1 **Introduction to**
Environmental Geology, 5e
Chapter 11
Coastal Processes

2 **Shorelines: summary in haiku form**
Build house on cliff
for a view of the ocean -
be one with said view.

3 **Case History:**
The Cape Hatteras Lighthouse
- Beach erosion threatens the historic Cape Hatteras Lighthouse
- 0.5 km (.3 mi) from the sea when constructed in late nineteeth century, only 100 m away from the sea in 1990s
- Much debate over three options:
- The U.S. Army Corps of Engineers originally proposed to protect the lighthouse by constructing a $5.6 million seawall around the base
- Do nothing and eventually lose the lighthouse and, thus, an important bit of American history
- Move the lighthouse inland. Many local people opposed this plan, fearing the lighthouse would collapse if moved

4 **Case History:**
The Cape Hatteras Lighthouse
- Much discussion, argument, and controversy over what to do
-
- In 1999, the National Park Service moved the lighthouse inland approximately 500 m (1,640 ft) from the eastern shore of Hatteras Island
-
- The lighthouse was moved 500 m further inland at a cost of $12 million
-
- Another lighthouse battle is looming on the East Coast, the famous Montauk Lighthouse

5 **Case History:**
The Cape Hatteras Lighthouse
Figure 11.1

6 **Introduction**
- Dynamic coastal environment: Convergent zone of continental and oceanic processes
-
- Varied topography, climate, and vegetation, more than 50 percent of world population concentrated in the coastal zones
-
- Long shoreline (93,000 mi), ~75 percent of U.S. population living in coastal states
-
- Largest cities in coastal zones, coastal hazard problems compounded by increased human activities

7 **Coastal Hazards**
- Tropical cyclones (hurricanes in the Atlantic and typhoons in the Pacific) and other severe storms
-
- Marine floods and inland floods due to tropical storms
-
- Coastal erosion
-
- Tsunamis and tidal currents

-
- Rip currents

8 **Coastal Processes: Waves**

- Formed by winds: Magnitude of waves controlled by
  - Speed of the wind
  - The duration of the wind
  - The fetch of the wind — the area or distance blown by winds
  -
- Tsunamis: Caused by earthquake or other seafloor movements

9 **Wave and Water Movement**

Figure 11.3

10 **<u>Properties of Waves</u>**

11 **Wave and Water Movement (2)**

- Swell: The wave groups generated by storms far out at sea
- As the swell enters shallower water, transformations take place that eventually lead to the waves breaking on the shore
- Wave energy is approximately proportional to the square of the wave height. Thus if wave height increases to 5 m (16 ft), increases 5^2, or 25 times over that of waves with a height of 1 m (3.3 ft)
- Waves are unstable when the wave height is greater than about 10 percent (0.1) of the wave length

12 **Wave Energy**

- Waves expend energy along the coastline
-
- Wave translation: Decrease in wave length and velocity, but increase in wave height; deep water wave energy translating into wave breakers,
  pounding the shore
-
- Wave refraction: The bending of waves (convergence) towards the protruding areas (headlands) and the divergence of waves at the beach or embayment
-
- The long-term effect of greater energy expenditure on protruding areas is that

13 **Wave Refraction**

- Long-term effect of wave refraction: Straightening the irregular shoreline, erosion of headlands

14 **<u>Wave Motion/Refraction</u>**

15 **Beach Form**

Figure 11.6

16 **Currents**

- Horizontal movement of a large volume of seawater
  - Due to oblique waves
  -
  - Due to differences in water temperature
  -
  - Due to differences in water salinity
  -
  - Global currents or more local currents

17 **Littoral Currents**

- Littoral currents and longshore beach drift
-
- Swash pushing sediment onshore in an oblique angle
-

- Backwash: Back flow of water and sediments perpendicular to shore by gravity
-
- Net effect: Zigzag longshore beach drift
-
- Changes of seasonal and weather conditions resulting in changes of beach faces and textures

18 **Rip Currents**

- Formation: A series of large waves surging to shore, then the rapid backflow of the piled up water in narrow zones
-
- Up to 200 people killed and 20,000 rescued from rip currents each year
-
- Importance for people to recognize rip currents and to swim parallel to the shore until out of the rip zone to escape the hazard

19 **Transport of Sand**

- A longshore current is produced by incoming waves striking the coast at an angle
- The longshore current is a stream of water flowing parallel to the shore in the surf zone
- Longshore sediment transport: The process that transports sand along the beach
- Sand is transported along the coast with the longshore current in the surf zone; and
- The up-and-back movement of beach sand in the swash zone causes the sand to move along the beach in a zigzag path

20 **Transport of Sand**

Figure 11.7

21 **<u>Beach Drift and Longshore Currents</u>**

22 **Beach Budget**

Figure 11.A

23 **Coastal Erosion**

- National and global problem
- Erosion factors
  - Constant wave actions
  - Tropical cyclones, Nor'easters
  - Tsunamis
  - Tidal actions
  - Long-term rise of sea level
  - Human activities

24 **Sea Cliff Erosion**

- Wave erosions and land erosion processes (landslide, mudflow, runoff)
-
- Human activities promoting sea cliff erosion
  - Urbanization
  - Added structures along the edge—pools and patios
  - Irrigation and other activities
  -
- Hazard reduction: Reducing runoff (drainpipes), planed development and activities

25 **Measuring Coastal Change**

- Remote sensing method of measuring and monitoring changes in the coastal environment
-
- LiDAR(Light Detection and Ranging) technology measures several thousand elevation measurements per second, with vertical resolution of better than 15 cm (6 in.)
-
- Once a baseline set of elevations is recorded, subsequent flights can detect changes in the coastal zone

26 **Measuring Coastal Change**
Figure 11.B

27 **Hard Stabilization: Engineering Structures**
- Common structures: Seawalls, groins, breakwaters, and jetties
- Benefits
  - Improve navigation
  - Retard erosion, recreational beach expansion
- Problems
  - Interference with longshore currents, causing unintended adjacent local erosion and deposition

28 **Soft Stabilization: Beach Nourishment**
- Alternative to coastal engineering structures
- Constructing a positive beach sand budget
- A successful case:
  - Miami Beach, Florida, 1970s–1980s
  - 200 m wide beach, survived major hurricanes in 1979 and 1992
  - The project cost approximately $62 million over 10 years
  - Foreign tourism alone brings in about $2 billion per year, over 650 times the cost of the nourishment
- Not all successful, some unsuccessful projects

29 **Human Activity and Coastal Erosion**
Atlantic Coast: Barrier islands from FL to NY
Example: Ocean City, Maryland
- Summer resort city, high-rise developments
- Inlet opened in 1933 hurricane, vulnerable for future hurricane or other severe storms, only matter of time
- Local erosions due to development and removal of natural dunes
- Rapid shoreline erosion in Assateague Island due to the starvation of sand supply blocked off by the Ocean City inlet jetties

30 **Ocean City, Maryland**
Figure 11.17

31 **Human Activity and Coastal Erosion (2)**
Gulf Coast
- Last 100 years, coastal erosion along Texas coast accelerated by 30 to 40 percent
- Coastal erosions along the Gulf of Mexico
  - Due to land subsidence from the groundwater withdrawal and petroleum exploration
  - Reduction of sand supply from the damming of rivers
  - Gradual rise of sea level due to global warming

32 **Human Activity and Coastal Erosion (3)**
The Great Lakes
- Periodic problems along the coasts of the Great Lakes
- Coastal erosions
  - Fluctuations of lake water level
  - Lack of natural frontal dunes

– Erosions more severe along the Lake Michigan shoreline
– Increased slope instability due to groundwater seepage

33 **Tropical Cyclones**
- Known as typhoons in most of the Pacific Ocean and hurricanes in the Atlantic
- Strong winds: Hundreds mph winds damaging structures, power lines, and trees
- Large areas: Diameter up to 600 km (370 mi) and 100s miles into inland
- Intense precipitation: Marine floods and inland floods
- Storm surge, if compounded with high tide: Great amount of flood and coastal erosion
- Annual average: Possible impact from five hurricanes along the Atlantic Coast

34 **Tropical Cyclones (2)**
Table 11.1a

35 **Tropical Cyclones (2)**
Table 11.1b

36 **Hurricane Paths**
Figure 11.22

37 **Perception and Adjustment**
- Perception: Largely affected by past experience, proximity to the coast, and probability of suffering damages
-
- Adjustment
  - Better protective structures
  - Better land use zoning
  - Better coastal mitigation planning and emergency management (preparation, evacuation and warning, post-storm management procedures)

38 **Managing Coastal Erosion**
Five general principles
- Coastal erosion: A natural process, posing natural hazards as development approaching shore fronts
- Shoreline construction causes changes: Often better for some, worse for others
- Stabilization of the coastal zone: Protecting the interests of few at the expense of the general public
- Engineering structures: Design and consequences
- Structural versus nonstructural alternatives to coastal erosion problems

39 **E-Lines and E-Zones**
Figure 11.E

40 **Tides**
- Daily changes in the elevation of the ocean surface
- Causes of tides
  - Tidal bulges are caused by the gravitational forces of the Moon, and to a lesser extent the Sun

41 **Tides are caused by the gravity of the Moon and Sun acting on the ocean**

42 **Tides**
- Monthly tidal cycle
  - Spring tides
    - Occur during new and full moons
    - Gravitational forces of the Moon and Sun are added together
    - Especially high and low tides
    - Large daily tidal range

43 **Spring Tide**

44 **Tides**

- Monthly tidal cycle
  - Neap tides
    - Occur during the first and third quarters of the moon
    - Gravitational forces of the Moon and Sun are offset
    - Daily tidal range is least

45 **Neap Tide**

46 **Monthly Tidal Cycle**

47 **Tides**

- Other factors that influence tides
  - Shape of the coastline
  - Configuration of the ocean basin
- Tidal patterns
  - Diurnal tidal pattern = a single high tide and a single low tide each tidal day
  - Semidiurnal tidal pattern = 2 high tides and 2 low tides each tidal day

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51 **Tides**

- Tidal patterns
  - Mixed tidal pattern = large inequality in high water heights, low water heights or both
- Tidal currents
  - Horizontal flow of water accompanying the rise and fall of the tide

52 **Tides**

- Tidal currents
  - Types of tidal currents
    - Flood current – advances into the coastal zone as the tide rises
    - Ebb current – seaward-moving water as the tide falls
  - Areas affected by the tidal currents are called tidal flats
  - Occasionally form tidal deltas

53 **Tidal delta and tidal flats**

54 **Tides**

- Tides and Earth's rotation
  - Tidal friction against the ocean floor acts as a weak brake that is steadily slowing Earth's rotation
    - The day is increasing by 0.002 seconds per century
    - This small effect becomes very large over millions of years
  - Length of each day must have been shorter in the geologic past
    - –

55 **Critical Thinking Topics**

- Are all coastal processes naturally hazardous? Explain
-
- What can be done to reduce damages from tropical cyclones?
-
- Beach nourishment project: an environmental decision or an economic decision or both?
-
- Will coastal hazards become more severe, less severe, or stay the same in the geologic future?
-
- What are the management procedures in place for your community, if you live in a coastal state?

56 **Chapter 11 Figures**

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125 **End of Chapter 11**