BEACH-DUNE SYSTEM
SUSCEPTIBLITY ASSESSMENT
FOR
THE BOROUGH OF MANTOLOKING, OCEAN COUNTY, NEW JERSEY

A view of the most recent bulldozing effort along the Mantoloking oceanfront during the spring of 2004. The machine harvests sand from the beach and pushes it up to the scarp (right middle edge) grading the slope upward. Each pass completes a section along the dune frontage approximately the width of the bulldozer blade. A cut of a foot in depth is taken from the beach in the process. Wave transfer of sand from offshore quickly replaces this sand in the absence of storm events.

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Summary of the Mantoloking Beach-Dune System Storm Susceptibility Assessment:

The dune system in Mantoloking is a vital natural resource that protects the Borough against storm damage. Dune system assessment is important for effective management and sustainability of this resource. An assessment facilitates more efficient use of limited State and municipal resources by optimizing storm hazard mitigation activities. In addition to the annual dune-walk inspection, an assessment of susceptibility to coastal storm damage in the Borough of Mantoloking was undertaken. This assessment was intended to determine the possibility that wave-driven storm waters, resulting from hurricane or northeast storms of a given intensity, would significantly erode the dune system, breach the dune crest, and overwash landward into the Borough. The baseline for the assessment is the year 2000, the latest date for which matched aerial photography and digital shore zone elevation data were available.

Assessment Overview and Definitions:

The Federal Emergency Management Agency (FEMA) has established storm intensity parameters for a variety of storm events starting with a typical northeast storm that would be expected annually. These parameters are also established for 2-, 5-, 10-, and 20-year events, increasing to 50- and 100-year storm events and larger. The parameters are specified for stretches of shoreline everywhere along the US coast. They define potential zones of wave action along the shoreline for all of these storm types, and consist of (1) wind velocity and direction, (2) wave spectrum (height and period), (3) storm duration and surge elevation (storm surface elevation at the "Stillwater" surface). In 2002, the US Army Corps of Engineers (USACE), Philadelphia District office, and the New Jersey Department of Environmental Protection (NJDEP) published a feasibility study for shore protection from Manasquan Inlet to Barnegat Inlet (New Jersey Shore Protection Study, Manasquan Inlet to Barnegat Inlet Feasibility Study, June, 2002). As part of this study, a one-dimensional wave run-up simulation program, called "S-Beach", was used to calculate the amount of beach and dune erosion expected from each of the FEMA storm events described above.

For the Mantoloking dune susceptibility assessment, the CRC has made use of some FEMA storm parameters and USACE/NJDEP analysis techniques, but has also extended the analysis to determine potential storm damage to the Mantoloking dune system at each oceanfront property in the Borough. The Borough contributed its digital tax map to which the CRC added 2000 aerial photography, 2000 digital elevation data, 2000 bathymetric profile data, and synthesized a series of criteria to evaluate the various impacts of storm, dune volume parameters, and cross section data to generate levels of "susceptibility" that the dune system would survive or fail during a particular storm event. Failure is defined as erosion retreat in the S-Beach storm simulation to the crest of the dune. While overwash does not necessarily commence the moment the erosion reaches the crest elevation, the decision was made to call this the point of dune failure. First, further erosion would rapidly bring the elevation down to where wave overwash could begin, and second, it is a fail-safe point for the simulation to formulate a go/no-go decision on failure. An additional consideration is the duration of the storm. The susceptibility assessment only addresses whether the dune system will fail, not how long it will take for a breach to fully develop, or what will happen afterwards (e.g., the degree and nature of storm damage, etc.). As such, if failure occurs at the beginning of a storm, chances are that the breach will grow and significant overwash may occur. Conversely, if failure occurs as the storm begins to wane, chances are that the breach will not grow and significant overwash will not occur. Whether or not it progresses to a fully developed breach, failure is nevertheless a serious compromise of the dune system. In addition, once a breach occurs the rate of loss in dune protection at the edges of the breach increases dramatically as the surging water slices away at the remaining adjacent dune, rapidly widening the breach.

Results of Assessment:

The assessment is presented as six large-scale "dune susceptibility maps" (see accompanying hardcopy plots, and Adobe Acrobat PDF files on CD-ROM). For any site or oceanfront property in the Borough, the maps show the potential for significant dune erosion or breach from 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year storm events.

The results of the assessment are conveyed as two multicolor strips that are overlain along the extent of the beachfront. The strips are superimposed on a 2000 black-and-white aerial photograph of the Borough so potential sites of storm breaching could be easily identified and addressed. The strips are subdivided into segments that correspond to the width of a given beachfront property (susceptibility at the beach assess ways was not assessed). The landward strip, "Beach-Dune System Susceptibility", is an absolute measure of vulnerability to storm erosion of the dunes. This absolute measure of vulnerability is made in relation to a 100-year intensity storm, which is taken to be the worst-case scenario for this assessment. The seaward strip, "Relative Performance of Beach-Dune System", is a comparative measure of vulnerability to storm erosion of the dunes. This comparative measure of vulnerability is made relative to all bins (properties) for a given storm intensity. Warmer colors (reds, oranges) represent higher susceptibilities to storm erosion, whereas cooler colors (blues) represent lower susceptibilities. Failure of the dune system occurs when the foredune is eroded landward far enough to breach the dune crest. Both of the assessment strips are best interpreted together. The seaward strip supplements the landward strip by providing an estimate of how much better or worse the dune system will perform relative to adjacent properties during a storm of given intensity.

Results of the susceptibility for a storm of given intensity are as follows:

- 2-Year Storm Intensity Assessment (50% chance of occurrence per year):

  The susceptibility maps indicate that the oceanfront dune system is an effective barrier for 2-year storm events. No property experiences dune breach or significant wave overtopping for this level of storm event. Any erosion is confined to the dune slope seaward of the crest elevation. Minor erosion may occur (1) to the properties just north of Downer, (2) just south of Herbert, and (3) from Herbert north to just short of the 2nd beach access way.

- 5-Year Storm Intensity Assessment (20% chance of occurrence per year):

  The susceptibility maps indicate that the oceanfront dune system is an effective barrier for 5-year storm events. No property experiences dune breach or significant wave overtopping for this level of storm event. Erosion is confined to the dune slope seaward of the crest elevation. Erosion can be expected in areas identified for the 2-year assessment. Minor erosion may occur at (1) the 4th lot north of the Princeton access way, and (2) between Albertson and Carpenter.

- 10-Year Storm Intensity Assessment (10% chance of occurrence per year):

  The susceptibility maps indicate that the oceanfront dune system is an effective barrier for 10-year storm events. No property experiences dune breach or significant wave overtopping for this level of storm event. Any erosion is confined to the dune slope seaward of the crest elevation. Notable erosion can be expected in the areas identified for the 2- and 5-year assessments. The most significant erosion occurs along a stretch of properties just north of Downer.

- 20-Year Storm Intensity Assessment (5% chance of occurrence per year):

  The susceptibility maps indicate that the oceanfront dune system is a reasonably effective barrier for 20-year storm events. While no property experiences dune breach or significant wave overtopping for this level of storm event, some properties may

experience significant erosion, but confined to the foredune seaward of the crest elevation. Areas identified in the 2-, 5-, and 10-year assessment can be expected to undergo significant erosion. Areas that may experience landward erosion up to 50% or more of the distance from the seaward dune toe to the crest include (1) just north of Downer, (2) just south of Herbert, and (3) midway between Herbert and the 1st beach access way to the north. Areas that will experience similar, but not as severe erosion, include properties between Albertson and Carpenter, and a couple of properties midway between Princeton and Downer.

- 50-Year Storm Intensity Assessment (2% chance of occurrence per year):

  For the 50-year storm event, there are failure and near-failure points along the Borough oceanfront. From north to south, these include the following 16 properties in shown in Table 5:

Table 1
Properties at Risk of Dune Failure for a 50-Year Storm Event
(Listed by Block/Lot and Street Address)

Failure	Near-Failure
23/37 - 1093 Ocean	1/4 - 911 East
23/38 - 1095 Ocean	23/1 - 1021 Ocean
23/42 - 1103 Ocean	23/28 - 1077 Ocean
23/48 - 1115 Ocean	23/39 - 1097 Ocean
26/1 - 1201 Ocean	26/7 - 1225 Ocean
26/2 - 1207 Ocean	35/4 - 1315 Ocean
26/8 - 1229 Ocean	36/6 - 1421 Ocean
26/9 - 1235 Ocean	
26/10 - 1237 Ocean	

Based on the total combined 2004 tax assessment ($397,378,108) for all 145 oceanfront lots, the average oceanfront property is worth $2,740,538, keeping in mind that there are several lots without structures. A 50-year storm could result in combined public and private storm damage of up to $43.8 million dollars (worst-case scenario, assuming that all 16 properties identified above were severely damaged or destroyed). The assessment indicates that the potential for dune failure is limited to these 16 properties, but with relatively modest increases in width and crest elevation to the affected properties, the entire Mantoloking oceanfront dune system could be made resistant to the 50-year storm event as predicted by the FEMA storm parameters and the other physical characteristics of the dune/beach system. Some perseverance will be needed by the municipality to impress upon each of the 16 property owners listed above that it would be in their best financial interests to cooperate in a Borough-wide mitigation of the indicated failure-prone dune segments.

By comparison, the northeast storm of 1992 (estimated between a 15- to 20-year event) resulted in over 2.2 million dollars of damage to both private and public properties. During this storm three major breaches occurred resulting in the loss of two homes and substantial FEMA damage claims to about 8 others. While the majority of the loss was focused on the two homes, ultimately torn down and replaced, the average loss from the 1992 event was $222,600 per impacted property. The 1992 dune scarp extended the entire length of the Borough and was between 6 and 12 feet in height. Mantoloking surveyed this scarp and incorporated its position into the municipal ordinances as a building setback for new or substantial re-construction of oceanfront properties.

- 100-Year Storm Intensity Assessment (1% chance of occurrence per year):

  For the 100-year storm event, the maximum intensity considered in this assessment, the estimates of failure are less meaningful or reliable at the lot-and-block level. The power of a storm increases dramatically from a 50-year to 100-year event, and it is likely that long stretches of the dune system extending along the oceanfront would be breached, overwashed, and even reduced to the elevation of the beach. Since the assessment methodology primarily focuses on individual dune profiles without computing adjacent dune weaknesses or strengths, as the storm intensity approaches catastrophic levels, predicting specific areas of failure becomes increasingly impossible.

  The longest and most significant of the 100-year storm failures extends from about 1091 Ocean Drive south to Downer Street. Another stretch that would be seriously affected extends from about 1315 Ocean Drive south to Albertson Street. Any attempt at predicting dune performance beyond the 100-year storm event essentially provided a portrait of nearly complete disaster for the Mantoloking oceanfront dunes.

Data and Methodology:

The assessment is a Geographic Information System-based (GIS), knowledge-driven modeling methodology that identifies weaknesses in the beach-dune system and highlights areas that may be vulnerable to storm damage (such as erosion, overwash, or breach).

The following data sources were used for the assessment:

- ***LI***ght ***D***etection ***A***nd ***R***anging (LIDAR) elevation data for 2000 (the most recent year for which data of this type was available). This dataset consists of 85,000 point-spot elevations (dune and shore zone only) with an average point-spacing of about 2-5 feet, and a vertical accuracy of less than 6 inches.

- CRC Mantoloking Borough Quarterly dune-beach-offshore profiles. Five profiles collected in 2000, nearshore and offshore portion only, extending about 385 feet offshore (approximately –15 feet of water).

- Seaward and landward dune toe lines, collected as Global Positioning System (GPS) points in 2004 and adjusted to 2000 LIDAR data. Note that the landward dune toe may appear to cut certain features, particularly newer construction. This is due to time differences between when the dune toe data were collected and when the aerial photograph was taken.

- Dune crest line, interpolated and digitized from 2000 LIDAR data.

- Vegetation coverage, extracted from 1-foot pixel resolution, color infrared aerial photography from 2002, and verified against the 1.5-foot pixel resolution black and white aerial photography from 2000.

From these data sources, several variables relating to dune, beach, and nearshore-offshore morphology were derived and evaluated in order to determine the susceptibility of the dune system to potential damage from storm activity. These variables include:

- Dune elevation
- Foredune width
- Backdune width
- Foredune slope
- Surficial vegetation coverage
- Substantial vegetation and structures coverage
- Backshore and foreshore elevation
- Nearshore-offshore bathymetry

The variables were then analyzed and averaged over a shoreline-parallel segment of the dune system (see Photograph 6). The segment is referred to as a "bin", and is delineated by the landward and seaward dune toe lines, and by the lot boundaries of each oceanfront property (digital lot boundaries were provided in 2002 by the Borough from Stetler & Guldin Engineering, Inc., and georeferenced by the CRC).

These variables were then quantified, and using expert knowledge, assigned a "weight" of influence with respect to their ability to withstand or counteract storm erosion, as shown in Table 6.

Elevation and bathymetry profile data were used in S-Beach wave run-up erosion simulations to determine the failure point of the dune system for each bin (the point of failure is defined as dune crest breach in response to landward erosional recession of the foredune). Simulations were run for 2-year, 5-year, 10-year, 20-year, 50-year, and 100-year storm events using parameters developed by FEMA. A map of "dune susceptibility" was generated by using fuzzy-set theory to combine the variables. The results of the erosion simulations were used to control the degree of variable combination, and to classify the susceptibility values into intervals.

Photograph 1. An aerial photograph from 2003 show analysis bins (white lines) that were clipped to lot boundaries and the seaward and landward dune toe lines (red lines).
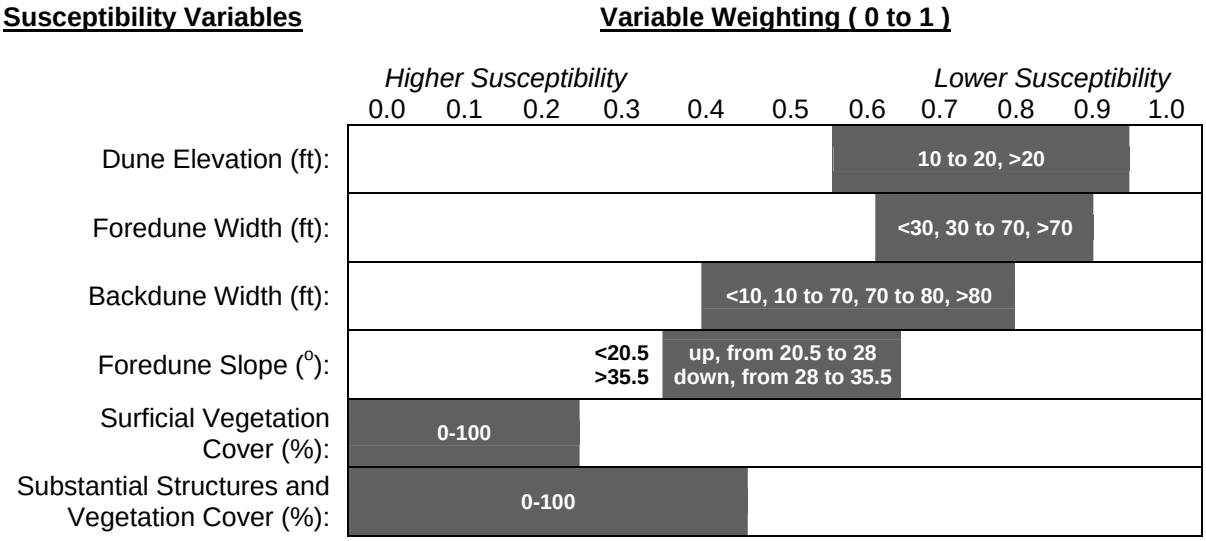
Table 2
Expert Weights Assigned to Variables Used to Assess Dune Susceptibility