Hydrology and Hydraulics Concepts

G282.4

Student Manual

June 2009

FEMA

Hydrology and Hydraulics Concepts

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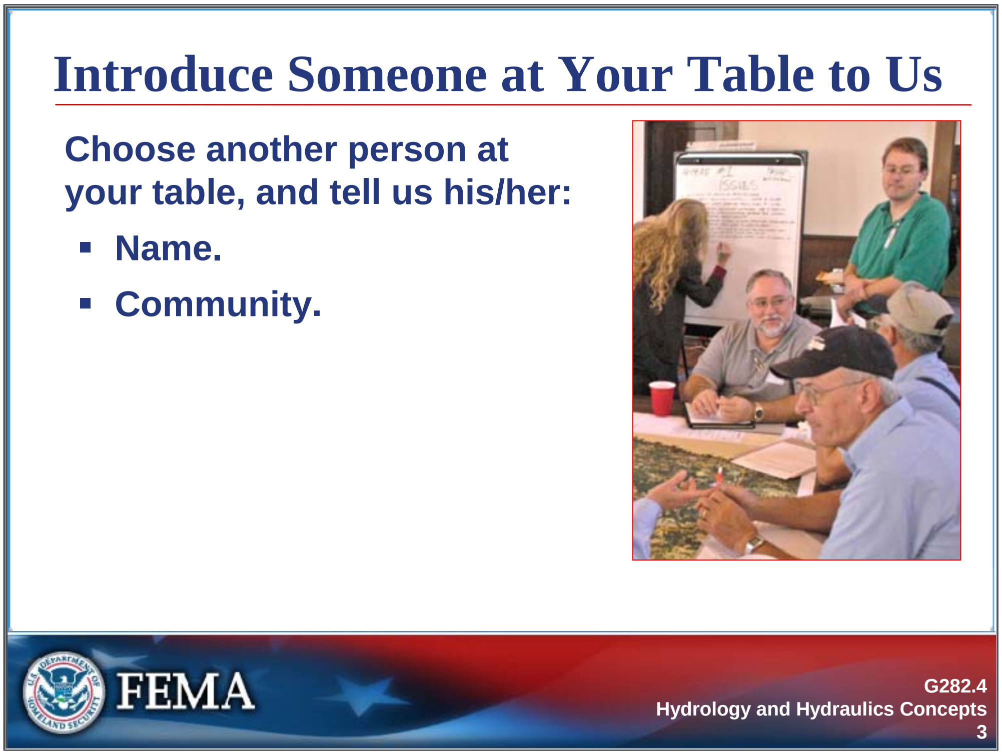
Key Points

Key Points – Introduction

Introduce yourself to the members of your table group. Give them your:

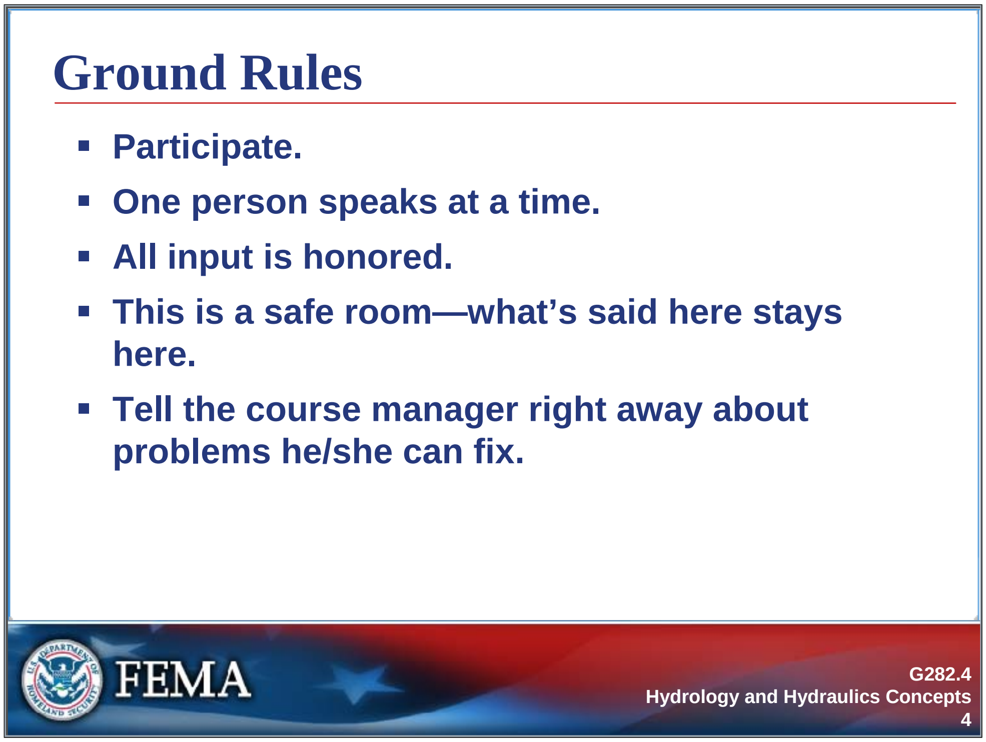
- Name.
- Community.
- Floodplain Manager (FPM) position in your community.
- Floodplain management concerns/need for improvement.



Key Points – Introduction

Introduce one person at your table to the rest of the group by presenting his or her:

- Name.
- Community.



Key Points – Introduction

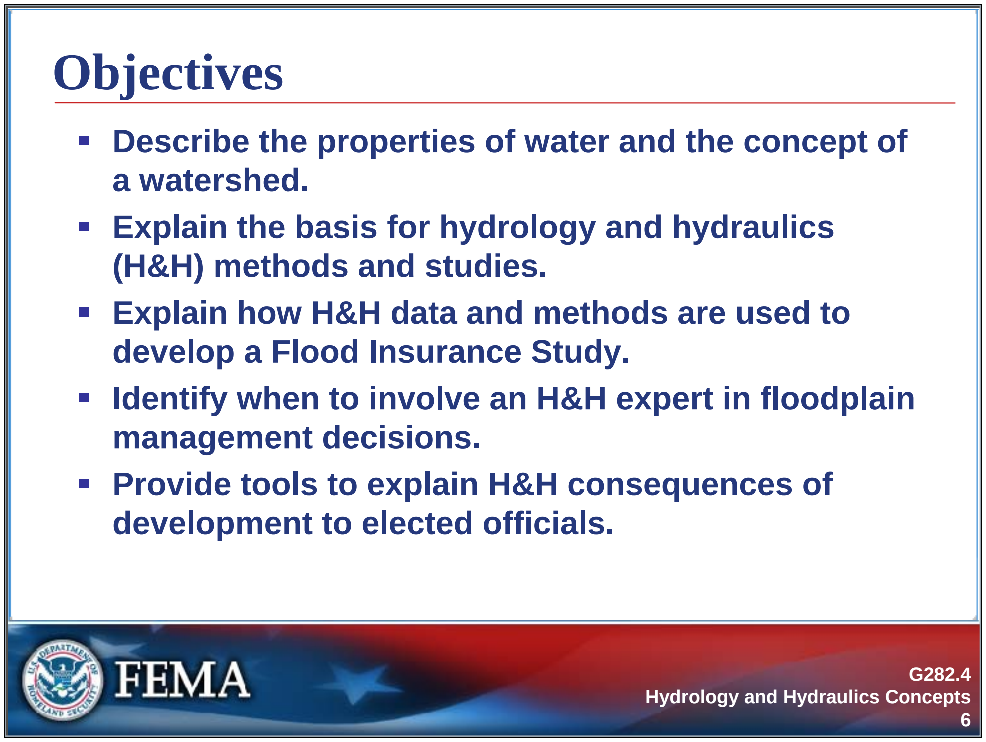
The course ground rules are:

- Participate.
- One person speaks at a time.
- All input is honored.
- This is a safe room—what’s said here stays here.
- Tell the course manager right away about problems he/she can fix.

Key Points – Introduction

Answer the following discussion question:

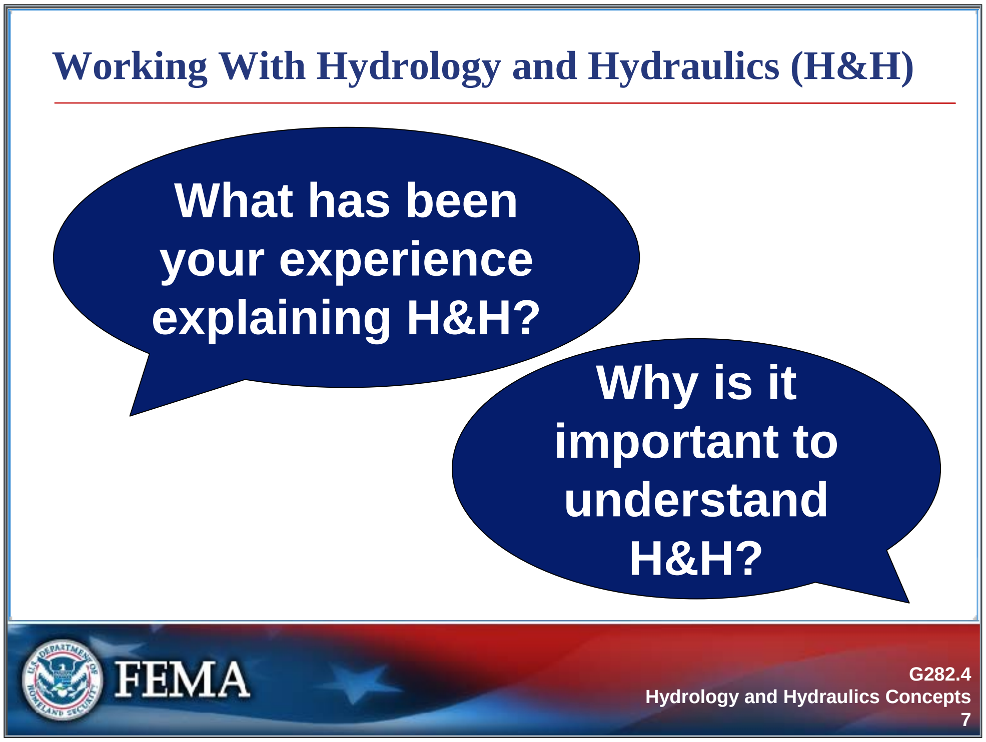
What do you want to gain from attending this course?



Key Points – Introduction

The objectives of the Hydrology and Hydraulics Concepts course:

- Describe the properties of water and the concept of a watershed.
- Explain the basis for hydrology and hydraulics (H&H) methods and studies.
- Explain how H&H data and methods are used to develop a Flood Insurance Study.
- Identify when to involve an H&H expert in floodplain management decisions.
- Provide tools to explain H&H consequences of development to elected officials.



Key Points – Introduction

Answer the following discussion questions:

What has been your experience explaining hydrology and hydraulics study results to officials and citizens?

Why is it important for the Floodplain Manager (FPM) to have a general understanding of hydrology and hydraulics?

Defining H&H

- Hydrology calculates quantities of water.
- Hydraulics calculates how water will move through your streams and rivers.
  - Where?
  - How fast?
  - How deep?
- The FIS reports H&H study results for your community.

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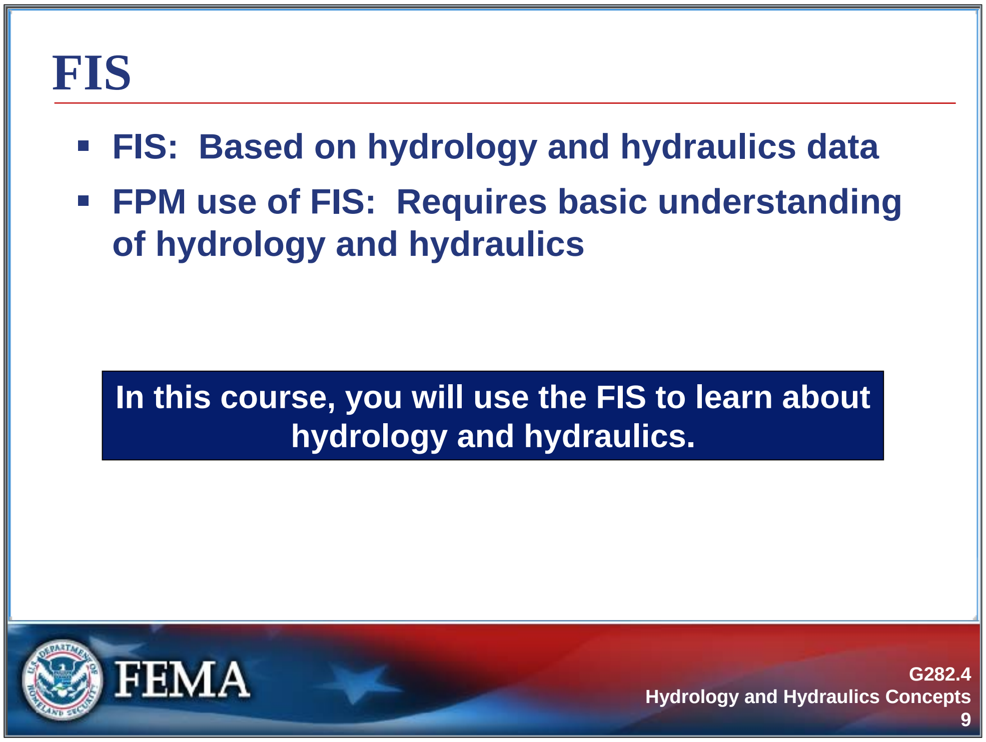
Key Points – Introduction

The definitions of hydrology and hydraulics:

- Hydrology calculates quantities of water and is the study of water, its properties, and its movement through the Earth's land and atmosphere, including the study of the distribution of water and accumulation of water—in lakes, oceans, and underground—and the effects of water on the Earth's surface.

  The Flood Insurance Study (FIS) deals primarily with surface water hydrology. Other types of hydrology are ground water hydrology and flood peaks versus drought hydrology.
- Hydraulics calculates how water will move through your streams and rivers:
  - Where?
  - How fast?
  - How deep?
- Hydraulics is the physical science dealing with the static and dynamic behavior of fluids. As FPMs, we deal with "open-channel hydraulics" open to the atmosphere rather than "closed-channel hydraulics."

  An example of closed-channel hydraulics is in the operation of heavy machinery such as a front-end loader.
- The FIS reports H&H study results for your community. The FIS primarily deals with the behavior of surface water in your streams and rivers.

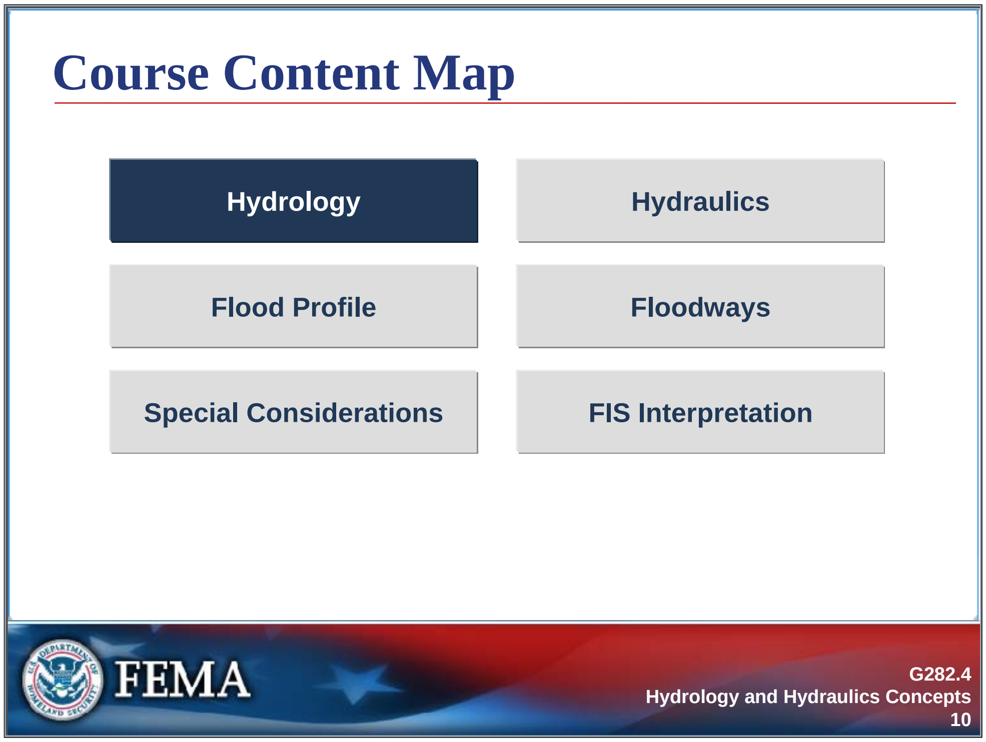


Key Points – Introduction

The tables and data in the FIS are based on hydrology and hydraulics.

To use the FIS, the FPM needs a basic understanding of hydrology and hydraulics. A graduate school degree in civil engineering is not required.

During this course, you will use the FIS, used to develop the maps for your community, to learn about hydrology and hydraulics.

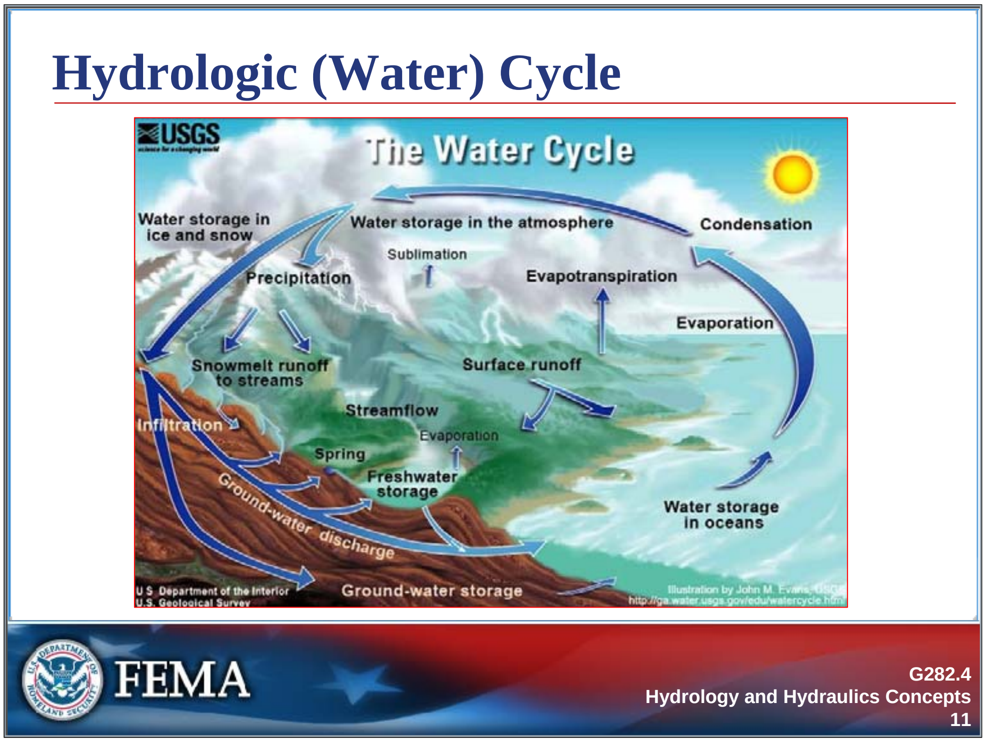


Key Points – Hydrology

This course includes the following major topics:

- Hydrology
- Hydraulics
- Flood Profile
- Floodways
- Special Considerations
- FIS Interpretation

This section of the course covers the science of hydrology, and that in many respects, hydrology is more of an art than a science.



Key Points – Hydrology

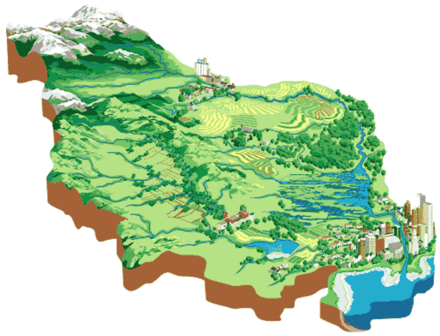
The hydrologic cycle is the circulation and conservation, or recycling, of Earth's water. The steps are:

- Water from oceans, lakes, and rivers evaporates.
- Evaporated water is stored in the atmosphere in clouds.
- Clouds produce precipitation in the form of:
  - Rain.
  - Snow.
  - Hail.
- Precipitation collects and moves overland and underground, leading back to larger bodies of water.

Note that water is a finite resource. The same quantity of water has been on earth as long as humans have been on earth.

- Water is manufactured on Earth from two parts hydrogen and one part oxygen.
- Water can exist simultaneously as a gas, a solid, and a liquid when weather conditions include humidity, sleet, and rain.
- Water is known as the "universal solvent." In a flood, dissolved solids such as salt enter a house in the floodwater.

Watershed



- A watershed is the region draining into a river, river system, or other body of water.
- Your community is located in one or more watersheds.

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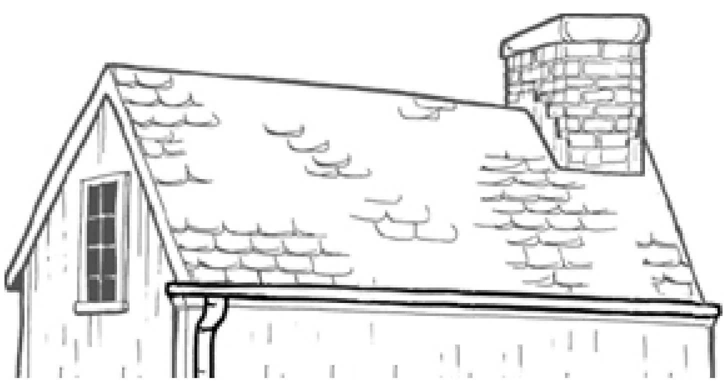
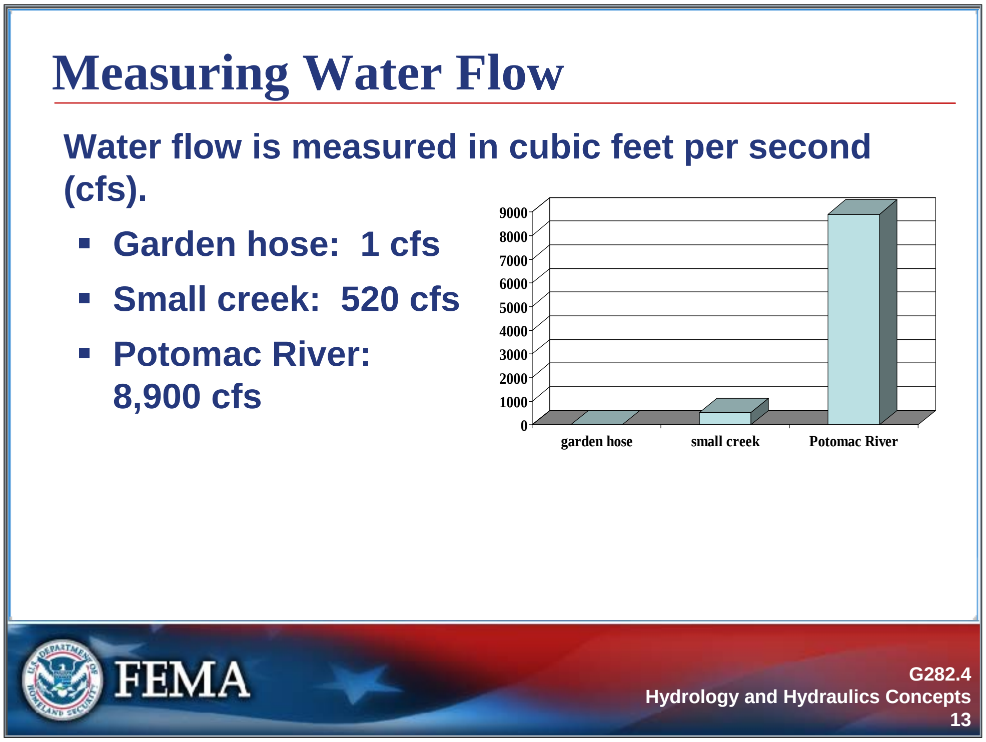
Key Points – Hydrology

Watershed:

- A watershed is the region draining into a river, river system, or other body of water. Watersheds are divided by ridges of high land dividing two areas that are drained by different river systems.
- Your community is located in one or more watersheds. Your home is located in one or more watersheds.

Visualize a peaked roof as shown below. Each surface of the roof is a small watershed. The water collects in a gutter and runs into a single discharge, a downspout.





Key Points – Hydrology

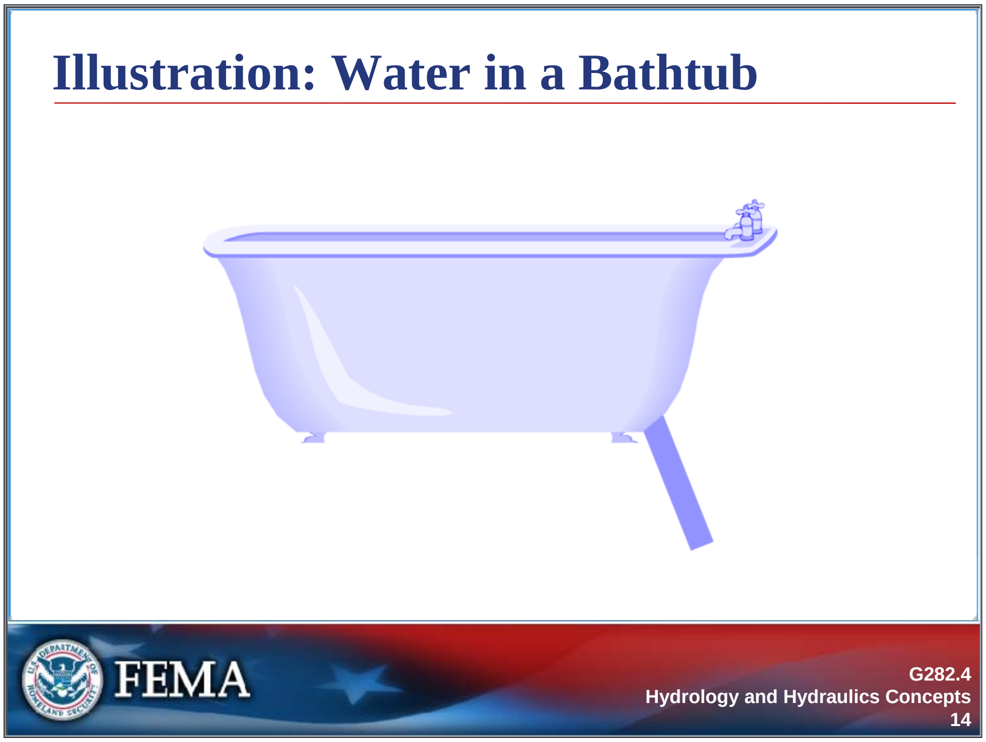
Water flow is measured in cubic feet per second (cfs)*.

Examples of relative water flow are:

- Garden hose: 1 cfs
- Small creek: 520 cfs
- Potomac River: 8,900 cfs
- Niagara Falls: 100,000 cfs

* Weight of water = 62.4 lbs/cubic foot. The water flowing over Niagara Falls is approximately 3,120 tons per second.

If the average vehicle weighs 2 tons, picture more than 1,500 vehicles falling every second over Niagara Falls.



Key Points – Hydrology

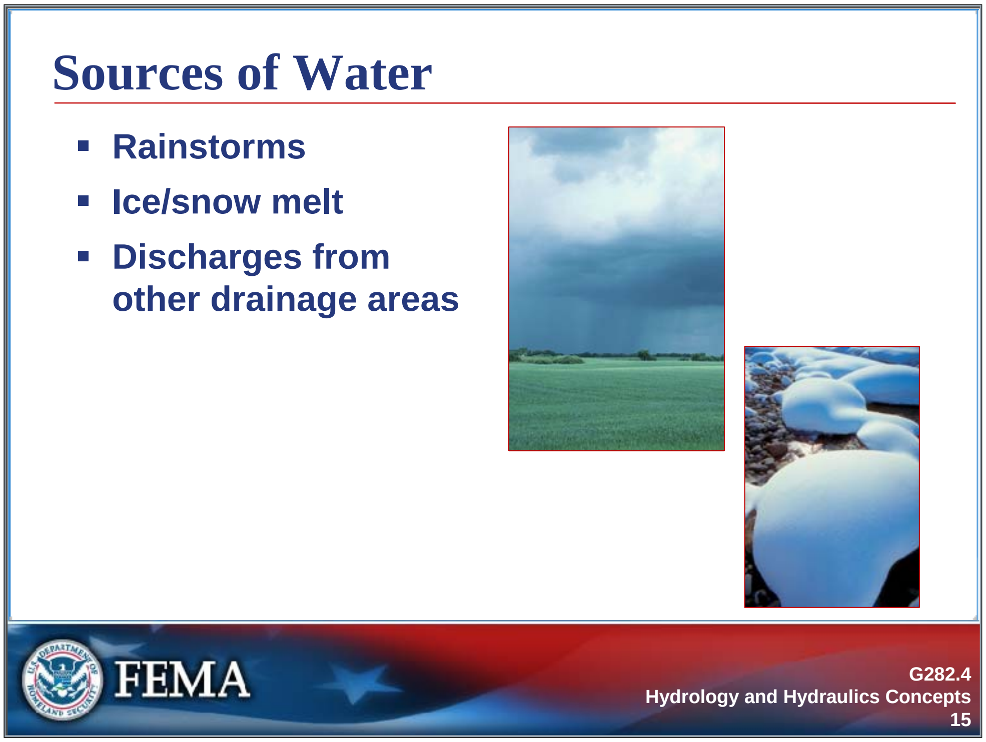
Water in a Bathtub:

- If the bathtub is filled less than half full, water drains out slowly when you open the drain.
- Fill the bathtub almost full, and then open the drain. The water drains faster because of increased pressure.
- The bathtub is a dynamic system. One aspect affects the other.

Think of a coffee urn; when the urn is full, the coffee comes out fast. When the urn is nearly empty, the coffee drips out slowly.

The difference applies to a river at flood stage versus a meandering slow flow in autumn.

Long periods of rain in a watershed result in saturated soils. Even a small amount of additional rain can cause a flood.



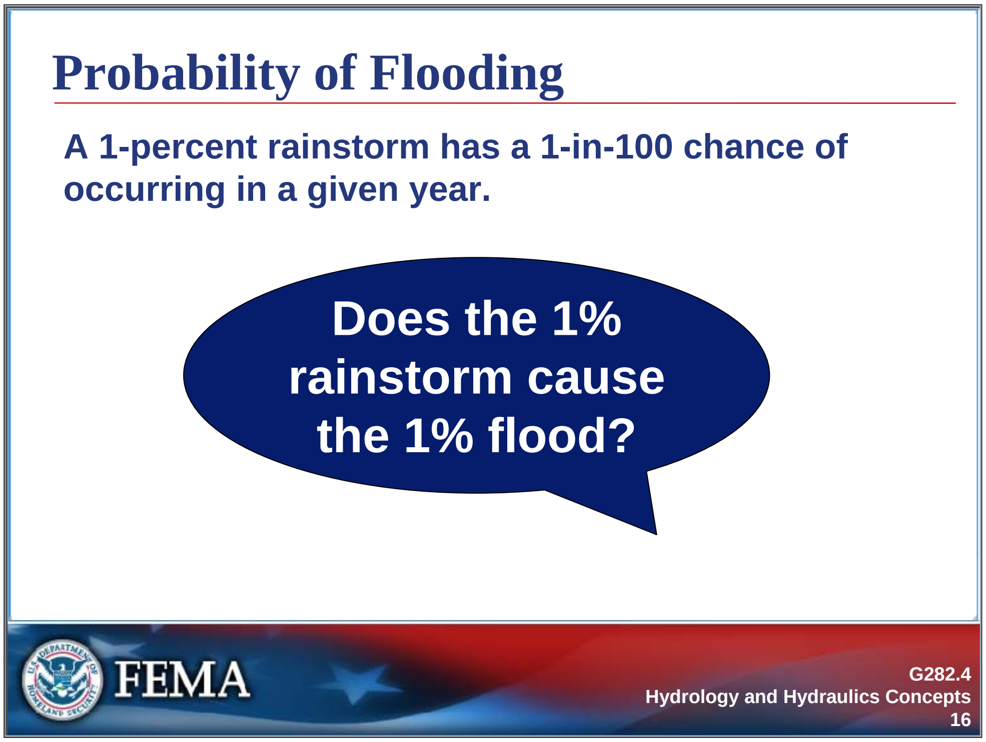
Key Points – Hydrology

Water in your watershed may come from:

- Rainstorms.
- Ice or snow melt.

A watershed also may be part of a larger drainage area. The watershed itself may have no precipitation, but could receive discharges from other drainage areas and experience flooding.

St. Louis and New Orleans may not have had rain for weeks or months, and yet may experience flooding on the Mississippi River due to snowmelt and spring rains in the Rocky Mountains and Canada.



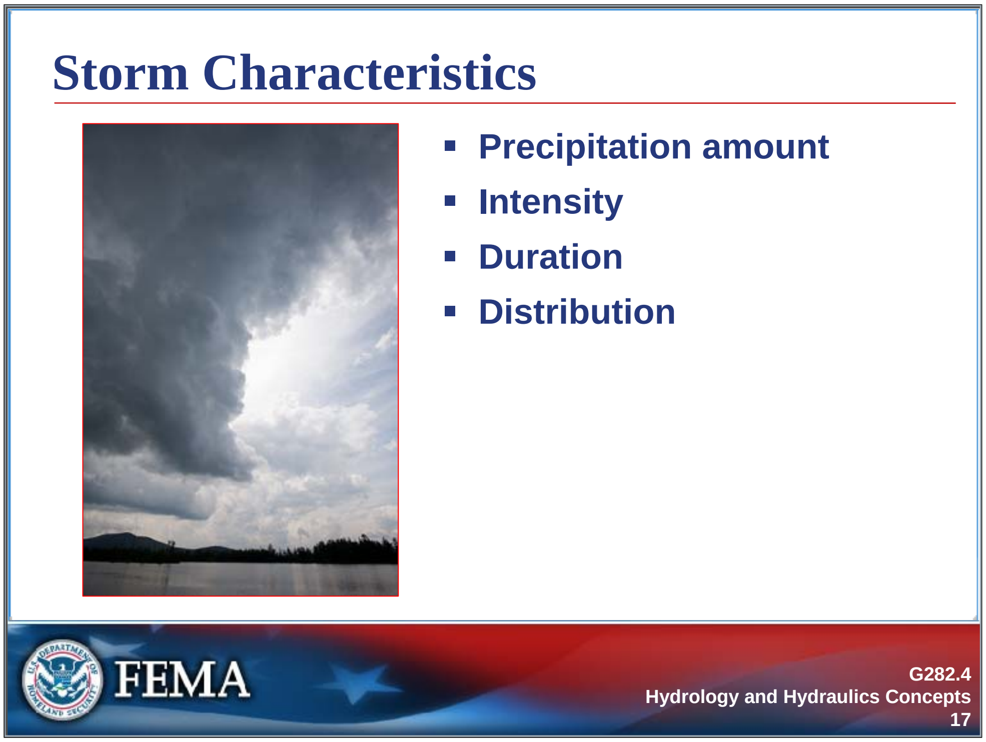
Key Points – Hydrology

A 1-percent rainstorm has a 1-in-100 chance of occurring in a given year.

Answer the following discussion question:

Does the 1-percent rainstorm cause the 1-percent flood?

Refer to the North Carolina USGS handouts in the Resource Booklet.



Key Points – Hydrology

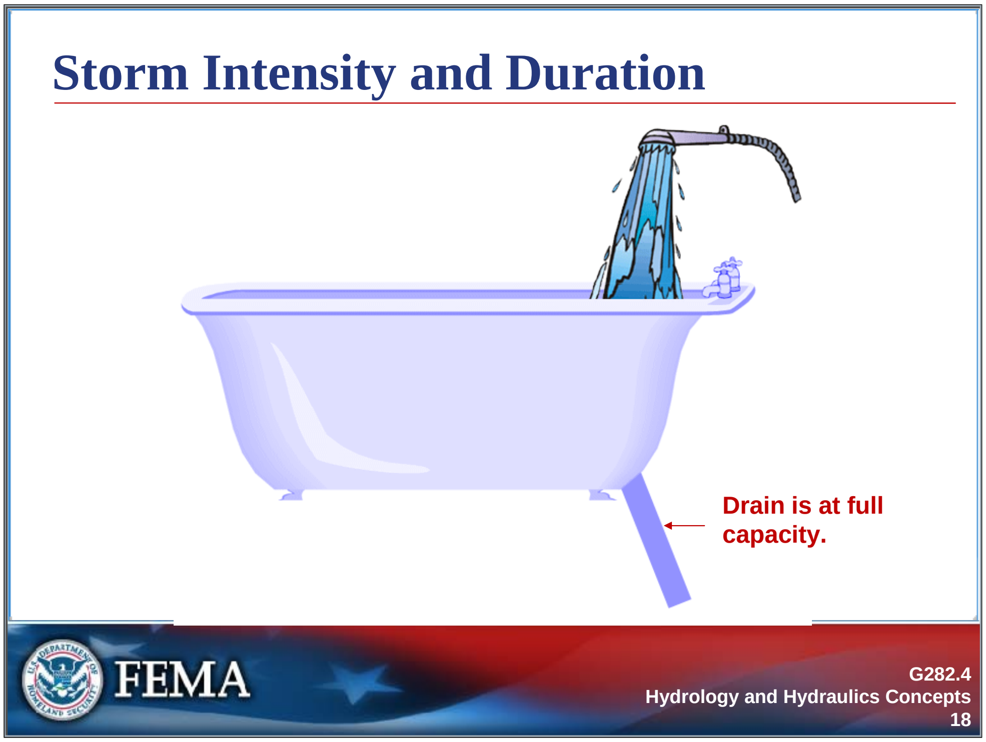
Storm characteristics include:

- Precipitation amount.
- Intensity.
- Duration.
- Distribution.

Characteristics are variable from one storm to the next, and are variable within the area experiencing the storm.

Rain falling within the boundaries of the watershed can:

- Evaporate.
- Collect in depressions.
- Infiltrate the ground and become groundwater.
- Become overland flow.



Key Points – Hydrology

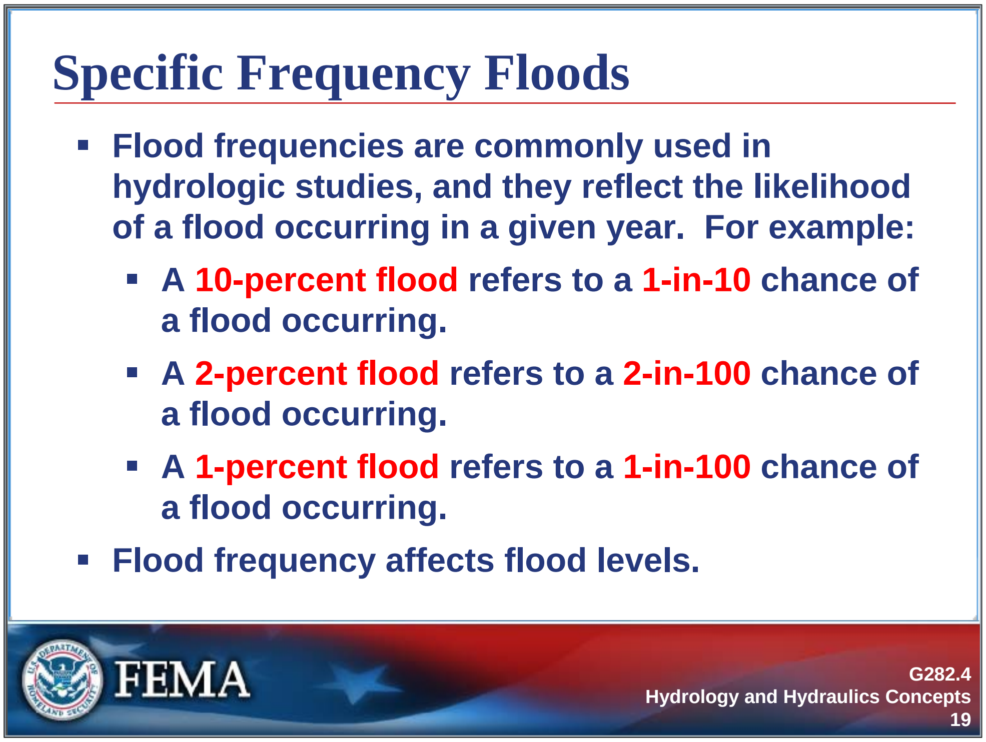
The amount of water from a storm is determined by:

- The intensity (in inches per hour), and
- Duration (storm length).

The illustration on the visual shows that by increasing the intensity and duration of water flow in a bathtub:

- Intensity increases: The tap is on all the way, and the shower is going.
- Duration: You left to answer the phone and forgot the water was on.
- The drain cannot keep up. The level in the bathtub rises, and eventually the bathtub overflows.

Storms that combine high intensity in inches per hour and long duration produce the same effect in a watershed: the watershed becomes saturated. The water that exceeds drainage capacity becomes a flood flow.



Key Points – Hydrology

A flood frequency is the chance that a particular flood will occur in a given year. A 10-percent flood has a 1-in-10 chance of occurring during a year, and a 1-percent flood has a 1-in-100 chance of occurring during the same time period.

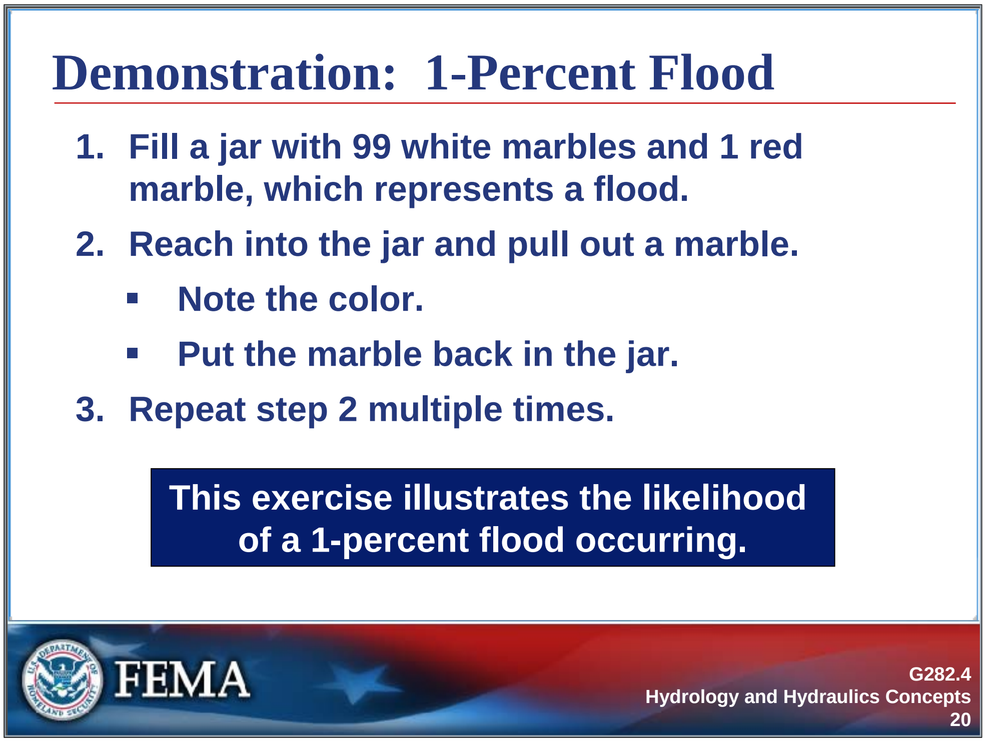
The FIS establishes the level of flooding that will occur with different flood frequencies.

The flood frequencies commonly used in hydrologic studies are:

- 10-percent flood
- 2-percent flood
- 1-percent flood
- 0.2-percent flood

Note that flood frequency affects flood levels.

The 1-percent "base" flood term applies because regulations are "based" on that flood frequency.



Key Points – Hydrology

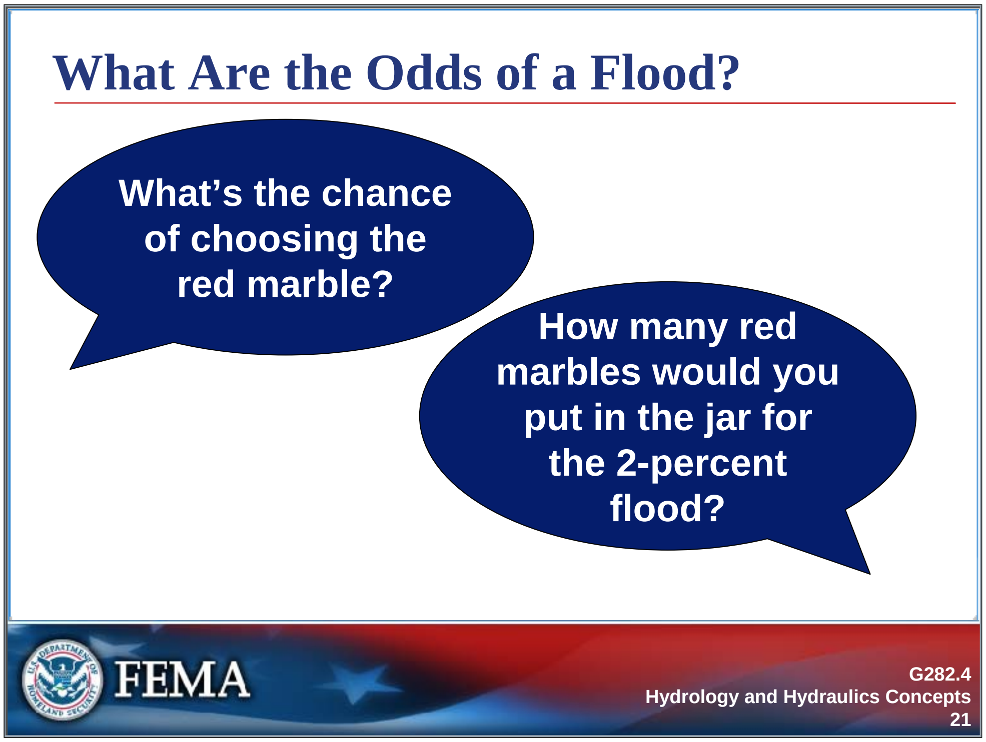
You can discover the probability of the 1-percent flood by completing the following steps:

1. Fill a jar with 99 white marbles and 1 red marble.
2. Reach into the jar and pull out a marble.
   - Note the color.
   - Put the marble back in the jar.
3. Repeat step 2 multiple times.

Note that the red marble represents a flood, and the frequency with which the marble is drawn is equivalent to the probability of a 1-percent flood occurring.

Key points:

- The process could be repeated 300 times without picking the red marble.
- The red marble could be picked two times in a row.
- Repeating the process 1,000 times, the red marble will be picked an average of 10 times.

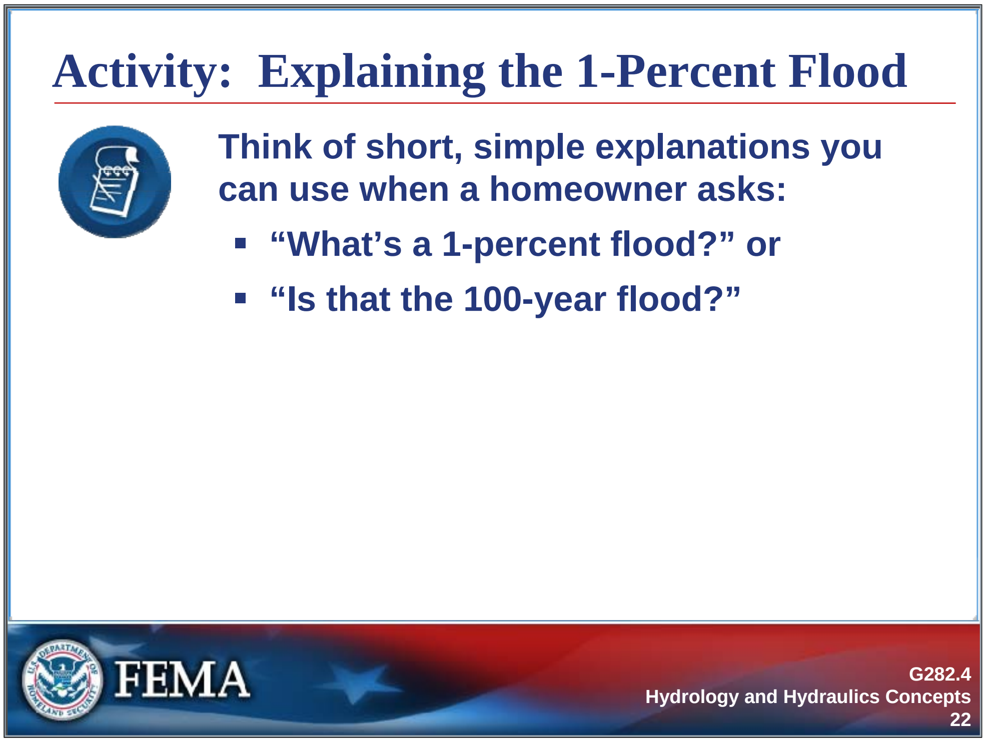


Key Points – Hydrology

Answer the following discussion questions:

What's the chance of choosing the red marble?

How many red marbles would you put in the jar for the 2-percent flood?

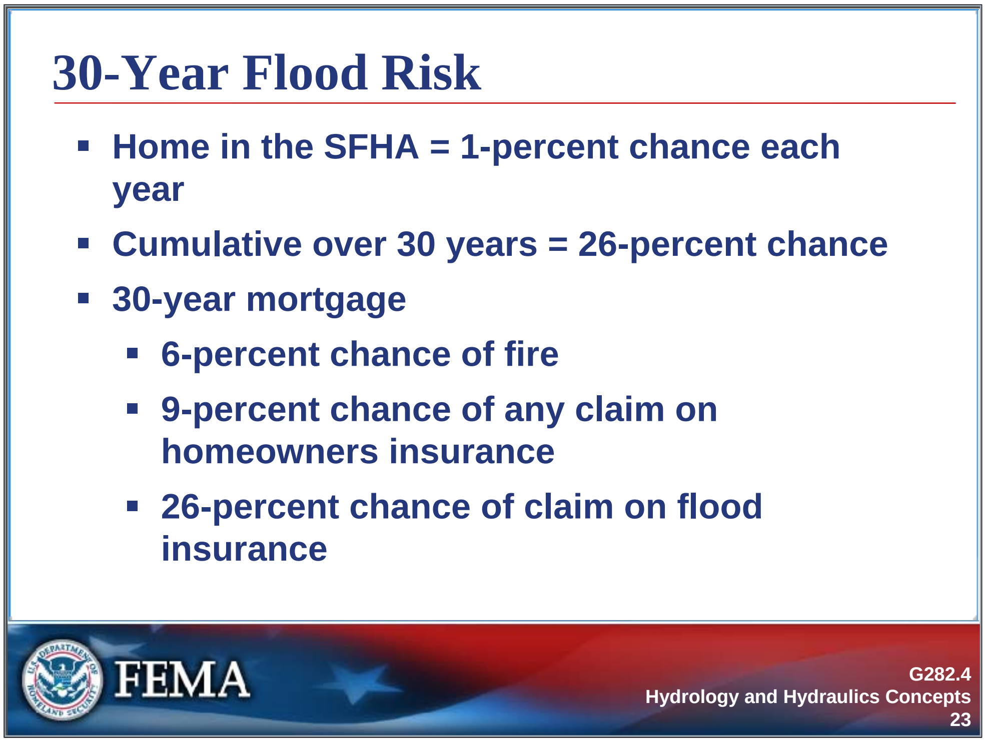


Key Points – Hydrology

Activity Instructions:

1. Explaining the 1-percent flood is a challenge for the FPM. Flood studies used to refer to the "100-year flood," and the public and media are used to the "100-year flood" term. However, "100-year flood" can be misleading. The 1-percent flood is a more accurate term.
2. Think of short, simple explanations for the 1-percent flood.
3. Record your suggestions on chart paper or whiteboard.

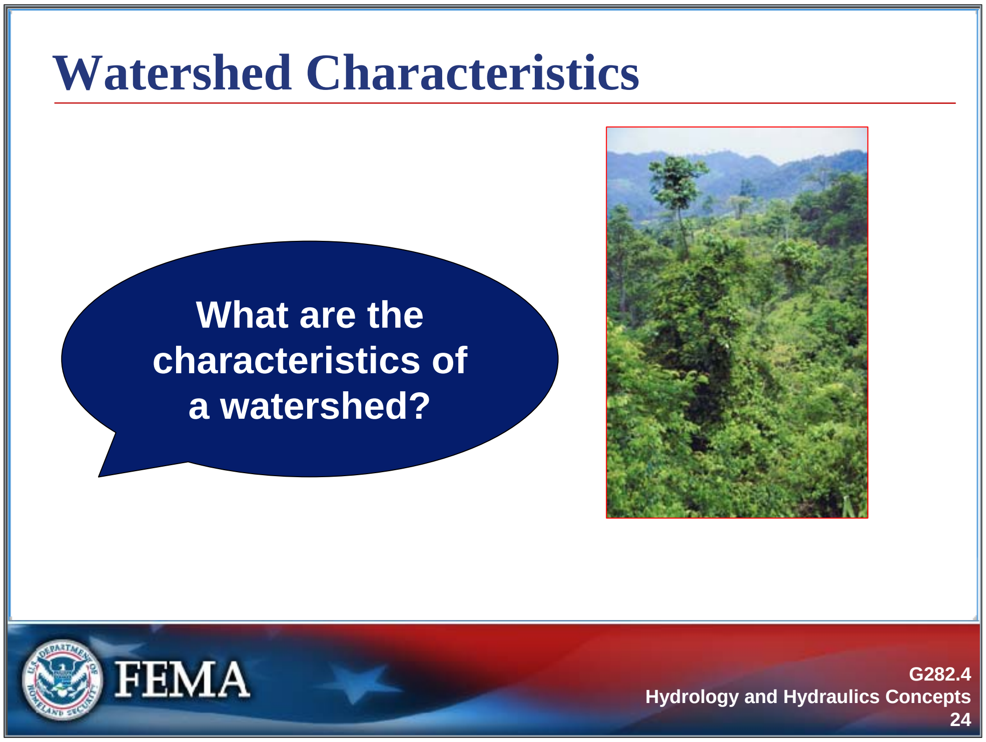
The concept of the 1-percent flood is valid only if historical record stays the same. As climate changes, the percentage may change. Conditions can always change, which is justification for freeboard and other higher standards.



Key Points – Hydrology

The risk of the 1-percent chance flood is repeated over the life of the residence, and the risk increases over time.

- A home in the SFHA = 1-percent chance of flooding each year.
- A home in the SFHA over a period of 30 years = 26-percent chance of flooding.
- During the term of a standard 30-year mortgage, a home has:
  - A 6-percent chance of a fire.
  - A 9-percent chance of any claim on homeowners insurance.
  - A 26-percent chance of claim on flood insurance.



Key Points – Hydrology

Answer the following discussion question:

What are the characteristics of a watershed?

Key Points – Hydrology

Answer the following discussion question:

What happens to stormwater in an area when trees are cut down and the ground is covered with parking lots, buildings, and streets?

Stormwater Runoff

- Total rainfall = the amount of water entering the watershed
- Some rainfall becomes runoff
- Greater land development = more impervious surfaces = more runoff

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Key Points – Hydrology

Note that:

- Total rainfall is the amount of water entering the watershed.
- Some of the rainfall becomes runoff. Other rainfall may evaporate, become groundwater or form puddles.
- Greater development leads to more impervious surfaces, which leads to more runoff.

Managing runoff is one way to achieve higher floodplain management standards.

Runoff Coefficients

Surface Type	Runoff Coefficients (% of rain that becomes runoff)
Asphalt, concrete pavement, roofs	95 - 100
Gravel surfaces	50 - 95
Residential (lot size 1/4 acre)	35 - 55
Residential (lot size 1/3 acre)	30 - 50
Residential (lot size 1/2 acre)	25 - 45
Residential (lot size 1 acre)	20 - 40
Lawns, pastures, hayfields	10 - 30
Parks, golf courses, farms	10 - 20
Woods	05 - 15

Most runoff → Least runoff

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Key Points – Hydrology

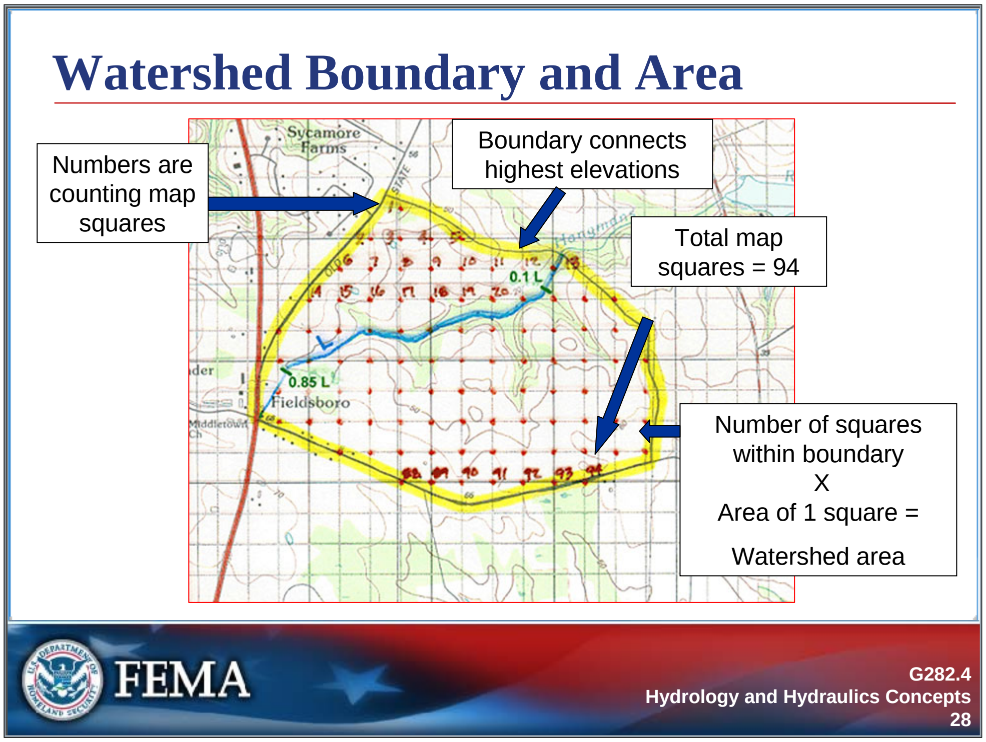
The chart shows how much of a total rainfall will be runoff on different surface types.

The runoff coefficient in the column on the right estimates how much of the total rainfall will be runoff for a given surface. Note that:

- On asphalt, concrete pavement, and roofs, almost all of the water is runoff—95 to 100 percent.
- On wooded areas, in contrast, the runoff is only 5 percent to 15 percent.
- As residential lot size increases, the amount of runoff is reduced.

Remember that one of the watershed parameters is slope.

The lower runoff coefficient for each surface type should be used in flat slopes (<2 percent grade) and the higher runoff coefficient for steep slopes (>7 percent grade).



Key Points – Hydrology

The graphic on the slide is a U.S. Geological Survey (USGS) quadrangle map. Note that contour lines show altitudes, and that the intervals between contours on the map are 10 feet.

The map shows a watershed for the Hangman's River near Fieldsboro, New Jersey. You will note that the river on the map flows from left to right.

Note that:

- After defining the watershed boundaries, the total acres within the watershed can be calculated.
- The watershed area, measured in acres, is needed to calculate the total amount of rainfall resulting from given storms.

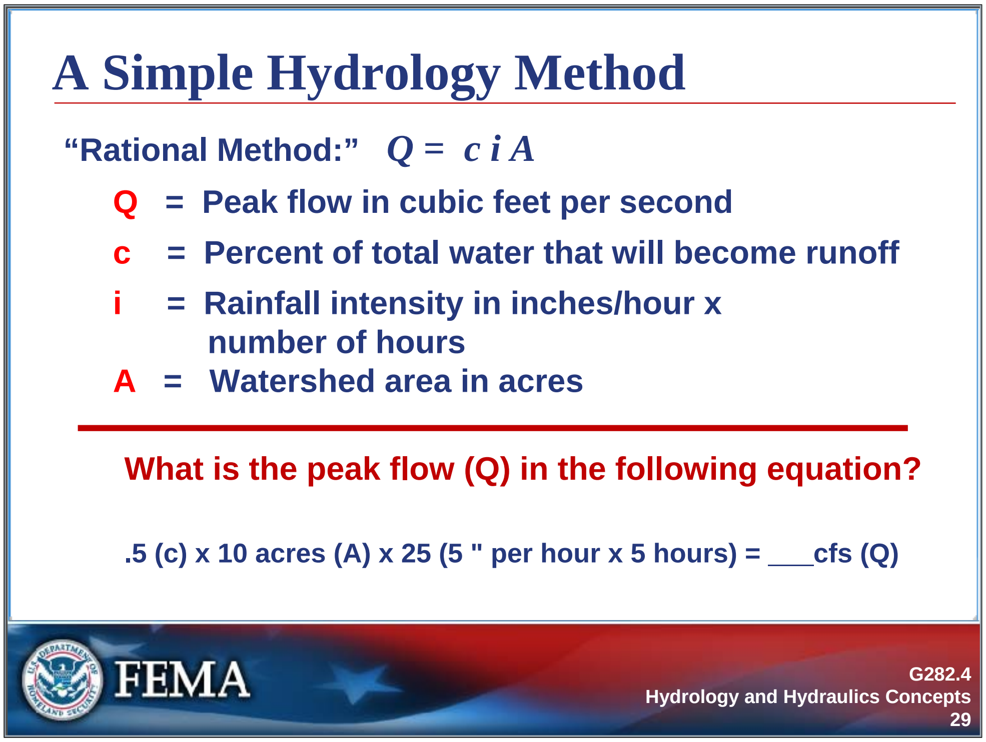
Steps to create a watershed boundary map are:

- Begin with a contour map.
- Use the contour lines to determine the elevations of the highest points on either side of the river.
- Connect the high points to draw the watershed boundary.

Steps to determine the watershed area are:

- Count the number of map squares within the boundary.
- Determine the area of each square according to the scale of the map used.
- Multiply the number of squares by the area of each square.

GIS programs can be used to calculate drainage areas.



Key Points – Hydrology

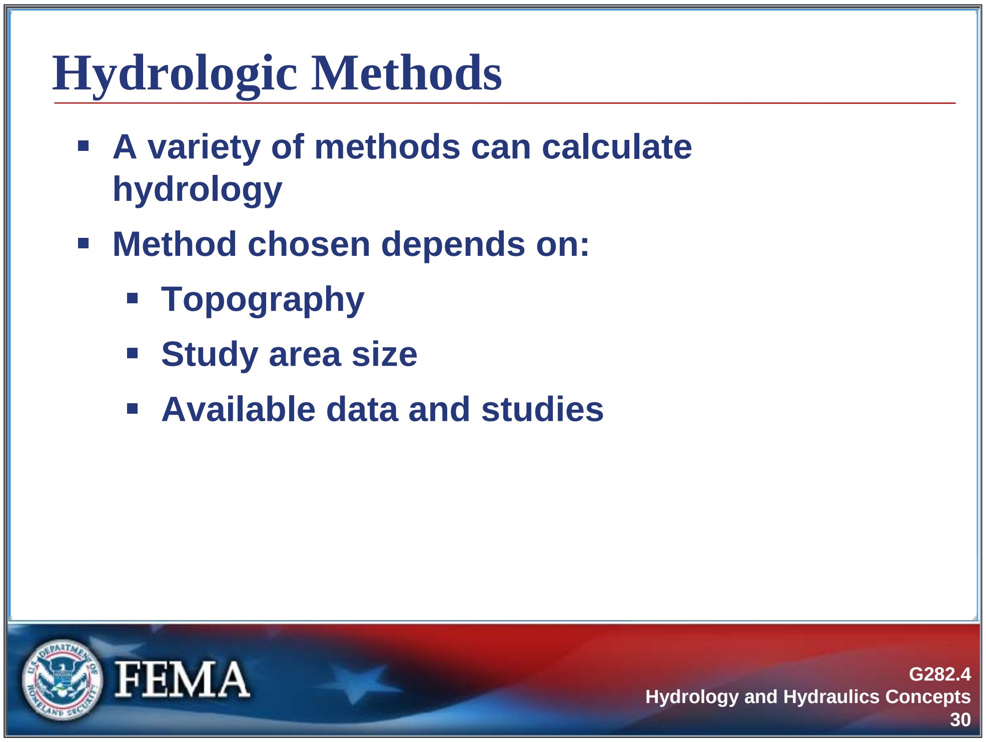
That the Rational Method is a simple calculation suitable for small areas.

The peak flow in cubic feet per second results from multiplying the following three data elements:

- The runoff coefficient, which reflects the amount of development in the watershed.
- The intensity of the rainfall, which varies according to storm frequency.
- The total area of the watershed, measured in acres.

Answer the following discussion question:

What is the value of Q in the example on the visual?

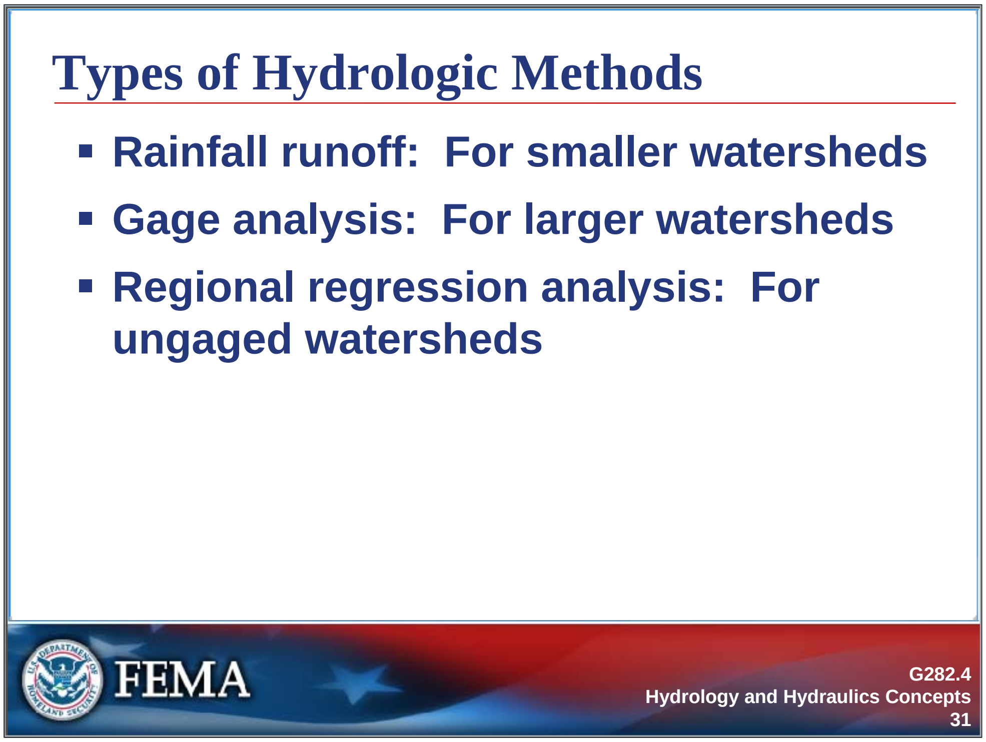


Key Points – Hydrology

The choice of methods to calculate hydrology within a watershed or in an area including multiple watersheds depends upon:

- Topography.
- Size of the study area.
- Available data and studies that can be used as resources.

Different sources have developed specific hydrology methods. When engineers conduct hydrology studies for an FIS, they determine the methods that most closely match the local area.

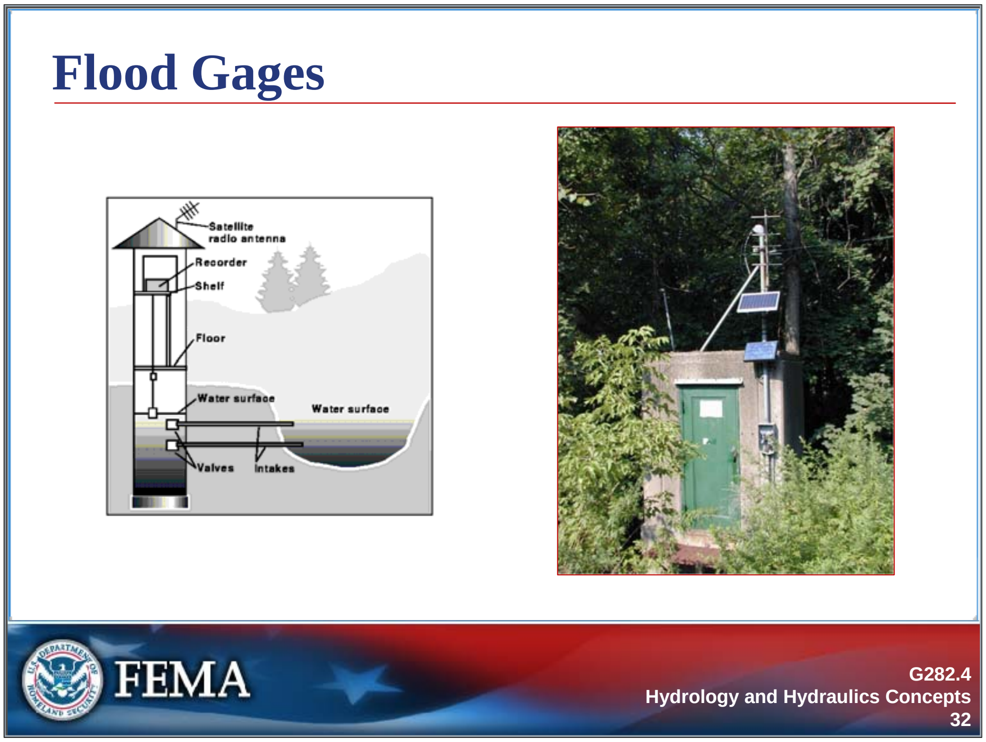


Key Points – Hydrology

Major types of hydrologic methods:

- Rainfall runoff methods, which are used for smaller watersheds. Some common examples are:
  - HEC-1, now HEC-RAS (USACE)
  - Rational Method
- Gage analysis, which is used for larger watersheds. USGS and the U.S. Army Corps of Engineers (USACE) are sources for historical gage data.
- Regional regression analysis, which is used for ungaged watersheds. Regional regression analysis:
  - Is the most commonly used method, because relatively few local areas have gage data.
  - Correlates input factors to develop regional calculations.

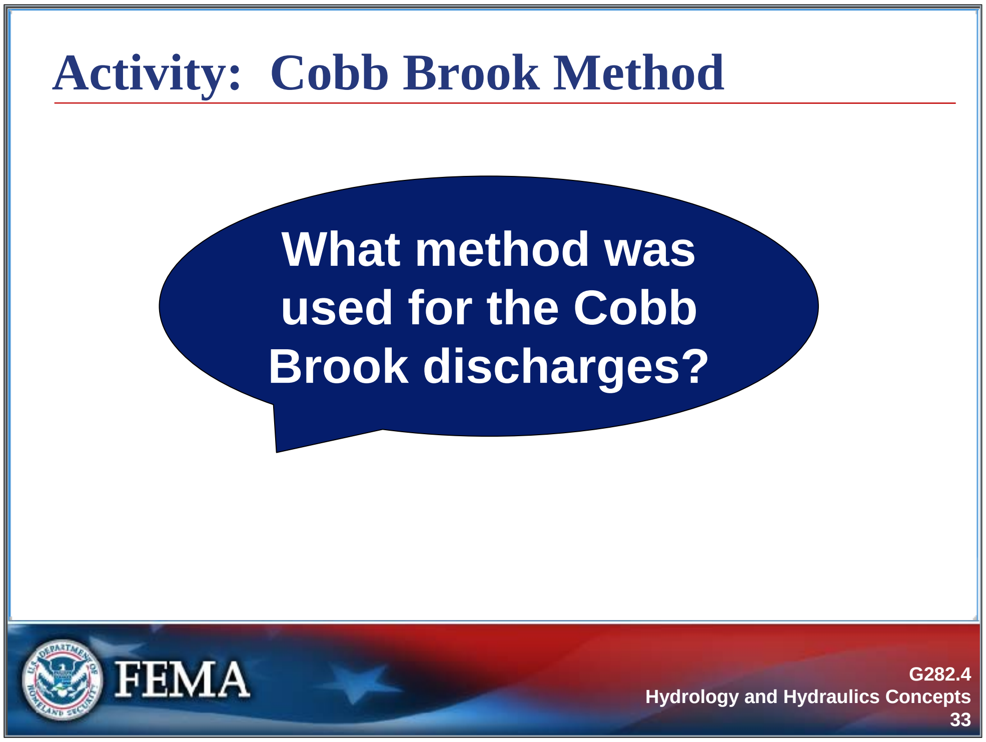
Sources for regional regression analysis methods include USGS, State highway/water resource departments, and universities.



Key Points – Hydrology

Flood Gages:

- A flood gage records water levels at a given location.
- Water in the gage is the same level as the water surface. The water level is automatically recorded as it changes inside the gage.
- Gages that do not transmit continuous data maintain a mechanical record.
- Gages are not affected by water velocity or by wave action.
- Historic gage records usually span decades, and provide detailed data.

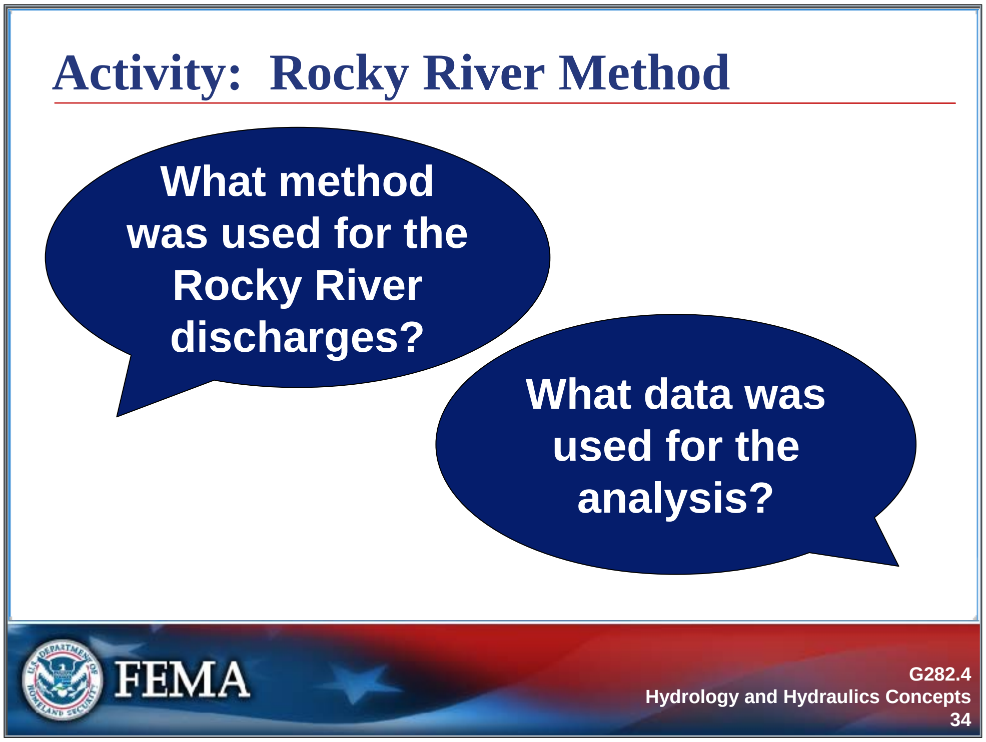


Key Points – Hydrology

Refer to page 9 of the Flood County FIS.

Answer the following discussion question:

What method was used for the Cobb Brook discharges?



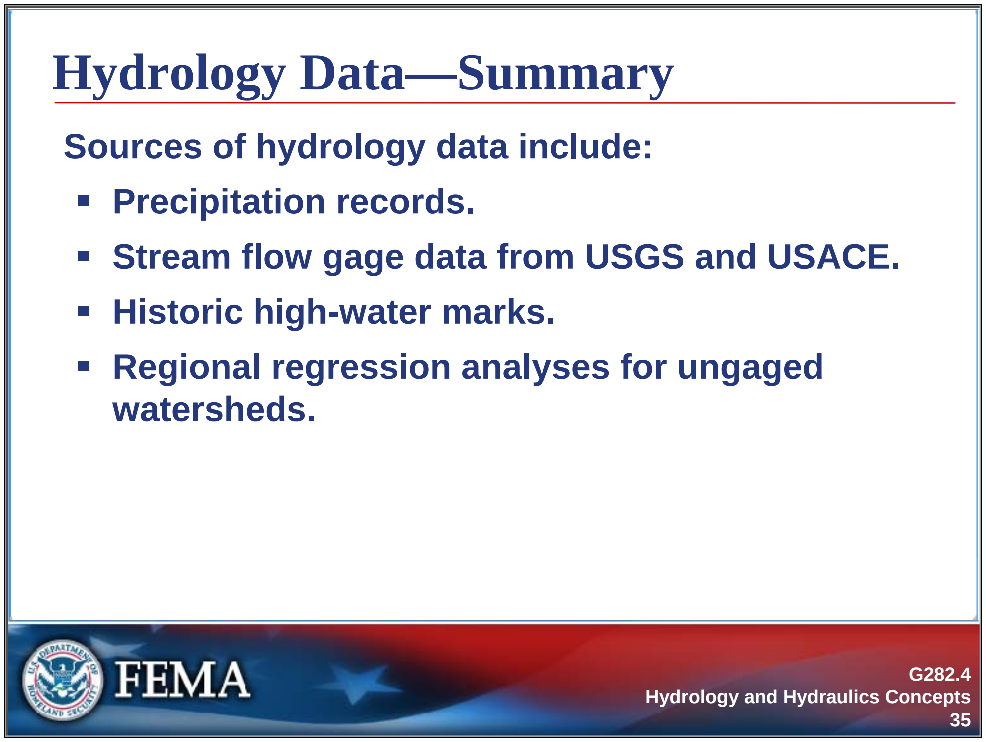
Key Points – Hydrology

Continue to refer to page 9 of the Flood County FIS.

Answer the following discussion questions:

What method was used for the Rocky River discharges?

What data was used for the analysis?



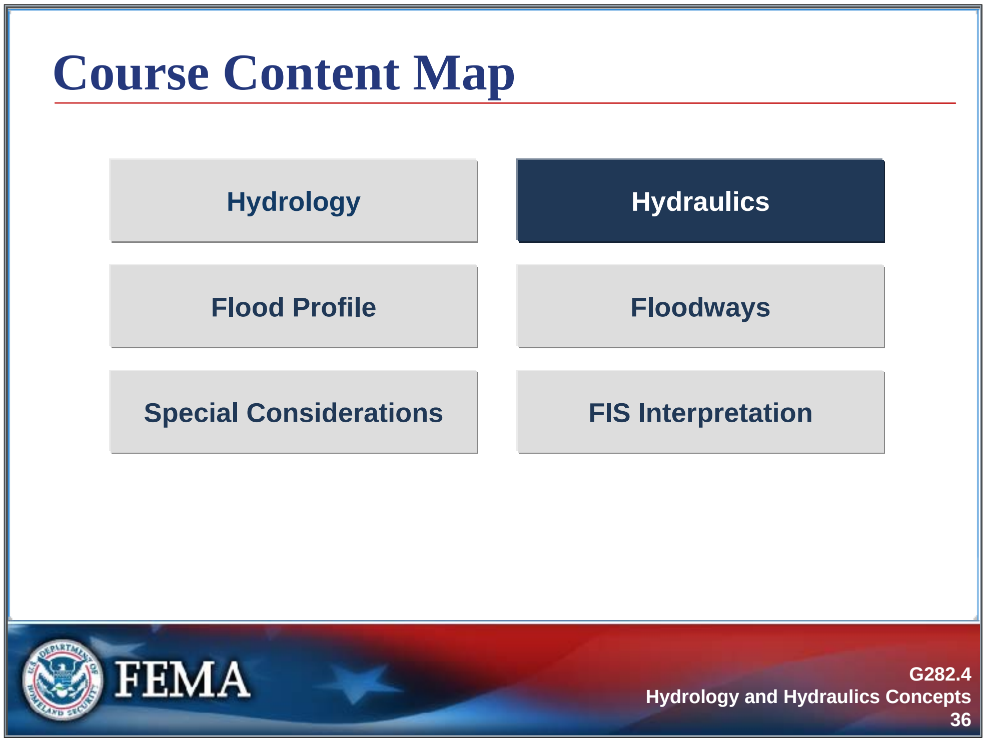
Key Points – Hydrology

The FPM needs to have confidence in data, and to be able to explain that standard engineering practices were used to derive the data. The FPM should be able to describe the techniques and explain their use for calibration and validation.

Sources of hydrology data include:

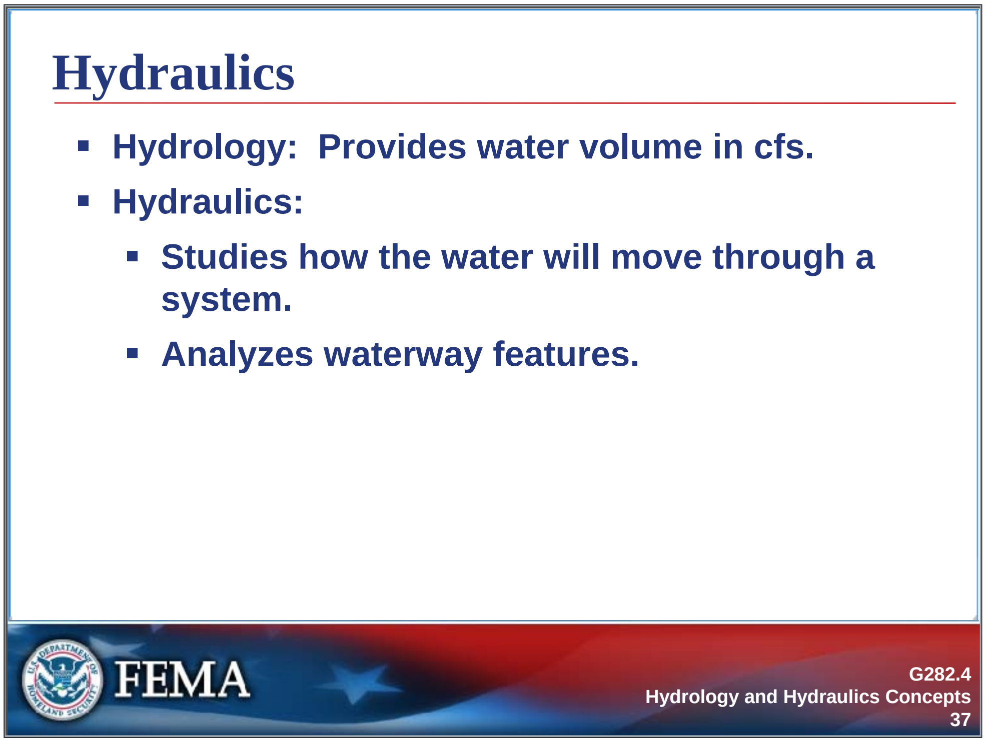
- Precipitation records
- Stream flow gage data from USGS and USACE.
- Historic high-water marks.
- Regional Regression analysis for ungaged watersheds.

Recognize that stream flow gage data are the most accurate sources of riverine hydrology data. The most accurate sources of coastal hydrology data are tidal or storm surge gages.



Key Points – Hydraulics

The next section of the course is a discussion of the science of hydraulics.

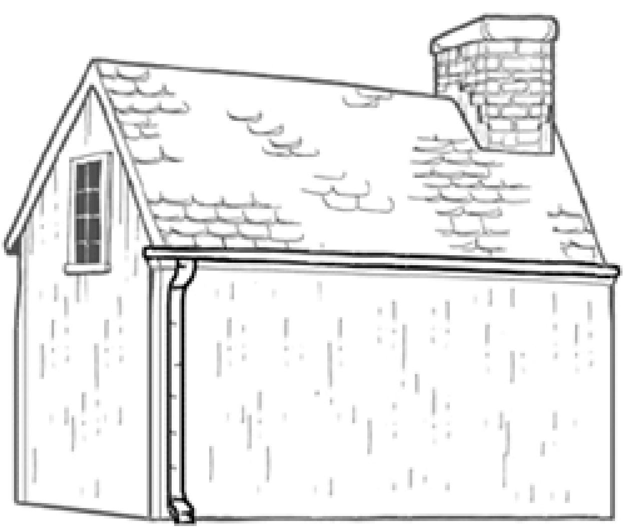


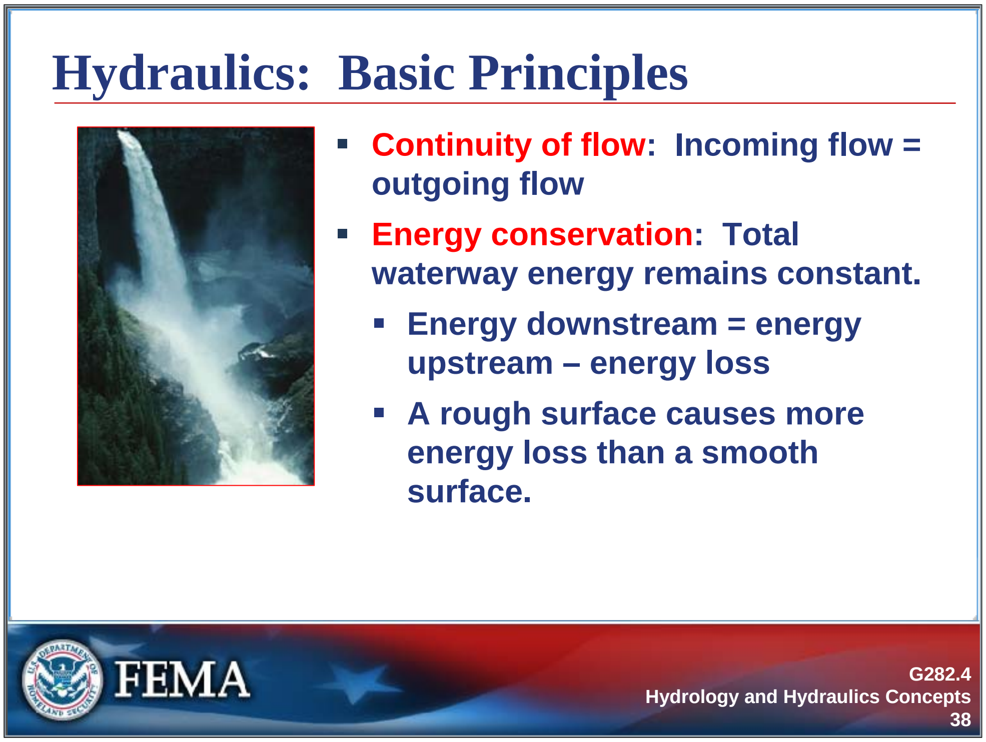
Key Points – Hydraulics

Hydraulics:

- Hydrology studies give us a volume of water, measured in cubic feet per second (cfs) at a given point.
- Hydraulic studies take that volume of water and describe how it will move a system.
- Hydraulics focuses on the waterways of the studied area. Where are the channels? How deep, wide, and steep are they?

Consider the graphic below, a roof with peaks, gutters, and a downspout. The hydraulic system includes the roof surfaces, the gutters, and the downspout.





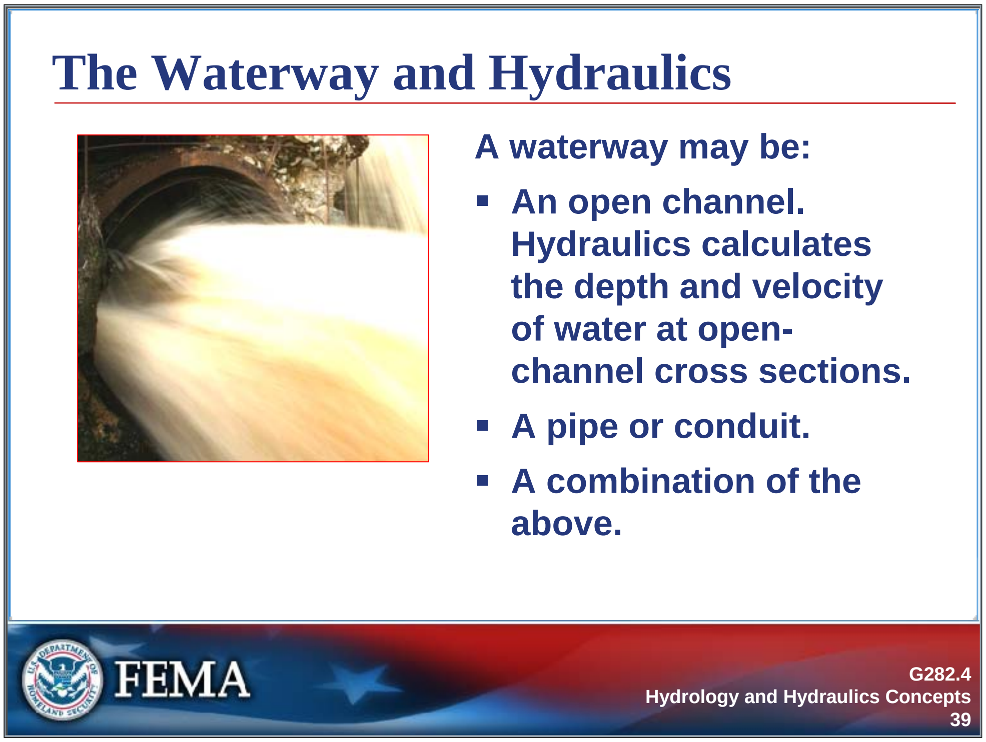
Key Points – Hydraulics

The two basic principles of hydraulics:

- **Continuity of flow** means that incoming flow equals outgoing flow.
- **Energy conservation** refers to the fact that total waterway energy remains constant and is described as: Energy upstream minus the energy lost in transit equals the energy downstream.

Energy loss relates to waterway surfaces. A rough surface causes more energy loss than a smooth surface.

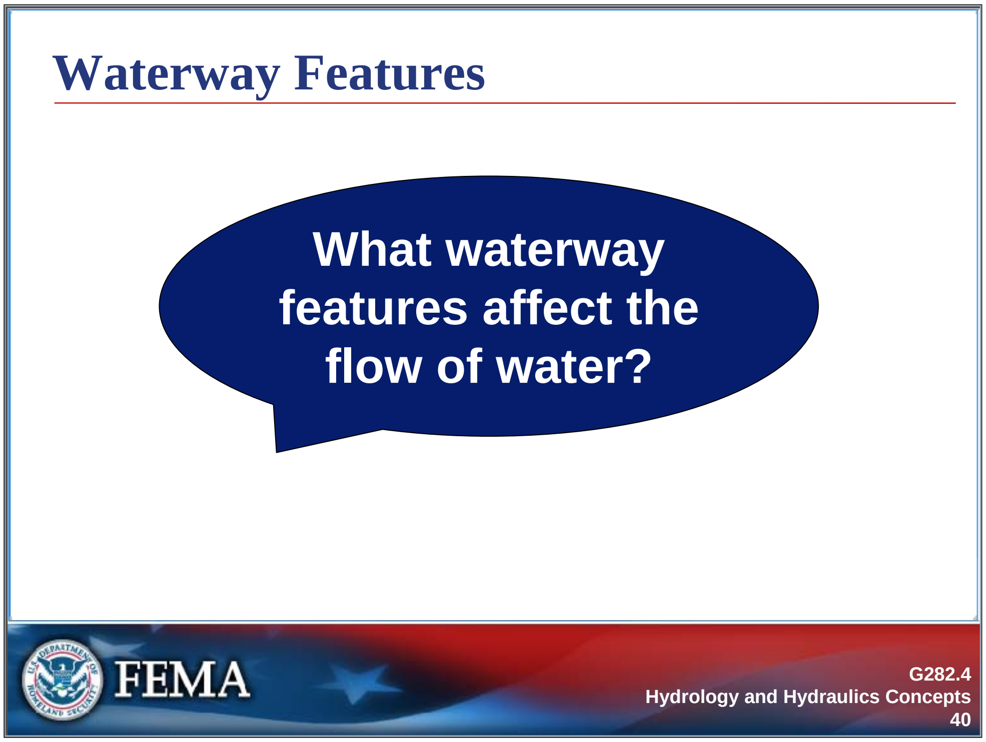
Hydraulic studies assume an unobstructed waterway. If a shopping cart blocks a culvert, the model no longer applies.



Key Points – Hydraulics

A waterway may be:

- An open channel. Open-channel cross sections are study sites on the waterway. Hydraulics includes methods to determine the depth and velocity of water at open-channel cross sections in the waterway.
- A pipe or conduit.
- A combination of an open channel and pipes or conduits.

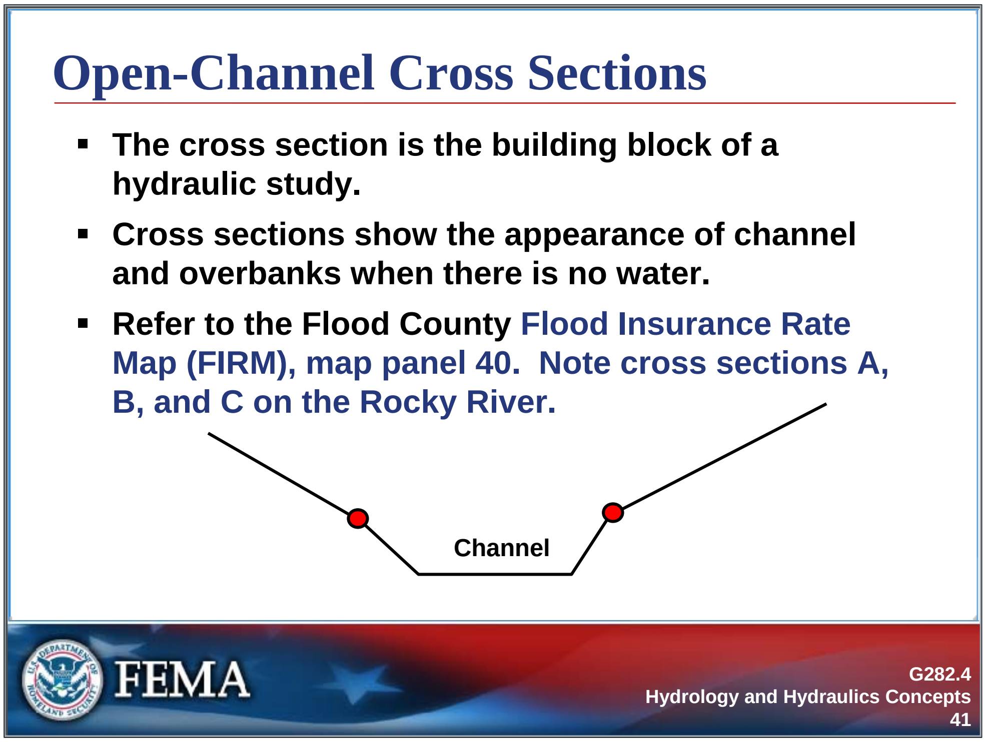


Key Points – Hydraulics

Answer the following discussion question:

What waterway features affect the flow of water?

Water may be turbulent, or may have a smooth flow, termed a laminar flow, and the channel-bed surface may be relatively smooth or rougher. Every river is different, and you need to know your particular river.



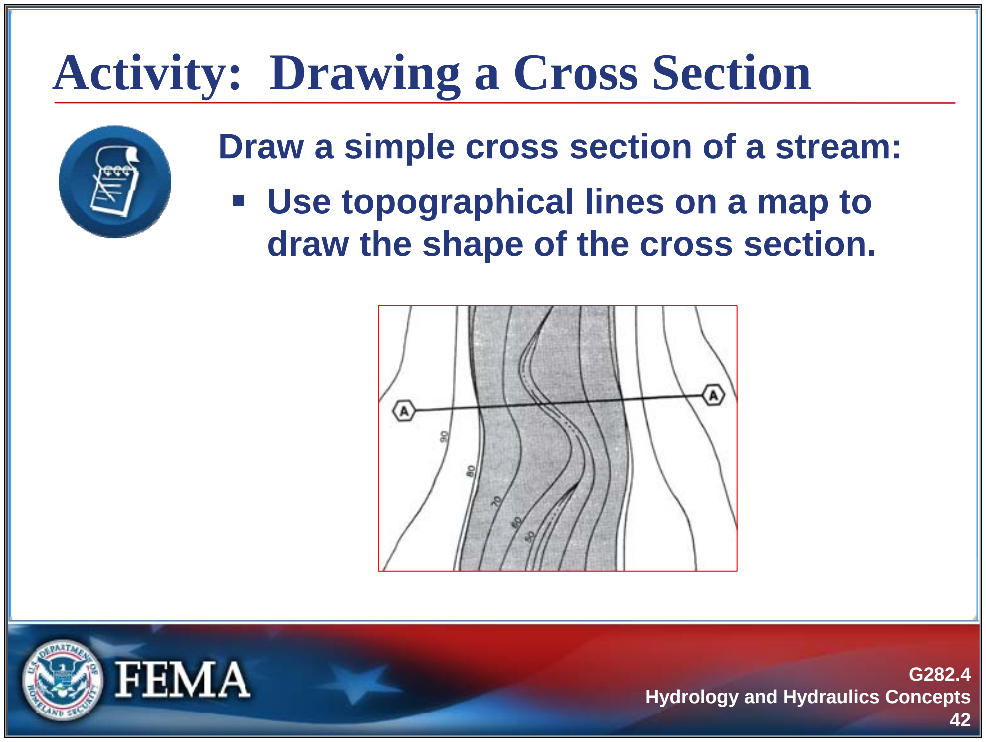
Key Points – Hydraulics

The cross section is the building block of a hydraulic study.

Refer to the Flood County Flood Insurance Rate Map (FIRM), map panel 40.

- Note cross sections A, B, and C on the Rocky River.
- Cross sections show the appearance of channel and overbanks when there is no water.

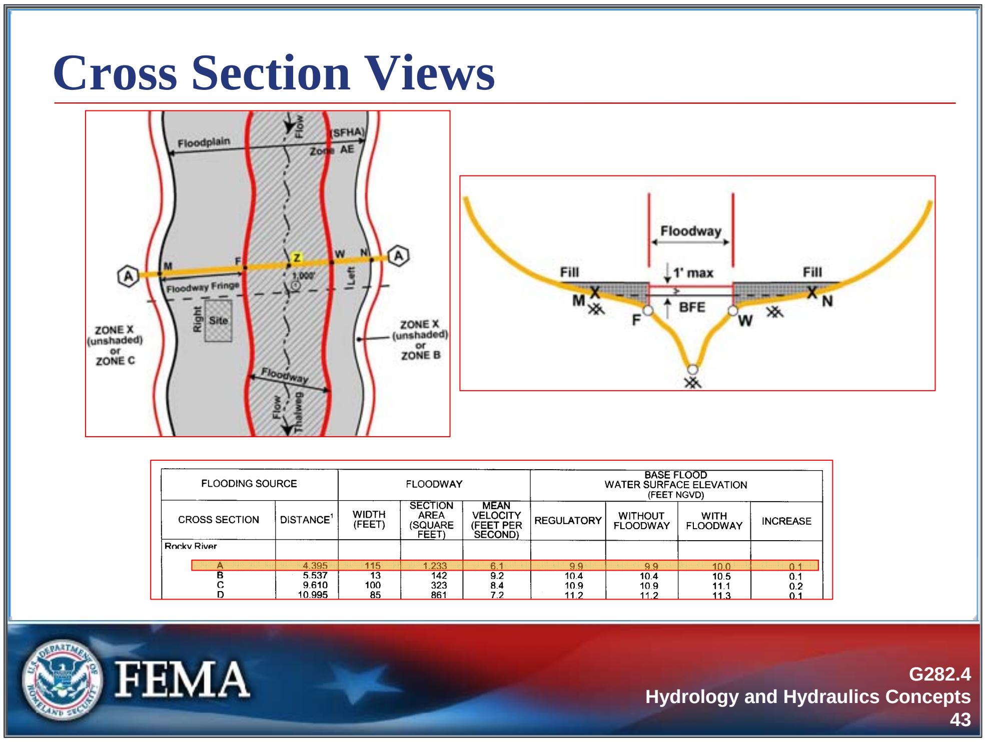
The diagram shows the cross section of an open channel. The cross section is perpendicular to the direction of the main flow in the channel.



Key Points – Hydraulics

Activity Instructions:

1. Notice the elevation data for a channel on the visual. The elevation for each contour line is shown on the left side of the stream, and continues in 10-foot intervals on the right side.
2. The dashed line to the right of the 50-foot elevation line is the center line of the channel, and does not indicate an elevation drop.
3. Refer to the Resource Booklet, and locate the Cross-Section Activity.
4. The top half of the sheet shows the topographic map, and the bottom has a grid with the beginning and end points of the channel cross section marked.
5. Mark the remaining points and connect the points to draw the cross section.
6. Work individually.



FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION (FEET NGVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Rocky River								
A	4.395	115	1.233	6.1	9.9	9.9	10.0	0.1
B	5.537	13	142	9.2	10.4	10.4	10.5	0.1
C	9.610	100	323	8.4	10.9	10.9	11.1	0.2
D	10.995	85	861	7.2	11.2	11.2	11.3	0.1

Key Points – Hydraulics

The three graphics on this slide illustrate different features of the same cross section.

- The view on the top left shows the appearance of the cross section on the FIRM.
- The view on the top right is a channel cross section that shows the shape at the channel bottom and sides.
- The bottom view shows cross-section data on the FIS Floodway Data Table, which ties the cross section to location, channel size, water flow velocity, and base flood elevation (BFE).

Roughness Factors

Channel surfaces affect flow rates:

- **Water flows faster on a smooth surface, such as concrete.**
- **Water flow is slowed by rocks or other rough surfaces.**
- **The relative smoothness/roughness of the surface is factored into hydraulics calculations.**

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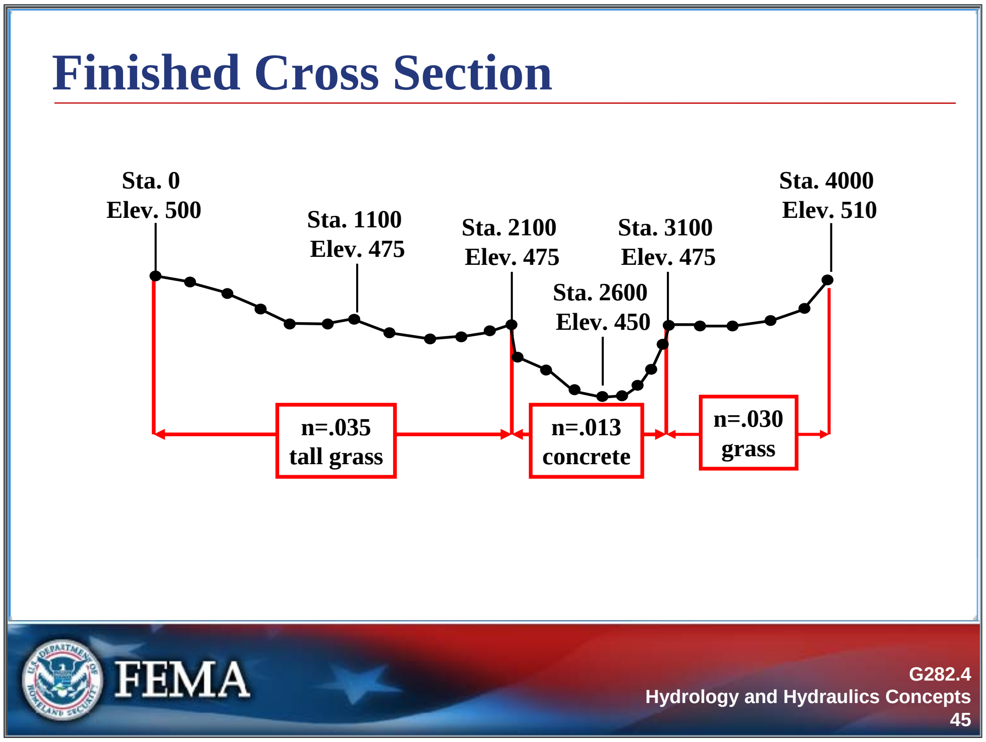
Key Points – Hydraulics

The surface of the open channel affects the flow of water. Water flows faster on a smooth surface, such as concrete, than on a rough surface, such as tall grass.

Note that concrete-lined channels have uniform cross sections. Examples are concrete-lined highway gutters and wide-cut channels next to interstate highways. For other examples, you might recall the motorcycle chase in the movie “Terminator 2,” or the race in the movie “Grease.”

The roughness of the channel can be applied to help determine flood depths at our cross sections.



Key Points – Hydraulics

This diagram shows a finished drawing of a cross section. The cross section was developed by an engineer using measurements taken at the site.

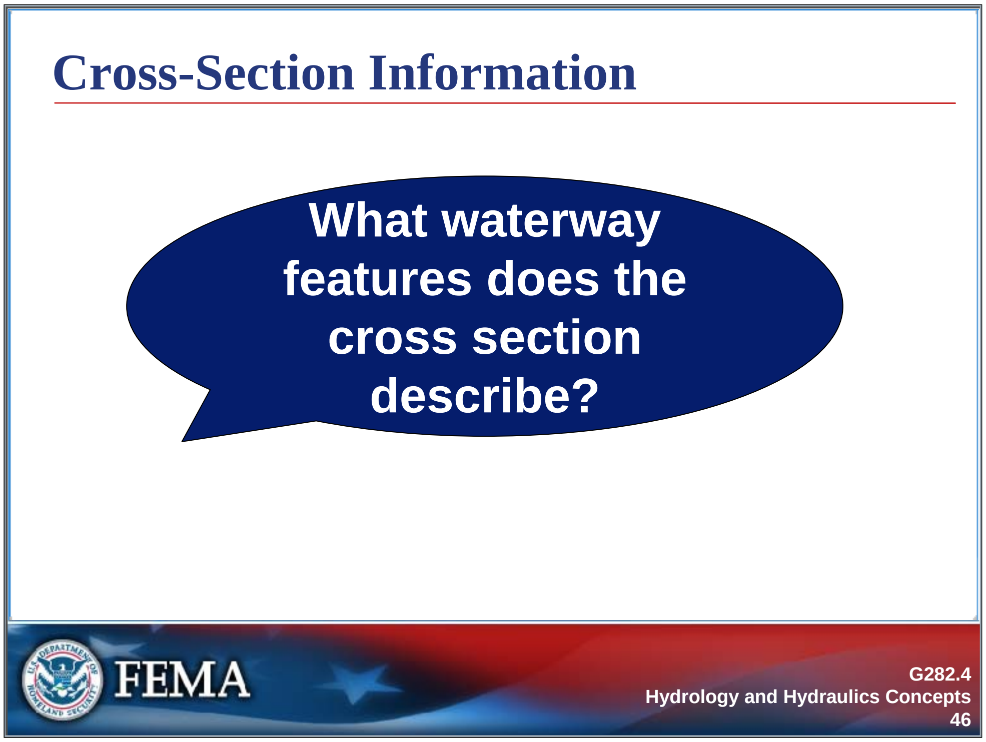
Note:

- The differences in elevation shown in the cross section.
- The central portion of the cross section is lined with concrete, and the sides with grass.
- The "n" figures are measures of roughness of the cross-section surface at different locations in the cross section. Note that higher values of "n" show increased surface roughness.

This engineered cross section provides data input for a hydraulic model. The model will link this cross section to other cross sections to calculate how water will flow through a portion of the waterway.

All lettered cross sections on the FIS have the information shown in the diagram.

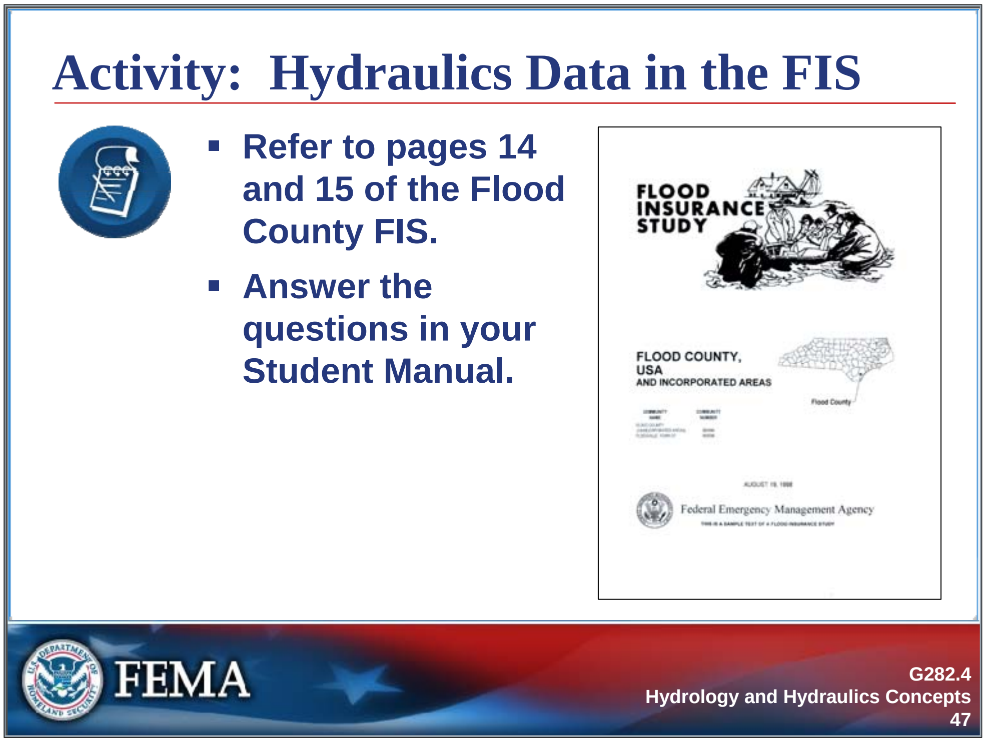
Typically there are many more cross sections taken than are shown on the FIS. There may have been a hundred cross sections, but for the sake of clarity, the map will show only four-lettered cross sections.



Key Points – Hydraulics

Answer the following discussion question:

What waterway features does the cross section describe?



Key Points – Hydraulics

Activity Instructions:

1. Refer to pages 14 to 15 of the Flood County FIS.
2. Use the FIS to answer the questions in your Student Manual.

Activity Questions:

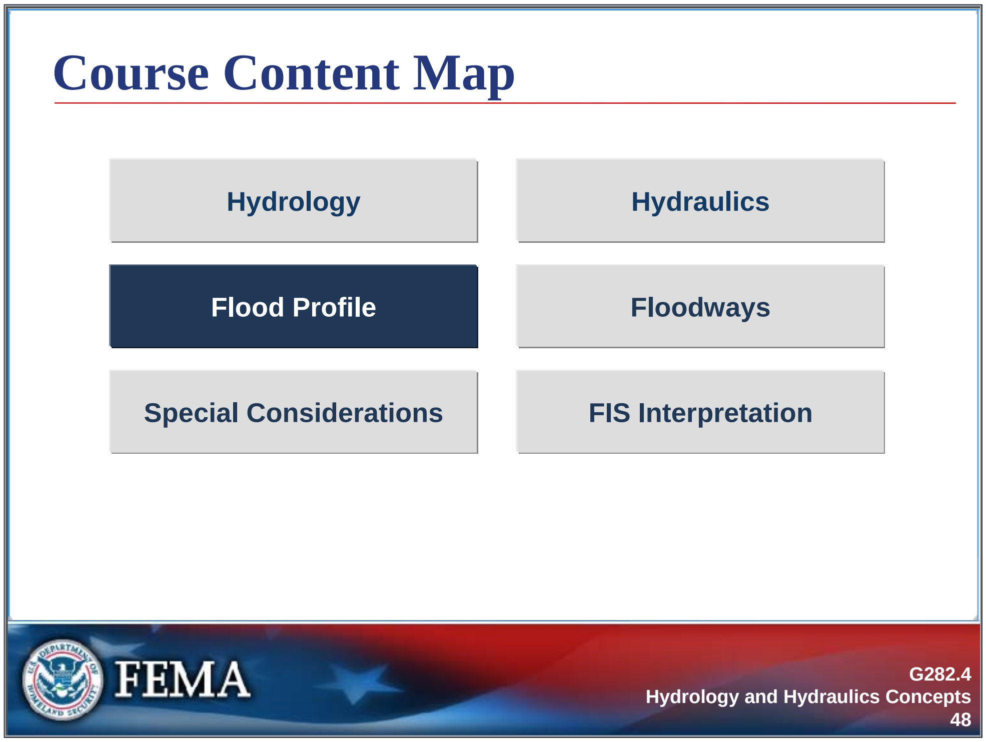
1. **How was elevation data and structural geometry of bridges, dams, and culverts obtained?**

2. **What was the scale of the topographic maps used to develop overbank cross-section data?**

3. **What was the source of the overbank topographic maps?**

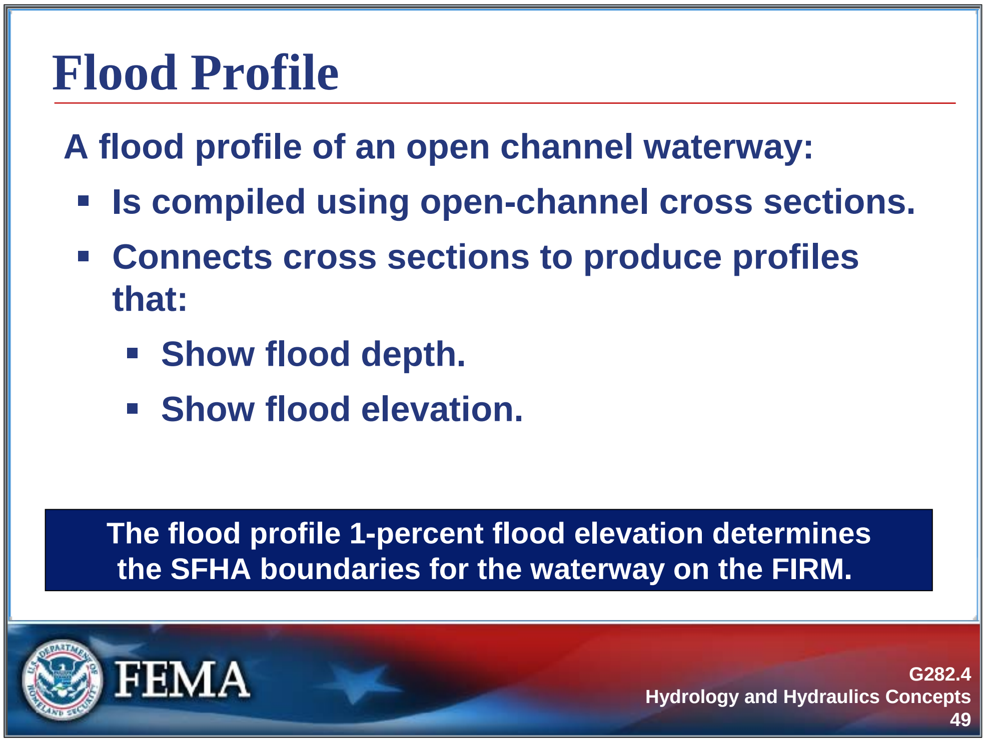
4. **What datum is used for all elevations?**

5. **What was the range of roughness factors for the Rocky River Channel?**



Key Points – Flood Profile

The next section of the course is a discussion about how to create a flood profile.

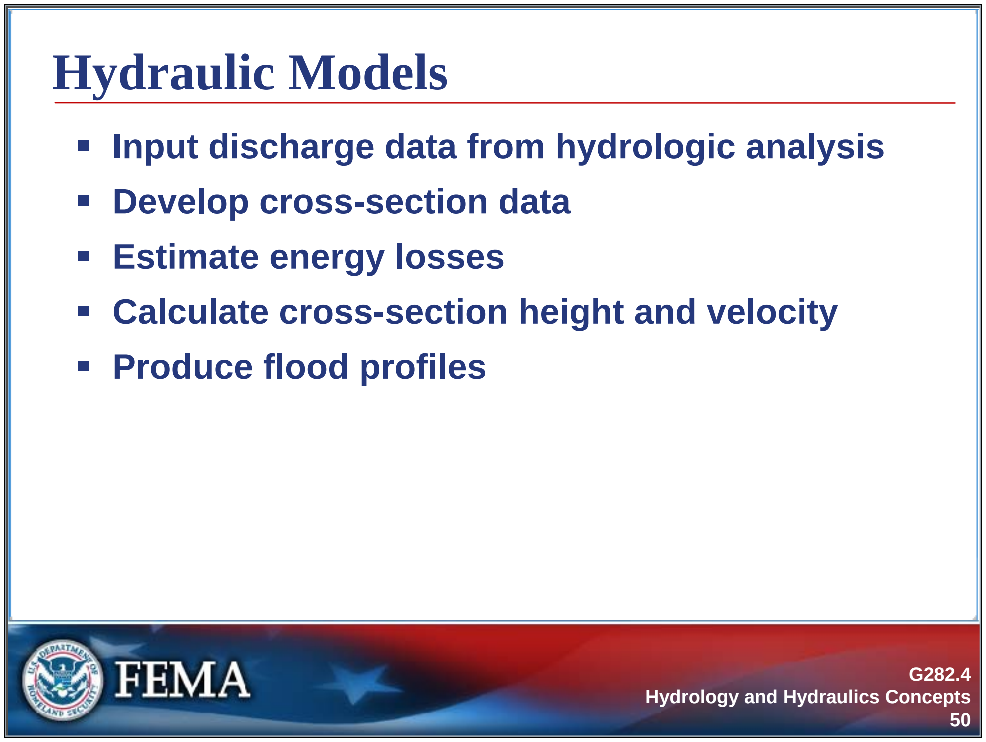


Key Points – Flood Profile

An important product of hydrologic and hydraulic studies is a flood profile. Flood profiles of open channel waterways:

- Are compiled using open-channel cross sections.
- Connect cross sections to produce profiles that:
  - Show flood depth.
  - Show flood elevation.

The flood profile 1-percent flood elevation determines the SFHA boundaries for the waterway on the FIRM.

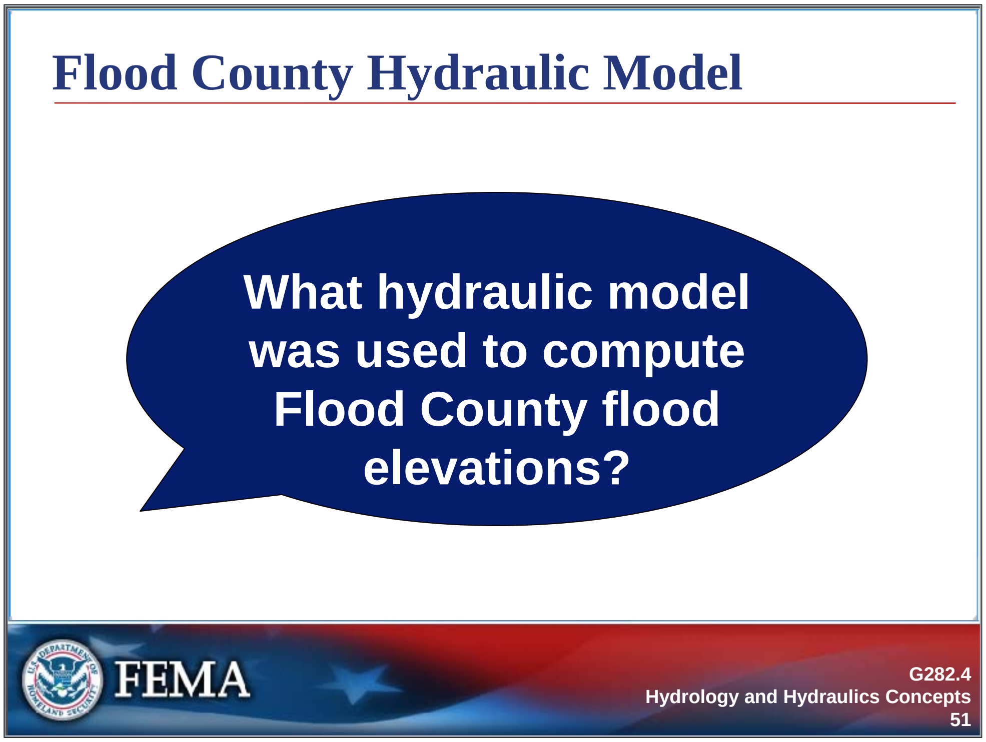


Key Points – Flood Profile

Hydraulic modeling programs:

- Input discharge data from hydrologic analysis.
- Develop cross-section data for:
  - Open channels.
  - Bridges and other obstructions.
- Estimate energy losses due to:
  - Surface roughness.
  - Expansion and contraction.
- Calculate for each cross section:
  - Height
  - Velocity
- Produce flood profiles from cross-section data.

The most complex part of hydraulic modeling is developing cross-section data for bridges and other obstructions.

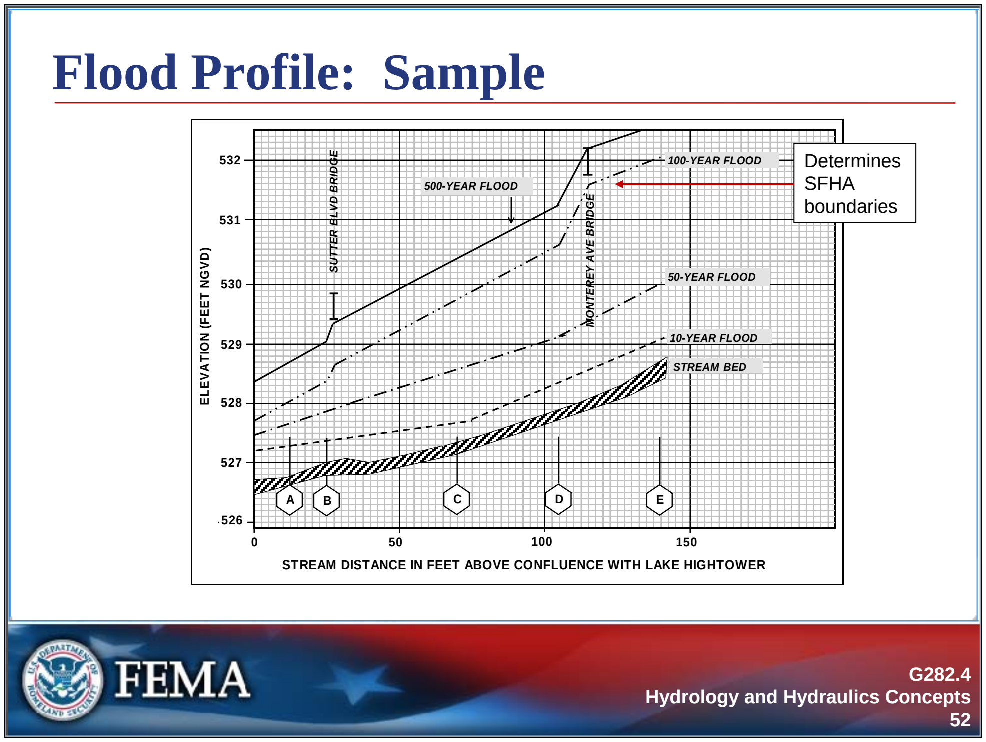


Key Points – Flood Profile

Refer to page 15 of the Flood County FIS.

Answer the following discussion question:

What hydraulic model was used to compute Flood County flood elevations?



Key Points – Flood Profile

Connecting the sections of open-channel cross sections results in a flood profile. Note that the heavy lines show the stream bed, and the dashed lines connect the cross sections and show flood depths for different flood events.

Refer to the flood profiles in the Flood County FIS for examples. Locate the 100-year (1 percent) flood line in the profiles.

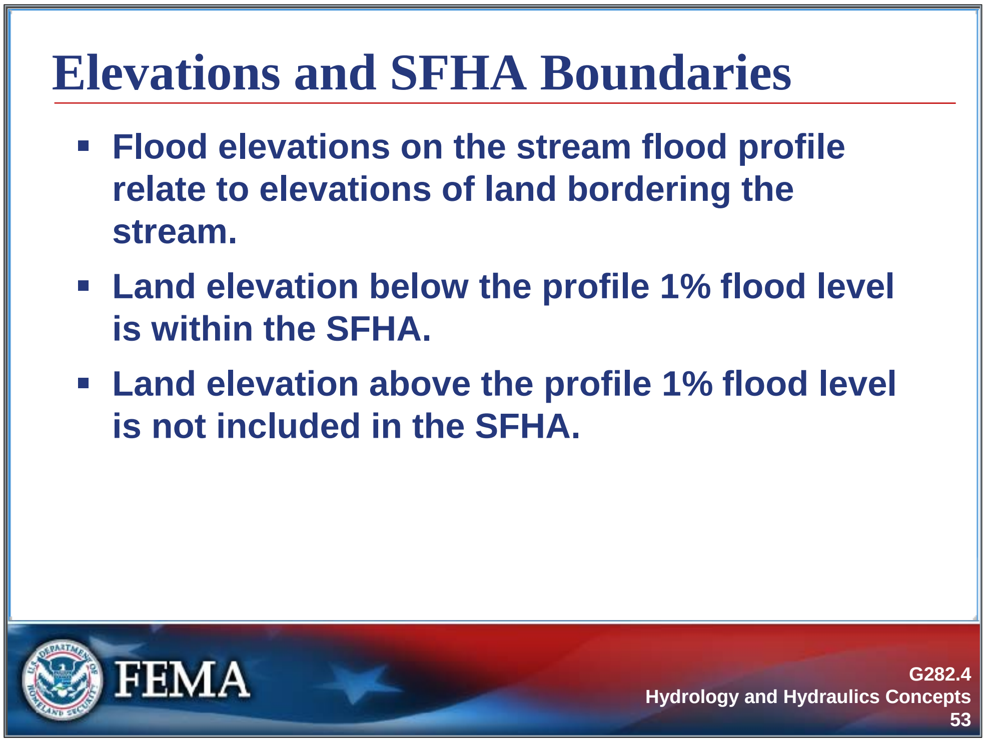
The Flood County FIS is still using the terms “100-year flood,” “50-year flood,” and so forth, rather than flood frequencies expressed in percents. New studies will use the percent frequencies.

All hydraulic structures with an impact on flow are studied using complex models.

When a little stream joins a big river, backwater from flooding on the big river will raise elevations on the stream.

Data on unlettered cross sections is available in models.

Either NAVD or NGVD base elevations may be used in hydraulic studies. All survey documents such as topographic maps, site plans, and elevation certificates need to use the same datum. The standards are equivalent, and can be converted, just as temperatures can be expressed as either Fahrenheit or Celsius.

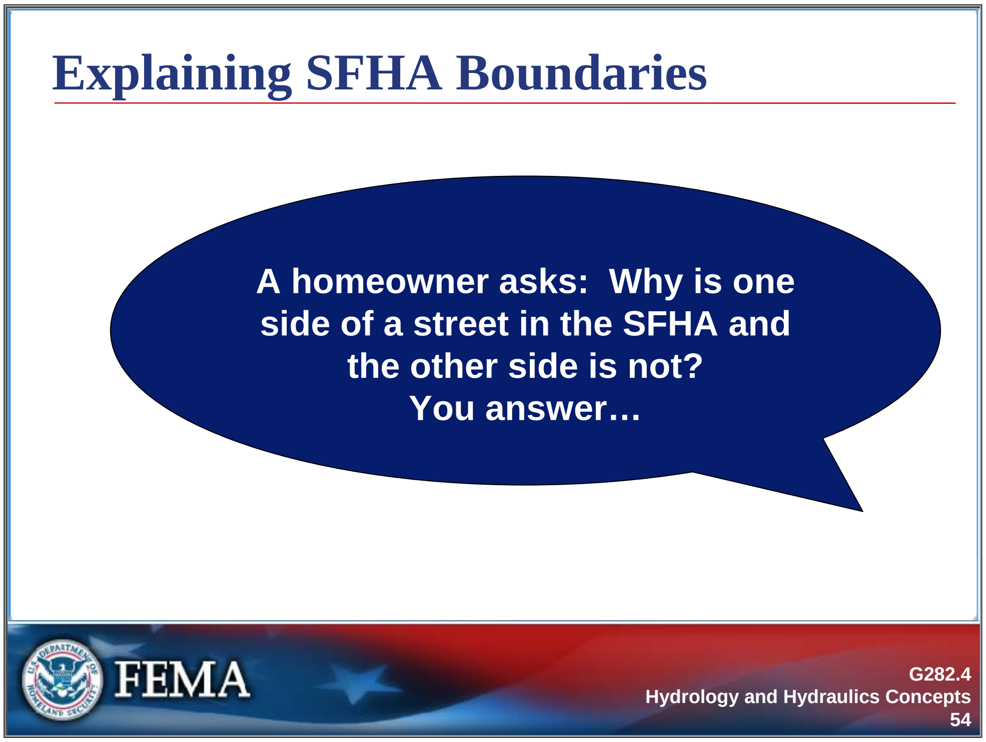


Key Points – Flood Profile

Elevations and Boundaries:

- Flood elevations on the flood profile relate to elevations of land bordering the stream.
- Land surface elevation below the profile 1-percent flood level is within the SFHA.
- Land surface elevation above the profile 1-percent flood level is not included in the SFHA.

Topographic maps provide surface elevations. The United States Geological Survey and the U.S. Army Corps of Engineers topographic maps are cited as references in the Flood County FIS as sources of elevation data.

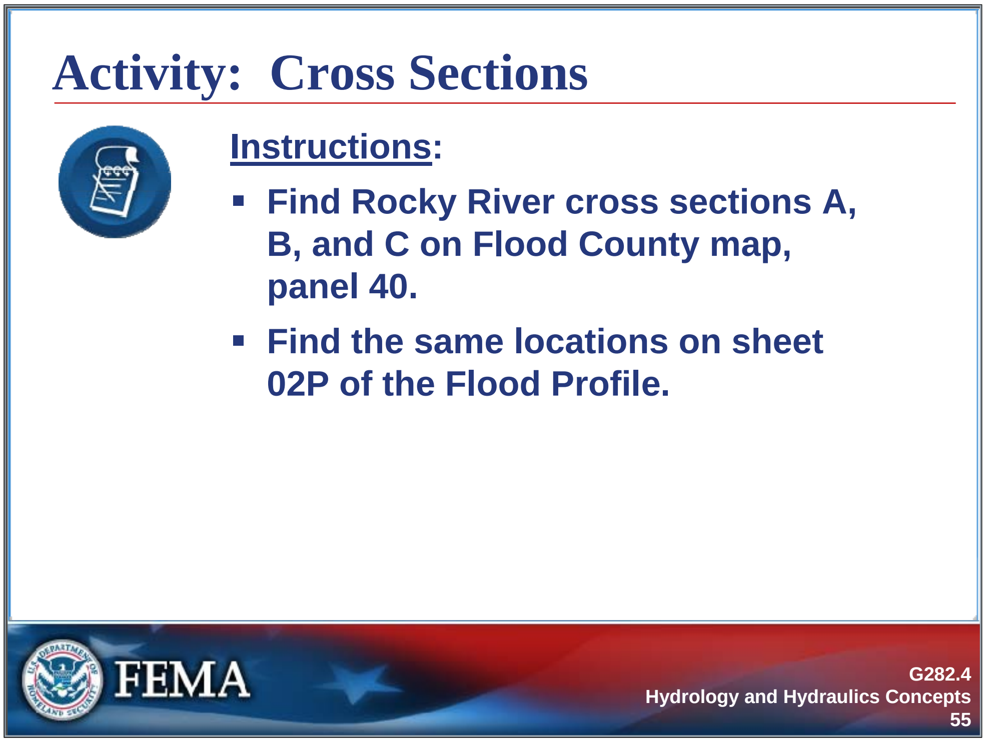


Key Points – Flood Profile

A common question from homeowners is “Why is one side of a street in the SFHA and the opposite is not?”

Answer the following discussion question:

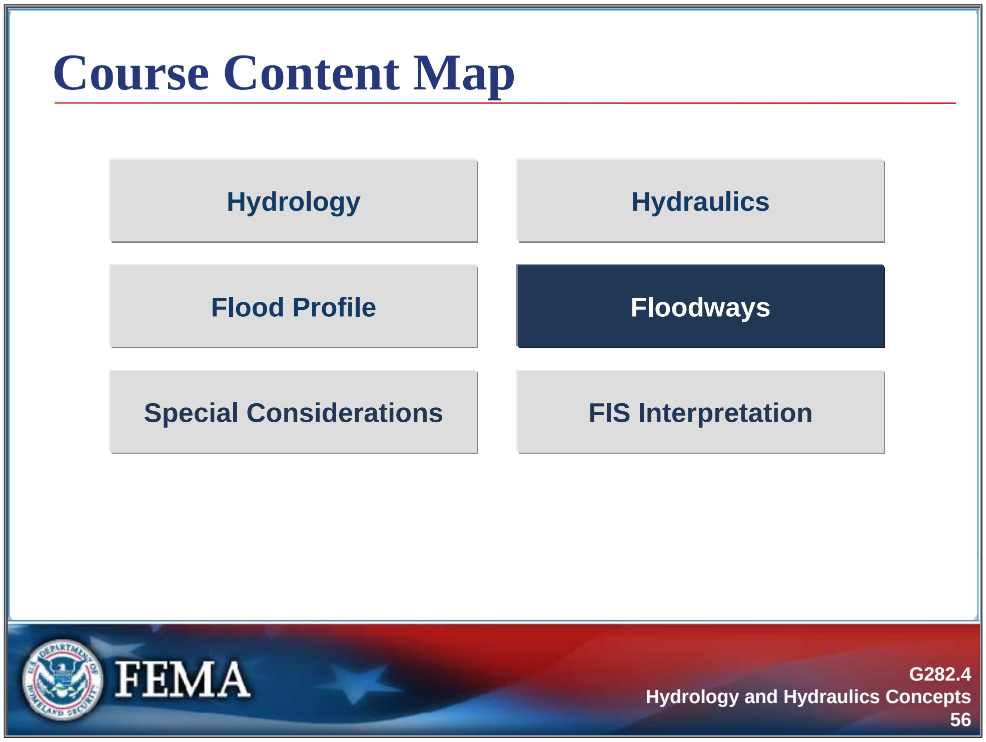
How can the FPM use the FIS and flood profile to explain to a homeowner why one side of a street is in the SFHA and the opposite is not?



Key Points – Flood Profile

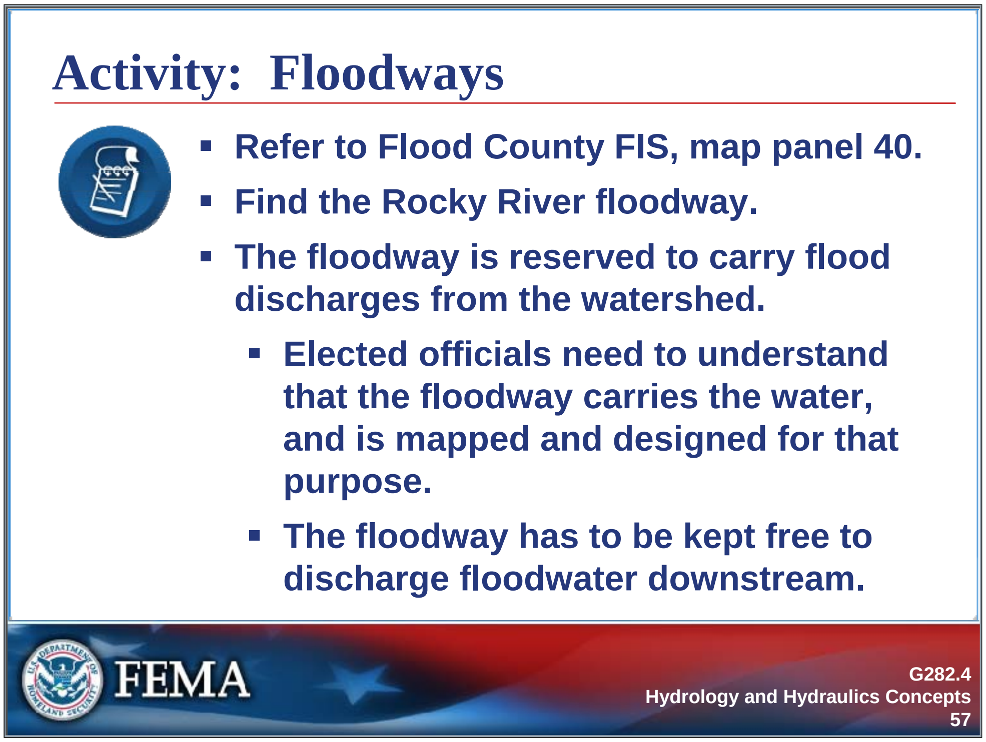
Activity Instructions:

1. Work individually to find Rocky River cross sections A, B, and C on Flood County map, panel 40.
2. Next, find the same locations on sheet 02P of the Flood Profile.



Key Points – Floodways

The next section of the course is about issues pertaining to floodways.

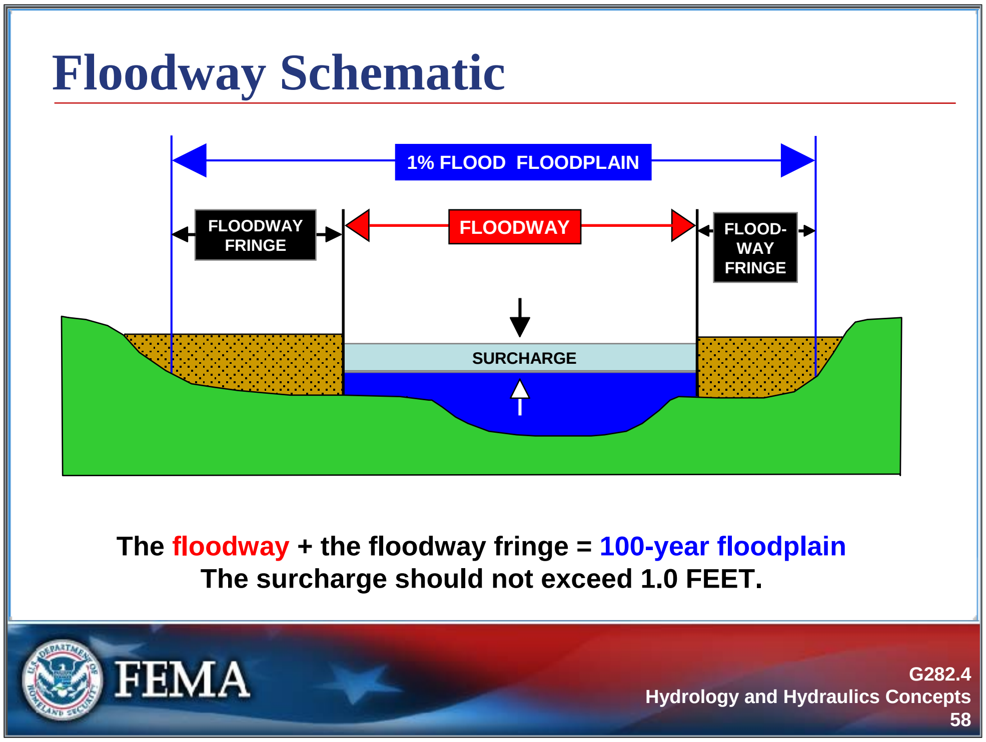


Key Points – Floodways

Refer to the Flood County FIS, map panel 40, which shows the floodway on the Rocky River.

The floodway is reserved to carry flood discharges from the watershed. Note that:

- Elected officials need to understand that the floodway carries the water, and is mapped and designed for that purpose. If they understand the consequences of obstructing the floodway, officials are better situated to resist proposals to place obstructions and development in the floodway.
- The floodway has to be kept free of development and any kind of obstructions to be able to discharge floodwater. If the floodway is obstructed, other parts of the community will be flooded.
- You need to train elected officials about flood maps, the floodway concept, and floodplain management ordinance provisions.



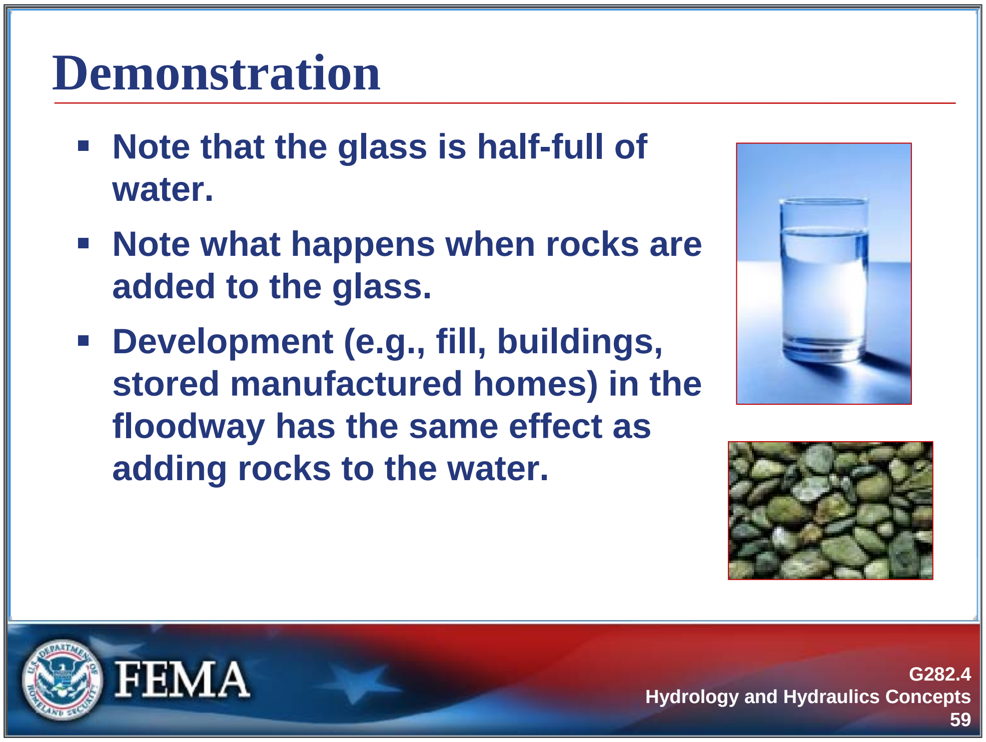
Key Points – Floodways

You will note that:

- View #1 shows the shape of the floodplain and stream level at a cross section.
- View #2 shows the location of the floodplain for the 1-percent flood.
- View #3 shows the addition of obstructions such as fill in the floodway.
- View #4 shows a rise in the water level caused by the obstructions. The rise is called the surcharge.
- View #5 shows the floodway and the floodway fringes on either side.

The view of the floodway is looking upstream, and the floodway is not something you can see when you look at a river.

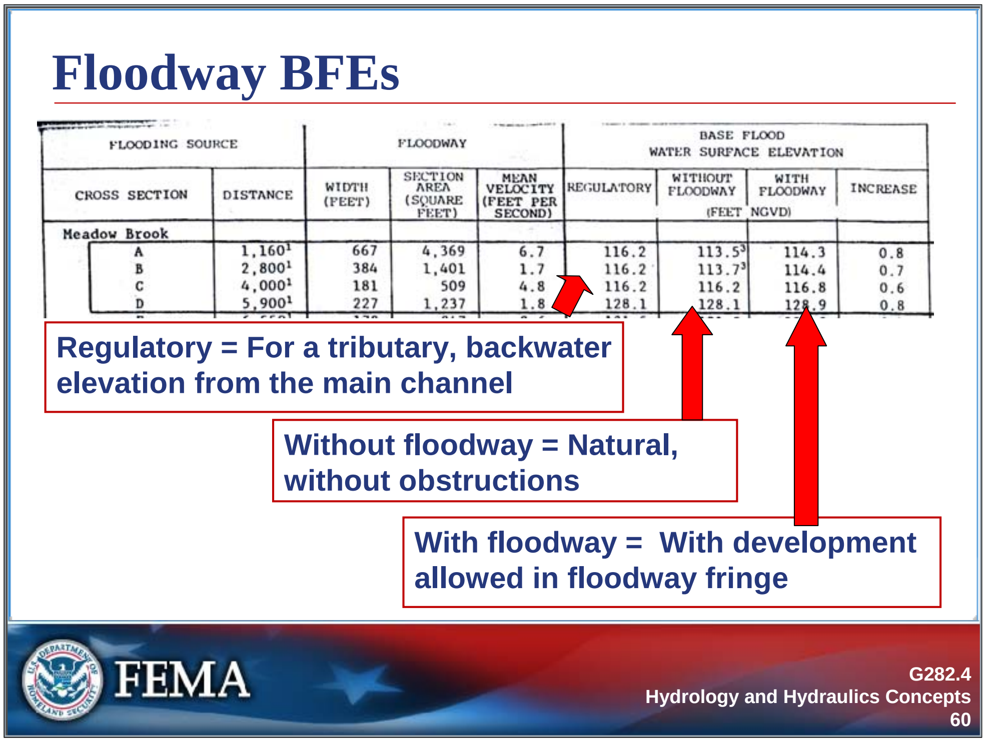
The floodway is like a setback line, a margin of safety. You wouldn't park a trailer right next to the Interstate, because sooner or later it will be hit. Putting the trailer in the floodway is like putting it next to the Interstate.



Key Points – Floodways

Development in the floodway has the same effect of raising the water level. Development is any kind of obstruction. Fill is development, buildings are development, stored manufactured homes are development.

The demonstration may be an effective way to communicate with elected officials. Keeping the floodway free of development is an important component of higher floodplain management standards.



FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Meadow Brook								
A	1,160[1]	667	4,369	6.7	116.2	113.5[3]	114.3	0.8
B	2,800[1]	384	1,401	1.7	116.2	113.7[3]	114.4	0.7
C	4,000[1]	181	509	4.8	116.2	116.2	116.8	0.6
D	5,900[1]	227	1,237	1.8	128.1	128.1	128.9	0.8

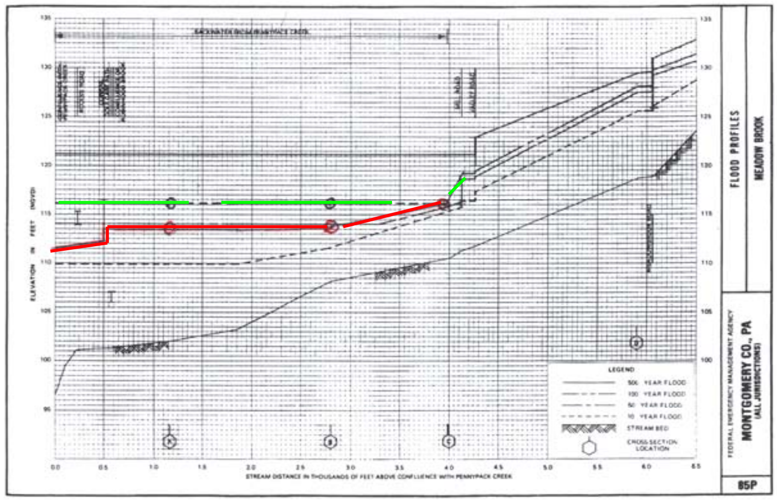
Key Points – Floodways

The visual shows part of Floodway Data Table for Meadow Brook in Montgomery County, Pennsylvania. Meadow Brook is a tributary of Pennypack Creek.

Note the difference in elevation between the Regulatory and Without Floodway columns.

The Without Floodway elevations are computed without consideration of backwater effects from Pennypack Creek.

Meadow Brook Profile



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Key Points – Floodways

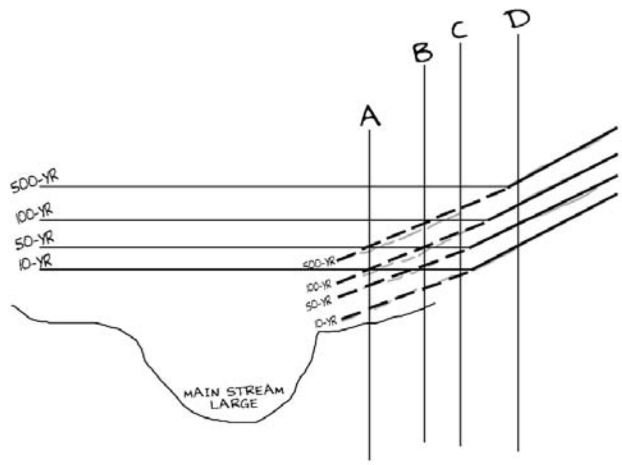
The profile shows the effect of the Pennypack Creek backwater on the Meadow Brook BFE.

The red line is the BFE for Meadow Brook without considering the backwater from Pennypack Creek. The green line shows the BFE with the backwater included.

A BFE diagram is on the next page.

Key Points – Floodways (Continued)

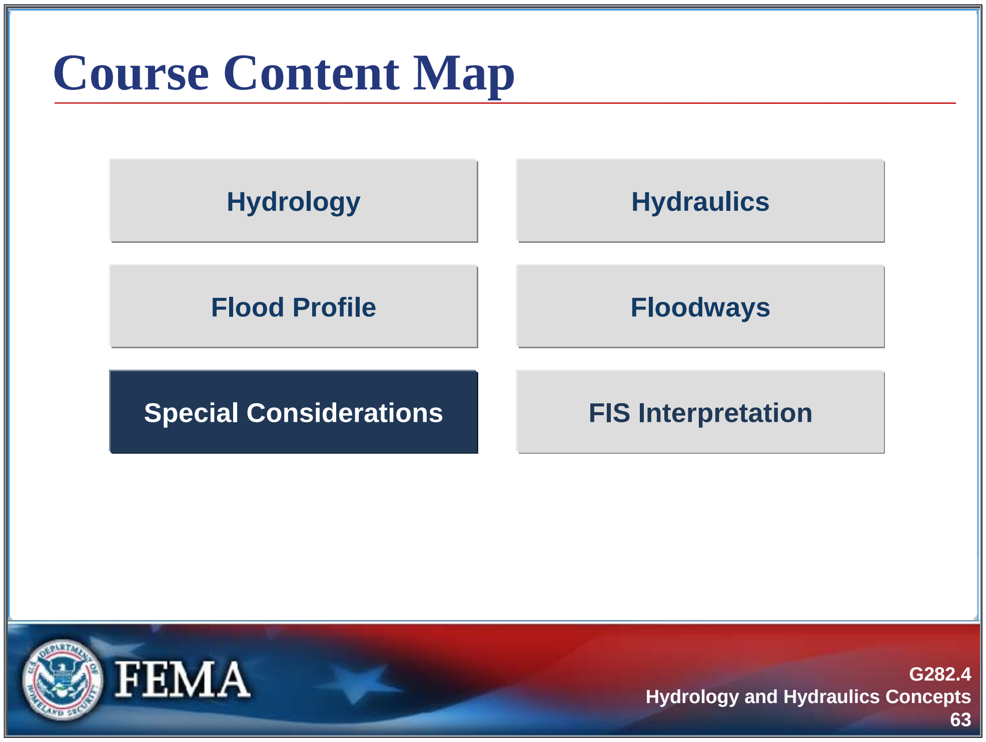
Refer to the diagram below, which illustrates the tributary BFEs without considering backwater, and the BFEs resulting from main channel backwater.



The regulatory floodway is developed using the red profile, representing the With Floodway and Without Floodway columns on the Floodway Data Table.

The regulatory BFE is the green profile, the higher of the two profiles, and represents the Regulatory column on the Floodway Data Table.

Refer to cross section D on the profile, and note that the Without Floodway elevation is 128.1. Now refer to the Floodway Data Table on Page 60. Note that the Regulatory Column figure for cross section D also is 128.1.



Key Points – Special Considerations

The next section of the course is about special hydraulics considerations and concerns.

Special Considerations

Other hydraulic concerns include:

- Coastal and lake flooding.
- Alluvial fans.
- Sedimentation and erosion.
- Ice jams.
- Floodborne debris.

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Key Points – Special Considerations

Depending on your location, there may be other concerns related to hydrology and hydraulics including:

- Coastal and lake flooding.
- Alluvial fans.
- Sedimentation and erosion.
- Ice jams.
- Floodborne debris.

Coastal and Lake Flooding

- Refer to the Flood County FIS, page 8.
- Note that Table 2 gives a summary of stillwater elevations.
- Refer to pages 11 and 12.
- Note that three different Atlantic Coast locations were studied.
- Page 12 gives stillwater and crest elevations at the locations.

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Key Points – Special Considerations

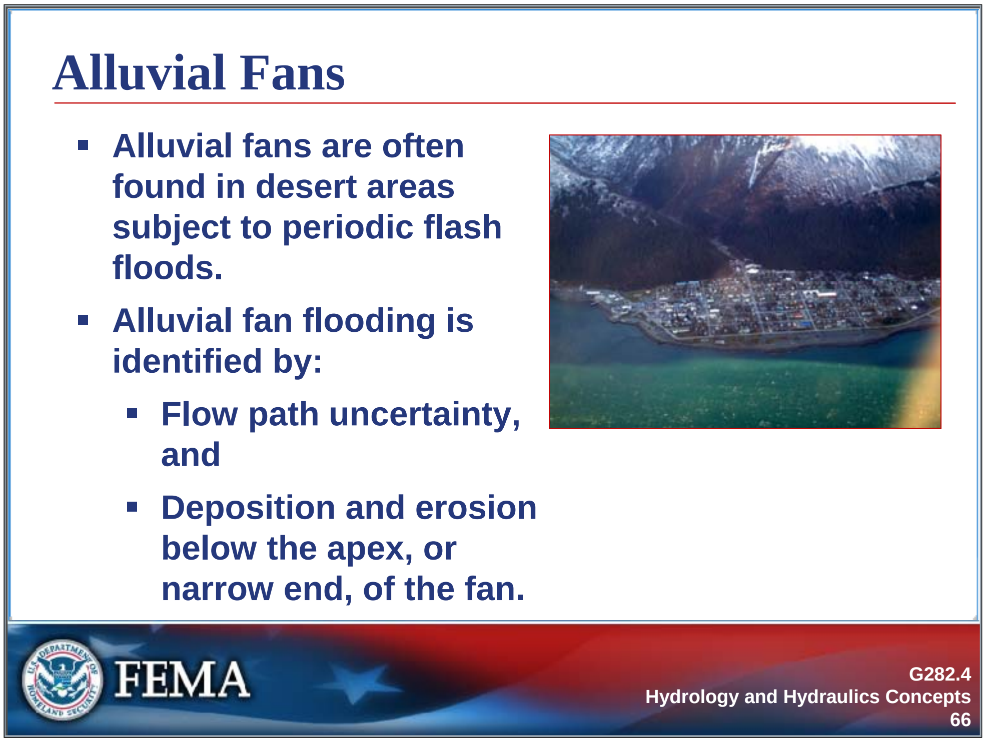
The FIS includes data on coastal and lake flooding for vulnerable communities.

Refer to page 8 of the Flood County FIS.

- Notice that Table 2 gives a summary of stillwater elevations.

Refer to pages 11 and 12 of the Flood County FIS. Note that:

- Three different Atlantic Coast locations were studied.
- Page 12 gives stillwater and crest elevations at the locations.



Key Points – Special Considerations

Alluvial fans are often found in desert areas subject to periodic flash floods from nearby thunderstorms in local hills. They are common around the margins of the sedimentary basins of the Basin and Range province of southwestern North America.

The typical watercourse in an arid climate has a large, funnel-shaped basin at the top, leading to a narrow defile, which opens out into an alluvial fan at the bottom. Multiple braided streams are usually present and active during water flows.

Alluvial fan flooding is identified by flow path uncertainty and deposition and erosion below the apex, or narrow end, of the fan.

The process of determining whether or not alluvial fan flooding can occur at a given location, and of defining the extent of the 1-percent chance flood, is divided into three stages:

- Recognizing and characterizing alluvial fan landforms.
- Defining the nature of the alluvial fan environment and identifying areas of active erosion, deposition, and flooding (as well as inactive areas).
- Defining and characterizing areas on active parts of alluvial fans that are subject to a 1-percent flood chance.

Other Considerations

Flood-related problems include:

- Sedimentation and erosion
- Ice jams
- Floodborne debris
- Lahars
- Tsunamis
- Playas
- Karst topography

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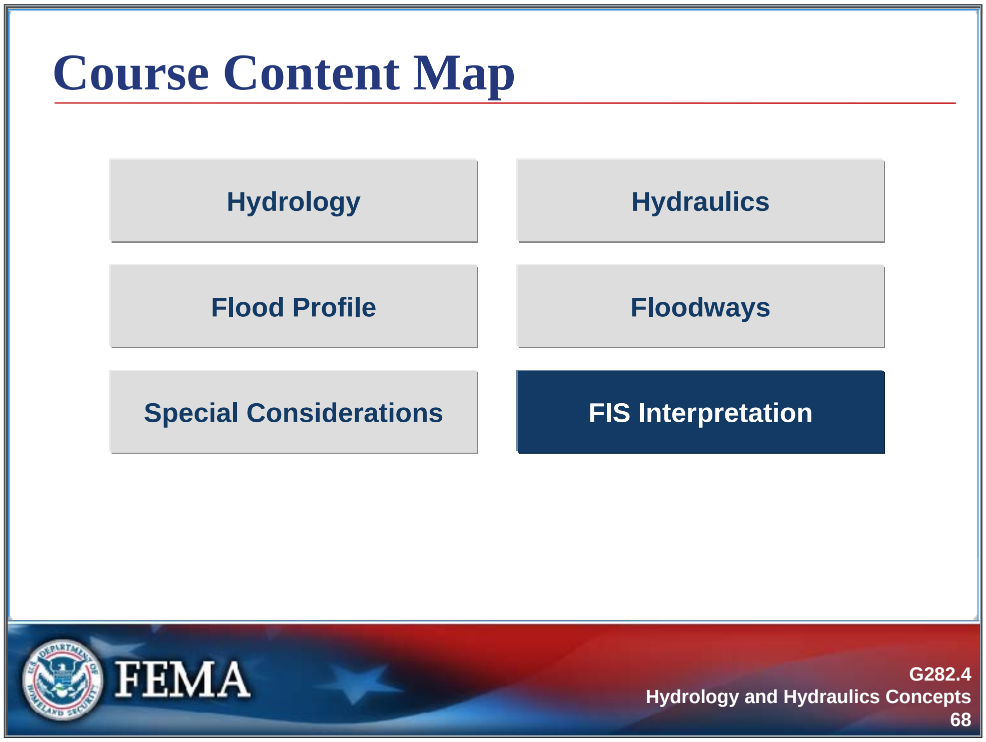
Key Points – Special Considerations

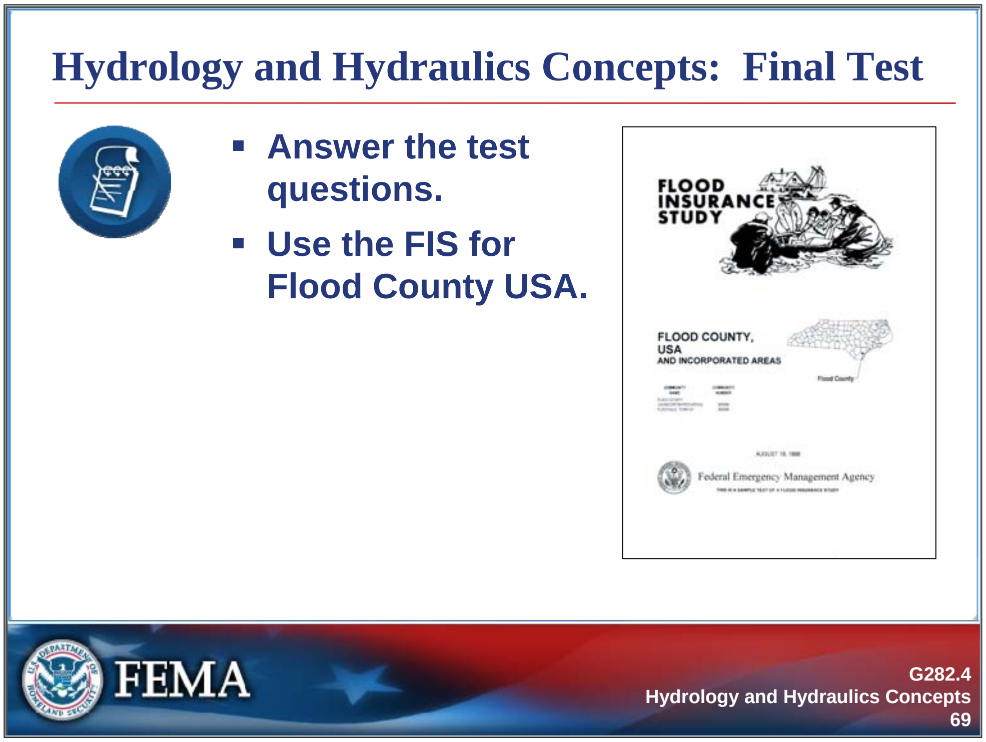
Problems that often accompany floods and increase flood damage, include:

- Sedimentation and erosion, which change the channel shape and contours, which in turn change the flow velocity and depth.
- Ice jams, which can dam the waterway and flood upstream areas.
- Debris, which also can form dams that cause upstream flooding.
- Lahars, which are landslides or mudflows of volcanic materials that flow down the slopes of a volcano.
- Tsunamis, which are waves resulting from undersea earthquakes.
- Playas, which are basins in undrained desert areas that may fill with water and form ponds.
- Karst topography, which features limestone caves and sinkholes.



Key Points – FIS Interpretation

The final section of the course is a test on finding information in an FIS.

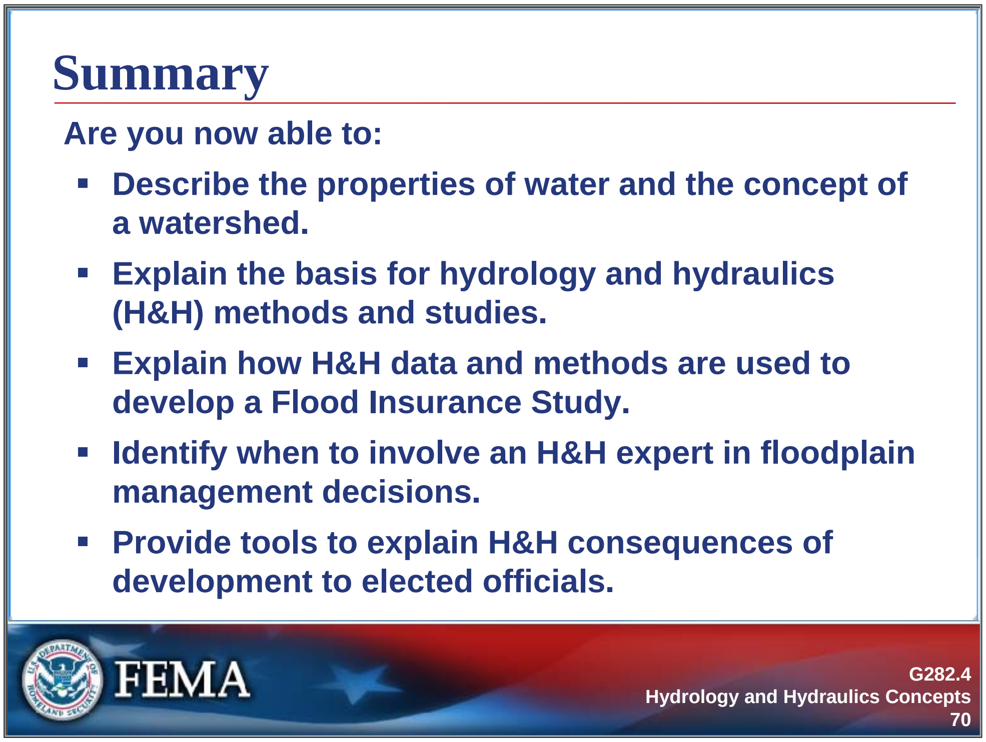


Key Points – FIS Interpretation

Test Instructions:

1. Your instructor will distribute the Final Test. Please answer all questions.

2. Use the Flood County FIS to answer the questions.



Key Points – Summary

You should now be able to:

- Describe the properties of water and the concept of a watershed.
- Explain the basis for hydrology and hydraulics (H&H) methods and studies.
- Explain how H&H data and methods are used to develop a Flood Insurance Study.
- Identify when to involve an H&H expert in floodplain management decisions.
- Provide tools to explain H&H consequences of development to elected officials.

Refer to your expectations posted at the beginning of the course. Answer the following discussion question:

Were your expectations met?