# Introduction to Environmental Geology, 5e

Chapter 9

*Rivers and Flooding*

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## Chapter 9: Overview

- Understand basic river processes.
- Understand the nature of the flood hazard.
- Understand the effects of urbanization on flooding in small drainage basins.
- Know the major adjustments to flooding and which are environmentally preferable.
- Know the potential adverse environmental effects of channelization and the benefits of channel restoration.

## Case History: Pakistan Floods of 2010

- 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 greatest monsoon rains in decades, caused catastrophic flooding in Pakistan
- July 29th, 12 inches of rain fell in the Upper Indus
- Killed about 1,600 people, 20 million people were affected, 1.4 million acres were flooded

## 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

How to compare this catastrophe with the US:

- Rethink our philosophy of how we adjust to the flood hazard in the United States as population grows
- Plans for future flood hazard reduction that do not require massive evacuation from flood prone areas
  - Avoid the hazard through land use instead of evacuation

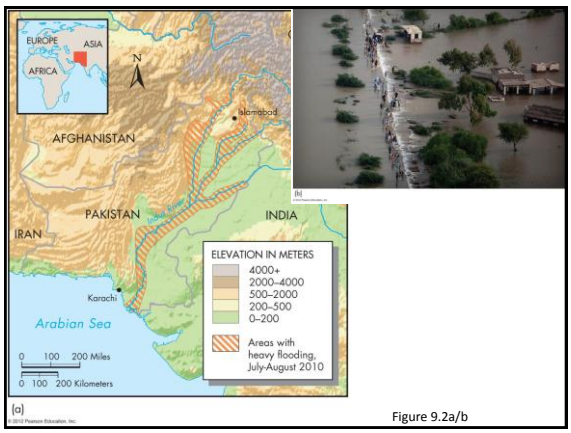
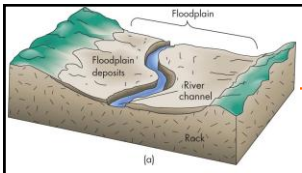



Figure 9.2a/b

## 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





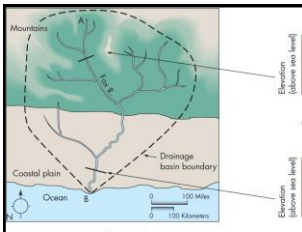
**Floodplain**: the flat surface adjacent to the river channel that is periodically inundated by floodwater.

Figure 9.3 a/b

## 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





## Sediment in Rivers

Stream total load = total amount of sediments

- Bed load: coarse particles moving along the bottom of river channel, <10% of total load
- Suspended load: accounts for about 90% of a river's total load, river can look muddy
- Dissolved load: carried in chemical sollutions such as $HCO_3^-$, $SO_4^{2-}$, $Ca^{2+}$, $Na^+$, $Mg^+$

## River - Fluid Dynamics

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

## Sediment in Rivers

Stream **competence** and **capacity** –

- Competence: measuring the maximum size of the sediments transported by a river
  - The largest size particle transported
- Capacity: total amount of sediments a river is capable of transporting
  - Volume-how many truckloads of material transported

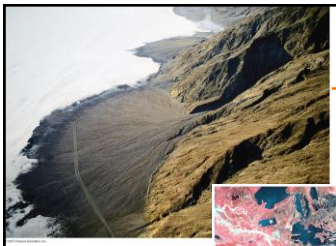


Figure 9.6 – Alluvial fan

Figure 9.7 - Delta

## River Erosion

- Methods of erosion –
  - Abrasion by sediments transported by river
  - Hydraulic action of moving water
  - Chemical corrosion (weathering and dissolution)
- Location of erosion –
  - Downcutting
  - Lateral…on outer bends
  - Headward erosion

## River Erosion Effectiveness

- Stream *velocity* – speed of the water
- Stream *discharge* – volume of water wrt time
- Stream *load* – volume of sediment
- Nature of the *rocks* – geology & rock type
- Regional topographic *relief* – steep or flat
- *Base level* – mountain or near ocean
- *Climatic* conditions – rain amounts or snow

## River Sediment Deposition

Conditions for *deposition* = reduction in velocity

- Decrease of stream gradient
- Decrease of velocity
- Decrease of discharge
- Change of channel shape – wide,flat
- Change in the amount of stream load (usually due to land-use changes) – suspended load
- Change of geologic setting (rock types along the river)

## River Sediment Deposition

Deposition features:

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

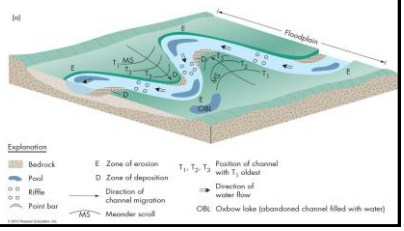



Figure 9.12a

## 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
  - Climatic variations

## Effects of Land-Use Changes

- 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

## Land use changes

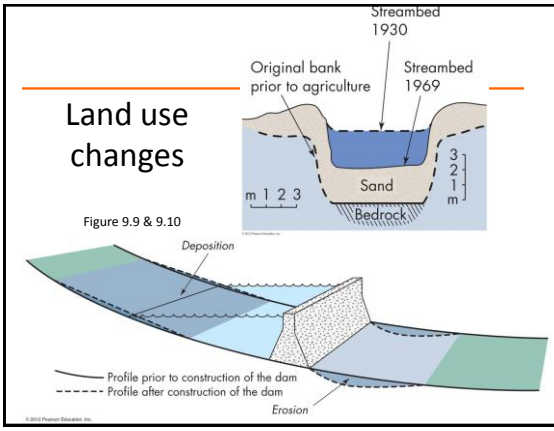



Figure 9.9 & 9.10

## Effects of Land-Use Changes

Forest to farmland

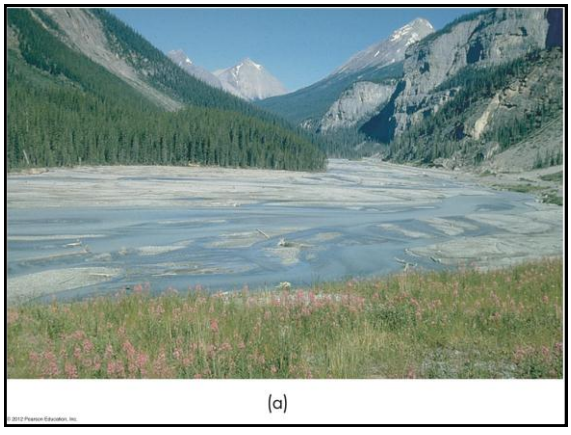
- Increases soil erosion, stream deposition
- Increases gradient and velocity
- Increases river-channel erosion

Urban build-up

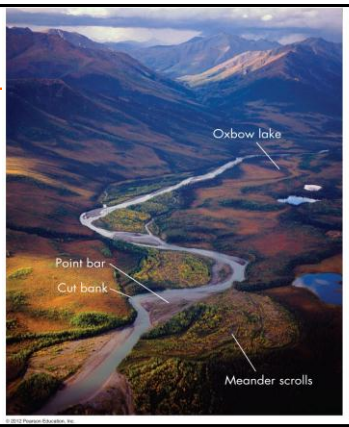
- Increases impervious cover
- Increases lower-magnitude flood frequency
- Reduces the lag time of flood

## Channel Patterns and Floodplain Formation

- *Braided*: 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
- *Meandering*: channels often contain a series of regularly spaced pools and riffles
  - Meanders migrate laterally by erosion on the cut banks and by deposition on point bars



(a)

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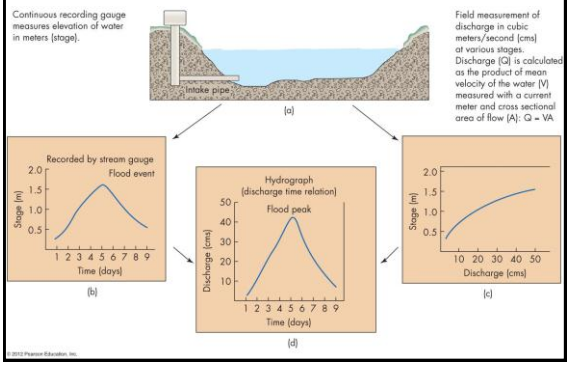
## River Flooding

- Flooding: Overbank flow condition, discharge greater than channel's holding capacity
- 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

## Flooding Data Measurement




## Frequency and Magnitude of Flood

Recurrence interval:

- R = (N + 1)/M … where N is 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
- Reality; two 25-year floods consecutively

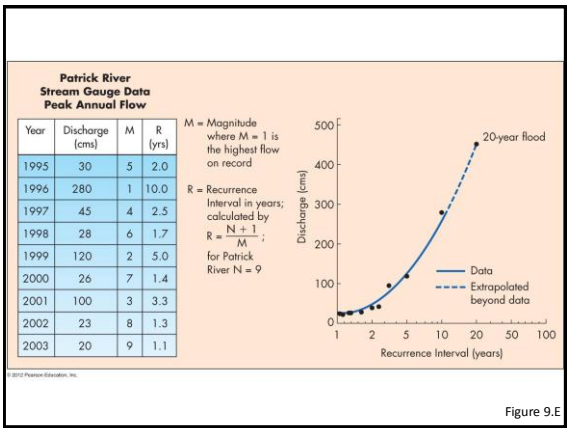



Figure 9.E

## 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

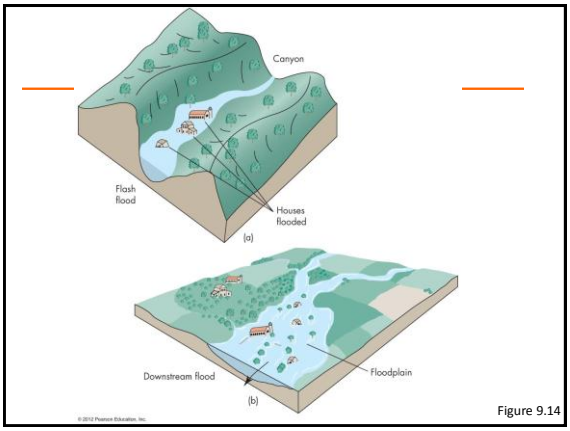



Figure 9.14

## Factors Affecting *Amount* of 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

## 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
- May cause flash flooding

## Impervious Cover

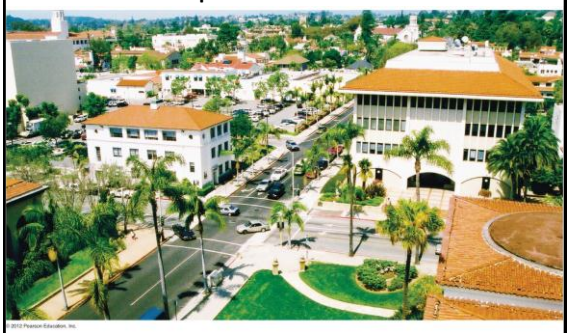
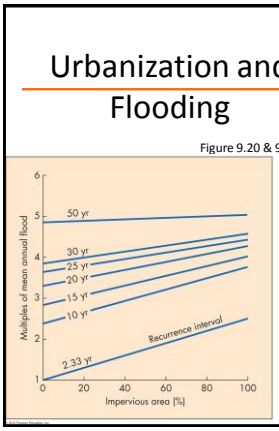
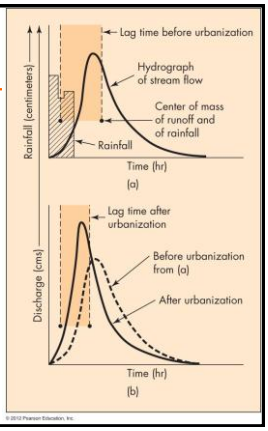


Figure 9.19

## Urbanization and Flooding

Figure 9.20 & 9.22




## Nature and Extent of Flood Hazard

Factors causing 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

## 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

## Adjustments to Flood Hazards

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

## Artificial Levee

## Channelization

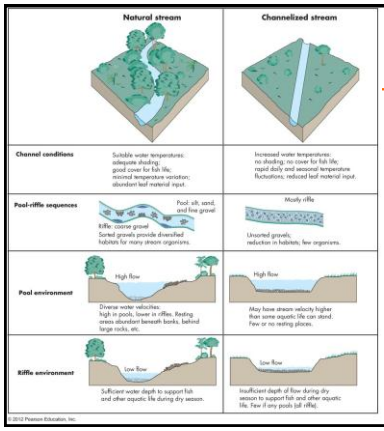



Figure 9.25

## Retention Pond

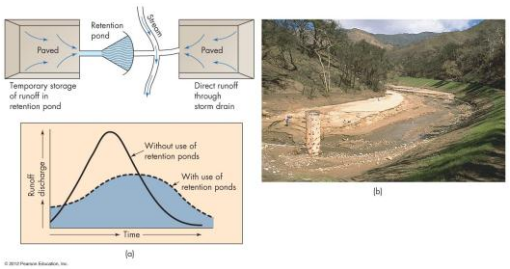
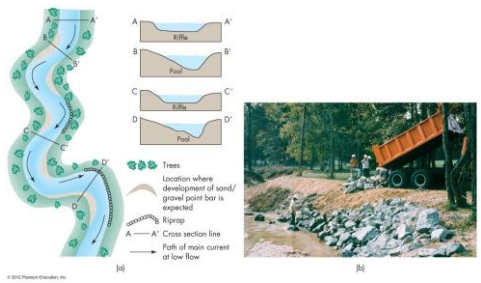


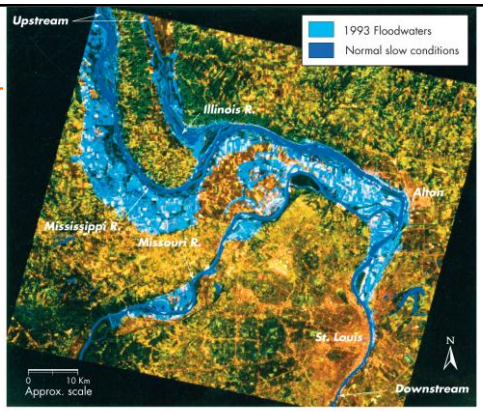

Figure 9.24

## Stream Restoration

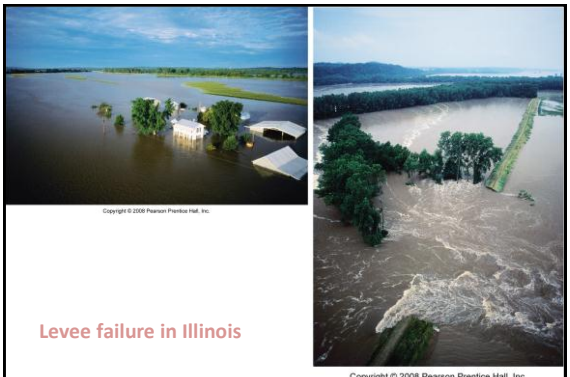



## Closer Look: Mississippi Flood

- 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 & snowmelt
  - Lasted from late June to early August
  - 50 deaths, $10 billion in damage
  - Levees can provide a false sense of security








Levee failure in Illinois



Figure 9.H & 9.I

## Adjustments to Flood Hazards

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

## Floodplain Zoning

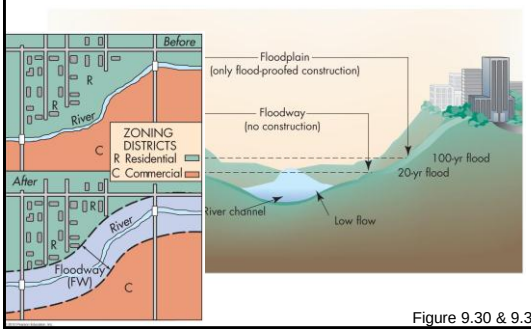



Figure 9.30 & 9.33

## Perception of Flooding

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