

GY325 Applied Geomorphology

Fluvial Erosion Landforms

Introduction

Running water is by far the most important erosional agent on Earth. Even in arid climates, it is the primary agent of erosion. This is evident from the abundance of stream beds found throughout desert areas. Although these areas receive little rain throughout the year, the few days of rainfall produce flash floods that erode and transport tremendous amounts of material because of the lack of vegetation.

Stream Gradient

The *stream gradient* refers to the slope of the land surface upon which a stream flows. The stream gradient is calculated by comparing two points of known elevation along the stream's course with the horizontal map distance between the two points:

$$\textit{Gradient} = \frac{\Delta \textit{elevation}}{\Delta \textit{map distance}}$$

The gradient is generally given in units of feet per mile (or m/km). When calculating a gradient do not try to convert the numerator and denominator of the fraction to equivalent units unless explicitly requested to do so. For example, if two points had an elevation difference of 200 feet according to the contour data, and the two points were 4 miles apart as measured along the stream course, the resulting gradient would be 50 feet per mile. The stream gradient bears a direct relationship with topographic contour spacing; if the stream course runs across many contours in a short distance the gradient will be high, whereas streams flowing across flat plains will have low gradients. The calculation of a stream gradient may be made from any two points along the stream since elevations may be interpolated from contours and map distance is determined by the map scale, however, it is more convenient to pick points that lay on contour lines to determine elevations.

The erosional power of a stream is proportional to the discharge of the stream which is, in turn, primarily a function of the size of the stream and the velocity of the stream water. Because an increased stream gradient is usually correlated with a higher velocity, the higher gradient streams will erode their channels at a faster rate than other lower-gradient stream systems.

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Divides

A stream *divide* separates stream drainage basins. The separation between two drainage basins is a linear topographic high such as a ridge or plateau; on opposite sides of the ridge streams of the different drainage systems flow in opposite directions. To delineate the divide one could draw a pencil line on a topographic map that connects points of maximum elevation along the ridge crest. This line will divide the two drainage systems because all streams will drain away from this line.

A stream system is typically made up of a *dendritic* pattern of tributaries that drain a large *drainage basin*. A ridge will separate individual drainage basins along a divide. A divide may be recognized on a topographic map as a ridge across which streams tend to flow in opposite directions. The continental divide west of the front range of the Rocky Mountains is but one example of a large divide. The divides are important to earth scientists because the water resources of one drainage basin are normally isolated from those of another drainage basin.

Alluvial Fans

Alluvial fans are common in arid to semiarid climates and are depositional products of running water that is, surprisingly, the primary erosional agent in these types of climates. Since arid landforms do not have the extensive vegetative cover found in humid climates the soil horizon is not well anchored in these types of terrains. Therefore, during rare but substantial rain or snow-melt the soil horizon is eroded very quickly. The drainage system of a desert landform is not well-integrated so most of the transported material is not moved a large distance. The deposited sediment tends to collect at slope breaks where the *capacity* of the stream is exceeded. These conical aprons of sediment that build-up along the flanks of mountain ranges are termed alluvial fans. Alluvial fans are easily recognized because of the characteristic shape of contour lines that cross the fan. The contours tend to form evenly spaced semicircular geometries because of the conical shape of the alluvial fan surface. Figure 8 is a portion of a USGS 7.5' quadrangle that contains an alluvial fan landform feature. Note that the contours are evenly spaced about the alluvial fan, indicating a relatively constant slope angle. Also note that a topographic profile taken perpendicular to evenly spaced contours produces a planar sloping surface. Natural landforms in arid regions will not possess contours that are perfectly spaced, therefore, the surface is usually slightly concave up in form.

Because the sediment incorporated into an alluvial fan has traveled a relatively short distance, the particles that compose the sediment tend to be angular and poorly sorted as compared to sediments deposited by streams in a humid climate. Because the particles

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have a short transport residence time, the materials composing the sediment may be only slightly affected by chemical weathering. This is also due to the low humidity in the arid climate. Streams that flow on top of alluvial fans are typically *intermittent* and form *braided channels* since they are often overloaded with sediment.

As erosion wears down mountain ranges in arid climates, alluvial fans build at the base of the mountain ranges. The alluvial fans become larger over time until several fans will merge to form a broad apron of debris that is termed a *bajada*. The bajada is recognized on a topographic map by the straight rather than crescent-shaped contour lines that have a constant spacing. In Figure 9 the bajada can be recognized from the relatively straight and equally spaced contour lines. A mountain range in the mature stage of the arid cycle of erosion may be entirely covered by a bajada on each flank. The elevated remnants of a mountain range surrounded by an expanding bajada is termed *inselberg*, which is a German derivation meaning literally "island mountain". Several inselbergs are present as topographic hills in Figure 9.

The low-lying valleys that lie between mountain ranges are the sites where runoff from alluvial fans collect. The collecting water forms broad shallow lakes during the spring when snow melts at higher elevations in the mountain ranges. However, this time of abundant runoff is short-lived. The lakes are termed *playa* lakes and soon completely evaporate. Because the water that formed the lake also contained dissolved material, the site of a playa is marked by deposits of various salts such as halite (NaCl) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). These can be recognized from aerial photographs which show these areas as patches of white.

Stream Systems in Humid Climates

Most of the United States east of the Mississippi River can be classified as a humid climate. In these areas the dominant erosional force is a well integrated system of streams. We are most familiar with the larger river systems such as the Mississippi, Ohio, and Missouri Rivers, but smaller streams also do much erosional work. The integrated stream systems found throughout the eastern United States also transport tremendous amounts of sediment to the ocean basins. The larger accumulations of this material are termed *deltas*.

Because the erosional work done by a stream is primarily a function of the stream velocity, the stream gradient is an important value to earth scientists that study the effects of stream erosion. The stream gradient, in addition to the shape of the stream channel and size of the channel, control the stream velocity. A term that is also useful in describing the streamflow is *discharge*. The discharge of a stream is the amount of water flowing within the stream channel over some specified period of time. For example, discharge may be measured in units of gallons per second, or liters per second. So how does an earth

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scientist measure discharge? It's actually quite simple. Two measurements must be completed: 1) the velocity of the stream is measured by timing a floating object as it moves from a previously measured start and stop point, and 2) the cross-sectional area of the stream must be calculated from a topographic profile of the stream channel constructed when the river is low. Since velocity is measured in units of length per time, and since area is measured as length², if we multiply velocity times area:

$$\text{meters/second} \times \text{meters}^2 = \text{meters}^3/\text{second}$$

we will have units of volume/time. This is a measure of discharge- in this case cubic meters per second are the units used.

Early Stages of Stream Development

When streams first form channels they tend to have specific topographic features independent of climate zones and other factors. These characteristics include:

- (1) Steep gradients.
- (2) No *floodplain*
- (3) Flat divides
- (4) Steep valley sides
- (5) "V" shapes profiles
- (6) Straight course

The early stages of stream development are closely linked to uplifts of the crust, and therefore tectonic activity. In other words, the early stage of stream development is generated by uplift of the crust, lowering of sea level, or both. This increases the stream gradient so that the primary erosional work of the stream is a downcutting action. This produces the steep valley sides characteristic of an early stage stream valley. Since the stream gradient is high and the stream quickly cuts down into bedrock, there is little opportunity for the stream to meander. Therefore the stream tends to be straight. Because the stream cannot meander, it also cannot erode laterally to produce a floodplain. When observing topographic maps, remember that the contours in the valley of the early stage stream should be closely spaced down to the edge of the stream indicating the steep valley walls and "V" shaped profile. No flat floodplain areas at the base of the stream will be present. The map should also display a relatively straight course. Away from the stream valley the divides will be flat; this is indicated by high elevation values but widely spaced contours.

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Mature Stage

The mature stage of stream valley development is marked by the development of a *floodplain*. As an early stage stream continues to downcut vertically over time the stream channel approaches the *base level*. The base level of a stream is defined as the lowest level to which a stream may erode its channel- usually this is sea level. When the stream channel elevation approaches the base level the stream begins to erode laterally producing a series of *meanders*. The meanders are confined to the floodplain. The floodplain itself can be recognized as the very flat area adjacent to the stream channel. The floodplain is usually quite swampy and is often marked with the map symbols for swamp or marsh terrain. This area of the floodplain that is swampy is known as the *backswamp*.

As lateral erosion produces meanders, the meanders progressively become more pronounced. This is produced by the tendency of the stream to flow at a higher velocity on the outside of a meander curve where water is deeper and less subject to frictional drag. This increases erosion of the channel on the outside of the meander. On the other hand, the shallow water depth and corresponding higher drag on the inside of the meander bend produces a lower than normal stream velocity. This causes deposition of sand particles to form a *point bar*. Point bars are one of the most common types of sand bars found in meandering river systems. As this trend of erosion and deposition occurs the meander bends become more and more extreme until finally adjacent bends may "neck down" to form a *cutoff*. Figure 10 displays a meandering stream system with a future cutoff location. When a cutoff actually forms, portions of the former main channel become silted-in isolating the meander bend from the rest of the river. This leaves an isolated lake termed an *oxbow* because it retains the arcuate shape of the meander bend. Most mature river system floodplains are littered with oxbow lakes. In addition to the oxbow lakes, the adjacent point bar deposits that are deposited on the inside of a migrating meander tends to build numerous arcuate sandy ridges that are parallel. These features are termed *meander scars*.

Stream systems are continually in a state of flux. During the spring when most areas of the northern hemisphere experience increased precipitation, the stream systems may be at or above flood stage. When the volume of water in a stream surpasses the size of the channel the river spills over its banks into the adjacent floodplain. Before this event, the velocity of the stream is commonly very high, therefore, the stream carries a large sediment load while it is confined to its channel. When the water leaves the channel, however, the velocity of the water drops dramatically. This loss of velocity rapidly decreases the ability of the stream to transport sediment. Directly adjacent to the stream channel the largest particles - usually coarse sand - are deposited first. The smaller clay-sized particles settle less rapidly throughout the floodplain. The annual cycle of flooding builds up deposits of sand along the banks of a river to produce a linear ridge termed a *levee*. Because levees are protection from future floods, humans often enlarge the levee system near populated

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areas. Since tributaries that feed into the main river channel cannot flow over the levee, the levee acts as a barrier. The tributaries are forced to closely parallel the main river channel for many miles until a break in the levee is encountered. These types of tributaries are termed *Yazoo tributaries* for the Yazoo River in Mississippi. In summary, look for the following key features to identify mature stream valley development:

- (1) Well-developed floodplain
- (2) Rounded instead of flat divides
- (3) Oxbow lakes
- (4) Levees
- (5) Backswamp
- (6) Meander scars
- (7) Cutoffs
- (8) Yazoo tributaries

Rejuvenated Systems

The final stages of the stream valley development occur when the stream has eroded down to base level over its entire course. In this state the stream is no longer downcutting but is instead laterally eroding the loose unconsolidated sediment of its own floodplain. The entire region will then be eroded to a flat plane. If this area is affected by uplift the stream system will react by sharply downcutting again. This produces very steep valley walls and flat divides that are characteristic of the early stage of stream valley development. However, in this scenario the extreme meandering of the former stream system may be inherited to produce *entrenched meanders*.

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EXERCISE 3: FLUVIAL (STREAM) SYSTEMS

For this exercise you will be using the USGS quadrangle maps located in room #335 in the map cases. The map names are labeled on the front of the drawers.

Problem 1: Cane Springs Mt., Arizona 7.5' Sheet

- a) Carefully inspect the quadrangle topography. Inspect the direction of flow of the various stream systems throughout the northern half of the quadrangle. In terms of stream flow direction what is significant about Hardscrabble Mesa? What landform term would best describe this feature?
- b) By inspecting the topographic contours of the map area, formulate an answer for the following question: on average, are the stream gradients larger north of the Hardscrabble Mesa, or south of it? Explain your reasoning.

Problem 2: Furnace Creek, CA 15' Sheet

- a) On this quadrangle along the west margin several areas are covered by arcuate topographic contours that are regularly spaced. What is the name of this landform feature?
- b) What is the term used for the shallow lakes near the center of the map?
- c) Calculate the stream gradient from where Tucki Wash intersects the west margin of the map (UTM 500,000e: 4,033,900n) to where it crosses the -240 contour line.

Problem 3: Antelope Peak, Arizona 15' Sheet

- a) Near the central portion of this quadrangle the contour lines tend to be relatively straight and equidistance apart. How would a topographic profile perpendicular to the contour lines appear? What kind of landform feature best describes this area?
- b) Section 36, T6S, R2E contains several hills surrounded by the gently sloping area of part (a). What is the term for these features?
- c) Calculate the topographic gradient from the southwest corner to the northeast corner of section 16, T7S, R3E in feet per mile units.

Problem 4: Jordan Narrows, Utah 7.5' Sheet

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a) The NE1/4, section 12, T5S, R1W contains several islands which are surrounded by the Jordan River. Describe how these islands form, and list the term for the type of landform feature present in this area of the map.

b) Give the location (nearest 1/4 section) of a place on the Jordan River that is most likely to evolve into a landform feature like the one in the NE 1/4 of section 12 at some time in the near future.

Problem 5: Lake Tapps, Washington 15' Sheet

a) At what stage of stream erosion is the valley between the towns of Orting and Sumner? Cite your evidence:

b) At what stage of stream erosion is the valley drained by the Carbon River near the town of Carbonado? Cite your evidence:

Problem 6: Philipp, Mississippi 15' Sheet

a) Along the western margin of the map are distinct crescent-shaped hills. What is the landform term for these hills, and how did they form?

b) What does state route 35 generally coincide with?

c) What landform feature is found in SW 1/4, section 19, T23N, R1E?

d) Estimate the elevation of Yonkapin Lake in the NE 1/4, section 26, T23N, R1E.

Problem 7: Chickasaw, Alabama and Hurricane, Alabama 7.5' Sheets

a) Align these two sheets together. Measure the maximum width of the Mobile Delta floodplain in miles.

b) On these two maps you can observe several tributary streams of the Mobile and Tensaw rivers that parallel both rivers closely for long distances before finally connecting with the main channel. Big Bayou Canot is but one example. What is the term used for these types of tributaries?

c) Assume that you are a geologist hired by a real estate firm to assess the danger of flooding in section 2, T3S, R1W. A study of flood records indicates that the largest recorded flood stage was 10 feet above the present elevation of the river. What percentage of

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section 2 has been flooded in the past? Answer with the value from the following list that is closest in value to your area estimate: 0%, 10%, 25%, 50%, 75%, 90%, 100%.

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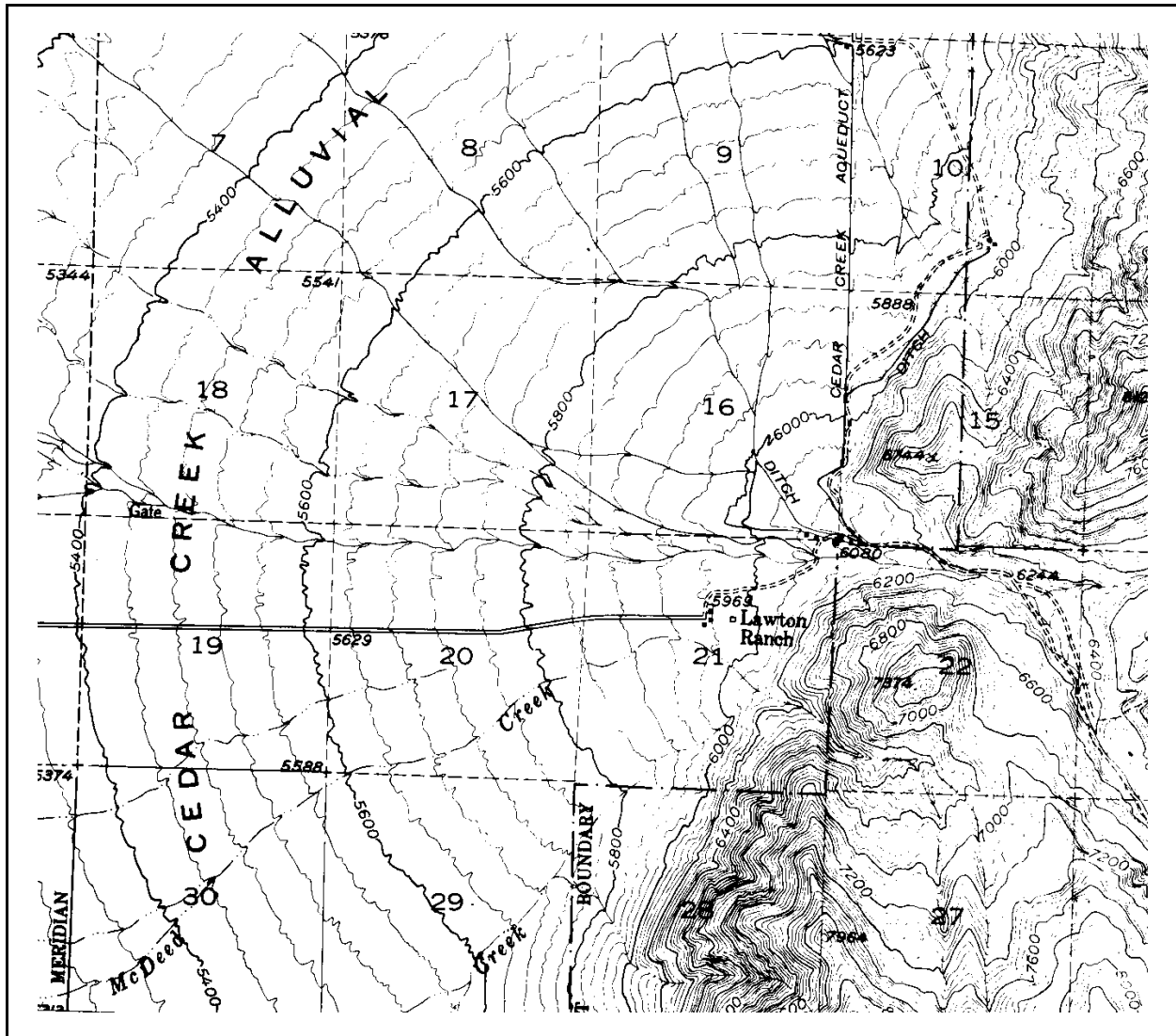


Figure 1 Alluvial fan.

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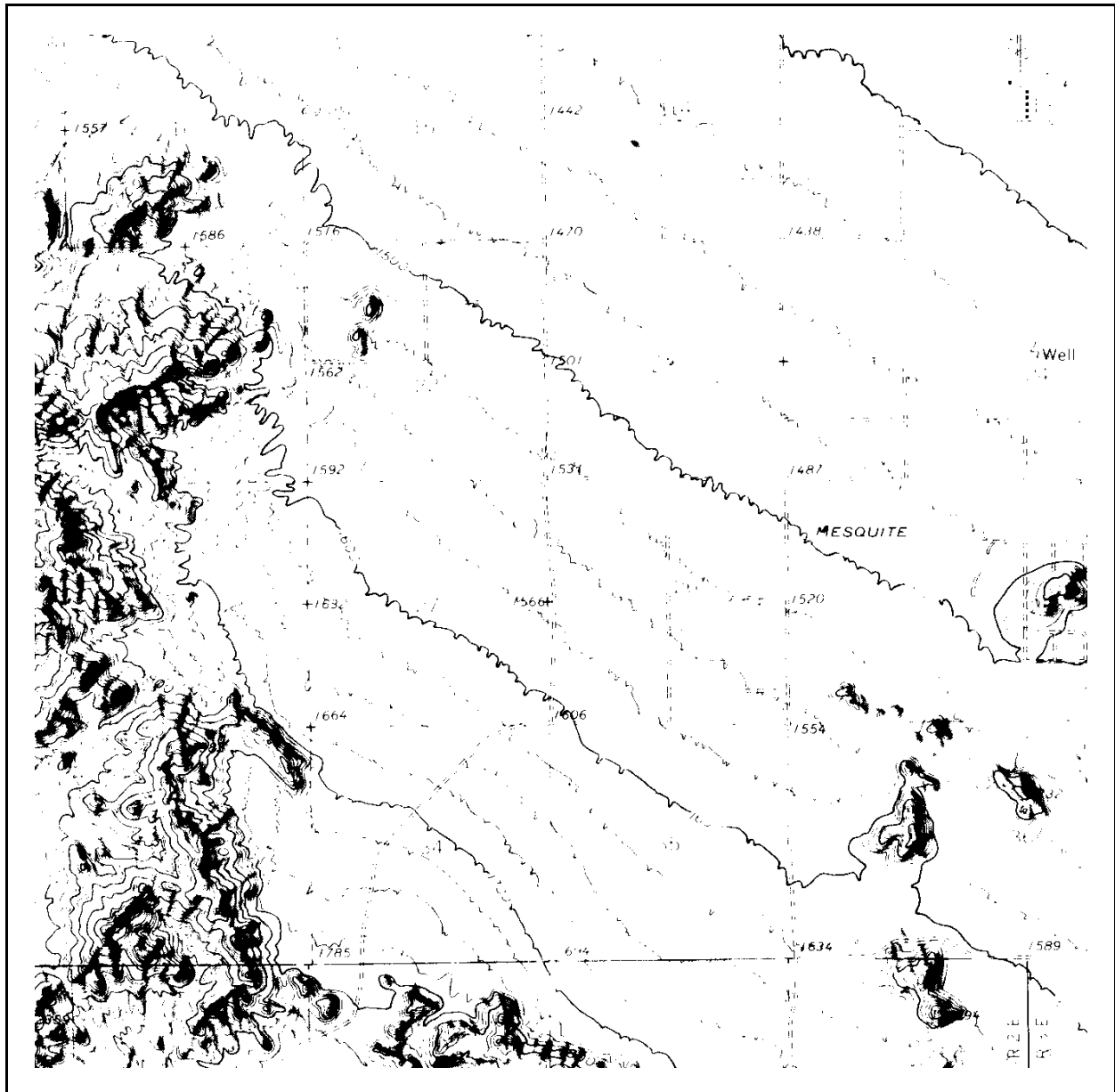


Figure 2 Example of bajada development with inselbergs.

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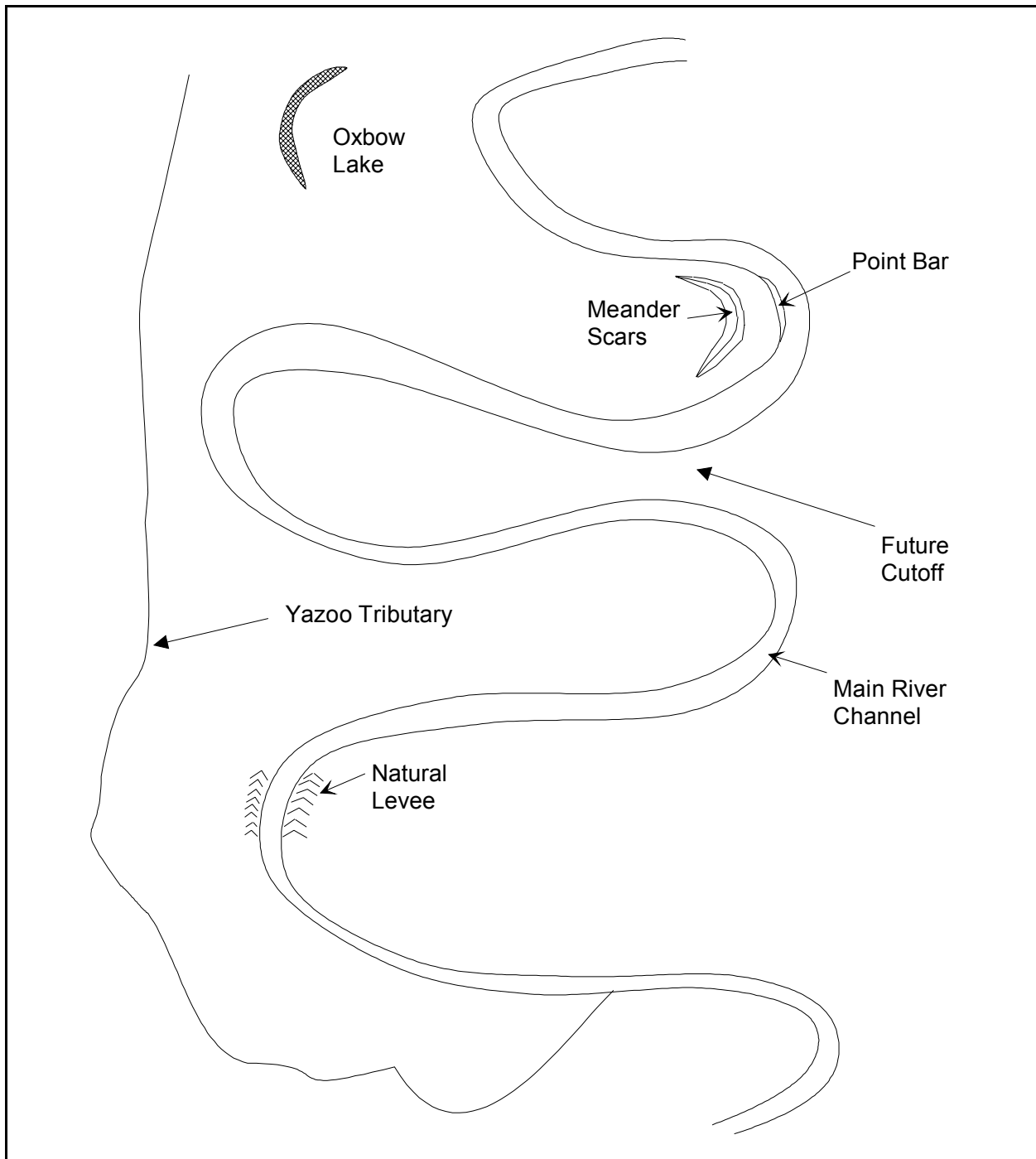


Figure 3 Meandering stream system with oxbow lake and future cutoff.

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