Name ____________________

Streams

Introduction

These exercises introduce some basic facts about streams. At any instant, only an extremely small fraction—about one-millionth—of all the Earth's water is present in rivers, but this water is disproportionately important. In examining its importance in streams, we consider drainage basins, stream channels, stream flow, and floods.

Exercise 25: The Long-Valley Profile

Introduction

The shape of river valleys can be considered in both the direction of flow—the **long-valley profile** or **longitudinal profile**—and perpendicular to the flow, the **cross-valley profile**. Here we consider the long-valley profile.

Question Set 44: Construction of a Long-Valley Profile

Table 2 lists points along the Yellowstone–Missouri–Mississippi River system with their elevations and distances from the Continental Divide.

i. Plot the elevation of each point listed in Table 2 on Figure 58.

ii. Calculate the stream gradients in feet per mile for the following sections, referring to data in Table 2:

a. Continental Divide, Wyoming, to Livingston, Montana ____________ ft/mi

b. Williston, North Dakota, to St. Louis, Missouri ____________ ft/mi

c. St. Louis, Missouri, to mouth of Mississippi River ____________ ft/mi

iii. Describe the long-valley profile of the Yellowstone–Missouri–Mississippi River valley.

Name ______________________

Table 2 Elevation and Distance of Points along the Yellowstone–Missouri–Mississippi River Valley from the Continental Divide to the Mouth of the Mississippi River

Location	*Elevation in Feet above Sea Level*	*Distance Down-Valley in Miles from the Continental Divide*
Continental Divide, Absaroka Mountains, Wyoming	11,000	0
Fishing Bridge, Yellowstone National Park, Wyoming	7,732	54
Livingston, Montana	4,450	151
Billings, Montana	3,100	268
Williston, North Dakota	1,838	590
Bismarck, North Dakota	1,620	813
Pierre, South Dakota	1,420	1,049
Sioux City, Iowa	1,080	1,368
Omaha, Nebraska	955	1,482
Kansas City, Missouri	722	1,698
St. Louis, Missouri	394	2,073
Memphis, Tennessee	183	2,459
Vicksburg, Mississippi	51	2,753
New Orleans, Louisiana	4	3,073
Mouth, Mississippi River	0	3,181

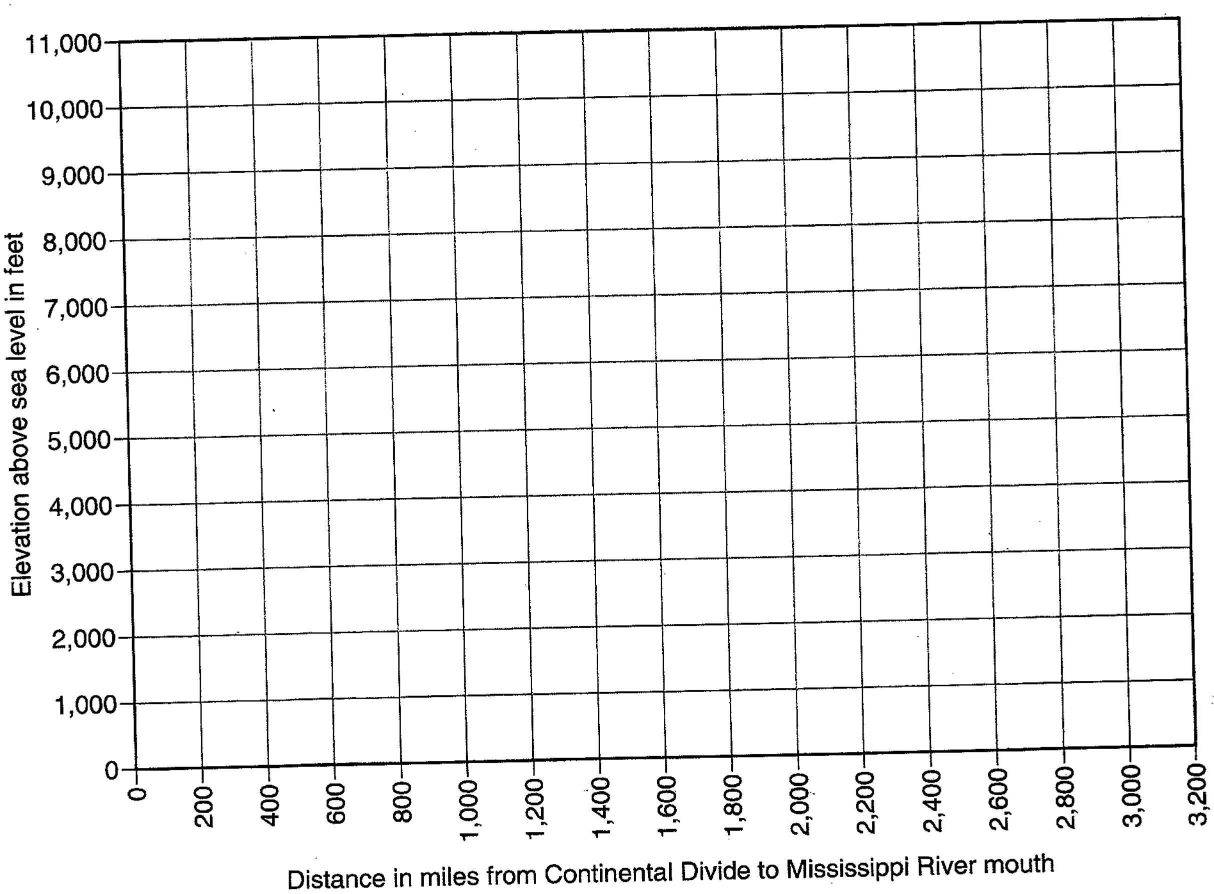

Figure 58. **Graph for plotting the long-valley profile of the Yellowstone-Missouri-Mississippi River system.**

Question Set 45: Potomac River Long-Valley Profile

Figure 59 is a plot of elevations of points along the Potomac River from the Appalachian Divide, West Virginia, to Washington, DC.

i. Complete Figure 59 by drawing the long-valley profile for the Potomac River.

ii. Calculate the stream gradients in feet per mile for the following sections, referring to Figure 59.

a. Divide, West Virginia, to Kitzmiller, Maryland __________ ft/mi

b. Cumberland, Maryland, to Harpers Ferry, West Virginia __________ ft/mi

iii. You will have noticed an abrupt increase in gradient downstream from the junction of Seneca Creek with the Potomac River.

a. What is a possible explanation for this increase in gradient? How would you check your answer?

iv. How does the Potomac River profile compare with the long-valley profile of the Yellowstone–Missouri–Mississippi River system?

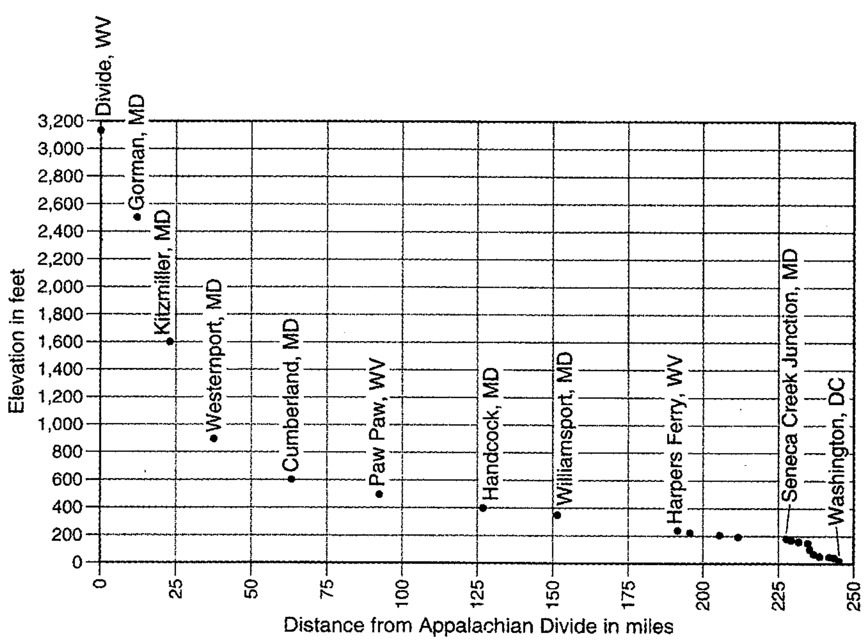

Figure 59. **Long-valley profile of the Potomac River from the Appalachian Divide, West Virginia.**

Name ______________________

Exercise 26: Drainage Basins

Introduction

The **drainage basin** of a river is the area of Earth's surface that contributes water to the stream. The lines on a map separating drainage basins are called **drainage divides**. For example, the Continental Divide is the major drainage divide in North America, separating basins that drain into the Atlantic Ocean from those draining into the Pacific Ocean. The longest channel in the network, defined by the distance from the mouth of the stream to the drainage divide, is the **trunk stream**. **Tributary streams** are channels that join larger flows.

Question Set 46: The Drainage Basin

The drainage network of streams in the Gaithersburg, Maryland, area northwest of Washington, DC, and adjacent to the Potomac River is shown in Figure 60. Seneca Creek and Watts Branch drain into the Potomac River. Both are labeled on the figure.

i. Use a green pencil to draw the approximate drainage divides of these two basins. A small part of Seneca Creek's drainage divide, near its mouth, has already been drawn in dashed lines to help you get started.

ii. Use a blue line to trace out the trunk stream in the Seneca Creek and Watts Branch drainage basins.

iii. With a different color, outline the area whose runoff drains through the gaging station on Seneca Creek.

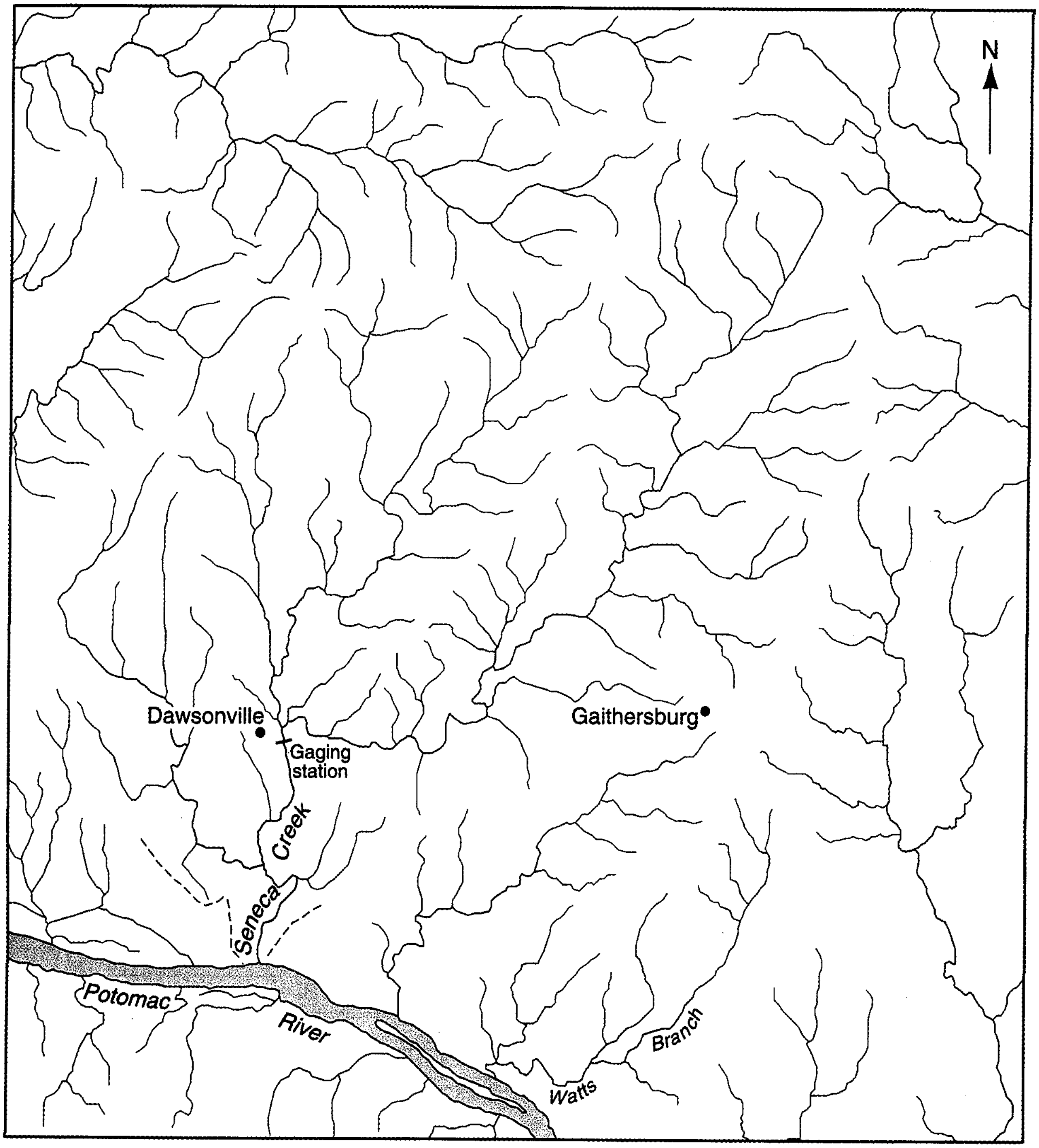

Figure 60. **Drainage network for the Gaithersburg, Maryland area, northwest of Washington, D.C.**

Name ____________________

Exercise 27: The Stream Channel Cross Section

Introduction

A stream flows in a channel, often bordered by a floodplain, both measurable features.

Question Set 47: Plotting a Channel Cross Section

Measurements were made at the Seneca Creek **gaging station** near Dawsonville, Maryland, located on Figure 60. The east–west cross-sectional data of the stream at that station are given in Table 3.

i. On Figure 61, plot these data to show the Seneca Creek cross-channel section. The east point has been plotted.

ii. What is the vertical exaggeration (see Exercise 4) of your cross section? Vertical exaggeration = __________

iii. On the cross section, label the following features: a. The main channel; b. The **floodplain**; and c. The natural **levee**. (Note: The west bank is very steep.)

iv. The **bankfull stage** of a channel is reached when waters fill the channel to its brim before spilling over its banks onto the floodplain.

a. Draw a line and label it at the bankfull stage on your plot (Figure 61).

b. What is the bankfull width of the channel at this location? __________ ft

c. What is the elevation of the bankfull stage? __________ ft

v. Determine the average depth of the bankfull channel by measuring the depth at 10-foot intervals across the channel. Begin on the west bank of the bankfull channel. Record your measurements below. The first value is given.

Distance from West Bank of Bankfull Channel	Depth (ft)
10	4.5
20	
30	
40	
50	
60	
70	
80	
Average depth (ft)	

vi. The bankfull cross-sectional area of the Seneca channel is its bankfull stage width multiplied by the average depth. Determine the bankfull cross-sectional area.

Width (ft) × avg depth (ft) = area (ft^2)

________ × ________ = ________

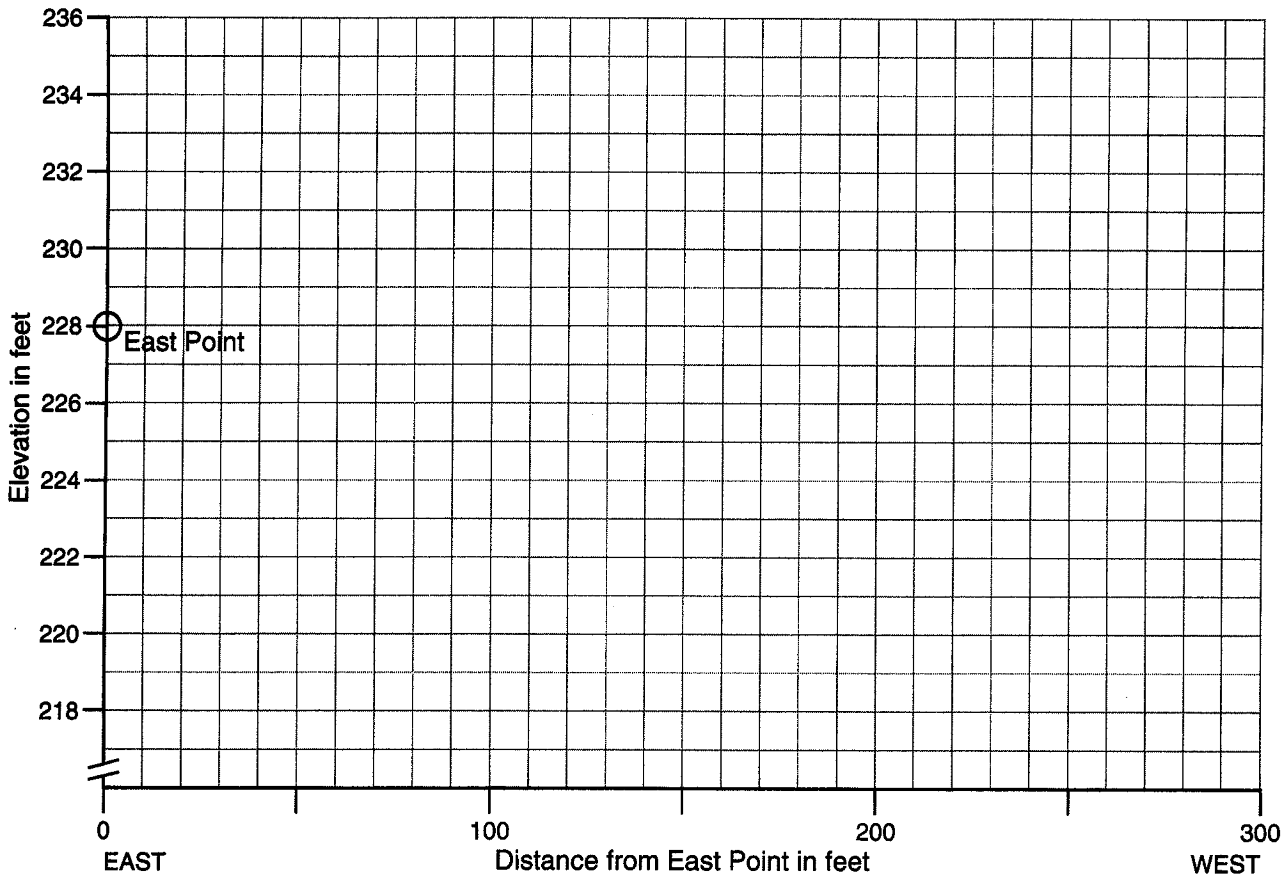

Figure 61. **Graph for plotting cross-channel section, Seneca Creek Gaging Station, Dawsonville, MD.**

Table 3 Valley Cross Section Survey Data, Seneca Creek Gaging Station, Dawsonville, Maryland

Distance from the East Point (ft)	*Elevation (ft)*	*Distance from the East Point (ft)*	*Elevation (ft)*
0	228.0	200	218.8
25	225.3	205	218.8
50	225.5	215	219.1
75	225.3	225	219.6
100	225.1	245	220.2
125	225.1	255	221.7
150	225.5	265	226.2
175	226.2	275	227.0
185	226.0	285	229.0
190	224.0	295	235.0
195	220.0		

Name ____________________

Exercise 28: Calculation of Stream Discharge

Introduction

Virtually all river flow is ultimately derived from precipitation. Rain falling on the surface may drain directly into river channels or may soak into the ground and later be delivered to the river as ground water. The rest of the precipitation is evaporated into the atmosphere (**evaporation**), or is transpired, which occurs when water is released by plants into the atmosphere (**transpiration**). The formula can be written

$$P_{(\text{precipitation})} = R_{(\text{runoff and infiltration})} + ET_{(\text{evaporation and transpiration})}$$

The amounts and percentages in this formula vary widely in both time and place. However, the average percentage values for the United States are sometimes used in a National Average Formula:

$$P_{100\%} = R_{30\%} + ET_{70\%}$$

Remember, also, that this is only an average, and the percentages will change with climate, topography, vegetation, and geology.

The stream's **discharge** is the volume of water flowing through a stream channel in unit time, usually expressed in cubic meters per second or cubic feet per second (**cfs**). To determine the stream discharge we need to know the width, depth, and velocity of the stream. The formula is

$$\text{Discharge} = \text{width} \times \text{depth} \times \text{velocity}$$

Question Set 48: Calculating Stream Discharge in Seneca Creek

You determined the bankfull cross-sectional area (width × depth) of the Seneca Creek channel in Question Set 47 vi, in the preceding question set. In order to calculate the stream discharge, we need to know the velocity of the stream when it is bankfull. This requires a field measurement. Here we assume a reasonable value of 4.47 ft/sec.

i. What is the bankfull discharge in cubic feet per second (cfs)?

Area (ft^2) × avg velocity (ft/sec) = discharge (cfs)

__________ × ______________ = ___________

ii. Under what conditions will Seneca Creek begin to flood?

iii. The area drained by Seneca Creek at the gaging station is 101 mi^2. The average yearly rainfall is 42 in/yr.

a. Using the National Average Formula, calculate the approximate annual discharge of Seneca Creek in cubic feet per year. Show calculations.

Discharge of Seneca Creek ____________________ ft^3/yr

b. Using the relation 1 ft^3 = 7.48 gallons, give the discharge in gallons. Show calculations.

____________________ gal/yr

iv. We can evaluate the National Average Formula figure computed above by using data from the Seneca Gaging Station itself. The U.S. Geological Survey reports that the average annual flow of Seneca Creek at the gaging station over a 49-year period is 102 cfs.

a. Using the USGS average of 102 cfs, what is the annual discharge in cubic feet per year at the gaging station? Show calculations.

____________________ ft^3/yr

b. What is the discharge in gallons? Show calculations.

____________________ gal/yr

v. By what percentage is the USGS average annual discharge higher or lower than that determined by using the National Average Formula for discharge? __________%

Name ______________________

Exercise 29: Floods

Introduction

Floods are simply large discharge events. An **annual flood** is the largest flood in any one year. The most dramatic floods are those that exceed the bankfull stage and spread out across the floodplain. On average, most rivers overflow their channel every other year. However, many streams top their banks at least once a year. Although flooding cannot be predicted accurately, it is possible to estimate the probability that a flood of a particular size will occur in any given year. **Flood frequency analysis** is a statistical method for estimating how often floods of different sizes are likely to occur.

Determination of flood frequencies are based on discharge measurements at gaging stations. Gaging stations are installations along rivers where discharge is monitored continuously. The U.S. Geological Survey and other federal and state agencies operate more than 11,000 gaging stations in this country. One of these stations is the Seneca Creek Gaging Station. Table 4 lists the largest flows recorded each year at this station for the period 1928–1987.

Question Set 49: Annual Flood Series

Referring to Table 4, the annual flood series for Seneca Creek over a 60-year period, answer the following:

i. a. Which year had the largest flood and which year had the smallest flood, and what was the difference in the discharges between the two?

Largest flood year _________ Discharge ___________ cfs

Smallest flood year _________ Discharge ___________ cfs

Discharge difference between floods ___________ cfs

b. Approximately how many times larger was the largest flood than the smallest flood?

ii. How many years did the stream overflow its channel onto the floodplain? For reference, the bankfull discharge you calculated in Question Set 48 i was __________ cfs. Taylor Note: use 2100 cfs for bankfull

a. Number of years exceeding bankfull discharge __________ years

iii. On average, how often was the bankfull stage exceeded and the floodplain flooded? Circle one.

every year   every other year   every three years

iv. What was the longest string of greater-than-bankfull years?

Number of years = _____ from the year 19_____ to 19_____

Table 4 Annual Flood Series from 1928 to 1987 Recorded at Seneca Creek Gaging Station, Dawsonville, Maryland. *U.S. Geological Survey*

Year	*Discharge (cfs)*	*Year*	*Discharge (cfs)*	*Year*	*Discharge (cfs)*
1928	3,800	1948	1,990	1968	1,640
1929	1,600	1949	2,240	1969	3,490
1930	1,450	1950	2,280	1970	2,200
1931	1,730	1951	2,420	1971	25,900
1932	1,380	1952	2,810	1972	26,100
1933	9,300	1953	7,330	1973	3,020
1934	2,410	1954	1,240	1974	3,160
1935	1,420	1955	2,620	1975	16,000
1936	2,020	1956	15,000	1976	4,900
1937	2,610	1957	959	1977	3,770
1938	2,280	1958	3,640	1978	7,850
1939	2,150	1959	1,970	1979	16,000
1940	1,240	1960	1,600	1980	10,800
1941	1,300	1961	3,070	1981	1,340
1942	1,460	1962	1,920	1982	3,160
1943	3,620	1963	1,480	1983	3,260
1944	2,660	1964	2,520	1984	3,010
1945	2,110	1965	2,640	1985	3,620
1946	2,940	1966	3,270	1986	1,070
1947	1,990	1967	2,660	1987	4,950

Exercise 30: Flood Frequency

Introduction

One type of flood frequency analysis is the annual flood series, which is based on the largest flow in each calendar year of record. The first step in the analysis is to rearrange the annual floods in order from the largest to the smallest (Table 5). A magnitude M is then assigned to each flood, with the largest flood assigned M = 1, the next largest M = 2, and so on. The **recurrence interval, RI**, is then calculated with the formula

$$RI = \frac{N + 1}{M}$$

where N is the number of years of record.

The recurrence interval is a statistical estimate of how often a flood of a particular size is likely to recur. A flood with an RI = 50 yr, for example, is likely to happen at least once in a 50-year period. Remember, however, that this is only an estimate. Furthermore, the recurrence interval indicates nothing about *when* a flood of a particular size might occur. A 50-year flood might be followed the next year, or the next month, by a 100-year flood.

Name ____________________

Question Set 50: Flood Recurrence Intervals

The annual flood record for Seneca Creek at Dawsonville, Maryland, has been ordered by magnitude in Table 5 and the recurrence interval (RI) for most of the record has been computed.

i. Complete Table 5 by calculating the RI value for the first 10 and the last 5 years. For the Seneca Creek data, N = 60.

ii. After recurrence intervals are calculated, the data are usually graphed so they can be interpreted more easily. Figure 62 is a graph of the Seneca Creek data. Notice that the axes of the graph are both logarithmic. If you are unfamiliar with logarithmic plots, you should ask your instructor how to read them. A "best-fit" line has been drawn through the data points. This line can be used to estimate the sizes of floods of various recurrence intervals. For example, the 10-year flood would be 9,000 cfs (Figure 62). Use Figure 62 to estimate the approximate sizes for floods of the following recurrence intervals:

5-year __________ cfs

50-year __________ cfs

100-year __________ cfs

iii. If you were on the zoning commission of the county government, what land use would you think should be permitted on the Seneca Creek floodplain, and why?

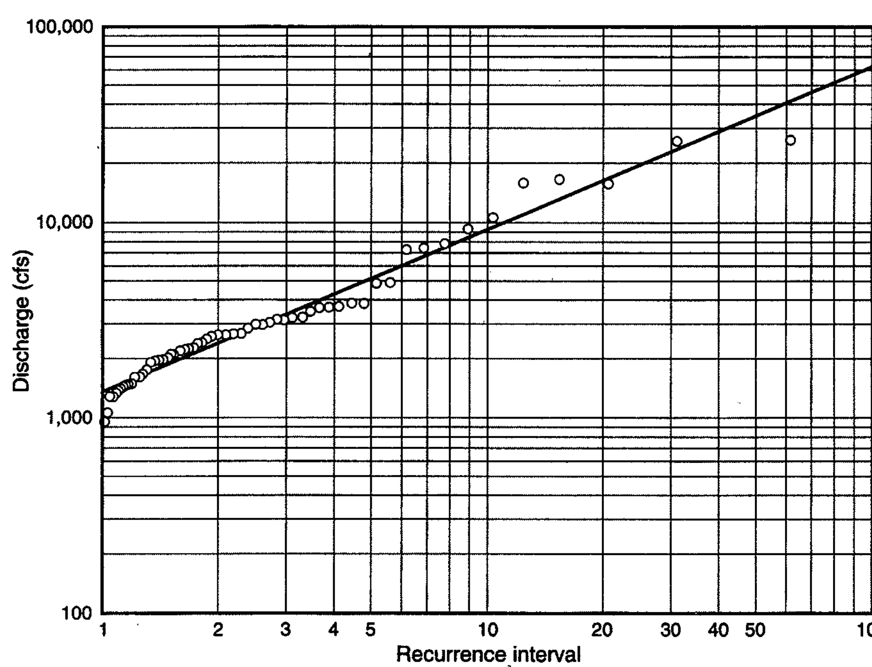

Figure 62. **Plot of annual flood series ordered by magniture as recorded at the Seneca Creek Gaging Station.** *U.S. Geological Survey.*

Table 5 Annual Flood Series Recorded at Seneca Creek Gaging Station, Dawsonville, Maryland (ordered by magnitude). *U.S. Geological Survey*

Year	*Discharge (cfs)*	*Magnitude (M)*	*Recurrence Interval (RI) (yr)*	*Year*	*Discharge (cfs)*	*Magnitude (M)*	*Recurrence Interval (RI) (yr)*
1972	26,100	1		1937	2,610	31	1.97
1971	25,900	2		1964	2,520	32	1.91
1975	16,000	3		1951	2,420	33	1.85
1979	16,000	4		1934	2,410	34	1.79
1956	15,000	5		1938	2,280	35	1.74
1980	10,800	6		1950	2,280	36	1.69
1933	9,300	7		1949	2,240	37	1.65
1978	7,850	8		1970	2,200	38	1.61
1953	7,330	9		1939	2,150	39	1.56
1987	4,950	10		1945	2,110	40	1.53
1976	4,900	11	5.55	1936	2,020	41	1.49
1928	3,800	12	5.08	1947	1,990	42	1.45
1977	3,770	13	4.69	1948	1,990	43	1.42
1958	3,640	14	4.36	1959	1,970	44	1.39
1943	3,620	15	4.07	1962	1,920	45	1.36
1985	3,620	16	3.81	1931	1,730	46	1.33
1969	3,490	17	3.59	1968	1,640	47	1.30
1966	3,270	18	3.39	1929	1,600	48	1.27
1983	3,260	19	3.21	1960	1,600	49	1.24
1974	3,160	20	3.05	1963	1,480	50	1.22
1982	3,160	21	2.90	1942	1,460	51	1.20
1961	3,070	22	2.77	1930	1,450	52	1.17
1973	3,020	23	2.65	1935	1,420	53	1.15
1984	3,010	24	2.54	1932	1,380	54	1.13
1946	2,940	25	2.44	1981	1,340	55	1.11
1952	2,810	26	2.35	1941	1,300	56	
1944	2,660	27	2.26	1940	1,240	57	
1967	2,660	28	2.18	1954	1,240	58	
1965	2,640	29	2.10	1986	1,070	59	
1955	2,620	30	2.03	1957	959	60	

 Name ______________________

Streams on the World Wide Web

A remarkable amount of data on stream flow is easily available through the Web site of the U.S. Geological Survey, which is

http://WWW.USGS.gov/

For example, if you are interested in the historical flow record of a particular stream, perhaps one close to your hometown, you can retrieve the data from the USGS files. To do this once on the USGS site, under *Science Topics* click **Water**; under *Water Resources of the US* and under *Water Data* click **Historical**, then click the *State* in which you are interested. Knowing the name or location of your gaging station, you can bring up the historical record of annual floods for the gaging station as well as historical daily flows for the station. With the annual peak flow data you can determine the flood recurrence interval, as you did in Exercise 30.

If you are interested in the current stream flow, you can get it by clicking **Real-time** and locating your gaging station. You will find the stream flow in cubic feet per second and the flood stage height (the height above an arbitrary datum) that this represents.

Through the historical link you can retrieve data for any particular time or time period. For instance, the data used in Exercise 29 for Seneca Creek gaging station end in 1987. What has happened since then? Would more up-to-date data change your answers to Question Set 50? If so, how significant would the changes be?

You may be interested in a more general way in reports on individual floods. You can find some under *Fact Sheets* by clicking on **Hazards** and scrolling down *Flood Hazards*. How does their nature compare with what you have already learned about stream behavior?