whether they also said “yes with restrictions”.) These results show that a subject’s property rights beliefs can help to explain the management options that he or she deems most reasonable in Matunuck.

Subject	Private property right?			Management Score
	Yes	Yes with restrictions	No	
M5	-	-	x	0.00
M3	-	-	x	1.00
M9	-	x	x	1.30
M4	-	-	x	1.73
M14	-	x	-	2.11
M15	x	x	-	2.88
M13	-	x	-	3.00
M6	x	-	-	3.21
M2	x	x	-	3.32
M8	-	x	-	3.40
M1	x	x	-	3.50
M7	x	x	-	4.00
M10	-	-	x	4.00
M11	x	-	-	4.00
M12	-	x	-	4.00
TOTAL	6	9	5	-

Table 10: Private property beliefs compared to management scores

The relationship between private property rights beliefs and management scores is not perfect – not all subjects who answered “yes” had a management score of 4.00, and not all those who answered “no” had a management score of 1.00. Many of these discrepancies can be explained by politics in an attempt to balance CRMC

regulations and the protection of private property. Nearly all subjects recognized that private property protection was a contentious enough issue that it deserved serious consideration, because it would be politically unacceptable to knowingly let so many structures fall into the ocean, even while acknowledging that most protective structures are not legal:

And of course there are the landowners...who are concerned that they're going to lose access to their property. That's a big investment for people. (Town Council member)

That's not right [to sacrifice the eight waterfront property owners] because these folks in front [waterfront] have been begging for help for years. (Town Council member)

The protection of private property was the factor that made subjects who wanted to suggest only retreat and relocation also offer ideas such as beach renourishment and sandbags in what they viewed as a compromise – protect the properties as much as possible without sacrificing the beach. These subjects were aware that sandbags and renourishment do not offer substantial protection to private properties, but this was their way of navigating the political process. One CRMC appointed council member said, “I am tentatively in support of much less permanent structures [like burritos], which would buy some time for those property owners without permanently altering the topography of the shoreline and doing permanent damage to the sandy beach.” The protection of private property is the heart of the issue in Matunuck, and is what the two opposing sides (CRMC versus South Kingstown residents and officials) are divided over.

While not all the variation in management scores can be explained by private property rights beliefs alone, these are the most important factor for subjects in the

Matunuck case as indicated by the number of subjects that cited private property protection as relevant in making their decisions. Private property rights are generally divided along the lines of the sovereignty and ecological cultural models discussed above; those that follow the sovereignty model believe structural shoreline should be a private property right and tend to have high management scores, and those that follow the ecological model do not believe that structural shoreline protection should be a property right and tend to have lower management scores. However, most management scores fall somewhere in the middle of the two extremes because many subjects realize that the most reasonable solution will be a compromise between the two cultural models, between the two opposing property rights beliefs, and between members of CRMC and South Kingstown residents and officials.

CHAPTER 7

CONCLUSION: SUMMARY OF FINDINGS AND RECOMMENDATIONS

Summary of Findings

The first research question was: With regard to *coastal geologic processes*, how do subjects' mental models compare to the expert model in terms of comprehensiveness and variance? The results of this question showed that no research subjects had very comprehensive models regarding coastal geological processes. Given this, property and business owners had the most comprehensive models of any group, and CRMC appointed council members had the least comprehensive models as a group. This is of interest because the appointed members of CRMC might be expected to have the most comprehensive mental models as they are statutorily charged with making binding decisions regarding the coastal resources of the state.

The findings for variance for mental models regarding coastal geologic processes demonstrate that the majority of research subjects shared a primary variation of the expert model: sediment is being removed from the system by the Harbor of Refuge and the Charlestown Breachway. While these two structures were addressed together, they have different implications for mental models analysis, which will be discussed further below. Variance also demonstrated that subjects were more likely to believe their own observations than information from a third party (such as CRMC) that was not consistent with these observations. Finally, property and business owners by far had the highest occurrence of variance, indicating that those that observe the beach regularly had the largest number of ideas that fell outside of the expert model. This was largely because subjects' observations led to conclusions different from

those in the expert model, because there were gaps in subjects' mental models that, if corrected, would allow these observations to be explained by the expert model.

The second research question was: With regard to the relevant aspects of *climate change*, how do subjects' mental models compare to the expert model in terms of comprehensiveness and variance? For comprehensiveness, CRMC appointed council members had the highest average score of all groups, however, the score was still not very high at 63%. It might be expected that CRMC appointed council members would have even higher scores because they are required by CRMC regulations to consider climate change in the decisions that they make.

Variance was high for both CRMC appointed council members and property/business owners. The most common variance concepts were that climate change is too far in the future to be considered today, and therefore is irrelevant for the Matunuck case. These subjects (including, interestingly, two thirds of CRMC subjects) are demonstrating the human tendency to think about the future hazards they face in terms of what they can comprehend based on experience, which is not inclusive of future circumstances. This problem is much greater than this case study itself; the battle over the reality of climate change and what should be done about it is a worldwide challenge. In the results from this study, nearly all coastal property owners choose to maximize short-term benefits without considering future climate change implications, and even a majority of coastal resources decision-makers believe that climate change should not be relevant when making decisions, which is in direct contradiction to the CRMC regulations they are supposed to follow.

Looking at subjects' mental models for climate change and geologic processes combined indicates that comprehensiveness scores are quite low overall. The highest "complete" full model score was 56%. Comprehensiveness scores were even lower for working models. This indicates that the information that subjects typically work with (because they have access to the additional information in the full model but do not tend to use this information) is even more limited, and therefore their decisions are made based on very limited understandings of the relevant natural science. Such low scores indicate that all subjects have major gaps in their comprehension of the climate change and geologic processes systems, and therefore do not fully understand the causes of the shoreline retreat, the effects of management options such as hard structures, or the implications of climate change. This suggests that it is unlikely that subjects have enough accurate information about these systems and their implications to be able to make good decisions.

Variance overall demonstrates where subjects have different understandings than the experts, either because their observations are inconsistent with the expert model, because there is disagreement among experts, or because experts have yet to be able to study every relevant concept and therefore cannot determine whether some variance concepts are right or wrong. Variance also offers insight into how subjects make sense of the science and causes behind the shoreline retreat that they observe in Matunuck, and consequently perhaps how they justify certain actions. Again, personal observations trump outside information if that information is not consistent with observations. Variance demonstrates where there is inaccurate or unexplored

information in mental models, whereas comprehensiveness demonstrates simply what is missing from mental models.

The third research question was: Can these mental models of coastal geologic processes and climate change be used to explain why subjects choose the management measures they see as most reasonable? In short, the answer to this question was no. There was no statistically significant relationship between comprehensiveness scores and management option scores; comprehensiveness scores were all relatively low, and most management scores fell between 3 and 4. It appeared that most subjects based their management choices on factors other than knowledge of the natural science of shoreline retreat and climate change, such as an interest in protecting private property and investments or public utilities. Subjects were essentially split into two cultural models: the sovereignty model, which emphasizes the rights of private property ownership and interests of citizens (generally municipal staff, town council, and property/business owners), and the ecological model, which emphasizes the interconnectedness of nature and society (generally CRMC appointed council members).

The final research question was: If mental models cannot explain the mitigation measures that subjects choose as most reasonable, what factors might explain these choices? A number of factors were identified by research subjects that influenced their decisions, but the protection of private property was the most common factor and was solely investigated. When comparing subjects' beliefs about private property rights (whether protecting coastal property by armoring should be a property right) to management option scores, a statistically significant relationship emerged:

those that believed coastal private property protection should be a property right were more likely to have a higher management option score, and those that did not believe this were more likely to have a lower management option score. This is consistent with what would be expected, because these opposing views on property rights are consistent with the two opposing cultural models: those in the sovereignty camp believe property rights should be accommodated above all else; those in the ecological camp believe nature should be accommodated regardless of property rights. For the purposes of this study, private property rights beliefs have more predictive power for management scores than mental model comprehensiveness, which suggests that values may be more important than scientific knowledge when stakeholders make coastal management decisions. However, unless further research is done in which mental model comprehensiveness scores become statistically significant, this cannot be confirmed.

Recommendations

The findings of the first two research questions most commonly lend themselves toward recommending further education to address gaps and inaccuracies in mental models. No statistical significance was found in the third research question, which could be the result of the low comprehensiveness scores or small sample size. Increasing comprehensiveness scores or sample size could result in statistically significant findings. Further research could be conducted to create such an education campaign and measure its effects, which could be done by offering educational materials to correct inaccuracies and fill in gaps in mental models, and then re-testing

for comprehensiveness and variance. In addition, the third research question in this study could be re-evaluated to see if subjects changed their management option scores or if a relationship between comprehensiveness and management scores emerged after the educational efforts. This educational effort could also be expanded to a larger population to increase the chances of finding statistical significance. In the absence of further research, an educational campaign could be undertaken by CRMC using what information is available from this study. To maximize participation, presenting the information at a joint work session between CRMC and the South Kingstown Town Council would be likely to reach a number of individuals of interest because typically those that are most involved in the Matunuck case participate in those meetings.

It is important that subjects have more comprehensive mental models and less variance compared to the expert model because the more accurate knowledge they have, the more likely they are to use that information to make good decisions. They do not have to have expert mental models because they are not experts in the field, but should have enough comprehension to allow for wise decision-making and use of the resource: “a mental model is not as complex as the system it represents, but to be useful must represent the main processes....an operator need only know enough to do the job” (Abel et al.,1998, p. 78).

In addition, when everyone has access to the same information and subjects’ mental models are compatible with one another, communication among groups can be enhanced (Abel et al., 1998 and Jones et al., 2011). “Although mental models approaches may not get conflicted groups to work together, they may identify where differences and similarities in their conceptualizations lie and then these can be used to

bring about better collaboration and enhance collective decision making” (Du Toit, 2011, p.25). According to the literature, the more compatible the mental models, the more likely a group with opposing views will be to cooperate and reach an agreeable decision (Abel et al., 1998, Jones et al., 2011). “To encourage people with contrasting views to work together, it is necessary to identify and support a shared understanding among relevant stakeholders” (Jones et al., 2011, p.49).

In order for education to be effective when addressing mental models, it must be presented in a manner that is compatible with existing mental models, because “information which does not reinforce [existing models] may be rejected” (Abel et al., 1998, p.86; see also Jones et al. 2011, p.50; Morgan et al., 2002). This means the comprehensiveness and variance of the existing models must be understood; Thompson (2004, p.145) states that “unless one understands how someone else conceptualizes a system, one cannot...successfully design educational materials”, and Jones et al. (2011, p.50) assume “that addressing the limitations and critical flaws in mental models can improve system functionality”. In some cases new information must correct existing inaccuracies, which must be done in a way that makes sense to the subject, or else the subject will disregard it and cling to the faulty information that makes sense to him or her; the same is true for incorporating subjects’ observations (Jones et al., 2011; Abel et al., 1998; and Morgan et al., 2002). As Abel et al. (1998) write in regard to effective education, “the art of communication is to find a metaphor that is better suited to the mental model of the audience, while remaining an effective analogy of the process it attempts to represent”.

For example, a widespread misunderstanding among research subjects is the idea that the Harbor of Refuge is taking sediment out of the system. This should be corrected to enhance understanding and communication between CRMC and other parties, and can be accomplished through educational materials that are designed to specifically address this misunderstanding. These materials must explain specifically why the Harbor of Refuge cannot be related to the shoreline retreat in Matunuck in a way that addresses subjects' observations and is consistent with their existing models. Subjects believe in part that the Harbor of Refuge is affecting shoreline retreat in Matunuck because they observe sediment moving east to west rather than west to east, and think the Harbor is blocking sediment from reaching Matunuck. Therefore it should be explained that there is a small cell in which sediment does move east to west, but that that cell does not run the length of the entire coastline, nor would it have moved sediment from Point Judith to Matunuck if the Harbor of Refuge had not been built. Although "replacing faulty mental models...can be difficult because people can tenaciously cling to them" (Thompson, 2004, p.145), it can be accomplished if new information is presented in the right way.

A follow-up to creating an education campaign is expanding the expert model where possible to include accurate local knowledge. This would require taking a closer look at aspects of variance of subjects' mental models to see if it is possible that they might be correct, and if so, incorporating them into the expert model. (If it is not correct, it should be addressed in the educational efforts discussed above.) For example, many property/business owners commented that the Charlestown Breachway is taking sediment out of the system that would otherwise reach Matunuck. This is

possible, but is not addressed in the expert model. If local knowledge is correct, it should be incorporated into the expert model to provide a more accurate model overall and enhance communication (Abel et al., 1998; Ozesmi and Ozesmi 2004). “We argue that merging the models of [different groups] can enrich separate models, enhance communication among the groups, and improve management” (Abel et al., 1998, p.79).

The final recommendation, with regard to the final research question, is that further research be conducted on the relationship between private property rights and mental model comprehensiveness. Although it was investigated in this study, the lack of statistical significance may have been (and likely was) the result of a small sample size; this can only be verified by conducting further research with a larger sample size. Ideally this would take place in concert with the educational research suggested above, so that property rights beliefs before and after these educational efforts can be measured along with any changes in comprehensiveness. Based on the public beliefs of the experts whose work was used in creating the expert model for this study, there is reason to believe there is a relationship between comprehensiveness and private property rights, but as of now there is no way to tell if that is a relationship exclusive to experts or if it could be expanded to laypeople. If there is a relationship between mental model comprehensiveness and property rights beliefs, it is possible that increased education (increasing mental model comprehensiveness) could increase the general public’s acceptance of coastal management practices that, although they may infringe on what some people see as private property rights, are intended to protect the public and allow for adaptation to future conditions.

APPENDIX A

DATA TABLES

Affiliation	Working Model	Full Model	Full Model Range
CRMC	26%	29%	21%
Municipal Staff	31%	40%	30%
Property/Business Owners	35%	42%	27%
Town Council	27%	34%	39%

Table 1: Geologic processes comprehensiveness scores by affiliation

Affiliation	Working Model	Full Model	Full Model Range
CRMC	50%	63%	70%
Municipal Staff	30%	45%	30%
Property/Business Owners	33%	42%	50%
Town Council	33%	43%	30%

Table 2: Climate change comprehensiveness scores by affiliation

Affiliation	Working Model	Full Model	Full Model Range
CRMC	30%	35%	30%
Municipal Staff	31%	35%	28%
Property/Business Owners	35%	42%	21%
Town Council	28%	41%	30%

Table 3: Combined geologic processes and climate change comprehensiveness scores by affiliation (“Complete” Models)

Subject	Working Model Comprehensiveness	% Prompted	Full Model Comprehensiveness
M1	41%	11%	52%
M2	46%	7%	54%
M3	17%	4%	20%
M4	48%	2%	50%
M5	26%	9%	35%
M6	39%	4%	43%
M7	30%	6%	35%
M8	24%	9%	33%
M9	28%	7%	35%
M10	44%	11%	56%
M11	17%	9%	26%
M12	17%	7%	24%
M13	15%	9%	24%
M14	33%	7%	41%
M15	46%	6%	52%

Table 4: Working model comprehensiveness, percent prompted, and full model comprehensiveness scores by subject

	CRMC	Municipal Staff	Property/ Business Owners	Town Council	TOTAL
CLIMATE CHANGE FACTORS					
erosion is not related to climate change	0	0	2	0	2
climate change is a long term problem	2	1	5	0	8
climate change is not important for Matunuck	1	0	4	0	5
SHORELINE RETREAT FACTORS					
longshore transport moves east to west	0	1	4	0	5
proposed seawall wouldn't affect downstream	0	0	1	1	2
erosion caused by Harbor of Refuge and Charlestown Breachway	1	0	6	4	11
erosion not caused by walls	0	0	1	0	1
erosion is related to seaweed loss from trawling	0	0	0	2	2
visible offshore sandbars should be dredged	0	1	2	0	3
storms (primarily tropical) bring in sand	1	0	6	2	9
TOTAL	7	4	37	12	

Table 5: Variance factors by number of subjects that mentioned each factor, by affiliation

Subject	Working Model Comp.	Full Model Comp.	Management Option Score	Management Option Choice(s)
M1	41%	52%	3.50	experimental mechanisms, seawall
M2	46%	54%	3.32	seawall, beach replenishment, breakwater, elevation, experimental mechanisms, riprap seawall
M3	17%	20%	1.00	improve the road, retreat
M4	48%	50%	1.73	burritos or sandbags, experimental mechanisms, move the road, remove existing walls, retreat
M5	26%	35%	-	none
M6	39%	43%	3.21	beach replenishment, experimental mechanisms, seawall
M7	30%	35%	4.00	seawall
M8	24%	33%	3.40	beach replenishment, experimental mechanisms, seawall
M9	28%	35%	1.30	move the road, plant dune grass, remove existing walls
M10	44%	56%	4.00	steel sheet pile wall
M11	17%	26%	4.00	steel sheet pile wall
M12	17%	24%	4.00	steel sheet pile wall
M13	15%	24%	3.00	experimental mechanisms
M14	33%	41%	2.11	beach replenishment, burritos or sandbags, move the road, retreat, seawall, steel sheet pile wall
M15	46%	52%	2.88	beach replenishment, burritos or sandbags, experimental mechanisms, seawall, riprap seawall, steel sheet pile wall

Table 6: Management option scores and choices compared to comprehensiveness

Factors in choosing best management option	CRMC n = 3	Municipal Staff n = 2	Property or Business Owners n = 6	Town Council n = 4	Mean
protect private properties	67	100	100	100	92
protect commercial businesses	33	100	50	33	54
economic or employment value (businesses)	33	100	83	67	71
community character	67	50	67	67	63
public road protection	67	100	50	67	71
public beach access	33	50	33	0	29
acting together to get best results, share costs, have more influence	0	50	67	33	38
avoid displacing the problem to the nearby areas	67	100	17	67	63
avoid interfering with natural system	33	100	33	0	42
cost	67	100	100	50	79
funding sources	67	50	100	50	67
longevity of potential solution	67	100	67	67	75

Table 8: Percent of subjects that mentioned each factor, by affiliation

Subject	Private property right?			Mental Model Comprehensiveness
	Yes	Yes with restrictions	No	
M3	-	-	x	20%
M12	-	x	-	24%
M13	-	x	-	24%
M11	x	-	-	26%
M8	-	x	-	33%
M5	-	-	x	35%
M7	x	x	-	35%
M9	-	x	x	35%
M14	-	x	-	41%
M6	x	-	-	43%
M4	-	-	x	50%
M1	x	x	-	52%
M15	x	x	-	52%
M2	x	x	-	54%
M10	-	-	x	56%
TOTAL	6	9	5	-

Table 9: Private property rights beliefs compared to comprehensiveness

APPENDIX B

EXPERT MODEL CODEBOOK AND SUBJECT MODELS

0 = the subject did not mention the concept, 1 = the subject mentioned the concept

EXPERT MODEL NODE	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M 10	M 11	M 12	M 13	M 14	M 15
1 : climate change	0	1	1	1	0	1	1	0	0	1	1	0	1	1	1
2 : storm surge retreat will cause more damage	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
3 : storms will reach further inland	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
4 : storms unprompted	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0
5 : negative effects on structures	1	0	0	1	1	0	0	0	1	1	0	0	0	0	0
6 : erosion and climate change	0	1	0	1	1	0	1	0	1	0	0	1	0	1	0
7 : make erosion worse	0	0	0	1	1	1	1	0	0	0	0	1	0	1	0
8 : sea level rise important in Matunuck	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1
9 : disruption of longshore transport unprompted	0	1	0	1	0	0	1	1	0	1	0	0	0	1	1
10 : impacts of hard structures	1	1	0	1	0	1	1	0	0	0	0	0	1	0	1
11 : transferring erosion to neighboring properties	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
12 : loss of beach in front of structures prompted	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0
13 : loss of beach in front of structures	1	1	0	1	1	0	0	0	1	1	1	0	0	0	0
14 : increased energy of waves in front of structure	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
15 : steepening of shoreface seaward of structure	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0

17 : locking sediment behind structures	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 : failure of edges and base of wall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 : dynamic system	0	1	1	1	0	1	1	1	1	1	1	1	0	1	1
20 : coastal processes	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
21 : longshore transport	1	1	0	1	1	0	0	1	0	1	0	0	0	0	1
22 : direction of transport	1	1	0	0	0	0	1	1	0	1	1	0	0	0	1
23 : both east and west	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
24 : west to east	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
25 : sand sources	1	1	1	0	0	1	0	0	0	1	0	0	0	1	1
26 : erosion	0	1	1	1	0	1	0	0	0	0	1	0	0	0	1
27 : visible sandbars	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0
28 : offshore deposits are beyond return depth	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0
29 : storm tracks	1	1	0	0	0	1	1	0	1	1	0	0	1	1	1
30 : storms to the west cause more damage	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
31 : fetch	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
32 : destructive storm waves	1	0	0	0	1	0	0	1	0	1	0	1	0	0	0
33 : wind	1	1	1	0	1	1	0	1	1	1	0	1	0	1	1
34 : waves	1	0	0	1	1	1	0	1	0	1	1	1	0	0	0
35 : tropical storms	1	1	0	0	0	1	0	1	0	1	0	0	1	1	1
36 : winds from south or southeast are worst	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1
37 : extratropical storms cause more erosion than tropical	1	1	0	0	0	1	1	1	1	1	1	0	0	1	1
38 : duration and storm surge	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0
39 : extra-tropical storms	1	1	0	0	0	1	1	1	1	1	1	0	0	1	1
40 : wave period	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
41 : storm surge	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
42 : beach migration	0	0	1	1	1	1	1	0	0	1	0	0	0	0	1

43 : tides	0	1	1	0	1	1	0	1	1	0	0	0	1	1	0
44 : high tide and storm surge makes erosion worse	0	1	0	0	1	1	0	0	1	0	0	0	1	1	0
45 : importance of healthy dunes	0	0	0	1	0	1	0	0	1	0	0	0	0	0	1
46 : storms general	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1
47 : storm type prompted	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
48 : caused by walls on either end	1	1	0	1	1	1	1	1	1	0	1	1	1	0	1
49 : shoreline composition	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1
50 : sand does not return during winter	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
51 : sand returns during calm summer weather	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1
52 : impact of beach development	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
53 : rip currents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54 : impacts on structures	1	0	0	1	1	1	1	0	1	1	0	1	0	1	0
55 : sea level rise	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TOTAL	28	29	11	27	19	23	19	18	19	30	14	13	13	22	28
COMPREHENSIVENESS SCORE (%)	52	54	20	50	35	43	35	33	35	56	26	24	24	41	52

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