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Cooperative Agreement: M14AC00011 University of Rhode Island
Identification of Sand/Gravel Resources in Rhode Island Waters While working Toward a Better Understanding of Storm Impacts on Sediment Budgets

Deliverable E:
FINAL FINDINGS REPORT

Estimating Necessary Volumes of Sand for Beach Replenishment Along the Rhode Island South Shore: Data from the Rhode Island Shoreline Change Special Area Management Plan ("BeachSAMP")

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*** Note:** The project team was deeply saddened by the loss of Co-PI Dr. Jon C. Boothroyd, who passed away unexpectedly before the conclusion of this project. Dr. Bryan Oakley, a former PhD student and close colleague of Boothroyd's, assumed his responsibilities on this project.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The Rhode Island Coastal Resources Management Council (CRMC), the University of Rhode Island Coastal Resources Center, and Rhode Island Sea Grant are currently undertaking a multidisciplinary science-based coastal management project known as the Shoreline Change Special Area Management Plan, (aka The "Beach SAMP"). The main goals of the Beach SAMP are to gather new data on impacts of sea level rise, storm surge and coastal erosion, provide educational outreach to the public and municipalities, create a policy framework for dealing with shoreline change, and develop tools and best practices to deal with shoreline change in Rhode Island. As part of the evaluation of best practices to mitigate the impacts of shoreline change, estimations of the sediment volume needed to replenish beaches along the Rhode Island south shore were calculated.

2. METHODS

The volume of sand needed to replenish the beaches along the Rhode Island south shore was calculated as a simple volume of sand yd^3 (m^3) per yard (meter) of shoreline length. While the entire shoreline between Napatree Point and Point Judith (Figure 1) encompasses approximately 24 miles (38 km) of linear shoreline, the undeveloped barriers (Napatree, Mashaug, Quonochontaug, East Beach, Quonochontaug and Moonstone [(9 miles) (14.5 km)] were excluded from the volume calculations in this report. Under the current coastal regulations and property ownership, these barriers will remain undeveloped in the near future, and natural processes should be allowed continue to operate on these barriers without replenishment. The till boulder and discontinuous bedrock headlands, [(3.4 miles) (5.5 km)] (Weekapaug, Green Hill, Point Judith and portions of Watch Hill and Quonochontaug) were also excluded. Additionally, while not part of the Rhode Island south shore, Scarborough State Beach [(3.4 miles) (1.5 km)] and the portion of the Narragansett Barrier that encompasses Narragansett Town Beach [(0.6 miles) (1 km)] were included in this analysis as beaches possibly replenished in the future. Taken together, this represents potentially replenished shoreline length of approximately 12.4 miles (20 km).

Various levels of replenishment, ranging from small-sale replenishment (widening the berm with no significant additions to the foredune/dike), to large-scale projects (constructing dikes and significant berm widening) were considered. The small-scale, berm only replenishment was based on the average alongshore volume of sand placed on Misquamicut State Beach in May 2014 ([85 yd^3 yd^{-1}] [65 m^3 m^{-1}]). Large-scale replenishment was considered as significant widening of the berm and enlargement of the foredune/dike, similar to the model presented for Mantoloking, NJ (USACE, 2013b), and represents an increase in 400 yd^3 yd^{-1} (305 m^3 m^{-1}). A 'moderate' scale replenishment volume with an arbitrary volume of 200 yd^3 yd^{-1} (150 m^3 m^{-1}) was included in the subsequent calculations.

Project cost was estimated based on the two possible sources of sediment using recent local and regional projects, and were averaged as a 'total cost' (i.e. the project cost/volume of sand). The cost for upland sources was based on the 2014 replenishment of Misquamicut State Beach \$36 yd^{-3} (\$47 m^{-3}). Costs for offshore sources of replenishment sand vary from \$5 to \$15 yd^{-3} (\$6.5 to \$20 m^{-3}) (Kana, 2012). Recent projects in New Jersey utilizing offshore sources have averaged \$12 to 15 yd^{-3} (\$16 to \$20 m^{-3}) (Keiser, 2009). The cost for offshore sources was assumed to be \$15 yd^{-3} (\$20 m^{-3}) for this report.

3. RESULTS

The small scale, berm-only level of replenishment extrapolated over the 12.4 mi (20 km) of shoreline likely to be replenishment requires 1,700,335 yd^3 (1,300,000 m^3) of sand. Large-scale replenishment would require 7,978,495 yd^3 (6,100,000 m^3) of sand for the same area. Estimated costs vary depending on sediment source and cost per yard; for upland sources, the total cost range from $61,100,000 to $287,000,000 for small-scale or large-scale replenishment respectively. Total estimated costs range from $26,000,000 to $122,000,000 utilizing offshore sources of sand. Table 1 summarizes the alongshore-average volume, total volume and assumed cost for the three replenishment scenarios. We used these estimates to formulate a preliminary hypothesis that the target areas identified off the southwest coast of Rhode Island (Figure 1) contain enough sand to meet Rhode Island's beach replenishment needs. However, additional geophysical surveying, geotechnical sampling, and refined volume calculations are required to test this hypothesis, and will be conducted in Phase II of this project.

Table 1: *Average replenishment volume, total sand volume and estimated project costs for the three replenishment scenarios.*

Scenario	Average Replenishment Volume yd^3 yd^{-1} (m^3 m^{-1})	Total Volume (yd^3)	Total Volume (m^3)	Cost (upland source; $36 yd^{-3} ($47 m^{-3}))	Cost (offshore source; ($15 yd^{-3}) ($20 m^{-3}))
Low	85 (65)	1,700,335	1,300,000	$61,100,000	$26,000,000
Moderate	200 (150)	3,923,850	3,000,000	$141,000,000	$60,000,000
High	400 (305)	7,978,495	6,100,000	$286,700,000	$122,000,000

4. DISCUSSION

Nationally, beach replenishment has been conducted most extensively along barrier islands and spits along the Mid-Atlantic and southern East Coast of the United States, with total replenishment volumes an order of magnitude larger than New England shorelines (Trembanis, 1999). Replenishment remains the most common mitigation technique in response to coastal storms and subsequent erosion (Trembanis et al., 1999). Replenishment is widely viewed as the most effective response to maintaining the shoreline in response to accelerating sea level rise (ASBPA, 2012; Houston, 2016). Despite this widespread view, the effectiveness of replenishment in a period of accelerating sea level rise and the potential for increased storminess remains in question, and is a subject of much debate within the scientific literature. A full discussion of this debate is outside the scope of this document. Briefly, Houston (2016) ascertains that replenishment can continue to maintain beaches (on the east coast of Florida) through the end of the century under most sea-level rise scenarios. These assumptions are based on the 'Bruun Rule' (Bruun, 1962), which itself is controversial (i.e. Cooper and Pilkey, 2004). Leonard et al., (1990) conclude that replenished beaches erode 1.5 to 12 times faster than non-replenished beaches, and while widely cited, this is also controversial (Houston, 1990; Houston, 1991; Pilkey and Leonard, 1990, 1991). However, many replenishment projects lack proper monitoring to evaluate the long-term erosion rate and lifetime of the project (Pilkey, 1990; Marine Board, 1995) and this monitoring remains a vital aspect of any future replenishment projects.

While common elsewhere, replenishment at a large scale has been rare in Rhode Island, with most projects placing a volume < 1,000 yd^3 (800 m^3) (Haddad and Pilkey, 1998). Replenishment will likely become a more common practice as shoreline change continues to affect developed shorelines. The USACE replenished a 1 km long segment of the Misquamicut Barrier (Misquamicut State Beach) in May 2014. This project entailed a nominal volume of 86,000 yd^3 (65,000 m^3) (USACE, 2013a) and represents the largest direct placement replenishment project in Rhode Island within the last several decades (a similar volume of sediment was added to the Matunuck, RI (Figure 1) shoreface in 2007 as beneficial reuse from a nearby dredging project). Misquamicut was also replenished following Hurricane Carol (1954), with approximately 80,000 yd^3 (60,000 m^3) placed in 1960 (Dixon and Pilkey, 1998). On-going monitoring of the Misquamicut replenishment project suggests that as of March, 2015, 35% of the added volume has been removed from the beach (Oakley et al, 2015, 2016). The high cost of the recent project on Misquamicut (3.1 million dollars; \$36 yd^{-3} (\$47 m^{-3}) was due to the sediment source (upland glacial stratified deposits). With the exception of beneficial reuse of sediment dredged from tidal inlets and tidal deltas, offshore sources have not been utilized in RI. Because of the high cost and increasingly limited availability of upland sources, any consideration of future large-scale replenishment projects as a response to storm-driven shoreline change and sea level rise will require the identification of feasible offshore sediment sources.

Local variation in shoreline configuration and modification of the profile by anthropogenic activities (infrastructure, sand fencing, dikes etc.) would result in each segment of the shoreline having a different design profile, however the volume of sand needed to replenish the profile either at the berm-only scale or at a larger scale would be similar along the various segments of the Rhode Island shoreline. While each beach has associated shape and morphology which is a function of grain size and wave height (Bascom, 1951), it was assumed in this report that the same volume would be spread evenly alongshore. Comparing the design profile for Mantoloking, NJ (USACE, 2013b) to the profile configuration at Misquamicut State Beach (Figure 3) and Narragansett Town Beach (Figure 4) gives some context for what a large-scale replenishment project would look on two different profile configurations along the Rhode Island shoreline.

The volumes presented here 7,978,495 yd^3 (6,100,000 m^3) are similar to the volumes being replenished for other shorelines in the northeastern United States. Along the 13.7 mi (21 km) segment of the New Jersey shoreline between Manasquan Inlet and the northern end of Island Beach State Park, a total of 10,700,000 yd^3 (8,200,000 m^3), and on Long Beach Island (18 mi; 29 km) total volume of 11,000.000 yd^3 (8,400,000 m^3) will be placed (NJDEP, 2016). It should be noted that the projects in New Jersey each have scheduled maintenance cycle of approximately 2,000,000 yd^3 (1,500,000 m^3) every seven years, to be maintained until 2065 (NJDEP, 2016). A similar maintenance schedule in Rhode Island would require identification of an additional 14,000,000 yd^3 (10,500,000 m^3) of sand.

Total costs of replenishment presented here are based on recent local and regional projects. Similar costs to the 2014 Misquamicut State Beach replenishment project for future upland sourced replenishment remains a valid cost estimate, given the likely distance between upland (glacial) sources of sand and replenished beaches along the south shore. The estimate for offshore sources of sand are at the upper end of recent projects [(\$15 yd^{-3}) (\$20 m^{-3})], however, given the lack of established offshore sources at similar distances offshore and lack of project precedent in Rhode Island, it is felt this is a fair assumption. This analysis omits mobilization costs that have ranged between \$3 - 5 million on recent projects (J. Waldner, personal communication, August 2016). Mobilization costs would be mitigated either by bundling and building several smaller projects within a region, or by undertaking larger projects.

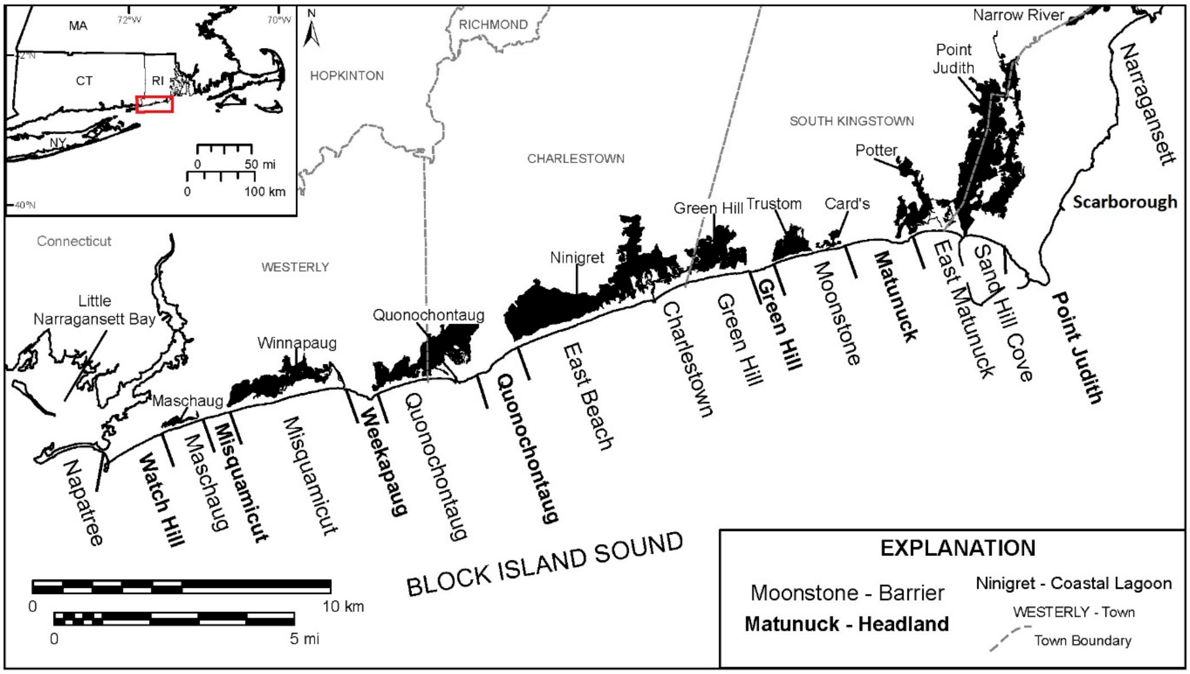

Figure 1. Barriers and headlands of the Rhode Island South Shore (modified from Boothroyd et al., 1998).

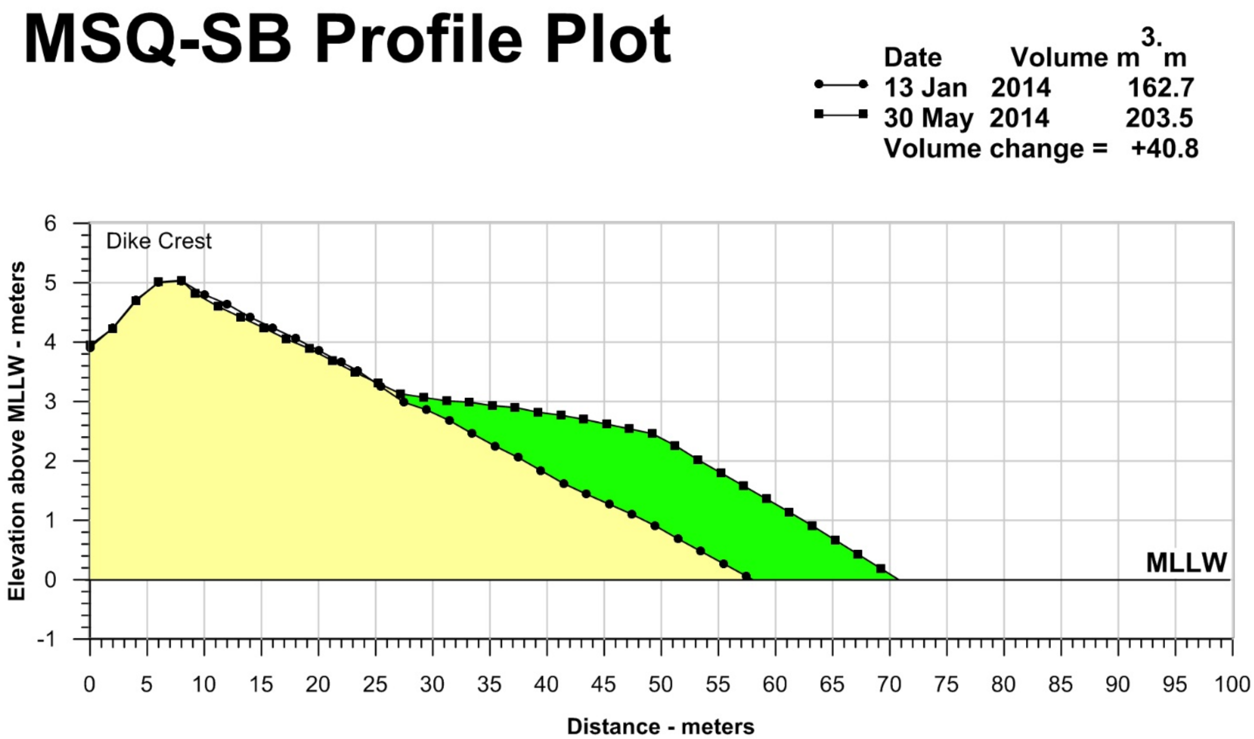

Figure 2. Measured profile for Misquamicut State Beach prior to (13 Jan 2014) and immediately following beach replenishment (30 May 2014). Green filled area represents the replenished volume at this profile. This volume/configuration is the basis for the small-scale replenishment (Table 1).

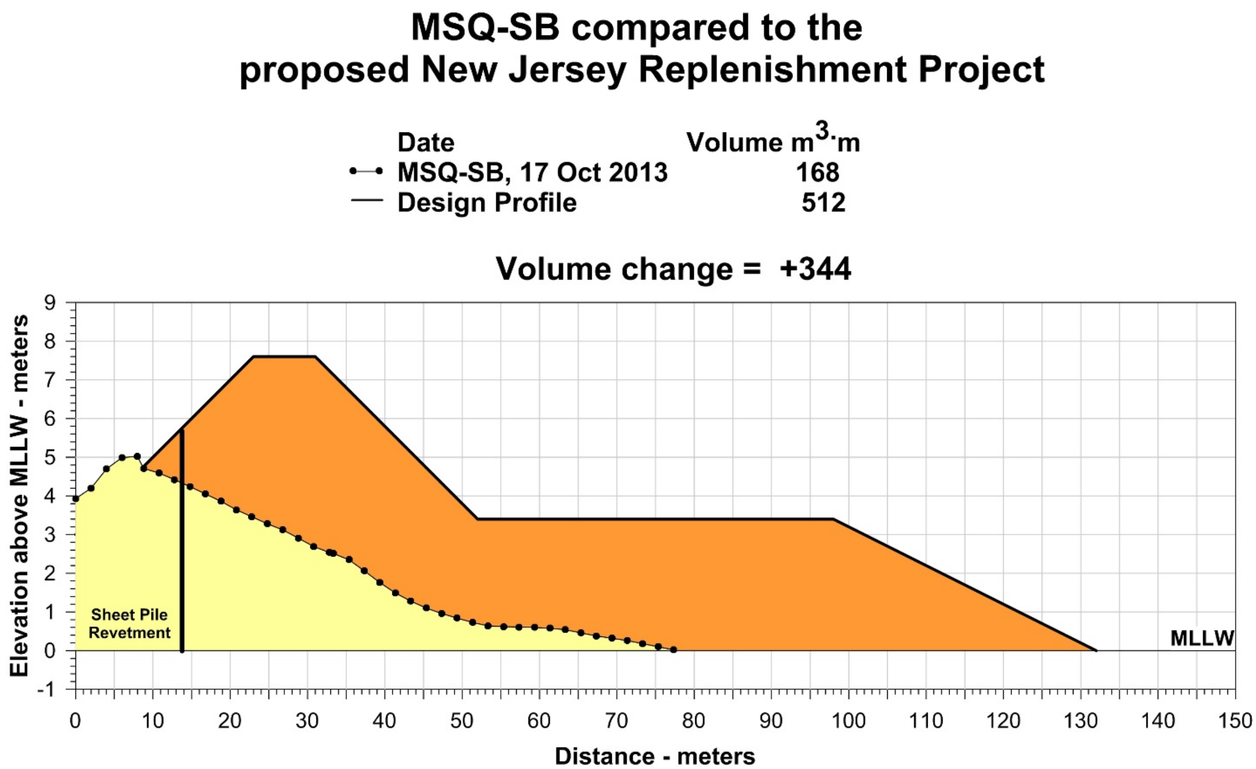

Figure 3. Pre-replenishment (2013) profile at Misquamicut State Beach plotted against a profile design (with sheet pile revetment) for Mantoloking, NJ (USACE, 2013b). The net increase in profile volume here is 344 m^3 m^{-1}. This volume/configuration is the basis for the large-scale replenishment (Table 1).

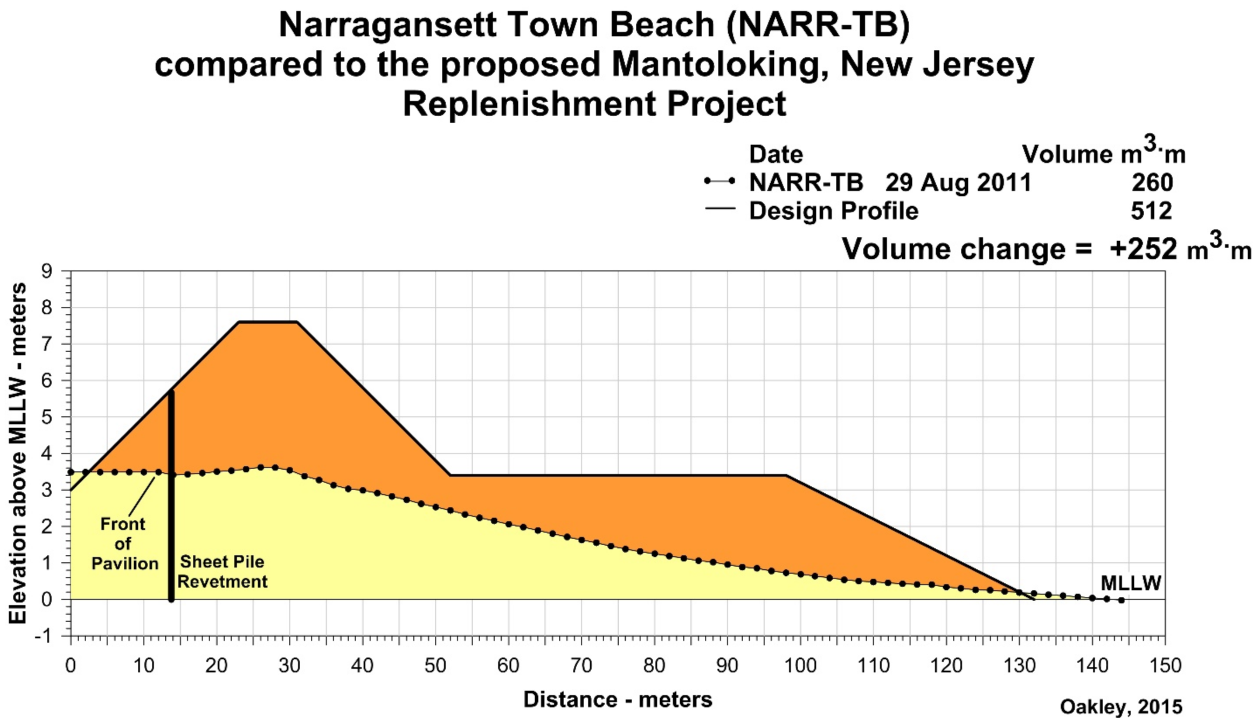

Figure 4. Pre-replenishment (2013) profile at Narragansett Town Beach plotted against the design profile (with sheet pile revetment) for Mantoloking, NJ (USACE, 2013b). The net increase in profile volume here is 252 m^3 m^{-1}. This volume/configuration is the basis for the large-scale replenishment (Table 1).

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