1 **Introduction to Environmental Geology, 5e**
Chapter 9
Rivers and Flooding

2 **Running Water: summary in haiku form**
The hydro cycle –
water returns from the sea.
All "toilet to tap."

3 **Case History: Pakistan Floods of 2010**
- Water covers about 70 percent of Earth's surface, and flood causes a significant hazard to human life and property
- The number of people killed or affected, along with economic loss, is the greatest in Asia
- A monsoon refers to a seasonal shift in air pressure and precipitation patterns (dry winter to wet summer)
- August of 2010, the greatestmonsoon rains in decades, caused catastrophic flooding in Pakistan
- Killed about 1,600 people, and 20 million people were affected

4 **Case History: Implications**
- The population of Pakistan has grown from about 34 million in 1951 to 170 million in 2010
- Most people in Pakistan live close to the river
- About 20 percent of Pakistan was flooded in 2010
- We need to rethink our philosophy of how we adjust to the flood hazard in the United States as population continues to grow
- We need plans for future flood hazard reduction that do not require massive evacuation from flood prone areas
- Avoid the hazard through land use instead of massive evacuation

5 **Case History**
Figure 9.2a

6 **Rivers: Historical Use**
- For more than 200 years, Americans have lived and worked on floodplains, depending on soil, water supply, ease of waste disposal, and the commerce
- If the floodplain and its relation to the river are not recognized, flood control and drainage of wetlands become prime concerns
- The pioneers moved west modifying the land: cutting and burning the trees, and then modifying the natural drainage

7 **Streams and Rivers**
- Part of the hydrologic cycle
- Streams: Small rivers
- River components
  - Network of streams
  - Watershed or drainage basin
  - Base level and slope/gradient
  - Latitudinal profile
  - Longitudinal profile
  - Grading processes

8 **Streams and Rivers**
Figure 9.5a

9 **Sediment in Rivers (1)**
- Stream total load: Total amount of sediments
  - Bed load: Coarse particles moving along the bottom of river channel, less than 10 percent of the total load
  -

  - Suspended load: Accounts for about 90 percent of its total load and makes river look muddy
  -
  - Dissolved load: Carried in chemical solutions, such as HCO_3^-, SO_4^{2-}, Ca^+, Na^+, Mg^+

10 **Sediment in Rivers (2)**

- Stream competence and capacity
  - Competence: Measuring the maximum size of the sediments transported by a river
  -
  - Capacity: Total amount of sediments a river is capable of transporting

11 **River Dynamic Characteristics (1)**

- Continuity equation:
  - Discharge: The volume of water passing through a given location of a river per unit of time
    $Q = W * D * V$
  -
- Gradient: Vertical drop over horizontal flowing distance, expressed in percentage, ft/mi, or degree of the slope
  -
- Stream velocity: Largely depending on stream gradient, discharge, channel shape, and turbulence

12 **River Erosion (1)**

- Erosion types
  - Abrasion by sediments transported by river
  - Hydraulic action of moving water
  - Chemical corrosion
  -
- Erosion location
  - Downcutting
  - Lateral: Concentrating on the outer bends

13 **River Erosion Effectiveness**

- Stream velocity
- Stream discharge
- Stream load
- Nature of the rocks
- Regional topographic relief
- Base level
- Climatic conditions

14 **River Sediment Deposition (1)**

- Deposition Condition: The flow of a river slows down
  - Decrease of stream gradient
  - Decrease of velocity
  - Decrease of discharge
  - Change of channel shape
  - Change in the amount of stream load (e.g., land-use change, vegetation cover)
  - Change of geologic setting (e.g., rock types along the river banks)

15 **River Sediment Deposition (2)**

Deposition features

- Floodplain
- Natural levee
- Point bar
- Island bar
- Alluvial fan

- Delta

16 **River Erosion and Deposition**

- Ever-changing processes: Time and rate of erosion and deposition
-
- Reasons for the changes—Complex, but related to
  - Changes in river channel (width, depth, and slope)
  - Composition of channel bed and banks
  - Vegetation cover
  - Variations of weather and climate pattern
  - Human activities, particularly land-use changes

17 **Effects of Land-Use Changes (1)**

- Changes in infiltration rate: Change of the amount of water flowing into a river
-
- Soil erosion: Change in the amount of sediments in a river
-
- Amount of water and sediments in river: Changes in the velocity of water flow
-
- Changes in river's velocity: Leading the change in river dynamics

18 **Effects of Land-Use Changes (2)**

- Forest to farmland
  - Increases soil erosion, stream deposition
  - Increases gradient and velocity
  - Increases river-channel erosion
  -
- Urban build-up
  - Increases impervious cover
  - Increases lower-magnitude flood frequency
  - Reduces the lag time of flood

19 **Channel Patterns and Floodplain Formation**

- Braided: If the river's longitudinal profile is steep and there is an abundance of coarse bed load sediment
- Braided channels tend to be wide and shallow compared with meandering rivers
- Associated with steep rivers being rapidly uplifted by tectonic processes or rivers receiving water from melting glaciers
- Meanders migrate laterally by erosion on the cut banks and by deposition on point bars
- Meandering channels often contain a series of regularly spaced pools and riffles

20 **River Flooding**

- Flooding: Overbank flow condition, discharge greater than channel's holding capacity
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- Stage: The height of the water level in a river at a given location at a given time
-
- Hydrograph: Graphic representation of a river's discharge over time
-
- Lag time: The amount of time between the occurrence of peak rainfall and the onset of flooding

21 **Flooding Data Measurement**

Figure 9.D

22 **Frequency and Magnitude of Flood**

- Recurrence interval

  $R = (N + 1)/M$

  N as the number of years of record, M is the rank

of individual flow within the recorded years

- The probability of a given magnitude flood
  P = 1/R
- Statistical probability versus reality
- Probability: One 25-year flood, on average, once every 25 years
- Reality: Two 25-year floods can occur in two consecutive years

23 **Types of Flooding**

- By stream location
  - Upstream flood: Shorter duration, smaller area
  - Downstream flood: Longer duration, greater magnitude, larger area
- By duration
  - Flash flood: High volume of flooding water in very short duration, characteristic short lag time, usually in upstream
  - Non-flash flood
- By magnitude/recurrence interval
  - 100-year, 50-year, 25-year, 10-year floods

24 **Factors Affecting Flood Damage**

- Regional land-use changes, such as urban development, deforestation, soil erosion, etc.
- Land use on the floodplain
- Frequency and magnitude of flooding
- Lag time and duration of flooding
- Sediment load
- Effectiveness of forecasting, warning, and emergency management

25 **Urbanization and Flooding**

- Impact on frequency and magnitude
  - Increase in both frequency and magnitude, especially in small drainage basins
- Impact on a river's discharge
  - Increase in runoff, without an increase in precipitation
- Significant reduction in lag time or *flashy discharge*

26 **Urbanization and Flooding**

Figure 9.20

27 **Urbanization and Flooding**

Figure 9.22b

28 **Nature and Extent of Flood Hazard**

Factors affecting the flood damage

- Type of land use on the floodplain
- Magnitude and frequency of flood
- Rate and duration of flood
- Season of the flood

- Population density
- Public awareness
- Effectiveness of forecasting, warning, and emergency planning

29 **Selected Floods in the United States**

Table 9.1a

30 **Selected Floods in the United States**

Table 9.1b

31 **Selected Floods in the United States**

Table 9.1c

32 **Effects of Flooding**

Primary effects

- Injury and loss of life, damage and destruction of property, erosion and deposition of sediments
  –

Secondary effects

- Water pollution
- Fire
- Diseases
- Displacement of people
- Interruption of social and economic activities

33 **Adjustments to Flood Hazards (1)**

- The structural approach
  - Physical/Engineering barriers: Levee augmentation (see next slide)
  - Channelization
  - River-channel restoration
  –
- Flood insurance: Shared responsibility and accountability
-
- Flood-proofing: Raised foundation, floodwalls, waterproof doors and windows, pumps

34 **Closer Look: Mississippi Flood**

- Two major recent floods, 1973 and 1993
- 1973 spring flood
  - Evacuation of tens of thousands
  - Inundation of thousands km^2 of farmland
  - $1.2 billion in property damage
- 1993 summer flood
  - Century flood in magnitude
  - From climatic anomaly, unusual precipitation and snowmelt
  - Lasted from late June to early August
  - 50 deaths, $10 billion in damage
  - Levees can provide a false sense of security

35 **Adjustments to Flood Hazards (2)**

- Floodplain regulation: Obtaining the most beneficial use of floodplains
  - Flood-hazard mapping
  - Floodplain zoning
  –
- Government buyout and relocating people from floodplain
-
- Personal adjustments

36 **Perception of Flooding**

- Individual level: Variable in their knowledge of flooding, anticipation of future flooding, and willingness to accept adjustments

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- Local and state level: Mitigation plans
-
- Federal government level
  - Mapping of flood-prone areas
  - Floodplain management plans
  - Public outreach

Critical Thinking Topics

- As a planner, outline a plan of action working for a community that is expanding into the headwater portions of drainage basins.
-
- What is the largest floods ever occurred in your area?
-
- With the global warming, what do you think the frequency and magnitude of flooding would change?
-
- Differentiate between competency and capacity. Does a stream's competency and capacity change over time?

Chapter 9 Images Follow:

End of Chapter