GEOG 101I	Physical Geography
Lab 9	Fluvial Systems – Geomorphologic Analysis and Stream Discharge

Tools

- Stream flowmeter
- Tape measure (30 m)
- Measuring stick (1 m)
- Gravelometer
- Waders
- Calculator
- Internet
- Google Earth

Introduction

Fluvial (moving water; overland flow and stream) erosion processes and their resulting landforms dominate land surfaces throughout the world.

Stream-related processes are termed fluvial. Fluvial systems exhibit characteristic processes and produce predictable landforms. The erosive action of flowing water and the deposition of stream-transported materials produce landforms. A stream system behaves with randomness, unpredictability, and disorder as described by the phenomena of chaos. Yet, enough regularity exists to allow some predictability.

A stream is a mixture of water and solids—carried in *solution*, *suspension*, and by *mechanical transport*. Alluvium is the general term for the clay, silt, and sand transported and then deposited by running water.

Streams may drain large regions. Think of the Mississippi River or Amazon River basins as very large examples, while the Sacramento River basin is much smaller. In any case, these river systems have many contributing tributaries, large or small, adding their discharge and sediment load to the larger river.

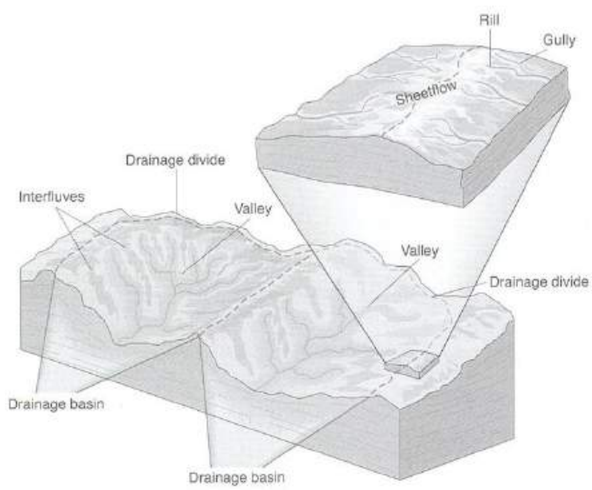


Figure 1: Drainage basins and watersheds

Streams are organized into areas or regions called drainage basins (Figure 1). A drainage basin is the spatial geomorphic unit occupied by a river system, defined by ridges that form drainage divides; that is, the ridges are the dividing lines that control into which basin precipitation drains. Figure 1 represents the drainage basin and its watershed separated from other basins by a drainage divide.

Drainage divides define a watershed, the catchment area of the drainage basin. A major drainage basin system, such as the one created by the Mississippi-Missouri-Ohio river system, is made up of many smaller drainage basins, which in turn comprise even smaller basins; each divided by specific watersheds. Surface runoff concentrates into distinct drainage patterns. The resultant drainage pattern is an arrangement of channels determined by slope, differing rock resistance, climatic and hydrologic variability, and structural controls imposed by the landscape.

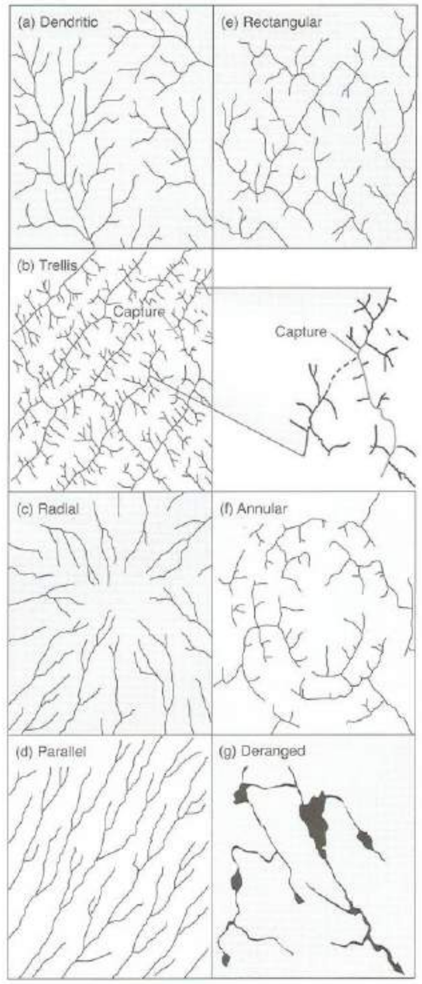


Figure 2: Seven common drainage patterns

Figure 2 shows seven common drainage patterns. The trellis drainage pattern (b) is characteristic of dipping or folded topography, which exists in the nearly parallel Ridge and Valley Province of the eastern United States, where drainage patterns are influenced by rock structures of variable resistance and folded strata.

The sketch in Figure 2 (b) suggests that the headward-eroding part of one stream could break through a drainage divide and capture the headwaters of another stream in the next valley, and indeed this does happen. The sharp bends in two of the streams in the illustration are called elbows of capture and are evidence that the stream has breached a drainage divide. This type of capture, or stream piracy, occurs in other drainage patterns.

The remaining drainage patterns in Figure 2 are caused by other specific structural conditions. Parallel drainage (d) is associated with steep slopes. A rectangular pattern is formed by a faulted and jointed landscape, directing stream courses in patterns of right-angle turns (e). A radial drainage pattern (c) results from streams flowing off a central peak or dome, such as occurs on a volcanic mountain. Structural domes, with concentric patterns of rock strata guiding stream courses produce annular patterns (f). In areas having disrupted surface patterns, such as the glaciated shield regions of Canada and northern Europe, a deranged pattern (g) is in evidence, with no clear geometry.

Open Google Maps (https://maps.google.com/) or any other online mapping website and type "Chico, CA" in a search box. Change the view to **Satellite** from Map. What type of general drainage pattern do those foothill areas to east of Chico and Los Molinos, and Richardson Springs have? (Question 1)

The low-lying area near a stream channel that is subjected to recurrent flooding is a floodplain, formed when the river leaves its channel during times of high flow. Thus, when the river channel changes course or when floods occur, the floodplain is inundated with water. When the water recedes, alluvial deposits generally mask the underlying rock. Episodic flood events are often devastating as we witnessed during the Mississippi flood of New Orleans in 2005 following the landfall of hurricane

Katrina. Figure 3 illustrates a characteristic floodplain, with the present river channel embedded in the plain's alluvial deposits.

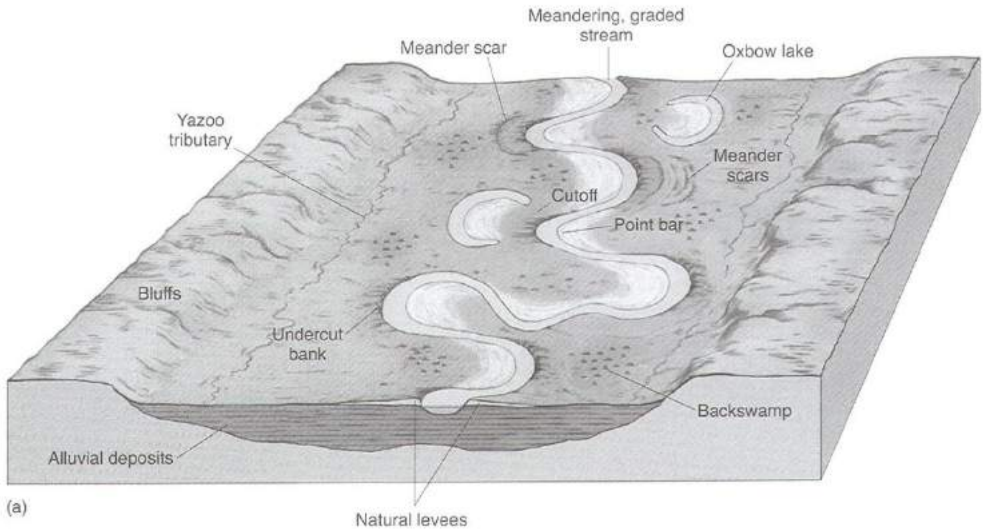
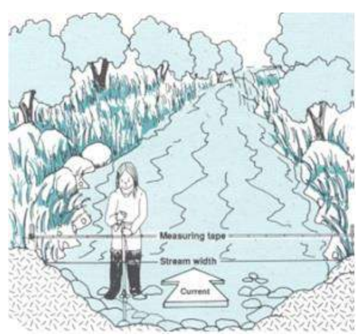


Figure 3: Floodplain features

On either bank of most streams, natural levees develop as by-products of flooding. When flood waters arrive, the river overflows its banks, loses velocity as it spreads out and drops a portion of its sediment load to form the levees. Notice on Figure 3 an area labeled backswamp and a stream called a yazoo tributary. The natural levees and elevated channel of the river prevent this tributary from joining the main channel, so it flows parallel to the river and through the backswamp area. When a meandering stream erodes its outside bank as the curve migrates downstream, the neck of land created by the looping meander eventually erodes through and forms a cutoff. When the former meander becomes isolated from the rest of the river, the resulting oxbow lake may gradually fill in with silt or may again become part of the river when it floods.

Section 1 **Stream Cross-section: Velocity, Discharge and Sediment Transport**

Now pulling it all together we will look at Big Chico Creek. Stream discharge is the amount of water flowing through a channel. Discharge directly affects velocity which determines a stream's ability to erode its channel and transport sediment. One way in which we can characterize a stream is to calculate its cross-sectional profile.



http://www.dep.wv.gov/WWE/getinvolved/sos/Pages/SOPflow.aspx

For this procedure, you will need a tape measure a measuring stick (1 m) marked to the nearest 1 cm.

Outdoor Activity

We conduct an on-campus field experiment and data collection in Big Chico Creek along Alumni Glen (Figure 4).

Outdoor Activity

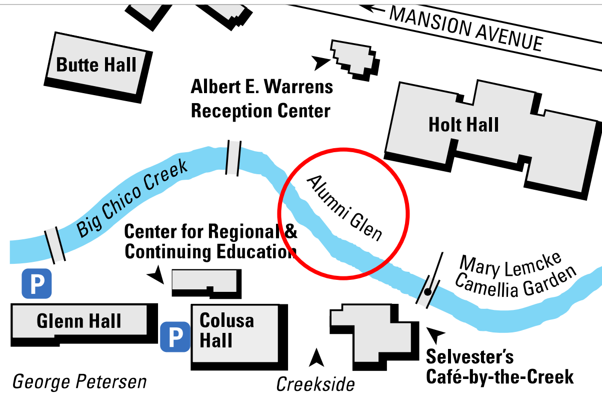


Figure 4: Location of the on-campus field experiments

We highly recommend that you volunteer to wear waders and go into the creek. Every semester, about a half dozen students wished they had volunteered to go into the creek after this lab. Answer the following questions based on your field observation.

Use the measuring tape to measure the width of the stream channel. What is the width of the channel?	m ①
Is the channel width along the creek at this location constant, or does it vary in width along the course of the stream?	Constant | Variable (Circle one)
If it is constant, then this width probably accurately represents the width of the stream channel, but how could you make the width more accurate if you noticed that the stream was significantly different in width along it course?	(Your instructor will lead this discussion.)

Outdoor Activity

Now that we have measured the *width* of the stream channel, we have to find the *depth* of the water in the stream channel. Using a measuring stick (with a *cm* increment) your lab instructor and volunteers will measure the depth of the water every 1 meter across the stream. Fill out the following table with data collected during the on-campus field experiments.

Distance from where you are (Alumni Glen)											
0 m	1 m	2 m	3 m	4 m	5 m	m	m	m	m	m	m
0 m											
Depth (m)											

Note: 100 m = 1 m

Is the depth similar for each of your measurements or does it differ significantly from one measurement to the next?	Similar | Different (Circle one)
What is an average depth? Add all values and divide by the number of values. For example, if you have three depth values of 0.5m, 0.6 m, and 0.7 m, then an average depth is (0.5 + 0.6 + 0.7) ÷ 3 = 0.6 (m).	m ②

Once you have completed filling out the table above (the stream transect with depth data at every 1 m), take a clear picture of the table above and upload this image file to Blackboard Learn. You may choose to turn in a hard copy of the table above to your lab instructor by the deadline. (Question 2)

Draw a sketch of the cross-sectional profile of your stream channel ***using Excel*** and label both axes as well as its title accordingly. Take a screen capture and upload this image file to Blackboard Learn. You will earn zero points if you upload any file other than an image file.

Watch Video

Note: when you enter depth data in Excel, you want to make the depth values negative so that a resulting graph will resemble streambed. Watch a video that shows how to draw a similar graph (using data from a previous semester). You are going to use the data you obtained from the on-campus field experiment. (Question 3)

Calculate the area of your cross-sectional profile (width × depth). Since both width and depth are in meters (m), the product of these values are in square meters (m^2).

Width ① × Average Depth ②	m^2 ③

Another stream characteristic is the discharge of the stream. The discharge (Q) in cubic meters per second (m^3/sec; cms) of the stream can be calculated by multiplying the width of the stream channel (W) in meters, the depth of the stream (D) in meters, and the velocity (V) in meters per second or **Q = W × D × V.**

Outdoor Activity

There are a number of ways to calculate the velocity of a stream, some of which require rather sophisticated equipment. **In this lab, you are going to use two different methods to determine stream velocity.** We will first use a method that requires only a measuring tape and a watch that displays seconds. With the tape, measure a 10-meter distance along the stream. Using the "orange peel method", throw a piece into the water at the upstream end of the 10-meter distance and determine the time in seconds required for the orange peel to travel the 10-meter distance. Carry out this procedure three times and average the velocities. Remember to divide 10 meters by your number of seconds recorded. For example, if it took 50 seconds for an orange peel to travel the 10-meter distance, the velocity of the stream would be 10 (m) ÷ 50 (s) = 0.2 (m/s).

Time it takes for an orange peel (or any other floating object) to travel a 10-meter distance	Average travel time (s)	Velocity (m/s)
seconds	seconds	m/s ④
seconds		
seconds		

Outdoor Activity

You can also determine the velocity of the stream using the electronic stream flowmeter for several parts across the stream channel. There is a conversion equation for flowmeter counts to velocity.

$$\text{Velocity (m/s)} = 0.000854 \times C + 0.05$$

where C is the number of rotations for a propeller for the flowmeter.

For example, let's say that the number of rotations per minute is 20. Then the velocity of the stream flow under this condition is:

$$\text{Velocity (m/s)} = 0.000854 \times 20 + 0.05 = 0.067808$$

So, the velocity under this condition is 0.0678 m/s.

Take an average and compare against the velocity value determined by the method above. How well do they compare?

The number of rotations per minute	Average rotation (C)	Velocity (m/s)
rotations		
rotations	rotations	m/s ⑤
rotations		

Practice

You now have three values that you need to determine a stream discharge value at this experiment site: the width of the stream channel (W) in meters, the depth of the stream (D) in meters, and the velocity (V) in meters per second ($Q = W \times D \times V$). Look at the values labeled with ③ for a product of width and depth, and ④ or ⑤ for a value of velocity determined by two different methods.

Discharge (Q) = ____________ × ____________ × ____________ = ____________ cms (m^3/sec)

Width (W) Depth (D) [③] Velocity (V) [④ or ⑤] Discharge (Q)

Blackboard Learn

Again, take a clear picture of each table above:

1. Stream velocity: the orange peel method
2. Stream velocity: stream flowmeter
3. Calculation of discharge (Q) value

Then, upload this image file to Blackboard Learn. You may choose to turn in a hard copy of the table above to your lab instructor by the deadline. (Questions 4 through 6)

Practice

According to the *Big Chico Creek Ecological Reserve* homepage of Chico State (http://www.csuchico.edu/bccer/natural_resources/geology.shtml), "Median discharge for Big Chico Creek in Bidwell Park about three miles downstream of the Reserve is 175 cubic feet per second (cfs) winter and 30 cfs summer." If 175 cfs [median discharge (Q) for winter] = 4.96 cms and if there are 1000 liters in a cubic meter of water, how many liters of water will flow past Bidwell Park in one 24-hour day?

1. Median discharge of 4.96 cms means that ***4.96 m³*** of water is flowing through a particular cross section of stream at a given location ***per second***.
2. Since there are 60 seconds in 1 minute, there is 4.96 m^3 × 60 = ***297.6 m³*** of water flowing through the same cross section of stream ***per minute***.
3. Likewise, there is 297.6 × 60 = ***17,856 m³*** of water ***per hour***, and ***428,544 m³*** of water ***in one 24-hour day***.
4. Given that there are 1000 liters in a cubic meter of water (m^3), there is ***428,544,000 liters*** of water flowing through Big Chico Creek in Bidwell Park ***in one 24-hour day***.

Blackboard Learn

Repeat the same calculations for median discharge for Big Chico Creek in Bidwell Park ***in summer*** (30 cfs). How many liters of water will flow past Bidwell Park in one 24-hour day? (Question 7)

Practice

Many rivers in California supply water to people. The average US person uses 757 liters of water per day. If we diverted *all* of the water flowing through Big Chico Creek in Bidwell Park (4.96 cms—see question above) over a 24-hour period, how many people could we supply with water in Chico?

1. There is ***428,544,000 liters*** of water flowing through Big Chico Creek in Bidwell Park ***in one 24-hour day***.

2. Since the average US person uses ***757 liters of water by day***, the amount of 428,544,000 liters of water that we just determined would satisfy ***566,108 people per one 24-hour day***.

Repeat the same calculations for median discharge for Big Chico Creek in Bidwell Park ***in summer*** (30 cfs = 0.85 cms). If we diverted *all* of the water flowing through Big Chico Creek in Bidwell Park over a 24-hour period, how many people could we supply with water in Chico? (Question 8)

Practice

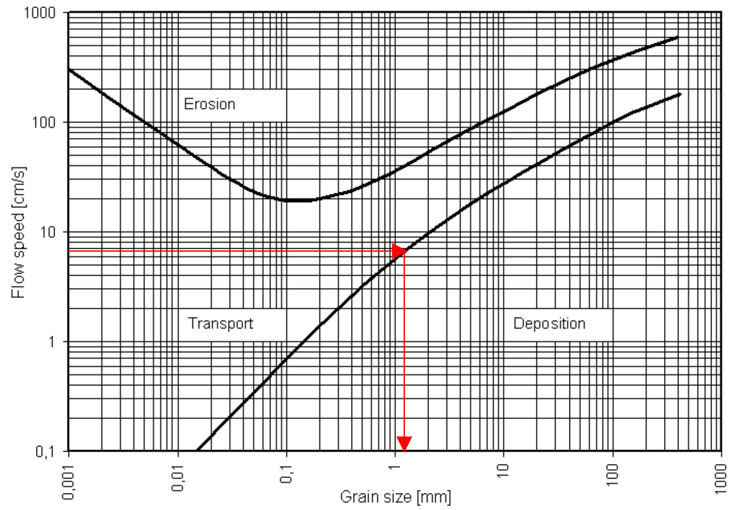


Figure 5: Hjulström curve: relationship between a particle size and the velocity of a stream flow
https://en.wikipedia.org/wiki/Hjulström_curve

The velocity of stream flow determines its ability to move or transport sediment. The Hjulström curve (Figure 5) shows the relationship between a particle size and stream flow velocity. That is, you can determine if a given velocity of stream flow is eroding, transporting, or depositing a given size of particle. For example, a stream flow with a velocity of 1.0 cm/s transports a particle size of 0.1 mm, but it deposits a particle size of 0.2 mm. Note both axes are in logarithmic scale, and the y-axis (flow speed) is in **cm/s**, not m/s. That is 100 cm/s = 1 m/s.

Let's use the same velocity value determined above (***0.0678 m/s***) for the flowmeter counts to velocity conversion. Changing the units for this velocity value from m/s to cm/s, the value is ***6.78 cm/s***. Based on this stream velocity, what is the largest particle size that can be moved today by referring to the Hjulström curve (Figure 4)?

Following the red arrows, you see that the division of transportation and deposition of particles carried by a stream flow with a velocity of 6.78 cm/s is slightly larger than 1 mm. That is, a stream flow can transport a particle size of 1 mm but cannot transport (thus deposit) a particle size of 2 mm.

Using an average velocity value (m/s) determined by a stream flowmeter (the value of ⑤ above), find out ***the maximum size of particle*** that the stream flow can transport. For "the name of the particle based on its size," refer to a previous lab (soil lab).

Average velocity ⑤ (m/s)	Converted average velocity (cm/s)	Particle (grain) size (mm)	Name of the particle based on its size

Take a clear picture of the table above and upload this image file to Blackboard Learn. You may choose to turn in a hard copy of the table above to your lab instructor by the deadline. (Question 9)

Outdoor Activity

Your lab instructor now uses a gravelometer to measure the particle sizes deposited on a streambed.

Watch Video	An ink pen is placed on the streambed for a reference. What do you notice about the particle size deposited as you go toward a deeper end of the streambed? You are going to answer a homework question based on your observation of particle sizes along the transect of the streambed.
Blackboard Learn	What do the size clasts (broken pieces of rock sediment) in the streambed tell you about this stream's power ability (or sediment carrying capacity)? (Question 10)
Section 2	**Geomorphologic Interpretation and Analysis**
	Open Google Earth and type in "Indian Fishery, Chico, CA" in the search box. Adjust the zoom level until the ***Eye Altitude*** becomes approximately 2.45 km (or 8000 ft). Use the illustration (Figure 3) in the beginning of this lab document to identify fluvial features.
Blackboard Learn	What is the water body (Indian Fishery) called next to the left (west) of where West Sacramento Avenue joins River Road? (Question 11)
Practice	This water body (Indian Fishery) used to be part of the Sacramento River. When the main flow of the river became highly meandering, the meander neck is cut and a straighter, more direct flow is established. The remnants of river's meandering can be seen as meander scars. You see a lot of meander scars along the Sacramento River near Chico.
Practice	Fluvial features often used as borderlines for political boundaries (such as county lines). This may have inadvertent problem when a river, for example, changes is course. Such event has taken place after a flood in Missouri River. Using Google Earth and go to "Carter Lake, IA". Make sure that you check the ***Borders*** box in "Borders and Labels."  Where is this city located with respect to the Missouri River? If you zoom out, you will see that the city of Carter Lakes is on the west side of the Missouri River. In the present-day geography, it appears that a portion of the state of Iowa is located on the state of Nebraska!
Blackboard Learn	Now go back to "Indian Fisheries, Chico, CA" while the ***Borders*** box checked. You will see the Glenn/Butte county border on the Sacramento River. Are there problems having dynamic features, such as fluvial bodies, used as a political border? From the bridge of Highway 32 at Hamilton City, CA to just south of Indian Fishery, how many respective land areas of Butte County and Glenn County are on the other side of the river? (Question 12)