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DOCUMENTING SHORT-TERM VARIABILITY OF BEACH REFERENCE FEATURES USING A VOLUNTEER BEACH & DUNE PROFILING PROGRAM IN MASSACHUSETTS

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INTRODUCTION

The scientific, engineering and surveying community has long sought to plot shorelines accurately and produce reliable long- and short-term shoreline change rates. Accurately plotted shorelines and calculated shoreline change rates are used for a variety of purposes, including establishing legal boundaries, determining construction set-backs, designing beach nourishment projects, calculating sediment budgets, testing numerical models, and developing coastal hazards management initiatives.

With recent advances in technology, errors inherent in plotting shorelines from aerial and orthophotographs and historic topographic sheets (T-sheets) have been documented and techniques developed to minimize these inherent errors (Crowell, et al, 1991; Morton, 1991). Furthermore, with the introduction of Differential Global Positioning Systems (DGPS) and Light Detection and Ranging (lidar) the accuracy of plotting recent shorelines has greatly improved.

Despite these improvements, the accuracy of estimating shoreline change rates remains questionable due primarily to the unknown variability of the ***shoreline reference feature*** used to plot the shoreline. Morton and Speed (1998) state that large error factors exist in many shoreline change data sets used to predict future shoreline positions due to the unknown variability of the shoreline reference feature. Ruggiero et al. (2003) state that the largest uncertainty associated with shoreline estimates and subsequent change analyses is often due to the natural short-term variability of both beach morphology and the water level on the beach.

SHORELINE REFERENCE FEATURES

Shoreline movement is documented by plotting the position of a selected reference feature, such as the seaward dune vegetation line, high tide wrack line, wet/dry line, or the berm crest. The feature is generally considered a proxy for the mean high water line and is stated to be easily field-located and photo-interpreted (Crowell, et al., 1991). Crowell et al. (1991) also suggest that the horizontal position of the high water line reference feature and actual mean high water are nearly equivalent, assuming moderate weather conditions. However, while possibly true in selected locations, little quantitative information exists regarding this relationship, and thus is an untested assumption (Pajak and Leatherman, 2002).

Early topographers with the U.S. Coast Survey (now NOAA/NOS) used 'markings left on the beach by the last preceding high water to map the approximate mean high water line' (Shalowitz, 1964) and plotted these proxies on T-sheets that are routinely used in calculating long-term shoreline change rates. These markings were typically a high tide wrack line or a wet/dry line and thus not an actual mean high water line. Shalowitz's estimate of horizontal error between the actual mean high water line and the selected beach reference feature is 3-4m.

Based on more than two decades of beach surveys and field observation, Morton and Speed (1998) demonstrated that along the Texas Gulf shore, the high water line mapped on aerial photographs (the instantaneous high water line or wet/dry line) and the berm crest are the least stable beach features and are therefore a less reliable indicator of shoreline position than other beach features, such as the dune vegetation or bluff line. Within a year at North Padre Island, Texas, they documented an instantaneous high water line (wet/dry line) and berm crest migration of 40 and 50m, respectively. Along the North Carolina shore, Pajak and Leatherman (2002) documented a range of high water line (wet/dry line) position movement of 32.6m with a standard deviation of 8m over a three year period, however only the months of July, August and September were analyzed. Along the high energy Pacific Northwest shore, Ruggiero et al. (2003) document total uncertainty estimates of the horizontal position of proxy-based shorelines to be approximately +/- 50 to 150m for T-sheets and aerial photography, and approximately +/- 15m for datum-based shorelines derived from ground or air-based topographic surveys. Zhang et al. (2002) found that the high water line at Duck, North Carolina had a monthly variability that ranges from less than 2 to nearly 10m. They state that fall, winter and early spring high water line variability is so large that individual surveys during those times cannot be expected to be useful for determining long-term shoreline trends. Thus, the seasonal variability of the shoreline reference feature used to plot shorelines is oftentimes unknown and may be the largest contributing error in shoreline change analyses.

REGIONAL BEACH & DUNE PROFILING PROGRAM IN MASSACHUSETTS

The Woods Hole Sea Grant Program and Cape Cod Cooperative Extension began a regional beach and dune profiling program in 1999, which now includes approximately 70 volunteers gathering profiles on 10 beaches in 7 communities along the South Shore, Cape Cod and the island of Nantucket, Massachusetts. The Emery Rod method is being used to capture profiles (Emery, 1965: O'Connell, 2001; 2004). The purpose of the program is to engage citizens, town officials, students, and coastal residents in documenting short-term beach and dune changes to gain a heightened understanding of the dynamic nature of beaches and dunes, while gathering useful scientific information. Project beaches face different geographic directions with varying sediment textures, tidal ranges and wave regimes. Monuments were installed in the back dune area and referenced to NGVD29, so accurate elevations and variability of the seaward dune vegetation line, wrack line(s), mean high water, wet/dry line, and the zero contour could be plotted (Figure 1).

Seasonal dune and beach profiling began at Rexhame Beach in Marshfield along the South Shore of Massachusetts in 1999, with monthly profiles captured between February 2002 and January 2005 (35 months). Rexhame Beach is wave-dominated facing north-

northeast and primarily a coarse-grained sand to cobble beach during winter, and medium to coarse grained sand beach with underlying cobble lag in the upper beach during other seasons. The average tidal range is approximately 9ft, with a 12ft spring tidal range. Figure 1 is a plot of one year (January-December 2003) of monthly profiles at station RB3.

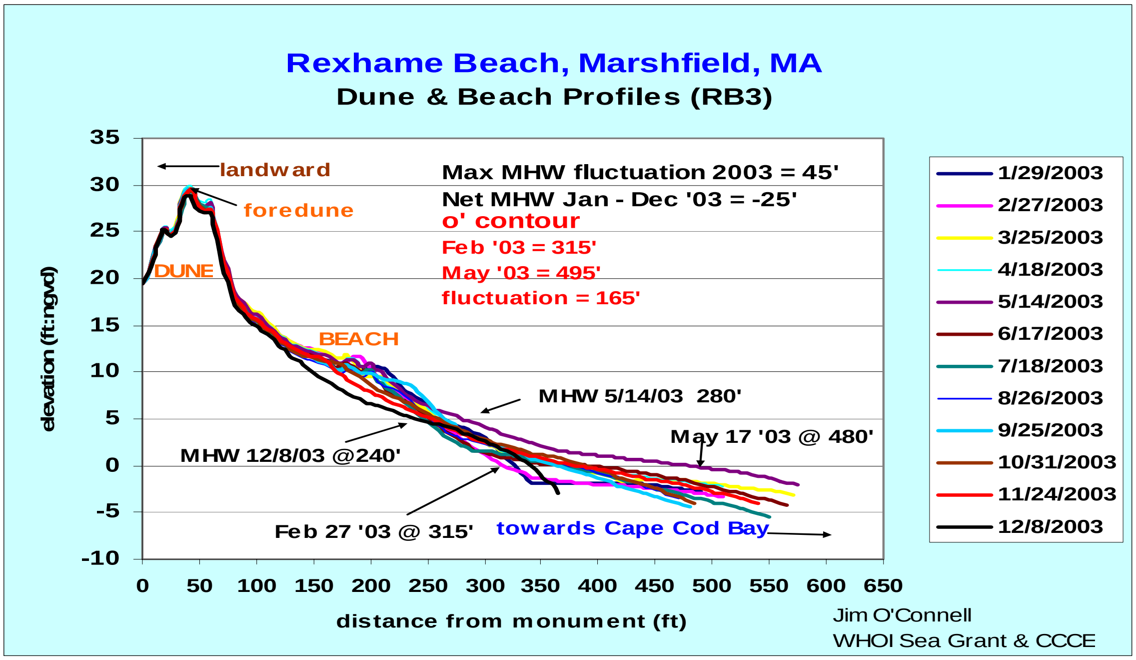

Figure 1. One year (2003) of monthly beach and dune profiles at Rexhame Beach, Marshfield, MA used for measuring the variability of beach reference features.

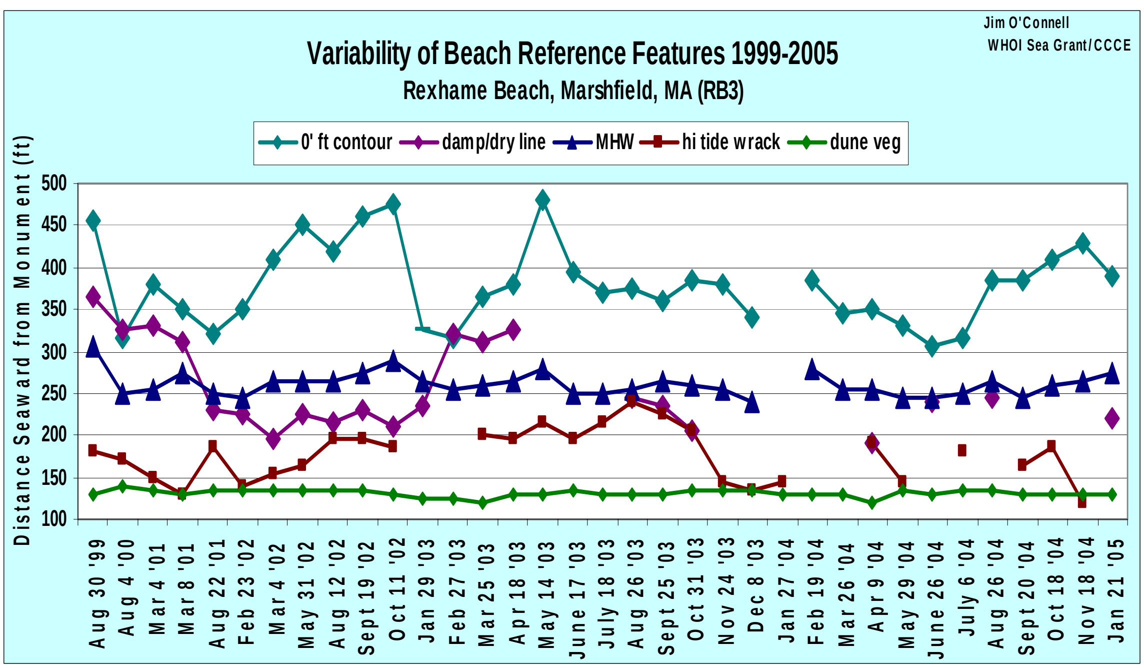

Figure 2. Plot of the variability of various beach reference features between August 1999 and January 2005 at Rexhame Beach.

Figure 2 shows the variability of various beach reference features between August 1999 and January 2005 at Rexhame Beach. Note that a damp/dry line and wrack line were not always present on the beach. Thus, these beach features may not be appropriate for plotting repetitive shorelines, particularly along coarse-grained New England beaches.

Profile Dates	**Seaward Dune Vegetation Variability Range (ft)**	**Hi Tide Wrack Variability Range(ft)**	**Mean High Water Variability Range (ft)**	**Damp/dry Line Variability Range (ft)**	**'0' foot contour Variability Range (ft)**
Jan'04-Jan'05	**15**	**70**	**35**	**55**	**125**
Jan'03-Jan'04	**10**	**105**	**40**	**120**	**165**
Feb'02-Jan'03	**10**	**55**	**45**	**40**	**150**
Aug'99-Aug'01	**10**	**55**	**65**	**135**	**140**
Aug'99-Jan'05	**20**	**120**	**65**	**175**	**175**
AVERAGE Variability (35 months)	**13**	**81**	**50**	**105**	**151**

Table 1. Monthly variability (range in feet) of beach reference features at Rexhame Beach for specified years.

Table 1 shows the monthly variability range of beach reference features surveyed at Rexhame Beach over a 35-month period between August 1999 and January 2005. Note that the seaward dune vegetation line has the least variability, and the zero contour, the farthest feature seaward from the monument, the largest. The surveyed mean high water contour moved 35 to 65ft during the survey period, with an average seasonal range of 50ft.

List and Farris (1999) measuring mean high water line movement in North Carolina and Cape Cod, Massachusetts indicate that shoreline position is most strongly associated with wave height that occurred during the two previous high tides. They also show that the shoreline can experience significant changes during periods of relatively calm conditions. The monthly variability of Rexhame Beach data suggests that wave parameters, sediment characteristics, and tidal range strongly influence the position of beach features.

CONCLUSIONS

Previous studies document shoreline variability that impacts the accuracy of shoreline change rates. This study provides documentation of substantial variability of beach reference features at Rexhame Beach, Massachusetts, that may be typical of many New England beaches. Thus, even with the introduction of relatively accurate datum-based shoreline mapping methods (DGPS and/or lidar), the variability of the 'shoreline' remains a major consideration in the accuracy of shoreline change rates. The uncertainties and the natural variability of shoreline indicators, specifically the high water line, need to be quantified (Pajak and Leatherman, 2002).

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