Visibility over Shorefront Sand Dunes: An Ocean View

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Introduction

Coastal sand dunes evoke a wide range of responses from various constituencies. Most people recognize that sand dunes provide a level of protection from coastal flooding and wave damage; however, high dunes can obstruct one's view of the ocean which is the reason many people visit the beach, build there or rent ocean front "cottages." A recent article in the *Philadelphia Inquirer* (Sunday, 16 May 2004) carried the headline, "Ocean view doomed by dunes" which decried the construction of sand dunes as part of Atlantic City's beach nourishment project. Visitors to Atlantic City seeking "soothing vistas and breezes" felt like they were in a "bunker" and that the "greatest asset that Atlantic City has" had been taken away. In fact, the project was delayed by ocean-front property owners in other communities that share Absecon Island with Atlantic City who did not want dune construction to be a part of the project. The design of coastal dunes involves numerous trade-offs and compromises. There are those who want the largest dune that nature or man can create. Others want low dunes. Some are concerned that dunes will exacerbate wave runup during storms leading to property damage. Others want an easement behind the dunes and closely-spaced cross-over structures for easy beach access, while some want no dunes at all. All are vocal and all have strong opinions.

Dune Erosion during a Storm

The coastal engineer tasked with designing a protective dune needs to be aware of the desires of local property owners and must reconcile those desires with local, state and federal requirements. While completely satisfying all parties may be impossible, compromises often are possible. One such compromise is to minimally interfere with the "ocean view" by lowering the crest elevation of the dune or raising the observation level. The level of wave protection afforded by a dune depends primarily on the volume of sand contained within it above the design storm surge level – usually the 100-year level. Often this volume can be increased by widening the dune rather than by increasing its height. Based on work by Hallermeier & Rhodes (1988), FEMA requires that a dune contain 540 ft^3/ft of volume above the 100-year surge level to protect landward development from wave action. In general, the volume needed to protect against a storm with a T-year recurrence interval is,

$$V = 86.1(T)^{0.4} \tag{1}$$

in which V = the dune volume in ft^3/ft and T = the storm's recurrence interval in years.

The Dutch use a method developed by Vellinga (1983) to estimate dune erosion resulting from a storm with a given surge level, offshore wave height and median sand grain size. The Vellinga method constructs a storm profile and, by horizontally shifting the storm profile over the pre-storm profile until erosion and accretion areas are equal, determines dune erosion. Both methods rely on the volume of sand above a given surge level to provide the protection. Thus, if the volume can be maintained while keeping a relatively low dune profile, the ocean view might be preserved while still providing protection.

The volume of sand contained in a dune is not the only factor that determines how much protection it provides. The dune's crest elevation determines how much protection against flooding, runup and overtopping it will provide; hence, there are limits on how low a dune crest can be and still provide protection. Certainly, the design surge level coupled with the requisite sand volume above that level leads to a practical minimum dune crest elevation. A dune, with the requisite volume above a given surge level, that is too flat will significantly reduce the beach area available for recreational use. Furthermore, overtopping can result in erosion of the back face of the dune which is not considered by the FEMA or Vellinga methods. The Corps of Engineers uses a numerical model, SBEACH, to predict the beach profile response to storm waves and surge levels (Larson & Kraus, 1989; Larson, et al., 1990; Rosati, et al., 1993 & Wise, et al., 1996). This model considers runup and overtopping. Also, the Corps' analyses are based on the economics of providing protection for a 50-year project lifetime. Thus visibility over a dune is only one additional factor to be considered.

<u>Visibility</u>

Obviously, the ability to see the ocean from behind a dune depends upon the elevation of the dune crest and the elevation of the observer's eye – with all elevations measured relative to sea level. The distances from the observer to the dune crest and to the shoreline are also factors. Figure 1 shows the relevant distances and elevations. The amount of ocean visible to an observer is Z_v and the fraction visible is Z_v/Z_{eye}. The relationship among these factors is easily defined by the geometry. Thus,

$$\frac{Z_V}{Z_{eye}} = \frac{X_{shoreline}}{X_{dune}}\left(1 - \frac{Z_{dune}}{Z_{eye}}\right) \tag{2}$$

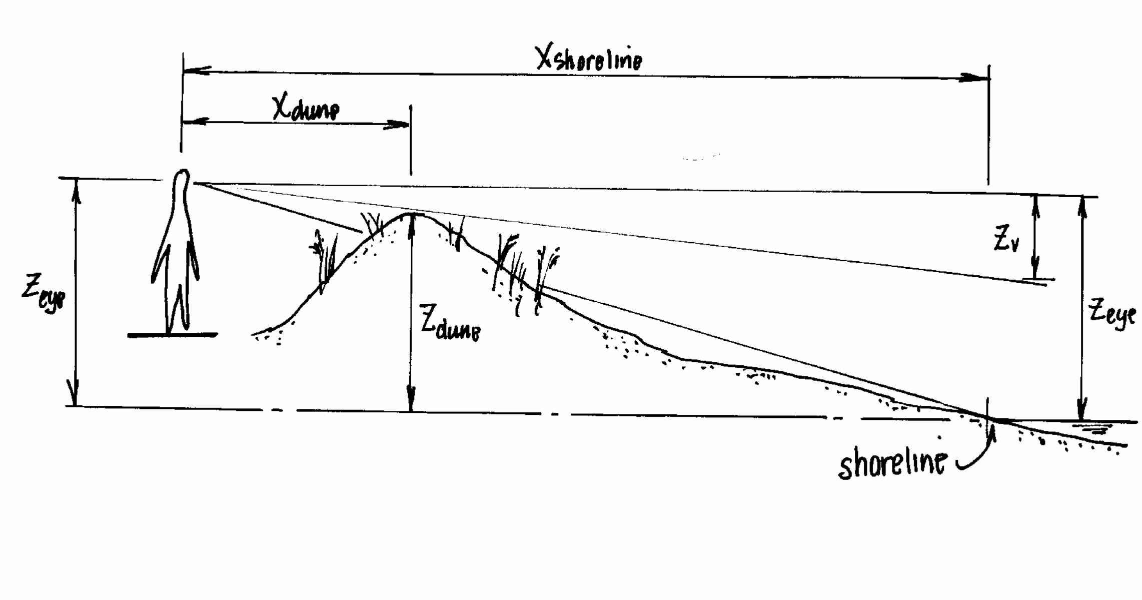

Figure 1 Schematic View of an Observer Looking Across a Dune to the

Note that in most cases the beach berm near the shoreline will limit ocean visibility even when the dune does not. Figure 2 graphically presents the relationship of equation 2.

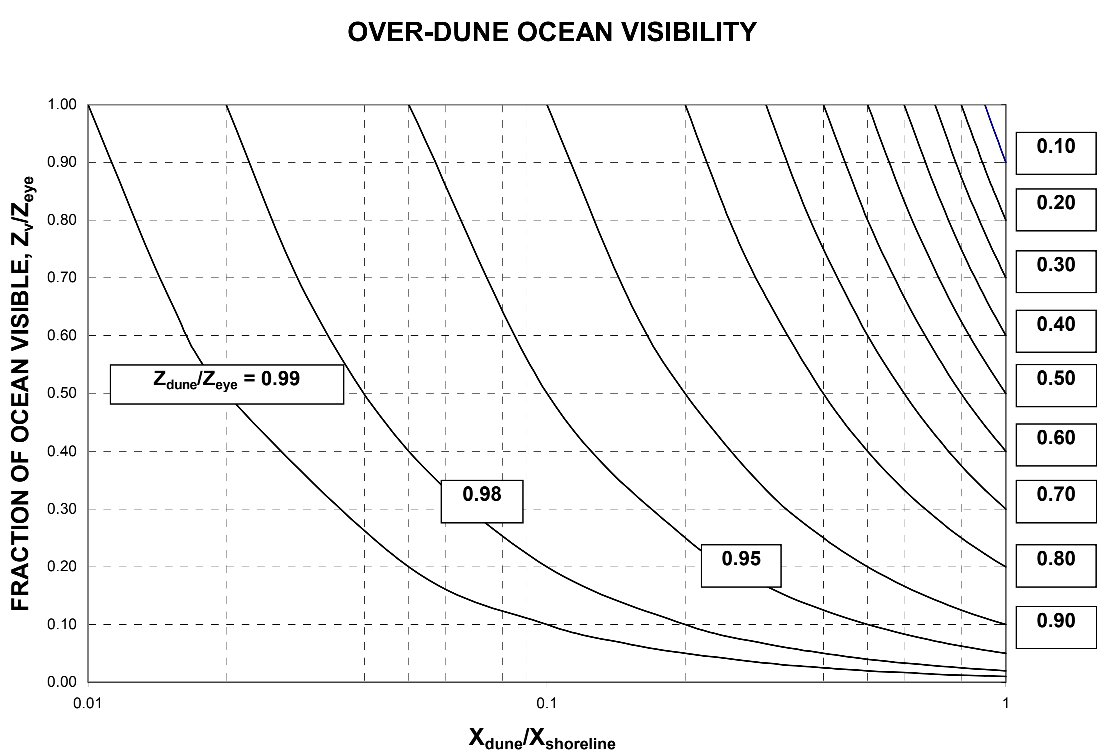

Figure 2 Relative Visibility of Ocean, Z_v/Z_{eye} as a Function of Z_{dune}/Z_{eye} and $X_{dune}/X_{shoreline}$.

The application of Figure 2 can be illustrated by an example.

Example Problem

Find: Determine the required elevation of the porch of an ocean-front cottage if a 5'-10" tall observer is to see over a dune having a crest elevation of 12 feet. The crest of the dune is located 50 feet in front of the observer and the distance to the shoreline from the observer is 400 feet. The berm elevation is 5 feet and it is 50 feet landward of the shoreline.

Solution: Check the visibility over the dune first. Calculate $X_{dune}/X_{shoreline}$ = 50/400 = 0.125. From Figure 2 for 100% visibility (Z_v/Z_{eye} = 1), Z_{dune}/Z_{eye} = 0.85; therefore, Z_{eye} = 12/0.85 = 14.12 feet. The observer's eye must be 14.12 feet above sea level. Eye level is about 92.8% of an adult's height so eyelevel for an observer 5'-10" (70") tall will be about 65" or 5.42 feet. The porch elevation must be 14.12 – 5.42 = 8.7 feet for the standing observer to see over the dune.

Checking the berm elevation, $X_{berm}/X_{shoreline}$ = 350/400 = 0.875 and Z_{berm}/Z_{eye} = 5/14.12 = 0.354. Entering Figure 2, with $X_{berm}/X_{shoreline}$ = 0.875 and Z_{berm}/Z_{eye} = 0.35 yields Z_v/Z_{eye} = 0.74. Thus, the berm reduces visibility of the ocean to 74% of maximum visibility. One can ask, how high the observer's eye must be to see the shoreline. From Figure 2, with $X_{berm}/X_{shoreline}$ = 0.875 and Z_v/Z_{eye} = 1.0, Z_{berm}/Z_{eye} = 0.12. Therefore, Z_{eye} = 5/0.12 = 41.7 feet; obviously an impractical elevation.

The distance to the horizon from an observer's eyelevel is given by,

$$X_{horizon} = \sqrt{(R_{earth} + Z_{eye})Z_{eye}}\ , \qquad (3)$$

in which R_{earth} = the Earth's radius, or, since $Z_{eye} << R_{earth}$,

$$X_{horizon} \cong \sqrt{20{,}900{,}000 Z_{eye}} \qquad (4)$$

which is plotted in Figure 3. Hence our observer can see about 3.25 miles to the horizon.

If the 100-year surge elevation is 7 feet, the volume in the dune above that elevation must be, $V = 86.1(T)^{0.4} = 86.1(100)^{0.4}$ or 540 ft^3/ft. Hence, the dune would have to be more than 100 feet wide to protect against the 100-year storm.

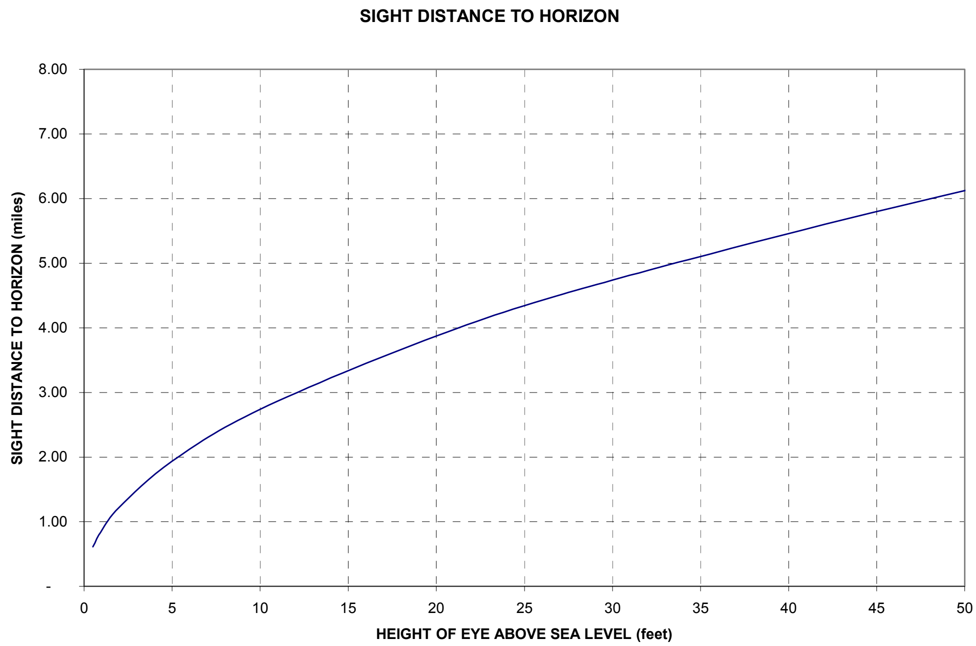

Figure 3 Distance to the Horizon as a Function of Eye Level above Sea Level.

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