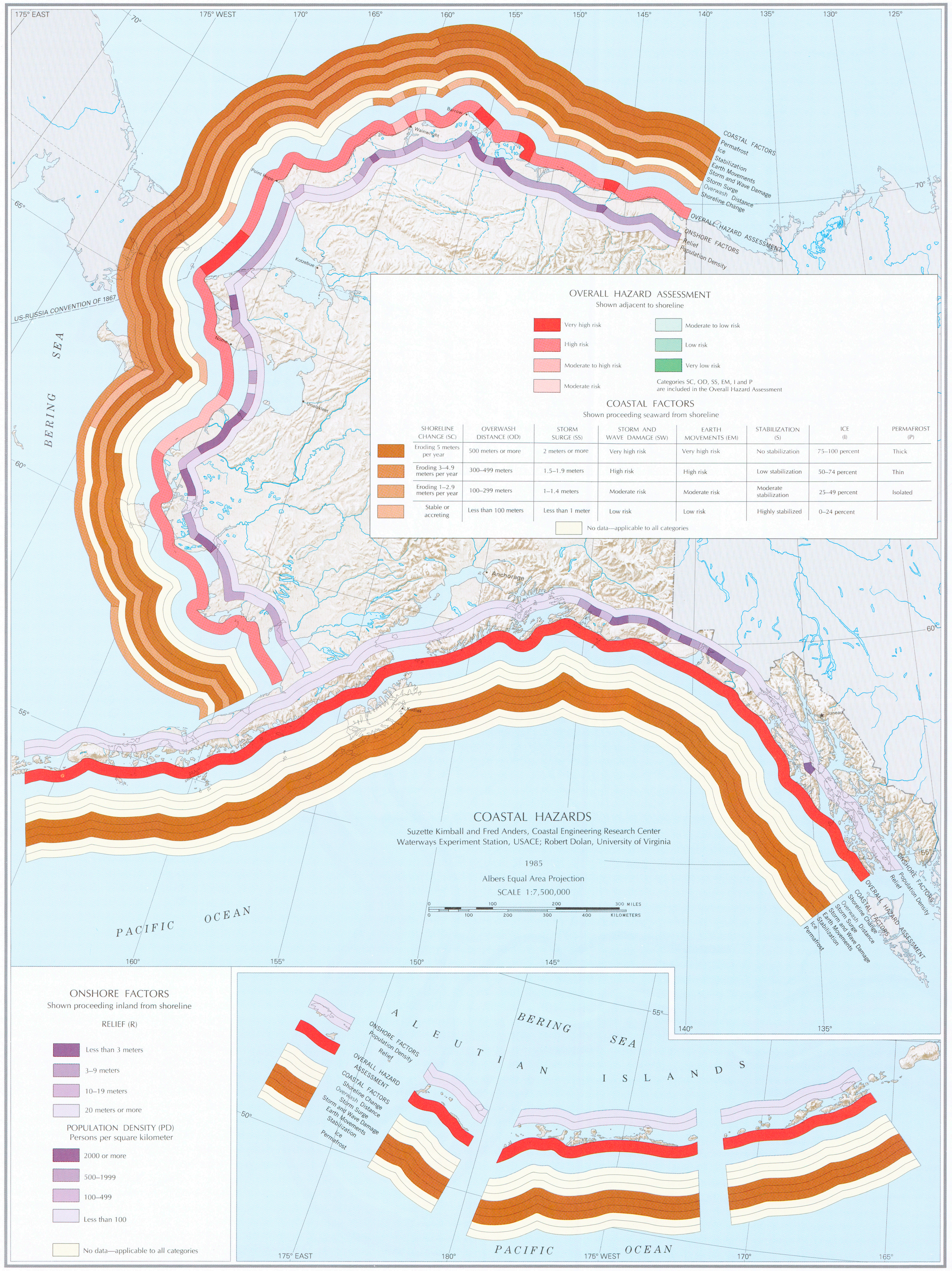

COASTAL HAZARDS

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INTRODUCTION

In the coastal zone, naturally occurring processes are constantly interacting to affect the landscape. Many of these processes operate imperceptibly, but some have the potential to reach great intensity and radically alter the coastal morphology in a short period of time. The resulting changes are part of the natural regime and, considered over geologic time, are a continuum of events in the evolution of the landscape. However, these same intense processes, when in conflict with man's activities in the coastal zone, are perceived as hazards. The conflict between humans and coastal processes revolves around the inability of man and the structures he builds to tolerate unstable conditions. In recent decades, Americans have flocked to the coastal zone in ever increasing numbers to enjoy the benefits of oceanside living. When the coastal zone has been developed without regard to its dynamic nature, the natural processes become natural hazards.

COASTAL AND MODIFYING HAZARD FACTORS

Coastal factors, represented by a series of offshore bands, depict the frequency and/or intensity of occurrence of a variety of factors. Proceeding in a seaward direction, the coastal factors are shoreline erosion, overwash penetration, storm surge, storm/wave damage, and earth movements. The outermost band (except in Alaska) shows stabilization measures along the coast. Such measures are not a process but man's response to the hazards. Along the Alaskan coast two hazard bands, ice and permafrost, have been added on the outside.

The *onshore factors* of relief and population densities (omitted in Hawaii for cartographic purposes) modify the overall hazard assessment. In most cases higher relief means lower risk, and higher population density implies a greater potential for disaster from hazards.

The effect of the hazards on the coastal zone varies considerably depending on the initial morphology. Much of the Atlantic and Gulf Coasts are fronted with barrier islands. A typical ocean to land cross-section (Fig. 1) shows a barrier island separated from the mainland by a lagoon or bay. The bay is of variable width; in some cases only a tidal creek separates the island from the mainland. The barrier islands are typically low in relief. The beach, dune, and back barrier are composed of sand, and the marsh is a combination of organic detritus and clays. These barriers are not static features, but instead are dynamic. They change over the long-term in response to sand supply, sea level variations, wave energy, and earth movements. At present, most barriers are moving landward in response to a worldwide rise in sea level. These processes are not hazards, but rather natural phenomena that are essential to the maintenance of the barriers through time. Their hazardous impact is related to burgeoning human development on the barrier islands, which has greatly increased the likelihood of disaster along the Atlantic and Gulf Coasts.

The Pacific Coast and the coast of Hawaii have a varied morphology, ranging from rocky headlands and narrow beaches backed by bluffs, to spits which are similar to Atlantic Coast barriers. These morphological differences are reflected in the individual factor rankings. For example, overwash is not a hazard on rocky headlands or bluffs, but the high probability of earth movements on steep slopes is a potential hazard. The processes active along the Pacific Coast result in dynamic beaches and active conditions in low lying areas, but in areas of high relief the danger to humans is reduced. The southern Alaskan coast has high relief and is similar in this respect to the Pacific Coast. The northern Alaskan coast, however, is similar to the Atlantic Coast, having barrier islands and low relief, but with the addition of cold climate-related hazards.

OVERALL HAZARD ASSESSMENT

The overall hazard assessment is shown by the wider single along-shore band. Each category for each coastal factor, except stabilization, was assigned a value from low (1) to very high (4). For each segment of the shoreline the numerical value for each factor was squared and then averaged to determine the overall hazard rating. The overall ratings range from very low (1) to very high (7). Squaring each value gives greater emphasis to extreme events which generally constitute the greatest hazard. For example, an area might rank low (1) in most hazards but high (3) in shoreline erosion. Unweighted averaging would give this area a very low hazard rating (1), even though the chance of damage to structures by erosion is quite high. By squaring each value first, the overall rating would still be relatively low (2) but the slight increase is more reflective of the actual danger involved in living in that coastal area.

The primary reason for the inclusion of the stabilization, relief, and population density bands is to allow the reader to evaluate the hazard potential and the modifying factors for any segment of shoreline, and to arrive at a conclusion regarding the potential threat to property and human life. These factors were not used in the overall hazard assessment, except in cases where the values calculated fell between two classifications. In these few cases, the final hazard rating was qualitatively determined by considering how stabilization and relief modify the hazard potential of each process, and how population density affects the likelihood of a coastal disaster.

DATA COLLECTION

The information presented was compiled from research conducted by a large number of people in many disciplines. The scientific literature was accessed through computer searches of reference libraries and was supplemented by checking printed bibliographies. In addition, the authors communicated directly with numerous researchers and officials to obtain unpublished information. All U. S. Army Corps of Engineers Division and District offices were contacted. Other Federal agencies contacted include: National Ocean and National Weather Services of the National Oceanic and Atmospheric Administration, Federal Emergency Management Agency, Bureau of the Census, Environmental Protection Agency, U. S. Geological Survey, and National Park Service. In some cases State agencies, such as Coastal Zone Management and Sea Grant Offices were contacted. Also, selected university faculty members and individuals within private organizations, with an interest in coastal research, were queried for additional references.

Data were most readily available for the Atlantic and Gulf Coasts, which are the areas of greatest overall potential hazard and highest population density. There are large gaps in the available data for the Pacific Coast and the coasts of Hawaii and Alaska. A catalogue of data sources used to compile the map is maintained as part of a shoreline information system by Dr. Robert Dolan at the Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903.

ACKNOWLEDGEMENTS

Mr. David Reed and Ms. Rebecca Savage provided valuable assistance in all phases of this work. Permission was granted by the Chief of Engineers, U. S. Army Corps of Engineers, to publish this information.

COASTAL FACTORS

Shoreline Change. Since the last glacial period worldwide sea level has been steadily rising. Today, the rise in sea level continues at a slow, but measurable rate. For most areas of U. S. coastline, this rise has been the primary factor behind a steady recession of the shorelines. The rise, however, has not been expressed uniformly along the coast. In areas such as Louisiana and Texas the rate of shoreline erosion is much greater than can be explained by sea level rise alone. Sediments originally deposited by the Mississippi River throughout the central Gulf of Mexico subside from their own weight. The result is a very rapid rise in sea level relative to other segments of the coastline and hence, rapid shoreline recession (Fig. 2). Subsidence by compaction and by tectonic movement occurs in many locations.

In areas that were covered by ice during the last glacial period, the relative rise in sea level may appear less than predicted. In these areas, the land is rebounding upwards as a result of the removal of the great weight of ice and water, producing a slower relative sea level rise. In recently deglaciated areas, such as portions of the Alaskan coast (Fig. 2), a decrease in relative sea level results. In other locations tectonic activity may be pushing the land upward, or large influxes of sediment from adjacent eroding cliffs or river mouths may produce a coastline that is stable or accreting.

Within the classification of erosion used here, coasts which are accreting, stable, or very slowly eroding over the long-term, do not present a hazard. However, it must be remembered that over the short term erosion and accretion of these beaches might be highly variable and therefore hazardous. The remainder of the classification is for categories of erosion. Erosion is accomplished both on a day-to-day basis and by storms. Damage to ocean front structures usually occurs during storms, but an underlying cause is the condition of the beach from daily erosion.

Overwash Penetration. During storms, wave attack along the beach can cause a break in the dune line, allowing water and sediment to pass through. Overwash may penetrate hundreds of meters landward of the beach. Once the waters recede, characteristic sand deposits are left behind (Fig. 3). Data presented here show the maximum known distance to which overwash has penetrated in the past. On developed coasts, an immediate hazard results from the moving water, and after passage of the storm, the sand deposits may hinder recovery operations.

Storm Surge. As storms approach the coast, they are generally accompanied by a storm surge, and an elevation of the water level above the normal tides. Storm surge is due to a combination of two factors. First, the low pressure storm center allows an elevation of the water surface beneath the storm. Second, water levels increase along the shoreline as wind-driven waves transport more water landward than can be returned offshore. In 1969, hurricane Camille produced a storm surge along the Mississippi coast of over 7m (DeAngelis and Nelson, 1970), but typical surge is less than 2m. The data represented on the map show the storm surge expected from a storm with a 10-year recurrence interval. Storms with a longer recurrence interval (e.g., a 100-year storm) would have a greater surge. Storm surge can cause flooding along the ocean and in bay areas. The higher water level means that larger waves can penetrate farther landward, increasing the chance of direct wave damage, overwash, and inlet formation. Severe damage from storms has a greater probability where storm surge and high tide coincide.

Storms/Wave Damage. This category is based on: (1) frequency of tropical storms, or (2) frequency of extratropical storms, or (3) frequency of tsunamis at least 1 meter high. The process which was found to be the greatest hazard for the segment of coast in question was used in the hazard analysis.

Tropical storms are those which originate between 23.5 degrees north and south latitude. Hurricanes, with winds greater than 117km/hr, are the best known tropical storms. Tropical storm damage results from strong winds, large waves, storm surge, heavy rains, and overwash. These storms rarely affect the Pacific Coast of the United States, but the Gulf Coast and middle to southern Atlantic Coast are very susceptible. The tropical storm season runs from July through November; September is the peak month.

Extratropical storms are those which originate outside of the tropics. The hazards associated with these storms are the same as tropical storms, except that in cold weather the precipitation may be in the form of snow. These storms have been known to cause damage equivalent to hurricanes when the storm surge and local high tides coincide. The February 1978 "Nor'easter" which struck the New England coast had a 1.2m surge, 3m-high breaking waves, and resulted in over $200 million in damages (Zaremba and Leatherman, 1984). These storms follow tracks which are roughly governed by the jet stream. Most Pacific Coast storms are extratropical.

Tsunamis are included in this category because the hazard associated with them is primarily wave damage and flooding. Tsunamis are usually the result of a rapid, underwater earth movement, such as an earthquake or volcanic eruption, which can cause long-wavelength low-amplitude waves to develop on the surface of the ocean. As they approach the shoreline the wavelength shortens and amplitude increases, and a series of large destructive waves can result. The passage of a tsunami on April 1, 1946, at Scotch Cap, Alaska, completely destroyed a two-story lighthouse, and removed a radio tower located on a cliff 31.4m above sea level (Bascom, 1980). The high incidence of seismic activity ringing the Pacific Ocean increases the hazard from tsunamis along the U. S. Pacific Coast and in Hawaii and Alaska.

Earth Movements. Data on seismic, tectonic, and landslide activity in coastal regions are combined in this category. The process found to be the greatest hazard for each segment of coast was used to define the hazard rating. The data represent the past frequency of occurrence of earth movements and are assumed to indicate the potential for future movements.

Their positions on the leading edge of drifting continental plates put the Pacific Coast and southern Alaska in a zone of high activity. The Gulf and Atlantic Coasts have low seismic hazards, although earthquakes can occur in these areas. In coastal locations, flooding can be an additional hazard caused by earth movements, as during the 1964 Alaskan earthquake when the tip of Homer Spit, located in Cook Inlet, lost over 2m of elevation within a short period of time (Smith et al., 1985). Along the Atlantic and Gulf Coasts, the slopes are generally low, but the steep bluffs which back many of the California, Oregon, Washington, and southern Alaskan coasts are susceptible to landsliding.

Stabilization. Most of the hazard categories are processes, but structures are a human response to the hazard presented by these processes in populated areas. Structures are assumed to reduce the effect of many of the hazardous processes. Data for the stabilization category were collected primarily from maps, and therefore tend to reflect the presence of hard structures which resist natural forces. Low stabilization includes areas where there were no more than four structures per mappable unit (15km), and highly stabilized areas have more than twelve structures.

Ice. In the conterminous United States, ice is not a coastal hazard, except in the Great Lakes. It can be a severe problem, however, along the northern coast of Alaska. Ice ride-up can erode beaches and ice cover can severely affect shipping. In this classification, the average percent of coverage along coastal waters is considered.

Permafrost. Permafrost is a hazard along the coast of northern Alaska, where soil can freeze to considerable depth. During the brief summers, only the upper surface of the permafrost thaws. This thawed layer can be very susceptible to erosion and mass wasting, and during the onset of winter, frost heaving can pose a hazard. The classification of permafrost used depends on its thickness and continuity.

ONSHORE FACTORS

Relief. Relief modifies the result of coastal processes. For example, landslide hazard can increase with higher relief, yet high relief reduces the danger resulting from storm surge. The effect of relief on erosion depends on the material composing the shoreline. The elevations adjacent to beaches along most of the Atlantic and Gulf Coast barrier islands are under 3m. In the northeast, the relief can increase to over 30m. Along the Pacific Coast many beaches are backed by cliffs, and in other areas rocky headlands project directly into the ocean. The southern coast of Alaska is mountainous, while the western and northern shorelines are generally less than 10m in elevation.

Population. The data (people per square km) represent the year-round population, which for many coastal areas is well below the summer population. For example, the 1984 census for Dare County, NC, a coastal county, is 16,400, but the average daily population during August is estimated to be 80,000. The number of buildings within most areas of the coast reflects more closely the summer population. The population categories shown here can be used with the hazard data to determine coastal areas where the potential for disaster is greatest.

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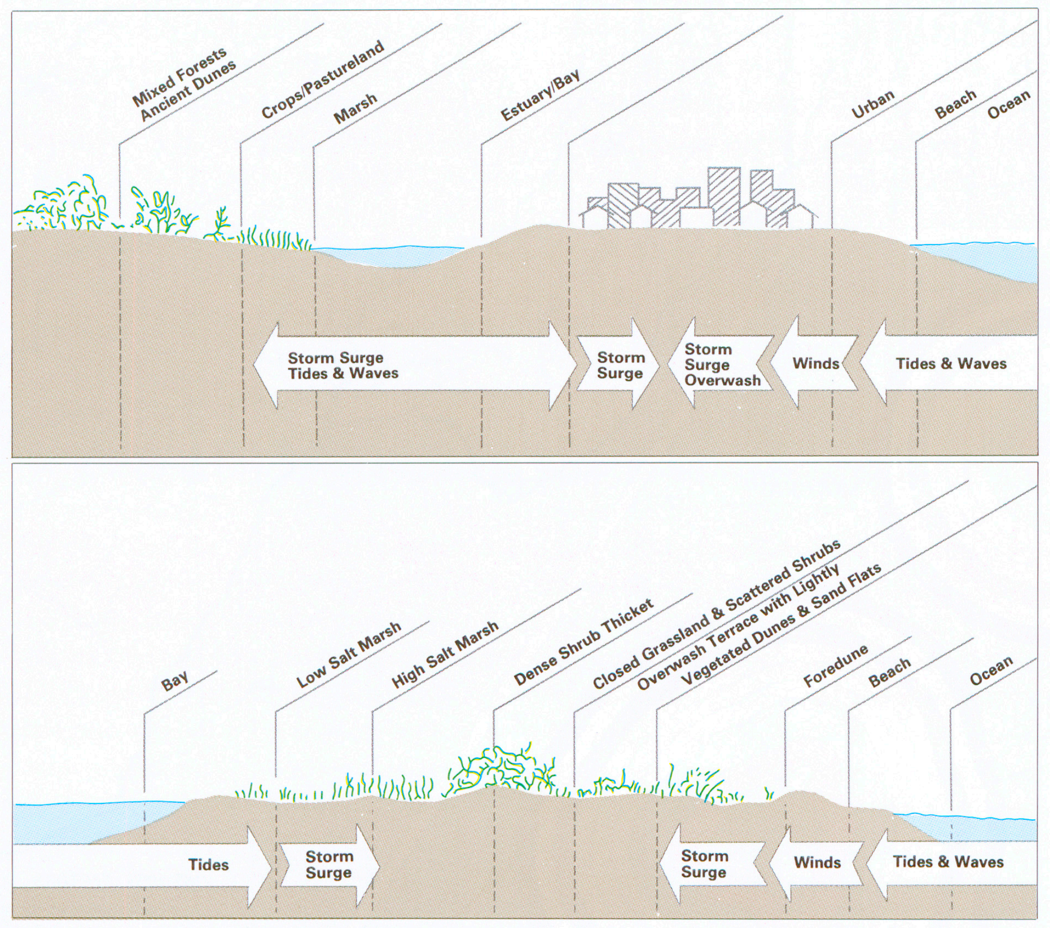

Figure 1. Developed and undeveloped barrier islands, depicting general locations of land use and land cover types in relation to dominant shoreline processes. (R. Dolan)

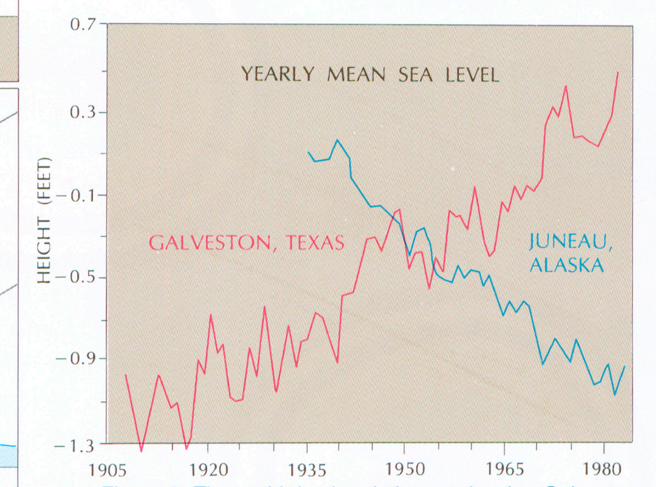

Figure 2. The rapid rise in relative sea level at Galveston is due in part to subsidence of the land. At Juneau, as along much of the Alaskan Coast, upward movement of the land by isostatic rebound and tectonic activity has resulted in a relative decrease in sea level. (S.D. Hicks, National Ocean Service)

Figure 3. This overwash feature was formed along the Gulf Coast at Cedar Lakes, Texas, during the passage of a hurricane. (Coastal Engineering Research Center)

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INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1989
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