Lab 9 Student Answer Sheet

Introduction to Stream Processes and Flooding

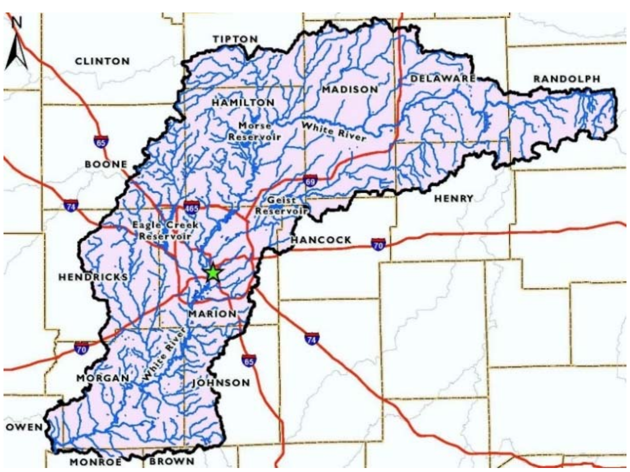
NAME (please print clearly) ____

Objective: **Understand stream systems and how streams do work. Understand runoff and how it relates to flood risk.** For this lab, we use the scientific method to determine which of three small watersheds would result in the greatest amount of runoff and have the highest flood risk. We will make some general observations then complete some calculations using actual data.

Materials: Foam board, pins, 10 pieces of blue yarn, pencil or marker, ruler, and a calculator.

Background: Streams do work (erode, transport, and deposit sediments) based on gradient or steepness of slope. But steepness of slope is not the only factor; the amount or *volume* of water in a stream is also related to how streams do work. A small stream which drains a small drainage basin, even though it has a steep gradient will not do nearly as much work as a larger stream at a lower slope which drains a large drainage basin. Why? Well, it's the difference between trying to spray off your grimy dishes using a small water gun versus a four inch fire truck hose. The smaller water gun might spray the water out at a faster velocity, but the fire hose would have much more water, a larger volume to do the work. How do streams collect more water? The amount of water in a stream is dependent upon the surface are of the area it drains. You can collect more water when it rains in a swimming pool (which has a large surface area) versus a tea cup (which as a small surface area).

In this lab, we will explore how streams collect water by looking at a simple stream system. We will base our stream system off a dendritic stream system (Figure 2) because that is what we have here in the Midwest, specifically, Central Indiana. Both the Upper White River Drainage Basin and the Mississippi River drainage basins have this dendritic or tree-like shape. See the figures below.



The outline and major streams of the Upper White River Drainage Basin in Central Indiana. This is an example of a dendritic stream system or drainage basin. (Image Source: UWRA)

The outline and major streams of the Mississippi River Drainage Basin. This is an example of a dendritic stream system or drainage basin. (Image Source: USGS)

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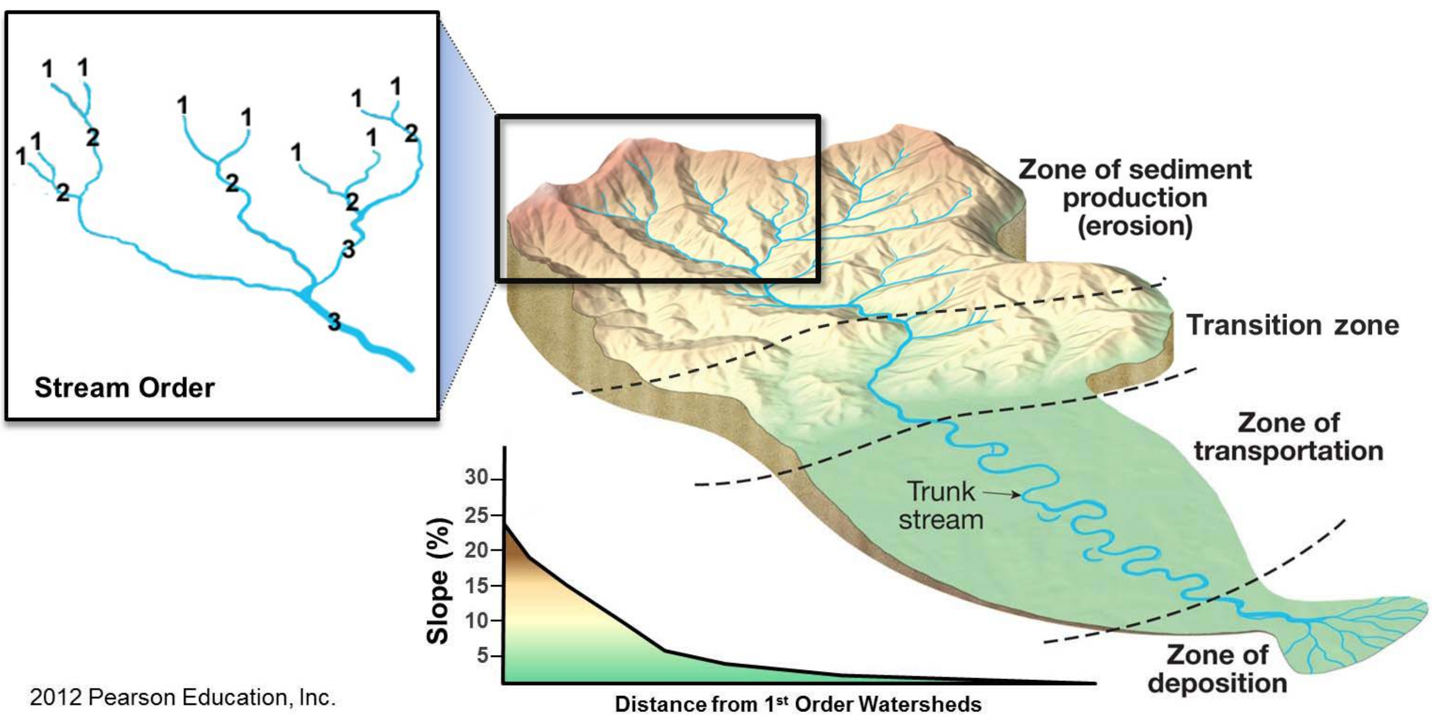
Streams are numbered using a system called a stream hierarchy. First order streams, are the smallest streams. They are defined as a stream into which no other stream flows. If you are walking around a corn field in Central Indian and find a stream in the field into which no other stream flows, you have found a first order stream. A second order stream is a stream which is formed by the confluence of two first order streams. A third order stream is formed from two second order streams flowing into each other. You must have two streams of the same order flowing into each other to move up in stream order. A first order stream flowing into a second order stream does not create a third order stream. The stream remains a second order stream.

The figure below shows the relationship between stream hierarchy, slope, and the type of work a stream does.



Original figure from Pearson Education, Inc., and modified by D.L. Pascual (IUPUI / Earth Sciences) to include stream hierarchy and slope graph.

Practice: Before we get started with generating a hypothesis, I want you to get some practice understanding how a stream system works to collect water and calculating *potential stream volume*. First we need to start by understanding topographic maps. Then you will interpret a contour map.

Practice interpreting contours. Use the Figure on the next page to answer the following questions.

A1)A contour line connects points of equal elevation. The difference in elevation between adjacent contour lines is called the contour interval. What is the contour interval on this map?: ___________________________________

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A2) Steep slopes are shown by closely spaced contours, while gradual slopes are shown by contours spaced farther apart. Relief is defined as the difference in elevation between two locations. How would you describe the relief on the west (left) side of highway? ______________________________

A3) What about the relief on east (right) side of highway? ______________________________

What is the highest point on the map and it's elevation? ____________________________

4) Draw the lowest exertion path on the topographic map. Give your reasons for choosing the easiest route in terms of elevation change per distance traveled:

A5) When contour lines cross streams, they form a V that points upstream. Locate and color the streams blue. Draw arrows to show the direction in which the streams flow.

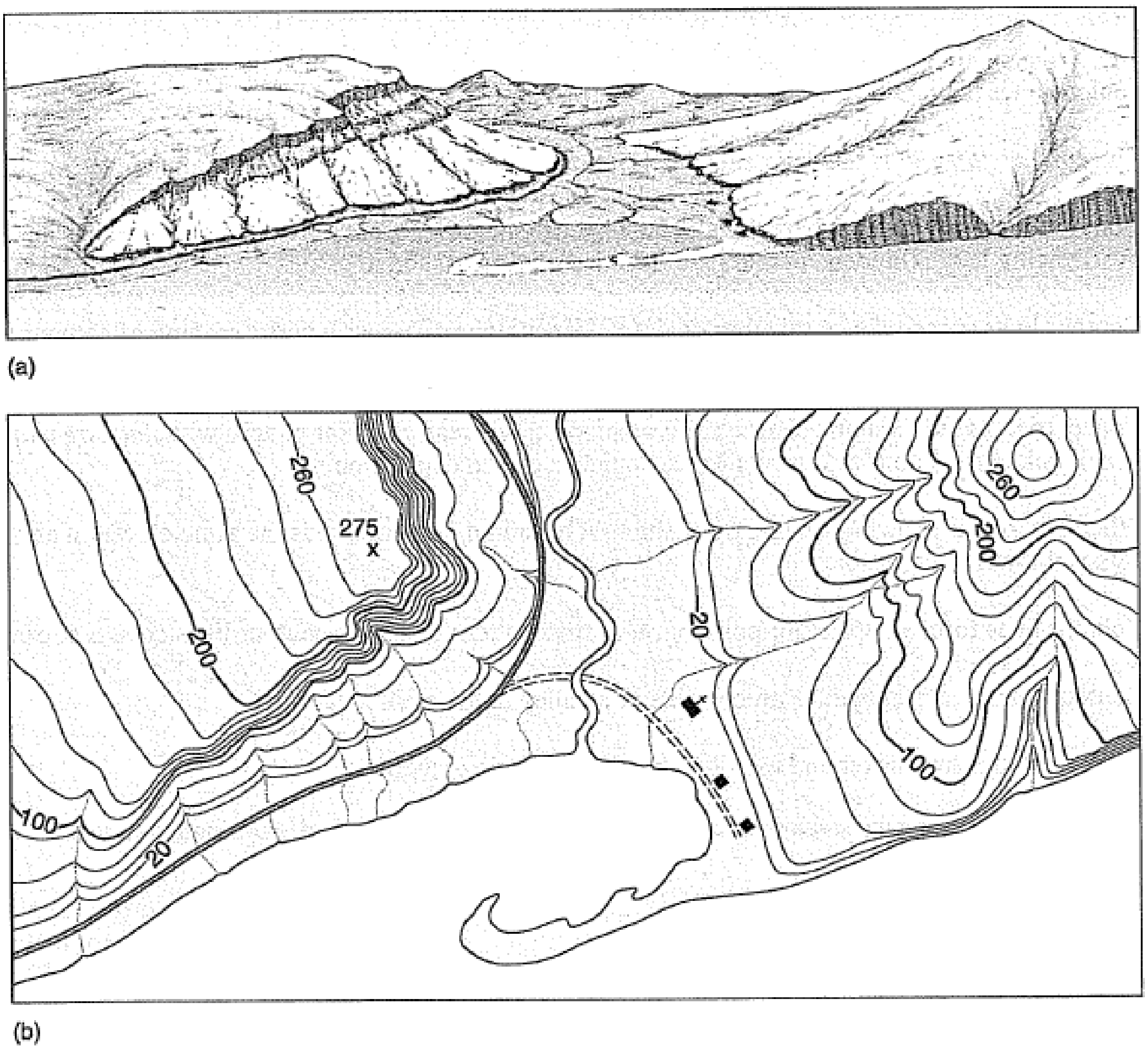

Figure 3 (a) Perspective view of a hypothetical landscape; (b) topographic map of that landscape.

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Practice drawing contours. **Use the figure below to answer the following questions:**

A6) Draw contour lines on the map using the rules below. Use 10 ft contour intervals.
- A contour line connects points of equal elevation.
- Hills are represented by closed contour lines.
- A contour line never branches or splits.
- When contour lines cross streams, they form a "V" that points upstream.
- Steep slopes are shown by closely spaced contours.
- Contour lines that occur on opposite sides of a valley always occur in pairs.

A7) Estimating the elevations of places not located on a contour line involves extrapolation. For example, a point half-way between the 100- and 200-foot contour lines would have an elevation of approximately 150 feet.

What is the elevation of the **X** on Figure 4a?______________________

What is the elevation of the **Y** on Figure 4b?______________________

A8) In terms of a steeper slope and a gentler slope, describe below the progression of the topography from the upper right corner to the bottom left corner.

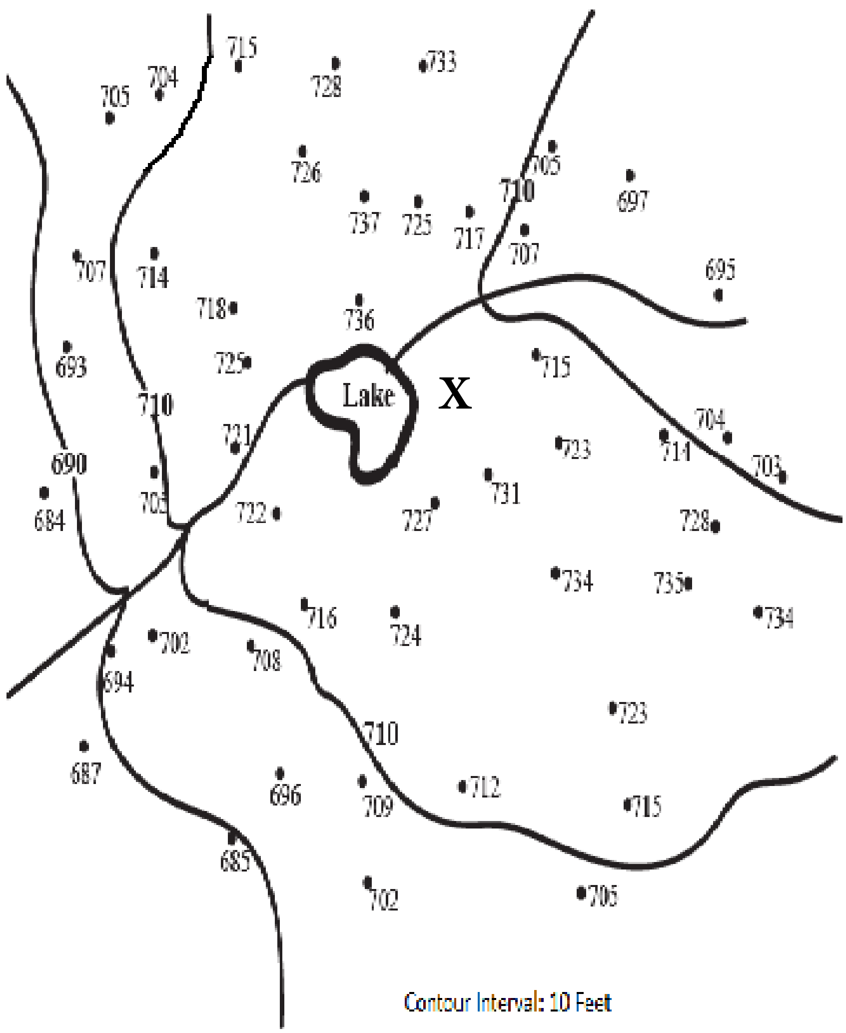

Figure 4 *Map to practice drawing contour lines. Some of the contour lines have already been drawn to give you a place to start. The elevations of these guiding contour lines are writton on the lines themselves. The bold line around the "Lake" is not a contour line.*

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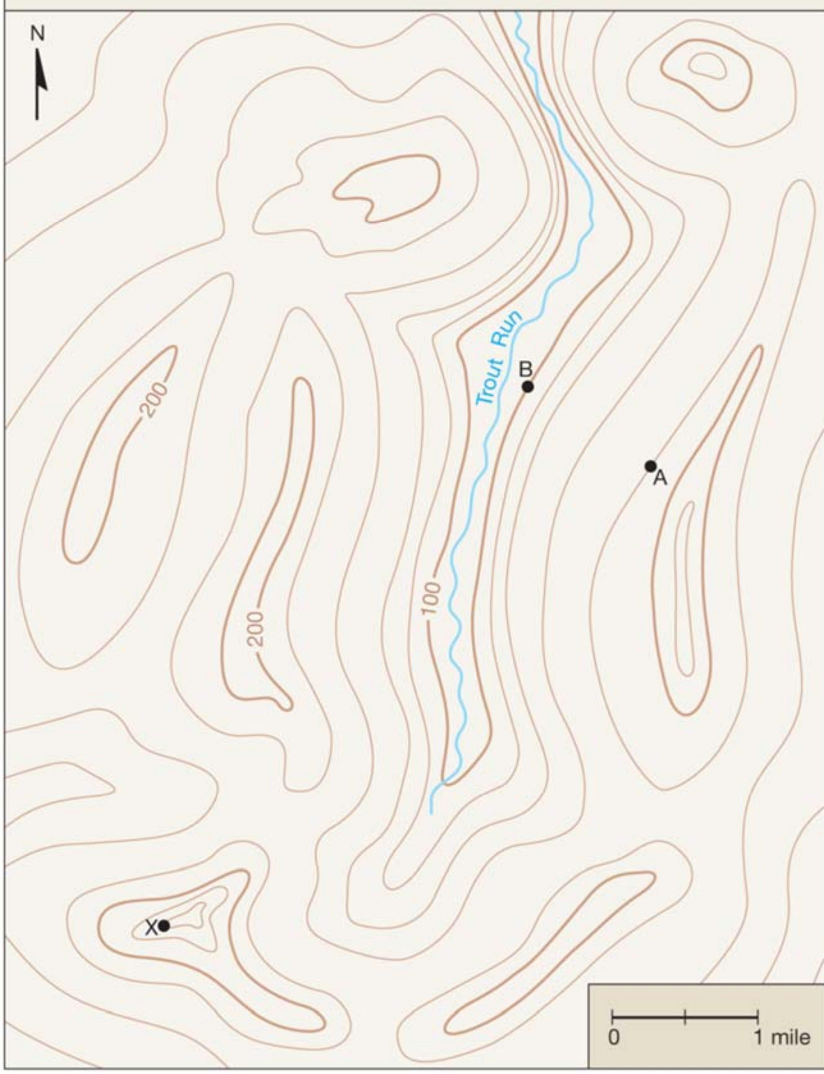
<u>Interpreting a contour map.</u> Next, you will interpret the contour map below and answer the questions. Surface water flows from upslope to downslope and flows perpendicular to topographic contour lines (It always flows down the steepest path in front of it). In a single drainage basin, all of the water flows into the same river/channel. Drainage basins are bounded by ridges/hilltops. Water will flow from these hilltops to the river downhill from them. All water that flows into a single river is part of the same drainage basin.

TOPOGRAPHIC MAP REVIEW FOR DRAINAGE BASIN MAPPING



a. This map is contoured in feet. The contour interval is: ____________ feet.

b. The elevation of point X is: ____________ feet.

c. The elevation of point B is: ____________ feet.

d. The elevation of point A is: ____________ feet.

e. The distance from A to B is: ____________ mile(s).

f. The gradient from A to B is: ____________ feet per mile.

g. Lightly shade or color the area inside each closed contour that represents a hilltop, then draw a dashed line to indicate the drainage divide that surrounds Trout Run drainage basin.

h. Trout Run flows (drains down hill) in what direction? ____________

C. Your instructor and your class will work through these questions as a group. You will learn how to approximate the amount of water flowing in a stream from precipitation runoff.

C1. How could you approximate the surface area of the Trout Run drainage basin?

C2. What is the approximate area of the Trout Run drainage basin? __________ square miles

C3. If it rains 2 inches how much (volume) water could then accumulate and flow through Trout Run? Give your answer in m^3. Show your work.

D. When we look at a river like the White River as it flows through campus, we often don't realize where that water came from. Naturally sourced water in a stream comes from upstream areas, direct runoff, and some shallow water intrusion. Runoff, as we learned above, is formed as water flows across a landscape into low lying channels to create streams.

For this activity, you will use yarn to represent a stream. You will create a third order stream system. The length of the yarn will represent how far that water had to travel. As streams converge, twist the yarn together to show how the streams add together as you move down the stream system.

D1. In the space below, sketch a diagram of what your third order stream system will look like.

D2. How many 1st order streams will you have to start? _______

D3. How many 2nd order streams will you have? _______

D4. How many 3rd order streams will you have? _______

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Directions:

a. Recreate this stream system using a sheet of paper, yarn, pins, and foam board. Remember to twist the yarns together to demonstrate that the streams are increasing in size. Your third order stream should flow into a lake with a shoreline at 100 ft. We will us a scale of 1 inch equals 1 mile or 1:64,000. Draw a shoreline boundary at the bottom of your drainage basin. North is the top of the paper when in the portrait orientation.
b. Define the drainage basins by first drawing 20 foot contours to describe where your drainage divides would be. Use 200 feet as your highest contour. The lake is at an elevation of 100 feet. **Then, draw a dashed line to delineate the drainage basins.**

Before moving on, show your map to your lab instructor for grading.

D5. What is the gradient (feet per mile) from your first order stream to the end of the stream at the lake? Show your work.

D6. As you *increase* in order, what happens to the gradient of your stream?

Observations: Now, I want you to get some practice understanding runoff. When rainfall lands on the Earth's surface, it begins moving downslope, but some of that water is lost to the atmosphere via evapotranspiration; some is absorbed into the surfaces through a process called infiltration. Some water is intercepted or taken up by plant life. Some water moves even deeper into groundwater. In urban areas, the majority of the water flows off the surface due to the presence of *impervious surfaces* (surfaces that water cannot penetrate such as rooftops, parking lots, and roads). Therefore, water will *runoff* in different amounts depending upon the landuse of the area. A *runoff coefficient* is the fraction (percentage) of water that flows off a surface. See the table and figure on page 7.

Look at the three surfaces your instructor provided. Make some general observations. Use the beaker to measure out a volume of water. Then collect the water that runs off. What do you think is the percentage of water that is running off these three surfaces? Percentage: run-off volume / original volume * 100

Surface	Description	Observed Runoff (%)
1		
2		
3		

E. Now, go back to the contour map you made.

E1. From left to right (West to East) label your first order streams A, B, C, and D. Imagine that 5 inches of rain have fallen over this area over the course of a day (24 hours). How many meters is this? _______ m (Show your work below.)

E2. Thinking about the explanation of landuse, describe a drainage basin that would create large volumes of runoff. What types of surfaces would dominate the landscape?

Hypothesis: Now, look at the table below which will give you the landuse of each drainage basin. Based on what you know, which of the following drainage basins (A, B, C, or D) would you expect to produce the greatest amount of stream volume (based on landuse) and which do you think would have the greatest risk of flooding? Write your hypothesis below:

Measurements: We will work through some calculations now to determine which drainage basin would be at the greatest risk of flooding.

E3. Use the table below to calculate the area of each landuse area in each drainage basin. Give your answers in m^2. Some calculations are given for you to check your answers.

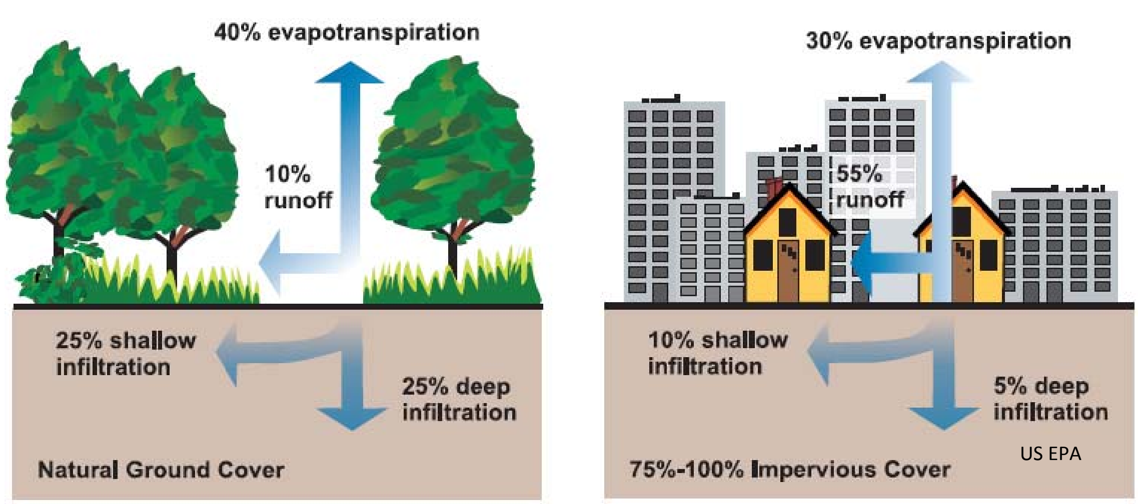
Land use	A	B	C	D
Total Area (km^2)	**3.5**	**2.1**	**2.3**	**3.0**
% Forested	100%	35%	20%	10%
% Agriculture	0%	25%	50%	0%
% Urbanized	0%	40%	30%	90%
Calculations				
Total Land Area (m^2)	*3,500,000*		*2,300,00*	*3,000,000*
Forested (m^2)	*3,500,000*		*460,000*	
Agriculture (m^2)	*0*	*525,000*		*0*
Urbanized (m^2)	*0*	*840,000*		

E4. Use the table below to calculate the *possible amount of water* which would runoff from the landuses given no losses due to infiltration or evapotranspiration. This is the greatest amount of water this area could contribute to the stream system. Give your answer in m^3. (Multiply the landuse area in square meters by the amount of rainfall in meters.)

Possible Water Contribution	A	B	C	D
Forested (m^3)	444,500		58,420	
Agriculture (m^3)	0	66,675		0
Urbanized (m^3)	0	106,680	87,630	

E5. Calculate the *actual amount of water* each drainage basin would contribute using the runoff coefficients. These are given as percentages and take into account how much water would be lost from runoff by infiltration and evapotranspiration processes. Note: some of these are also dependent upon slope. Because we used an elevation change of only 100 feet and a scale of 1:64,000, our slope is relatively *low*.

Landuse	Slope	Runoff coefficient
Forest	***Low (< 2%)***	***10 – 15% (0.10 – 0.15)***
	Moderate (2 – 7 %)	10 – 15% (0.10 – 0.15)
	High (>7%)	10 – 20% (0.10 – 0.20)
Agriculture (in production)	***Low (< 2%)***	***20 – 23% (0.20 – 0.23)***
	Moderate (2 – 7 %)	20 – 25% (0.20 – 0.25)
Agriculture (tilled, bare)	Low (< 2%)	30 - 40% (0.30 – 0.40)
	Moderate (2 – 7 %)	30 - 49% (0.30 – 0.49)
Urbanization	***Single-family***	***30 - 50% (0.30 – 0.50)***
	Apartments	60 - 75% (0.60 – 0.75)
	Industrial (light)	50 – 80% (0.50 – 0.80)
	Industrial (heavy)	60 – 90% (0.60 – 0.90)



Multiply the amount of water calculated in question E4 by the coefficient for the landuse in the table above. Use the *highest* number in the range of coefficients in ***bold italics***. Add all of the landuse contributions up (Total Water) to determine the total amount of water.

Actual Water Contribution	**A**	**B**	**C**	**D**
Forested (m^3)	*66,675*			
Agriculture (m^3)	*0*		*33,592*	
Urbanized (m^3)	*0*	*53,340*		*177,165*
Total Water	***66,675***		***86,170***	

Summary and Conclusion: Given your observations and measurements, would you accept or reject your hypothesis? (Circle one.)

ACCEPT REJECT

F1. How do you think the surfaces you observed relate to the coefficients in the table on page 7?

F2. Which first order drainage basin contributed the **most** amount of water to your third order stream? _______

F3. Which first order drainage basin contributed the **least** amount of water to the stream? _______

F4. Why do you think there was this difference in the amount of water each stream contributed?

F5. Were any of your results surprising? Why or why not?

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Reflection and Learning: In October of 2013, many residents in and around Indianapolis saw their Flood Insurance premiums increase. This was due to a reassessment of flood risk using updated maps. Scientists use satellite Imagery to assign landuse/land cover to different areas, then use runoff coefficients to determine the possible amount of water on the landscape given different amounts of rainfall. The analysis is similar to what we did in this lab. Look at the imagery below, showing the area of Indianapolis and some of the surrounding areas. The light green areas are likely agricultural fields in production, the dark green areas are tree-covered areas, and the gray areas are buildings, roads, and parking lots. The area of Indianapolis is approximately 953.5 km². (Your instructor will show you this imagery on the projector.)

We learned that different land use surfaces result in different runoff coefficients. When you look around Indianapolis, what type of surfaces do you see? Does Indianapolis have a high or low risk of runoff? Why or why not? How do you think this affects flood risk downstream of Indianapolis?