

EENS 2040	Natural Disasters
Tulane University	Prof. Stephen A. Nelson
River Flooding	

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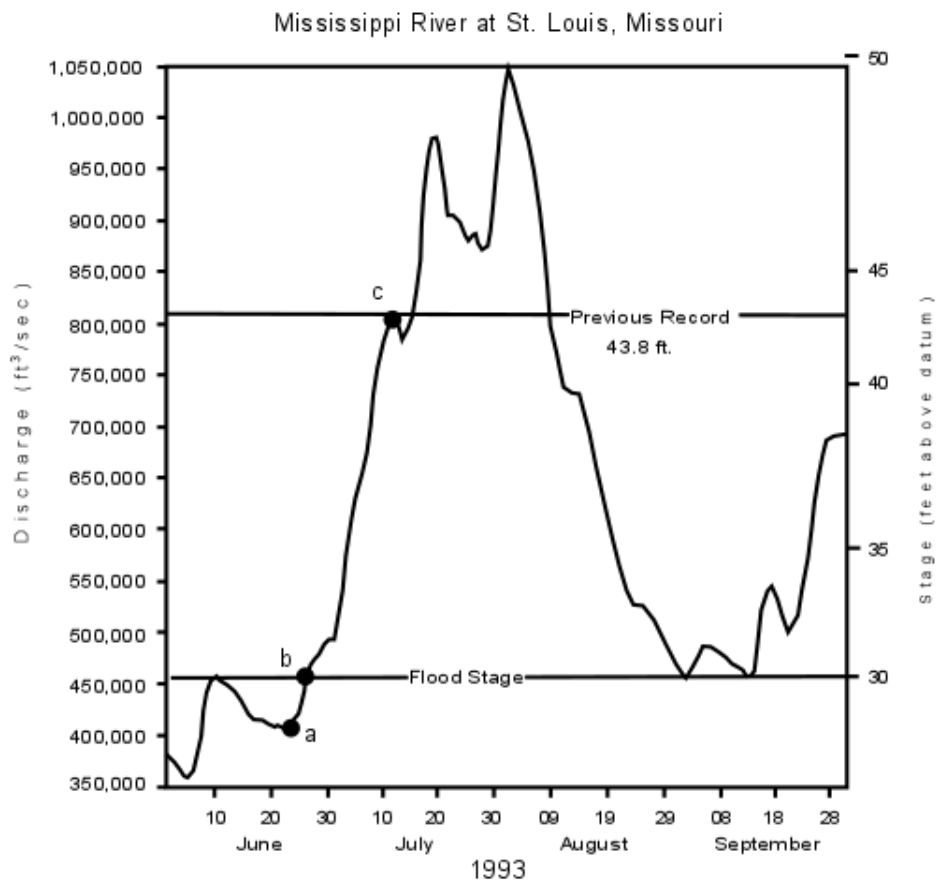
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## River Flooding

Having covered the basics of stream systems we now turn our attention to the details of flooding associated with rivers and streams.

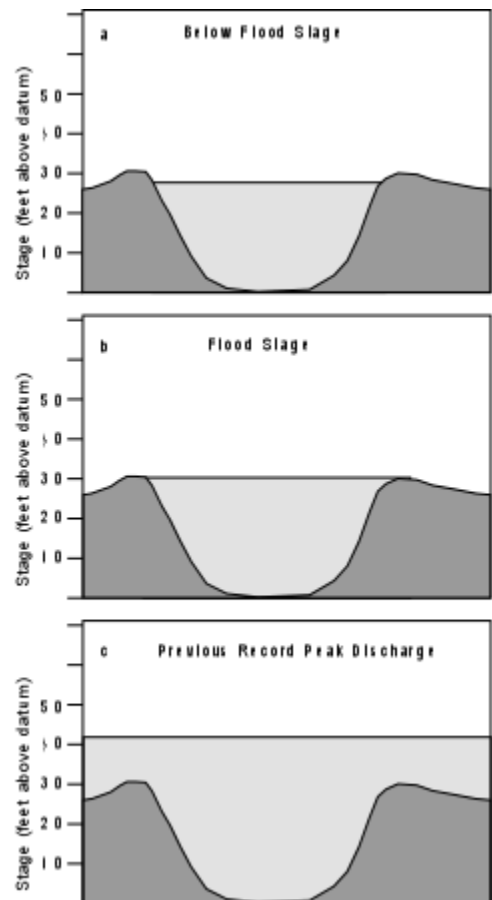
### Flood Stage

- The term *stage* refers to the height of a river (or any other body of water) above a locally defined elevation. This locally defined elevation is a reference level, often referred to as datum. For example, for the lower part of the Mississippi River, reference level or datum, is sea level (0 feet). Currently the Mississippi River is at a stage of about 3 feet, that is 3 feet above sea level. Other river systems have a reference level that is not sea level. Most rivers in the United States have gaging stations where measurements are continually made of the river's stage and discharge. These are plotted on a graph called a hydrograph, which shows the stage or discharge of the river, as measured at the gaging station, versus time.
- When the discharge of a river increases, the channel may become completely full. Any discharge above this level will result in the river overflowing its banks and causing a flood. The stage at which the river will overflow its banks is called *bankfull stage* or *flood stage*. For example, the flood stage of the Mississippi River at New Orleans is 17 feet. Discharge that produces a stage over 17 feet will result in the water nearing the top of the levee with potential flooding of the city of New Orleans (the top of the levee is actually at 25 feet above sea level). (Note that for the Mississippi River and other large rivers in Louisiana, the current stage and flood stage are published on a daily basis in the weather section of the Times-Picayune newspaper).
- Discharge is not linearly related to stage because discharge depends on both the depth and width of the stream channel, or more precisely, on the cross-sectional shape of the channel. Stage refers only to the height of the water above some reference level. For example, the graph below is a hydrograph of the Mississippi River at St. Louis, Missouri during the time period of the 1993 flood. Discharge is plotted on the Y-axis, and dates are plotted on the x-axis. Note that stages corresponding to various discharges are shown on the left-hand y-axis, and that the spacing between equal units of stage are not equal along the y-axis.



- Note that for the 1993 Mississippi River Flood, the river reached flood stage of 30 feet above datum on about June 26 and peaked (or crested) at just under 50 feet above datum on August 1. The sudden drops seen in discharge around July 15 and July 20 corresponded to breaks in the levee system upstream from St. Louis that caused water to flow onto the floodplain upstream, thus reducing both the stage and discharge measured at St. Louis.

To illustrate, for the Mississippi River flood at St. Louis, idealized cross sections of the River are shown here for points a, b, and c in the diagram above.



## Factors that Affect Flooding

As discussed previously the main factors that cause flooding are heavy rainfall, sudden or heavy snow melt, and dam failure. Now that we understand something about levees and floodplains, we can add to this list the possibility of levee failure. All of these factors can suddenly increase discharge of water into streams, within streams, and out of streams. Furthermore, as we have just seen, when the discharge causes the river to rise above flood stage water runs onto the floodplain. Here we discuss the main cause of flooding, that is heavy rainfall over a short period of time.

When rain falls on the surface of the Earth, some of the water is evaporated and returns to the atmosphere, some of it infiltrates the soil and moves downward into the groundwater system, and some is intercepted by depressions and vegetation. What remains on the surface of the Earth and eventually flows into streams is called *runoff*. In general, then:

$$\text{Runoff} = \text{Precipitation} - \text{Infiltration} - \text{Interception} - \text{Evaporation}$$

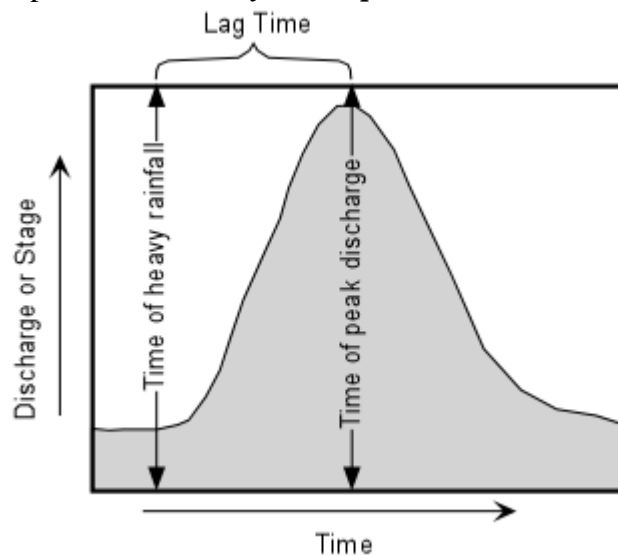
Evaporation tends to be the least of these quantities, particularly over short periods of time, and thus precipitation, infiltration, and interception are the most important variables that determine runoff and eventual discharge into streams.

### Rainfall Distribution

If rainfall is heavier than normal in a particular area and infiltration, interception, and evaporation are low then runoff can be high and the likelihood of flooding will increase. Heavy rainfall can be depicted on maps that show curves of equal rainfall. Such curves are called *isohyets*, and the resulting maps are called *isohyetal maps*.

- Lag Time - The time difference between when heavy precipitation occurs and when peak discharge occurs in the streams draining an area is called *lag time*.

Lag time depends on such factors as the amount of time over which the rain falls and the amount of infiltration and interception that takes place along the path to a stream.



- If the amount of rain is high over a short time period, lag time is short.
  - If the amount of rain is high over a longer time period, lag time is longer.
  - Lack of infiltration and interception reduce lag time.
- Upstream flooding and flash floods  
In areas where large amounts of rain fall over a short period of time within a small area, streams in the local area may flood, with little or no effect on areas

downstream. Such floods are referred to as *upstream floods*. In such floods, water rises quickly and flows away quickly after the storm has passed. Lag times are measured in days.

*Flash floods* occur when the rate of infiltration is low and heavy rains occur over a short period of time. They are upstream floods with very little lag time (lag times may be only a few hours). Because they come with little warning, flash floods are the most dangerous to human lives.

- Downstream flooding

If large amounts of rain fall over an extended period of time over a large region, *downstream floods* (also called *regional floods*) may occur. Lag times are usually longer as tributary streams continually increase the discharge into larger streams. Such floods extend over long periods of time and affect the larger streams as well as tributary streams. The 1993 flood on the upper Mississippi River is considered a downstream flood. Water levels rise slowly and dissipate slowly (in the case of the 1993 flood, the increase in discharge to the peak occurred over several weeks after several weeks of intense rainfall, and it took several months for river stages to return to normal levels).

### **Infiltration**

Infiltration is controlled by how readily the water can seep into the soil, be absorbed by the soil, and work its way down to the water table. Several factors determine the rate of infiltration:

- Extent of water saturation of the soil

If the soil is already saturated with water and the water table has risen as a result of rainfall prior to a heavy storm, then little further water can infiltrate the soil, and the rate of infiltration will be highly decreased.

- Vegetation cover

Vegetation can aid infiltration by slowing the flow of water over the surface and providing passageways along root systems for water to enter the soil. In desert regions or areas that have recently been deforested either by fires or humans, infiltration will be reduced, thus increasing the rate of runoff and decreasing the lag time.

- Soil types (dependent on climate)

Different soil types have different capacities to absorb moisture. Soil type is to a large extent dependent on climate. For example a type of soil that forms in dry, desert-like environments has a thin layer of poorly developed soil overlying a crust of caliche. Caliche is calcium carbonate that has precipitated out of water infiltrating through the thin soil. The caliche zone acts as an impermeable layer through which water can only penetrate with difficulty. Such soils in deserts, combined with the lack of vegetation make flash flooding in desert areas more common.

- Frozen ground

If the ground is frozen little water can penetrate. Thus rainfall after a period of cold temperatures may not be able to infiltrate through the frozen ground.

- Human construction

Humans tend to pave the Earth with such things as parking lots, highways, sidewalks, and plazas that prevent infiltration of water into the soil. Furthermore they tend to channel the water into storm sewer systems and concrete lined drainages, all of which increase runoff and decrease infiltration.

### **Interception**

Interception involves anything that traps rainwater and prevents it from contributing to runoff. This includes water that is stored on leaves and branches of trees until it evaporates and water that is gets stored in ponds or lakes. Thus, removal of vegetation decreases interception and results in more runoff. Increasing vegetation or construction of retention ponds, increases interception and results in less runoff.

### **Levee Failures**

Natural levees are constructed as a result of flooding, as we saw in the discussion last lecture. But, natural levees tend to be relatively low and do not offer much protection from large discharge because they can easily be overtopped. Human made levees, such as we see on the Mississippi River along much of its length, are much higher and are constructed to prevent flooding from high discharges on the River. Most levees are constructed of piles of dirt (rock and soil) with a concrete cover on the river side of the levee. Such levees often give a false sense of security for those living on the floodplain the levee was built to protect, because failure of such levees can lead to flooding, either because discharge can become great enough to overtop the levees or the levees can become weakened and fail. Levees can fail for three main reasons.

#### 1. Overtopping of levees

If high discharge in the river leads to a river stage that is higher than any point on a levee, the water will overtop the levee and start to flow onto the floodplain. Because the initial gradient from the river to flood plain is relatively high, the velocity of the stream as it overtops the levee will be high. High velocities can result in high rates of erosion, and thus the levee that is initially overtopped will soon become eroded and a channel through the levee will soon be created.

#### 2. Undercutting and slumping of levee

Higher discharge in the river will lead to higher velocities with the stream trying to increase its width and depth. Higher velocities can lead to higher rates of erosion along the inner parts of levees and thus lead to undercutting and slumping of the levee into the river. Heavy rainfall or seepage into the levee from the river can increase fluid pressure in the levee and lead to slumping on the outer parts of the levee. If the slumps grow to the top of the levee, large sections of the levee may slump onto the floodplain and lower the elevation of the top of the levee, allowing it to be more easily overtopped.

#### 3. Seepage and Piping

Increasing levels of water in the river will cause the water table in the levee to rise. This will also increase fluid pressure and may result in seepage (water being pushed through the levee to rise as springs on the surrounding flood plains). If a high rate of flow is

developed due to the increased fluid pressures, then a high velocity pathway to the flood plain may develop piping may occur. Piping will erode the material under the levee, undermining it and causing its collapse and failure.

### **Dam Failures**

Failure of natural dams or human made dams results in flooding downstream from the dam. Natural dams result from natural events that block streams, such as landslides, lava flows, or pyroclastic flows into streams. Humans build dams for flood control, water storage, and the for the generation of electricity.

Dam failures in the past include the failure of the Johnstown dam in Pennsylvania in 1899 killed over 2,200 people. In 1976 the failure of the Teton Dam in Idaho, caused over \$1 billion in property damages.

Dams fail as a result of overtopping, foundation defects, seepage and piping of water under or through a dam, structural failure, and inadequate maintenance. As of 2008, it is estimated that in the U.S. there are over 4300 dams that are in severe need of repair to reduce the hazard. Furthermore there are over 13,000 high-hazard potential dams (dams whose failure would cause loss of human life) See - [Association of State Dam Safety Officials-Dam Safety 101](#).

### **Video**

The last 50 minutes of this lecture will involve the showing of a video entitled "Flood", about the 1993 Mississippi River Flood that affected over 40,000 km<sup>2</sup> of the Midwestern states of North Dakota, South Dakota, Minnesota, Wisconsin, Nebraska, Iowa, Illinois, Kansas, and Missouri. Up to 80% of the final exam will be on this video.

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### **Examples of questions on this material that could be asked on an exam**

1. Define the following: (a) flood stage, (b) discharge, (c) runoff, (d) lag time, (e) flash flood.
  2. Explain why discharge is not linearly related to stage in most streams.
  3. What is a hydrograph? Illustrate an example of a hydrograph.
  4. What is infiltration as it relates to runoff? What things can reduce infiltration?
  5. What might cause a levee or dam failure?
  6. What caused the 1993 Mississippi River flood?
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