

Nantasket Beach
Hull, Massachusetts
Economic Analysis
July 2013

INTRODUCTION

This report presents the economic analysis for coastal storm damage reduction benefits at Nantasket Beach in Hull, Massachusetts. Four plans that reduce the damages caused by hurricanes and storms at Nantasket Beach are evaluated. For each alternative a benefit-cost ratio is determined by dividing annual benefits by annual costs. An alternative is considered economically feasible if the benefit-cost ratio exceeds or is equal to one. A benefit-cost ratio greater than or equal to one-to-one is required for Federal involvement in coastal storm reduction projects.

METHODOLOGY

Economic benefits are based on damages prevented by the project for different storm events. A stage damage function was developed to correlate damages with still-water flood elevations of each coastal storm event. The damages prevented by each level of protection provide the benefit for each alternative. The benefits and costs were then annualized using a CRF (Capital Recovery Factor) of 0.00457 based on the FY 2013 interest rate of 3.75% for a 50 year project life. The cost benefit analysis follows guidance from ER 1105-2-100, Appendix E, Section IV.

STUDY AREA

Nantasket Beach is located in Hull, Massachusetts, in Plymouth County. It is designated as a barrier beach by the Massachusetts Office of Coastal Zone Management (CZM). The town of Hull is approximately 12 miles southeast of Boston, Massachusetts and approximately four miles south of the entrance to Boston Harbor. The beach is within the MA Dept. of Conservation and Recreation (DCR) Nantasket Beach Reservation, and is bordered by commercial and residential areas along the backshore. DCR Reservations are regional park systems that protect land and water resources and preserve the natural and cultural resource legacies of an area while providing recreational opportunities. The DCR Reservation for Nantasket Beach extends from its southern limit at Atlantic Hill, north to Phipps Street for a total of 6,800 feet. Currently the DCR (formerly the Metropolitan District Commission-MDC) maintains a 5,400 foot seawall and backshore facilities, including a pavilion, a bath house and parking areas. The seawall was constructed in stages from 1915 through 1938. Over time, sand has eroded from the beach, exposing and undermining the footings of the seawall over most of its length.

The study area was originally divided into three hydrological zones spanning 6,800 feet from Phipps Street to Atlantic Hill as illustrated in Figure 1 below. Since the original 1992 analysis, storms at Nantasket Beach have caused significant property damage to

areas behind the beach and the subsequent flood protection measures put in place by the DCR have reduced the current scope of the project to include only Zone 2.

Figure 1 Nantasket Beach Zone 2 Study Area located between the North Revetment and the Temporary Seawall Fortification (TSF)



The storm of record for Nantasket is the blizzard of 1978. This storm was characterized as having a 0.01 (100-year) probability of recurrence. Total damages in the town of Hull that were covered by the flood insurance program (FIP) amounted to more than \$7 million dollars. Additionally, the Federal Disaster Assistance Administration (FDAA) funding to Hull as a result of the storm amounted to approximately \$3.0 million dollars.

The 2002 economic analysis states that local officials estimated the damages due to flooding in the study area were approximately 3% of total insurance claims, or \$300,000. This is approximately \$410,000 in 2013 dollars as updated by the average Construction Cost Index and Implicit Price Deflator.

While the Blizzard of 1978 remains the most damaging storm event to date, the town of Hull has experienced 17 additional natural hazards that have triggered federal or state disaster declarations since 1991. The majority of these events involved flooding. Over the last 20 years the Town of Hull has received funding from FEMA for five mitigation projects under the Hazard Mitigation Grant Program (HMGP) and the Flood Mitigation Assistance Program (FMA).ⁱ Two storms in particular caused substantial damage to the seawall located within the study area.

The storm of October 31, 1991 damaged the seawall, beach access stairways, and ramps. This storm event was estimated to have a 0.06 (17-year) probability of recurrence and damages in the town of Hull that were covered by the flood insurance program (FIP) amounted to more than \$5.6 million dollars. Federal Disaster Assistance Administration (FDAA) funding to Hull as a result of the storm amounted to approximately \$583,300 dollars. Approximately 6 feet of sand was lost during the storm; exposing footings and rendering the wall susceptible to future damage. The deteriorated condition prompted the DCR to close the damaged ramps and stairways, limiting public access to and from the beach.

In the coastal storm of December 11 to 13, 1992, an event estimated to have a 0.10 (10-year) recurrence probability; the wall either failed or was considerably weakened for a length of approximately 650 feet at its northern end. Total damages in the town of Hull that were covered by the flood insurance program amounted to more than \$1.5 million dollars. FDAA funding to Hull as a result of the storm amounted to \$46,353.

Storm damages that were covered by the Federal flood insurance program (FIP) for the three major storms are shown in Table 1 below. A comparison of the Zone 2 damage amounts to the total FIP claims data indicates that the majority of damages were incurred outside the study area. A total of 65 structures in Zone 2 are within the reach of the 100 year flood plain. There were only 10 structures in Zone 2 that submitted claims from the 1978 event, indicating the majority of homeowners do not avail themselves of the Federal Flood Insurance program. The number of claims rose to 12 in 1991 even though still-water elevations were lower than in 1978. This may be because the Blizzard of 1978 induced additional enrollment in the flood insurance program.

Table 1 - Damage Claims made through the Federal Insurance Program

| STORM EVENT | 1978 | 1991 | 1992 |
|-------------------------------------|-------------|-------------|-------------|
| Damage Claims Made for Town of Hull | \$7,121,216 | \$5,666,900 | \$1,512,201 |
| Damage Claims Made in Zone 2 | \$108,707 | \$76,919 | \$15,904 |
| Number of Covered Structures | 10 | 12 | 2 |
| Damage per Structure | \$10,871 | \$6,410 | \$7,952 |
| Damage per Structure (2012 \$) | \$18,041 | \$10,638 | \$13,197 |

Following more recent and severe coastal storm events in December of 2003, New England District staff inspected the wall and subsequently performed a stability analysis based on three failure criteria; overturning, sliding and bearing capacity. The analysis concluded the seawall was unstable in all three reaches but the southernmost reach warranted a higher level of concern than the remaining length. The results of the stability analysis are documented in a letter from the Corps to the MA DCR dated February 18, 2004.

As a result of the stability study, MA DCR stabilized the southernmost 2,200 feet of existing wall by constructing a stone revetment in front of the wall in Zone 3 known as the Temporary Seawall Fortification (TSF). The TSF was put in place in 2004 as an emergency action in response to beach erosion that had reached a point where no dry beach in front of the sea wall existed at high tide. In Zone 1 at the northern end of the study area, MA DCR has replaced a failed wall segment by building the Northern Revetment. Plans for Corps projects in Zones 1 and 3 are no longer being considered due to the changes made by MA DCR. The current study focuses on Zone 2; the 2,200 foot length in the center of Nantasket Beach located between the north end of Bay Street (Water Street) and Wharf Avenue.

EXISTING CONDITIONS

The existing seawall in Zone 2 was constructed of concrete revetment sections which relied on the existing beach to provide scour protection. No toe stone was included in the original design because the width and height of the beach at that time was adequate to protect the structure from undermining due to erosion. The seawall relied on the existing beach to aid in protection against wave action and storm surge. Existing conditions have eroded the beach to the point that it is no longer wide enough to prevent undermining of the wall. Portions of the existing structure have exposed footings and steel rebar and are subject to failure during relatively frequent storm events. Photos showing portions of the damaged wall are presented in Figure 2 below. The erosion of the beach and the sea wall damage has increased the risk of wall failure during coastal storms causing flooding of properties in the back shore.

Figure 2 –Damaged Seawall Sections



WITHOUT PROJECT CONDITIONS

The probability of failure of the seawall at Nantasket Beach was investigated using data derived from computer analyses of the beach elevations (SBEACH) during post-storm event scenarios coupled with stability analyses of the wall in reference to sliding, overturning, and bearing capacity. The results of the stability analysis are detailed in a Memorandum for the Record dated 11 July 2007. Based on the existing damaged conditions of the wall and the history of wall overturning, as seen in Figure 3 below, this economic analysis assumes a 100% probability of wall failure in the project base year because the current beach does not meet the original design requirements and the beach is only expected to degrade further over time. Failure of the wall would provide no residual protection and would expose back shore properties to flood risk.

Figure 3 Collapsed Wall Section



There are currently 34 commercial structures and 31 residential structures within the FEMA-designated 100-year flood plain that would experience flood damage in the event of a seawall failure at Zone 2.

BENEFIT ANALYSIS

Inundation damages were developed for each property using a typical stage damage function for residential, commercial and institutional structures. The stage or elevation at which flood damage begins is at the ground elevation for each property. Estimates of potential damages were made in one foot increments of stage, to a level six feet above the first floor. Dollar value estimates were made for physical damages to site, structure, contents and utilities. Seepage through the bottom of the foundation was not assumed as the start of damage. First floor and ground elevations were measured by Corps survey crews.

The feasibility study considers benefits for four alternatives. The first two alternatives are for stone revetment to protect the existing seawall against storm events having a 0.1 and 0.04 probability of recurrence (the 10- and 25-year return interval). The third and fourth alternatives are for beach renourishment that would create a beach profile able to withstand storm events having a 0.1 and 0.04 probability of recurrence (the 10- and 25-year return interval).

STONE REVETMENT ALTERNATIVES

Stone revetment placed at the toe of the existing wall would prevent wall collapse due to undermining during storm events. Based on the existing wall conditions and the high probability of failure, estimated annual damages of \$1,408,100 would be incurred from flood water flowing over the collapsed wall and reaching the backshore properties. Most, but not all of these damages would be prevented if the seawall remains standing due to revetment placed in front of the wall.

The Benefit-Cost Analysis for stone revetment options is presented in Table 2 below. Residual damages of \$332,800 are expected to occur if the seawall remains standing but is over-topped. Total annual benefits of \$1,075,300 (\$1,408,100 - \$332,800) represent reduction in storm damages for the 10- and 25-year revetment alternatives. Net annual benefits for the 10-year revetment alternative are \$812,259 with a BCR of 4.09 while net annual benefits for the 25-year beach alternative are \$778,549 with 3.62 as the BCR.

Table 2 Revetment Plan Cost-Benefit Analysis

| 10 Yr Stone | |
|----------------------------------|--------------------|
| Construction Cost | \$5,133,686 |
| IDC | \$24,114 |
| E&D | \$308,021 |
| S&A | \$410,695 |
| Project Cost | \$5,876,516 |
| Annual Cost | \$261,941 |
| Annual O&M | \$1,100 |
| Total Annual Cost of Alternative | \$263,041 |
| Annual Benefit | \$1,075,300 |
| Annual Net Benefit | \$812,259 |
| BCR | 4.09 |
| 25 Yr Stone | |
| Construction Cost | \$5,800,224 |
| IDC | \$27,245 |
| E&D | \$348,013 |
| S&A | \$464,018 |
| Project Cost | \$6,639,500 |
| Annual Cost | \$295,951 |
| Annual O&M | \$800 |
| Total Annual Cost of Alternative | \$296,751 |
| Annual Benefit | \$1,075,300 |
| Annual Net Benefit | \$778,549 |
| BCR | 3.62 |

BEACH RENOURISHMENT ALTERNATIVES

The Coastal Engineering Analysis concluded that beach renourishment projects would prevent all computed natural damages by placing enough sand in front of the seawall to absorb and dissipate wave energy and prevent wall failure. Annual storm damages to properties in the back shore would amount to \$1,408,100 without the protection of the beach and seawall. These damages would be prevented with beach renourishment.

Project construction costs were based on initial volumes of sand required to establish a beach profile capable of withstanding the design storm. Initial volumes were based on Historical sea level rise in order to assess how often the beaches would need to be renourished. Beach profiles were established by coastal engineering to withstand storms having recurrence probabilities of 0.5 (2-year return interval) and 0.2 to 0.1 (5- to 10-year return interval). Initial sand requirements and renourishment volumes are presented in Table 3 below. For a detailed analysis of Sea Level Rise, please see the Coastal Engineering Appendix.

Table 3 Renourishment Volumes for Zone 2

| Initial Volume (yds ³) | 2 Yr Return Period Storm | | 5 to 10 Yr Return Period Storm | |
|------------------------------------|---------------------------|----------------------------|--------------------------------|----------------------------|
| | Fill Interval (yrs) | Volume (yds ³) | Fill Interval (yrs) | Volume (yds ³) |
| 257,462 | 5.4 | 125,462 | 5.1 | 121,462 |
| 286,468 | 9.4 | 154,468 | 8.5 | 150,468 |
| 315,378 | 12 | 183,378 | 10.5 | 179,378 |
| 344,154 | 12 | 212,154 | 12 | 208,154 |
| | | | | |
| Initial Volume (yds ³) | 15 Yr Return Period Storm | | 50 Yr Return Period Storm | |
| | Fill Interval (yrs) | Volume (yds ³) | Fill Interval (yrs) | Volume (yds ³) |
| 257,462 | 4.7 | 116,462 | 3 | 88,462 |
| 286,468 | 7.3 | 145,468 | 5.1 | 117,468 |
| 315,378 | 9.3 | 174,378 | 6.6 | 146,378 |
| 344,154 | 12 | 203,154 | 7.7 | 175,154 |

The beach profiles established for the 2 renourishment project alternatives were based on design storm events having a 0.04 (25-year return interval) and 0.1 (10-year return interval) probability of recurrence. Initial fill volumes were determined to be 246,000 cubic yards (CY) for the 10-year alternative and 378,000 CY for the 25-year alternative.

Renourishment volumes and intervals were calculated from the initial fill and the storm return periods listed in Table 3. The calculated fill volumes are presented in Tables 4 and 5 below. The fill volume for the 25-yr alternative is 235,531 CY and the fill volume for the 10-yr option is 110,400 CY. The costs per yard were determined by the Cost

Engineering Branch and include the cost of the sand itself, the cost of transporting the sand, placing it on the beach and smoothing it over the study area.

Despite the smaller fill volume for the 10-year alternative, the total renourishment cost over the 50 year project life is more expensive than the 25-yr plan. This is because the 10-yr beach needs to be renourished every four years while the 25-yr beach can go 13 years before it needs to be replenished. The total cost of renourishment for each plan is calculated by using fill volumes, fill intervals and cost per cubic yard of sand fill. The total cost over the 50-year project life is discounted back to the 2013 base year by using a discount factor based on the Federal Interest Rate of 3.75% for FY 2013. The total costs for beach renourishment are presented in Tables 4 and 5 below.

Table 4 Beach Renourishment Intervals and Costs

| 10 yr Return Period | | |
|------------------------------------|---------------------------|---------------------|
| Original Cubic Yards (CY) | 246,400 | |
| Fill Interval (yrs) | 4 | |
| Fill Volume (CY) | 110,400 | |
| x Filled over Proj. Life | 13.15 | |
| Cost Per CY | \$63.00 | |
| Cost Per Fill (before discounting) | \$6,955,200 | |
| | | |
| <u>Year</u> | <u>PV Factor at 3.75%</u> | <u>Cost</u> |
| 4 | 0.8631 | \$6,002,846 |
| 8 | 0.7449 | \$5,180,895 |
| 12 | 0.6429 | \$4,471,491 |
| 16 | 0.5549 | \$3,859,224 |
| 20 | 0.4789 | \$3,330,792 |
| 24 | 0.4133 | \$2,874,717 |
| 28 | 0.3567 | \$2,481,091 |
| 32 | 0.3079 | \$2,141,363 |
| 36 | 0.2657 | \$1,848,153 |
| 40 | 0.2293 | \$1,595,091 |
| 44 | 0.1979 | \$1,376,680 |
| 48 | 0.1708 | \$1,188,175 |
| Total | | \$36,350,517 |

Table 5 Beach Renourishment Intervals and Costs

| 25 yr Return Period | | |
|------------------------------------|---------------------------|---------------------|
| Original Cubic Yards (CY) | 378,400 | |
| Fill Interval (yrs) | 13 | |
| Fill Volume (CY) | 235,531 | |
| x Filled over Proj. Life | 3 | |
| Cost Per CY | \$68.00 | |
| Cost Per Fill (before discounting) | \$16,016,100 | |
| | | |
| <u>Year</u> | <u>PV Factor at 3.75%</u> | <u>Cost</u> |
| 13 | 0.6197 | \$9,924,563 |
| 26 | 0.3840 | \$6,149,871 |
| 39 | 0.2379 | \$3,810,840 |
| Total | | \$19,885,274 |

RECREATION BENEFITS

Beach renourishment plans consider recreational benefits in addition to prevented storm damages because of beach construction. Beach renourishment provides enhanced recreational benefits based on an increased number of visitors and the overall enhanced beach experience. Recreational benefits for Federal Water Resource Projects are calculated using the Unit Day Value Method (UDV) as detailed in Corps Economic Guidance Memorandum #13-03, "Unit Day Values for Recreational, Fiscal Year 2013." The recreation experience is evaluated through a point system which rates the beach using the five criteria listed in Table 6 below. The number of points attributed to the overall visitor experience is cross-referenced to dollar values provided in the economic guidance memorandum to determine the average dollar value per day per user, or UDV. Beach renourishment alternatives at Nantasket generate a total of 38 points and a UDV of \$6.74. The UDV amount is multiplied by the number of beach visitors to determine the value of recreational benefits. The UDV and calculation of beach capacity for visitors are provided in Tables 6 and 7 below. Combining annual attendance with a unit day value of \$6.74 yields a recreation benefit value for dry beach space at Nantasket Beach of \$1,197,400.

Table 6 Unit Day Value Calculation

| UDV CRITERIA | POINT RANGE | With Project POINTS |
|------------------------------------|--------------------|----------------------------|
| Recreation Experience ¹ | 0 - 30 | 9 |
| Availability of Opportunity | 0 - 18 | 3 |
| Carrying Capacity | 0 - 14 | 9 |
| Accessibility ² | 0 - 18 | 11 |
| Environmental Aesthetic | 0 - 20 | 6 |
| | | 38 |
| | | |
| \$ Value/User/Day Hard-Keyed | | \$6.74 |
| | | |
| Annual Usage | | 177,660 |
| Recreational Benefits | | \$1,197,400 |

The capacity of Nantasket Beach was determined by obtaining the area of Zone 2 and dividing by 75 square feet per person to obtain instant capacity ($180 \times 2100 \div 75 = 5,040$). Daily capacity was developed by multiplying the instant capacity by a turnover rate of $1 \frac{1}{2}$. Weekend demand is assumed to be 50 percent of capacity, while average daily demand is assumed to be 25 percent of capacity. This computation yields an estimate of 3,780 weekend visitors and 1,890 weekday visitors. Daily attendance is then multiplied by the number of days to determine an estimated annual attendance of 177,660.

Table 7 Recreational Demand for Zone 2

| Zone 2 Beach Capacity | |
|------------------------------|---------|
| Width (feet) | 180 |
| Length (feet) | 2,100 |
| Area Zone 2 (sq. ft.) | 378,000 |
| Area/User | 75 |
| Instantaneous Users | 5,040 |
| Turnover | 1.5 |
| Daily Capacity-Zone 2 | 7,560 |
| Zone 2 Beach Demand | |
| Available Days | 98 |
| Beach Days % | 0.75 |
| Yearly Beach Days | 74 |
| Weekend | 20 |
| Weekday | 54 |
| Weekend % Cap. | 0.5 |
| Weekday % Cap. | 0.25 |
| Weekend | 3,780 |
| Weekday | 1,890 |
| Annual Usage: Zone 2 | 177,660 |

BEACH RENOURISHMENT BENEFIT-COST ANALYSIS

The Benefit-Cost Analysis for beach renourishment options is presented in Table 8 below. Total annual benefits of \$2,605,500 include \$1,408,100 for reduction in storm damages and \$1,197,400 for increased recreational benefit. The full amount of recreational benefits can be used because it is less than half of the overall project benefits. Net annual benefits for the 10-year beach alternative are \$187,769 with a BCR of 1.08 while net annual benefits for the 25-year beach alternative are \$384,591 with 1.17 as the BCR.

Table 8 Beach Renourishment Cost-Benefit Analysis

| 10 Yr Beach | 2013 |
|---------------------------------|---------------------|
| Construction Cost | \$15,457,528 |
| IDC | \$268,463 |
| E&D | \$927,452 |
| S&A | \$1,236,602 |
| Renourishment | \$36,350,517 |
| Project Cost | \$54,240,562 |
| Annual Cost (CRF = .04457) | \$2,417,731 |
| Annual Benefits | \$1,408,100 |
| Annual Rec Benefits | \$1,197,400 |
| Total Annual Benefits | \$2,605,500 |
| Annual Net Benefit | \$187,769 |
| BCR without Recreation Benefits | 0.58 |
| BCR with Rec Benefits | 1.08 |
| 25 Yr Beach | 2013 |
| Construction Cost | \$25,868,782 |
| IDC | \$449,284 |
| E&D | \$1,552,127 |
| S&A | \$2,069,503 |
| Renourishment | \$19,885,274 |
| Project Cost | \$49,824,969 |
| Annual Cost | \$2,220,909 |
| Annual Benefits | \$1,408,100 |
| Annual Rec Benefits | \$1,197,400 |
| Total Annual Benefits | \$2,605,500 |
| Annual Net Benefit | \$384,591 |
| BCR without Recreation Benefits | 0.63 |
| BCR with Rec Benefits | 1.17 |

NATIONAL ECONOMIC DEVELOPMENT PLAN

A project is considered economically justified if it has positive net benefits and a benefit to cost ratio (BCR) of 1.0 or greater. The alternative which maximizes net annual benefits with a BCR greater than 1.0 is the National Economic Development (NED) plan. A comparison of costs, benefits and BCRs is presented in Table 9 below.

The NED plan would be the 10-year stone revetment alternative because it has the highest amount of net benefits (\$812,259) when compared to the other alternatives. The 10-year stone revetment alternative also has a BCR of 4.09 based on flood damage reduction benefits alone. The total net annual benefits and high BCR support the 10-year stone revetment alternative as the recommended plan.

Table 9 Comparison of Alternatives

| | Revetment | | Beach Nourishment | |
|---------------------------------|-------------|-------------|-------------------|-------------|
| | 10 yr Stone | 25 yr Stone | 10 yr Beach | 25 yr Beach |
| Annual Cost of Alternative | \$263,041 | \$296,751 | \$2,417,731 | \$2,220,909 |
| Annual Flood Reduction Benefits | \$1,075,300 | \$1,075,300 | \$1,408,100 | \$1,408,100 |
| Annual Recreation Benefits | \$0 | \$0 | \$1,197,400 | \$1,197,400 |
| Annual Net Benefit | \$812,259 | \$778,549 | \$187,769 | \$384,591 |
| BCR with Rec Benefits | N/A | N/A | 1.08 | 1.17 |
| BCR without Recreation Benefits | 4.09 | 3.62 | 0.58 | 0.63 |

ⁱ Town of Hull Hazard Mitigation Plan Update, March 2011
http://www.town.hull.ma.us/Public_Documents/HullMA_EmPrepare/FinalDraft.pdf (accessed 2 February 2012)