**LAB MODULE 16: FLUVIAL PROCESSES AND LANDSCAPES**

**Note:** Please refer to the GETTING STARTEDmodule to learn how to maneuver through, and how to answer the lab questions, in the Google Earth () component.



**KEY TERMS**

You should know and understand the following terms:

|  |  |  |
| --- | --- | --- |
| Alluvial fan | Drainage divide | Oxbow Lake |
| Basin | Drainage pattern | Sinuosity |
| Braided streams | Entrenched meander | Stream discharge |
| Cutbanks | Hydrograph | Stream order |
| Delta | Meandering river | Watershed |
| Drainage density | Meander scar |  |

**LAB LEARNING OBJECTIVES**

After successfully completing this module, you should be able to do the following tasks:

* Describe the concepts of sub-basins and watersheds
* Identify different human water uses of a river
* Construct a stream order for a river system
* Compute drainage density of a given basin
* Identify drainage patterns of river networks
* Explain how braided rivers and meandering rivers are formed
* Identify the physical features common to a meandering river system
* Describe the physical conditions necessary to form alluvial fans

**INTRODUCTION**

This module examines fluvial processes and landscapes. Topics include watersheds, drainage patterns and densities, stream order, meandering and braided streams, and alluvial fans. While these topics may appear to be disparate, you will learn how they are inherently related. The modules start with four opening topics, or vignettes, which are found in the accompanying Google Earth file. These vignettes introduce basic concepts of fluvial processes and landscapes. Some of the vignettes have animations, videos, or short articles that will provide another perspective or visual explanation for the topic at hand. After reading the vignette and associated links, answer the following questions. Please note that some links might take a while to download based on your Internet speed.

Expandthe **INTRODUCTION** folder and then select **Topic 1: Introduction**



Read **Topic 1: Introduction**

**Question 1:** What is the name of the river/lake where your town is located?

Read **Topic 2: Rivers of Life**

**Question 2:** If our ability to predict floods have improved significantly, why does economic loss continue to rise?

Read **Topic 3: Rivers of Waste**

**Question 3:** What is one potential outcome or condition resulting from too much nitrogen running off from agricultural fields?

Read **Topic 4: Erosion**

**Question 4:** List three ways in which humans contribute to stream bank erosion.

Read **Topic 5: Transportation and Deposition**

**Question 5:** What impacts do dams have the transportation of sediment?

Collapse and uncheckthe **INTRODUCTION** folder



For the rest of this module, you will identify and explain the geographic distribution, patterns, and processes associated with fluvial environments. In doing so, you will recognize and appreciate the impact of rivers.

**GLOBAL PERSPECTIVE**

Expand the **GLOBAL PERSPECTIVE** folder and then expand the **World Rivers** folder. Double‑click and select any continent or world region. To display river information (name and approximate length), click any river in the Google Earth map pane.

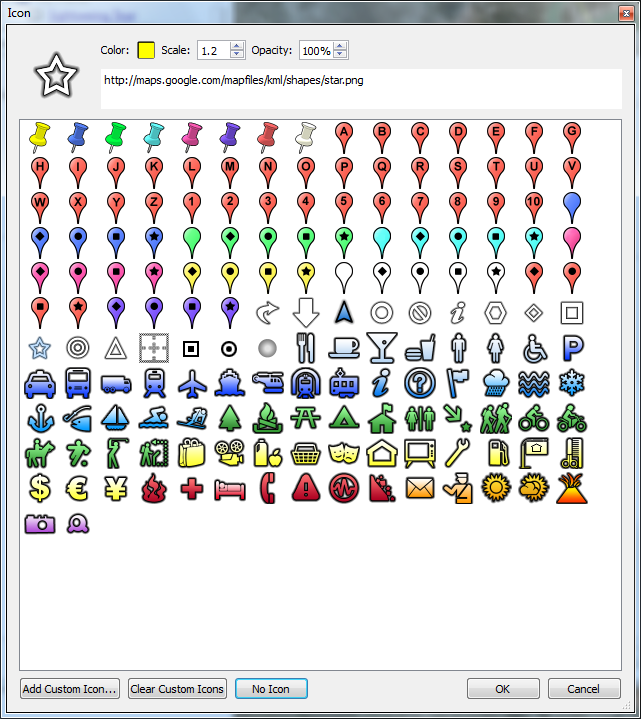


Condense the **World Rivers** folder.



**Major Cities on Rivers**

For each question below, type the latitude and longitude coordinates into the **Search** tab and press Enter. When you arrive at your destination, click the star icon to find the information that you will use to fill in the blanks below:



**Question 6:**  33 18 59 N, 44 23 33 E

City:

Population:

River:

**Question 7:** 30 03 29 N, 31 14 05 E

City:

Population:

River:

**Question 8:** 48 51 26 N, 2 21 04 E

City:

Population:

River:

**Question 9:** Montreal, Canada.

Latitude:

Longitude:

Population:

River:

Condense anduncheck the **GLOBAL PERSPECTIVE** folder



**WATERSHEDS AND DRAINAGE DENSITY**

Expand the **WATERSHEDS AND DRAINAGE DENSITY** folder.



A drainage basin is an area of land in which a stream receives water, predominately by surface runoff, through flow, and groundwater flow. Drainage basins are topographically divided from each other by the highest points of elevation, so that all water from the ridges and hills flow into a given drainage basin and thereby into a given stream. This topographic delineation is commonly referred to as a watershed (the drainage divide between two drainage areas), although many in the United States use the term watershed interchangeably with drainage basin or catchment.

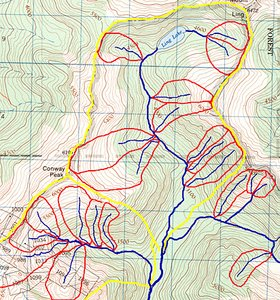


Figure 1. Watershed map ([Physical Geography](http://www.physicalgeography.net/fundamentals/10aa.html)).

A large drainage basin can contain several smaller drainage basins or sub-basins. The nested nature of these sub-basins is determined by topography as well as where the water flows out of the drainage area, known as the outflow point. In Figure 1, the red lines demarcate the watersheds of the tributary streams, while the yellow lines delineates the watershed of the larger drainage basins for the larger streams, which includes the smaller tributaries and their sub-basins.

Understanding watersheds are important because stream flow and water quality are influenced by the nature of and changes in the drainage basin. We can determine what is happening in our river basins by examining the water flow and water quality from a river’s outflow point. Changes to water flow or water quality in rivers could be due to either natural events (such as lightning induced forest fires increasing soil erosion) or human modifications (such as agricultural practices increasing pollution).

Double-click and select **Columbia River Watershed**.



The Columbia River watershed encompasses 258,000 square miles (approximately the size of France), with 220,000 square miles in the U.S. and 38,000 square miles in Canada. The length of the river is approximately 1243 miles, making it the 15th longest river in the United States.

Uncheck **Columbia River Watershed**.



Check the **Columbia River Sub-basin US only** folder. Click on each sub-basin in the Google Earth map pane to identify its name.



**Question 10:** How many sub-basins in the United States are displayed on the map?

Uncheck **Columbia River Sub-basin US only**.



Expand the **Columbia River Watershed - Fly Over** folder.



The Google Earth flying simulation of the Columbia River shows how the basin is a multi-use watershed. Do the following steps to reduce confusion for the duration of the simulation:

1. Uncheck all the check boxes in the Google Earth’s **Places** and **Layers** panes.
2. Check only the **Enable this check box for the tour** check box to display the text in the simulation.
3. Double-click **here to view the tour (Running Time: 2:06)**.



When the simulation stops, close the simulation control panel:



**Question 11:** What water uses did you see as you traveled upstream on the Columbia River?

Uncheck **Columbia River Watershed - Fly Over**.



Expand the **Stream Order**folder.



**Stream Order**

*Stream order* is a measure of the size of a stream based on a hierarchy of tributaries. Using the Strahler stream order method, the smallest tributaries are assigned the value of 1. When two streams with different order numbers join, the resulting stream is assigned the value of the higher order numbered stream.

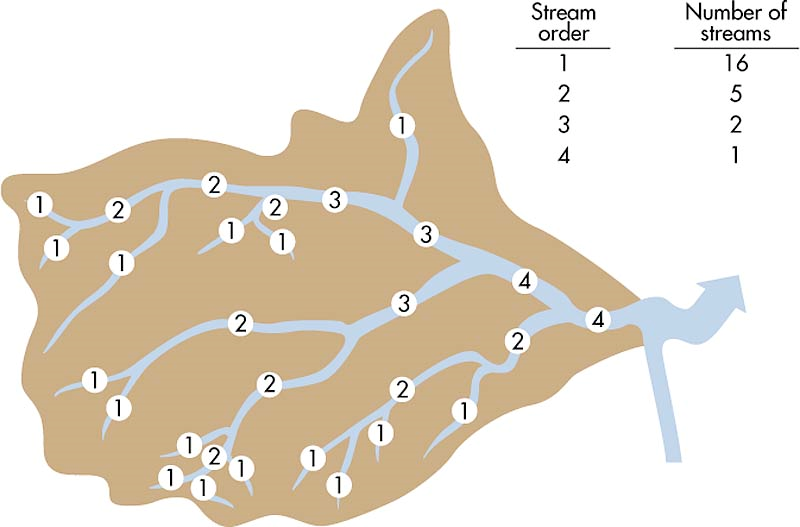


Figure 2. Stream order (16.9 Arbogast 2nd. Ed.).

In Figure 2, two streams with an order number of 1 join to form a stream with an order number of 2. However, when one stream with an order number of 1 joins a stream with an order number of 2, the stream remains a 2. Large river systems typically have a higher stream order. The Mississippi River for example has a stream order of 10.

The Strahler stream order number for a given stream is dependent on the scale as which one views a stream network. A stream with an order number of 3 on a 1:24,000 map, for example, might have an order number of 1 on a 1:1,000,000 scale map, as fewer rivers are displayed on a smaller scale map.

Double-click and select the **Willamette River** folder.



In this particular map, the Willamette River has a Strahler stream order of 5. Though not all streams are labeled with their order, you should be able to determine how the stream ordering system works. You might have to zoom in to see the labels clearly.

Double-click and select the **Snake River** folder.



For Questions 12 to 15, identify the stream order number for rivers A, B, C, and D:

**Question 12:** A:

**Question 13:** B:

**Question 14:** C:

**Question 15:** D:

Uncheck the **Stream Order** folder.



**Stream Density**

Double-click and select the **Stream Density** folder.



Notice the two sub-basins that are highlighted. The smaller one is the Willamette River watershed and the larger one is the Snake River watershed. The drainage density of a basin measures how well a watershed is drained and depends largely on the underlying bedrock and topography of the basin. Basins with high relief and exposed bedrock tend to have a higher drainage density.

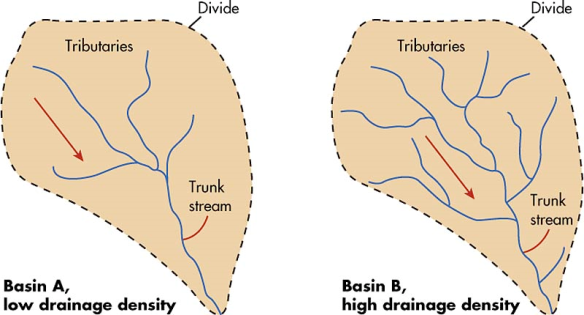


Figure 3. Drainage basins (16.8 Arbogash 2nd. Ed.).

Use the following formula to calculate the stream density of each sub-basin (show your work):

drainage density = total length of all streams / area of the drainage basin

Willamette River watershed:

* The area of the Willamette River sub-basin is 11,500 square miles.
* The total length of all streams in the Willamette River sub-basin is 12,800 miles.

**Question 16:** What is the stream density of the Willamette River sub-basin?

Snake River watershed:

* The area of the Snake River sub-basin is 108,000 square miles.
* The total length of all streams in the Snake River sub-basin is 138,000 miles.

**Question 17:** What is the stream density of the Snake River sub-basin?

**DRAINAGE PATTERNS**

Uncheck and collapse the **WATERSHEDS AND DRAINAGE DENSITY** folder. Check the **DRAINAGE PATTERNS** folder.

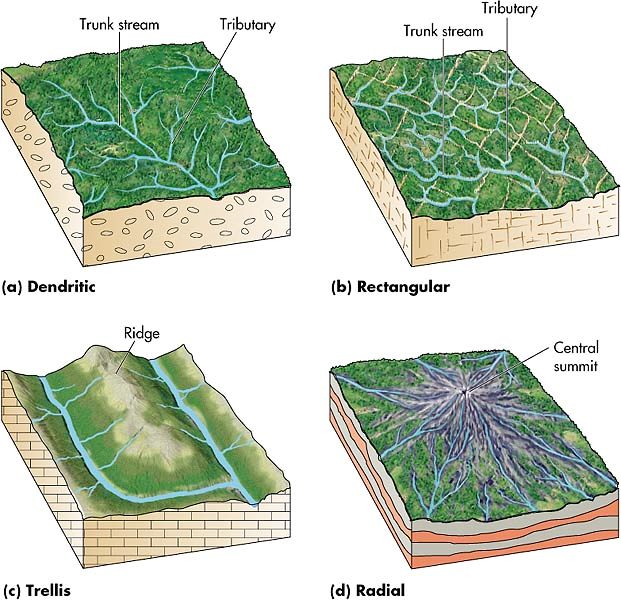


Figure 4. Drainage patterns (16.7 Arbogast 2nd Ed.).



The *drainage patterns* of a stream system (a network of streams and tributaries) depend largely on the topography on the land as well as the structure of the underlying bedrock. Areas subject to faulting often produce rectangular drainage patterns, while areas with folded topography (mountains) often have trellis drainage patterns. Volcanoes typically form radial drainage patterns. Dendritic drainage patterns are common in areas with non-porous, impermeable bedrock.

Expand the **DRAINAGE PATTERNS** folder. Double-click and select **Drainage pattern 1**.



**Question 18:** Identify Drainage pattern 1:

Now that you have identified Drainage pattern 1, double-click and select drainage patterns 2 to 5 to identify them.

**Question 19:** Identify Drainage pattern 2:

**Question 20:** Identify Drainage pattern 3:

**Question 21:** Identify Drainage pattern 4:

**Question 22:** Identify Drainage pattern 5:

Condense anduncheck the **DRAINAGE PATTERNS** folder **BRAIDED STREAMS**



Double-click and select the **BRAIDED STREAMS** folder.



Fast moving streams originating from mountainous glacial areas or regions with an abundance of erodible sediment, often transport great quantities of course material such as sand and gravel within the channel. As the stream velocity decreases (as topography becomes less steep); however, the discharge is insufficient and can no longer carry the sediment load. In essence, the deposited bed load forms bars (or *eyots*) within the stream channel, forcing stream channel to diverge and converge among the deposits. These constantly shifting channels within the larger river channel are what give the stream its braided appearance.

The Delta River is an example of a braided stream near the town of Delta Junction, Alaska. Notice the network of broad yet shallow stream channels that diverge and converge, separated by bars of deposited bed load.

**Question 23:** Based on the location and the deposition type, explain why this stream forms a braided pattern.

**Question 24:** Where does the sediment (deposition material) come from?

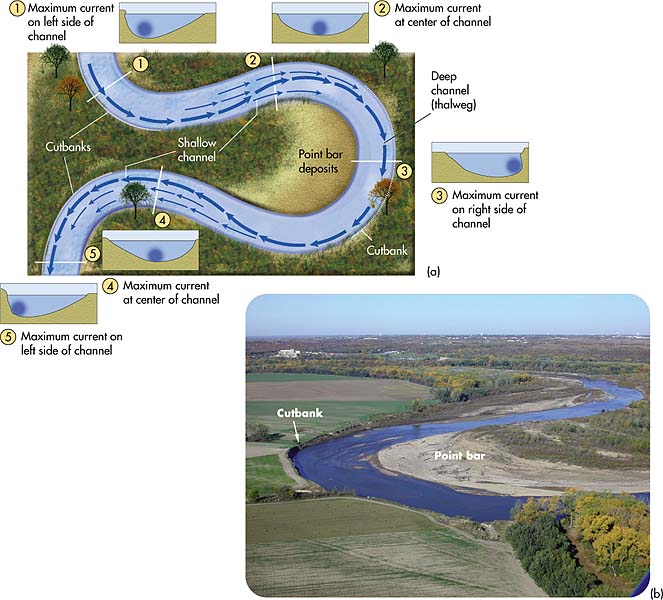
Uncheck **BRAIDED STREAMS** **MEANDERING STREAMS AND FLOODPLAINS**



Expand the **MEANDERING STREAMS AND FLOODPLAINS** folder.



In contrast to braided streams, meandering streams are formed in landscapes with little relief, are generally slower moving, and carry finer sediments. In addition, water flow within meandering stream typically is constrained to a single channel. As their name suggests, meandering streams are identifiable by their *sinuosity*, or the bends and turns of the stream channel across a floodplain. The meander of the channel occurs with the scouring of the channel on the outside of the bend (where flow is faster) and deposition on the inside of the bend (where flow is slower). This constant erosion or removal of sediment from *cutbanks* and deposition of sediment from point bars produces the movement of the meander across the landscape, with past meanders evident from *oxbow lakes* and *meander scars.*



Click **Stream Process Animation** and view the animation.



Erosion and deposition occurs primarily during periods of flooding. Many rivers are prone to flooding, with some large flooding events changing the course of the stream channel (by bypassing the meander altogether and producing a straight reach). While natural or artificial levees might prevent a stream from flooding, large flood events compromise levees, with water and its suspended sediment spilling over the levees and depositing onto the surrounding floodplain.

Close the **Stream Process Animation** window. Double-click and select the **Mississippi River - Identify Features** folder.



Using the following list of meandering stream features, answer Questions 25 to 29 that apply to the Mississippi River map image in Google Earth.

|  |  |  |  |
| --- | --- | --- | --- |
| 1. Cutbank | 1. Inside of meander | 1. Meander scar | 1. Point bar |
| 1. Deep channel (thalweg) | 1. Island | 1. Outside of meander | 1. Shallow channel |
| 1. Floodplain | 1. Low ground | 1. Oxbow lake |  |

**Question 25:** A

**Question 26:** B

**Question 27:** C

**Question 28:** D

**Question 29:** E

**Question 30:** Identify two dominant land uses surrounding the river.

**Question 31:** Do these land uses indicate this area as a floodplain? Explain.

Double-click and select the **Mississippi River - Measure Distance** folder.



Do the following steps to examine river sinuosity.

1. Verify that **Mississippi River** *-* **Measure Distance** is the only item checked in the **Places** pane.
2. Go to the Google Earth icon bar and click the **Show Ruler** tool .  
   **Note:** Verify that the simulation control panel is closed:



1. In the Ruler window, click the **Line** tab and select **Miles** for the units.



Figure 7. Stream distance (image from Google Earth).

1. Draw a straight line between the two points; that is, click point and then click point to determine the distance.



1. Press the **Esc** key to stop.

**Question 32:** What is the length, in miles, of the channel?

Measure the distance of the channel (the meander):

1. In the Ruler window, click the **Path** tab and set the units to **Miles**.
2. Click point and click you as trace the path of the river until you get to point . Figure 7 shows an example of how your path might appear.



**Question 33:** What is the length, in miles, of the channel?

The sinuosity index (SI), also known as the meander ratio, calculates how much the stream channel deviates from the shortest path. Straight rivers have a SI close to 1, but this number increases the more a river meanders.

**Question 34:** Use the following formula to calculate the SI for this reach of the Mississippi River:

SI = channel length / downvalley length = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Close the ruler tool. Uncheck **Mississippi River - Measure Distance**. Double-click and select the **San Juan River - Compare Features** folder.



The San Juan River is another meandering stream, yet we do not see the classic oxbow lakes and meandering scars we saw with the Mississippi River.

**Question 35:** Compute the SI of the San Juan River from point A to point B (show your work).

**Question 36:** Which river (Mississippi River or San Juan River) has a higher SI?

Use the following navigation steps to examine the terrain:



1. Press and hold the Shift key.
2. Use the scroll button on the mouse to see the landscape in 3D. You can also use the Ctrl or Shift keys in combination with the arrow keys to pivot and rotate the image.

**Question 37:** Explain why there are no classic oxbow lakes or meandering scars.

Condense and uncheck **MEANDERING STREAMS AND FLOODPLAINSALLUVIAL FANS**



Expand the **ALLUVIAL FANS** folder. Double-click and select **Alluvial Fan**.



Alluvial fans are comprised of water-transported material or alluvium. Most alluvial fans consist primarily of course grained material. In Death Valley, California, notice the series of alluvial fans.

Do the following steps to get a better view of the landscape and to explore the topography:



1. Check the **Nova Canyon 7.5 minute map** check box and compare the contour lines on the alluvial fan to those contour lines on the northeast portion of the map.
2. Zoom in to the Death Valley region.
3. To see the landscape in 3D:  
     
   PC: Press and hold the Shift key and use the scroll button on the mouse. You can also use the Ctrl or Shift keys in combination with the arrow keys to pivot and rotate the image.  
     
   Mac: Press Shift in combination with the up and down arrows. You can also use the mouse scroll wheel to zoom.

**Question 38:** What geographic and topographic land features are necessary to create alluvial fans? Hint: where are the fans located physically as well as what features are required to develop them?