Most shoreline erosion does not occur on a day-to-day basis, but rather it is a product of high-energy storm events. Consequently, in any specific location, erosion is a process that is extremely variable from year to year and depends on the following climatic conditions:

1. Storm frequency
2. Storm type and direction
3. Storm duration and intensity
4. Resulting storm tides, currents, and waves

Most of the ocean shoreline, as well as the estuarine shorelines within the Northern Coastal province, are in a general state of recession. The N.C. Division of Coastal Management has documented the average annual shoreline erosion rates for the entire ocean shoreline of the state over a 52-year period (1946 to 1998). This study established that the annual ocean shoreline erosion rates for the Hatteras and Raleigh Bay compartments vary from zero up to an average of sixteen feet per year.

Within the large, open water estuaries of the Northern Coastal province, Riggs and Ames (2003) documented average annual sediment-bank erosion rates up to -23 feet per year and marsh shoreline recession rates up to -7.5 feet per year. Because there is minimal astronomical tidal fluctuation in these estuaries and the large surface areas of estuarine water or fetch (the distance that the wind blows over the water) are so great, these estuaries are dominated by storm-tide and wind-wave processes that lead to serious coastal erosion problems.

Storm winds readily push water around, blowing it out of upwind areas and piling it up against the opposite downwind shoreline as large water ramps or storm tides. This effect is illustrated in figure 1-9. With no wind, the water surface tends to be a flat, smooth surface without waves or slope. As the wind begins to blow, waves form, and wave size increases through time. As the wind builds, the water currents begin to move in the direction of the wind, lowering the water surface in the upwind direction and raising the water surface in the downwind direction, causing flooding of the adjacent lowlands. The wind-generated waves on top of this sloping ramp, or storm tide, erode the shoreline and cause property damage to piers, roads, and land structures. The sloped water ramp will be maintained as long as there is a wind holding it up. When the wind diminishes, the water will flow back down the ramp to its original flat surface.

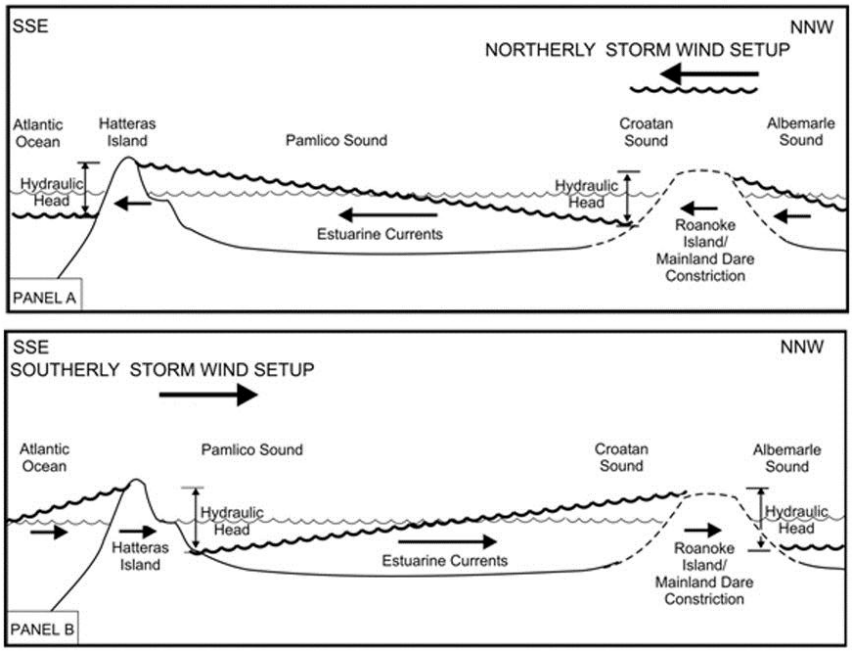

Figure 1-9. Model of estuarine storm tides in the North Carolina sounds that form in response to different storm events. Wave energy added to both high and low storm tides is the primary process driving estuarine shoreline recession.

Panel A. High storm tides occur along southern shores in response to events dominated by northeast, north, or northwest wind directions, whereas low storm tides occur along the northern shores.

Panel B. High storm tides occur along the northern shores resulting from events dominated by winds from the west, southwest, or south wind directions, whereas low storm tides occur along the southern shores. Figure 5-2-1, p. 57 in Riggs and Ames (2003).

Storm tides occur whenever a major storm associated with a weather front, tropical depression, or hurricane impacts the North Carolina coast. The resulting storm tide is dependent upon the intensity, duration, and direction of movement of each storm. Frontal storms (i.e., nor'easters) are characterized by winds that range from 25 to 50 miles per hour, whereas tropical storms and hurricanes will typically come ashore with winds in considerable excess of this. Consequently, frontal storm tides generally range from two to five feet above mean sea level (msl), whereas tropical storms can range upwards of ten to fifteen or more feet above mean sea level.

The direction from which strong winds blow determines where coastal flooding within the estuaries occurs (figure 1-9). The coast on the leeward side of the water body will generally experience low water levels, whereas the windward shore will experience high water. The effects on the ocean side of the islands work the same way. As you would expect, winds from the north or northeast produce high storm tides on the shores that face north or northeast. That is the reason for the high rates of coastal erosion on the Outer Banks north of Cape Hatteras, caused by the frequent nor'easters that pummel the islands during the winter.

Hurricanes that cross the Northern Coastal province coastline in any direction produce estuarine storm tides that slosh back and forth and may impact either the inner or outer portions of the estuaries or both. The initial winds will often blow the waters up the estuaries, producing low wind tides along the south side of the barrier islands and high wind tides in the upper reaches of the trunk estuaries. As the eye of the hurricane passes and storm winds come from the opposite direction, there is a rapid back flow, causing high water and resulting in catastrophic coastal consequences on the sound side of the barrier islands.