UNDERSTANDING DEMS AND MAPPING WATERSHEDS

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OVERVIEW

Today you will be introduced to two important concepts: **Digital Elevation Model (DEM)** and **Watershed**. A DEM is a digital model or 3D representation of a terrain's surface [1]. With the help of various remote sensing data and technologies such as satellite imagery, lidar, IfSAR, land surveying, etc., we are able to build an accurate DEM database for the Earth [2]. Common products derived from DEM include terrain analysis, 3D flight planning, intelligent transportation system, and navigation system. DEM is also very useful for hydrological study and watershed is one of the common topics benefited from DEM.

A **watershed** is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel [3]. A watershed can be massive in terms of size for example the Mississippi River watershed extends from the Allegheny Mountains in the east to the Rocky Mountains in the west, and it includes all or parts of 31 states and two Canadian Provinces [4]. But a watershed can also be local for instance the drainage area of a storm drain on campus.

In this exercise, you will be using ArcGIS Online to explore DEM data and the relationships between elevation and river systems. Then you will manually create some point data and use it to calculate watersheds. You will relate watershed to the key water-related concepts such as evapotranspiration and precipitation by observing how the values of evapotranspiration and precipitation vary across the watersheds you will create.

PREREQUISITES

None. This lab is intended for lower division undergraduate students in the sciences. It does not require prior knowledge of the concepts or GIS skills.

DATA, SOFTWARE TOOLS, AND WORKFLOW

ArcGIS Online is the sole software for this exercise. All the data can either be found inside the software or be created by you.

This exercise consists of the following tasks:

- Explore DEM data
- Create point data on map
- Calculate and compare watersheds
- Assess evapotranspiration and precipitation of watersheds

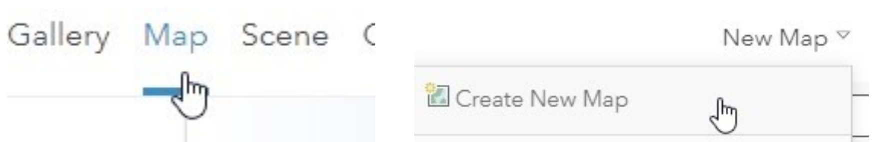
At the end of the exercise, you will complete a Lab Report, answering the questions posed, and turn it in (via Blackboard).

There are 32 steps to the exercise.

INSTRUCTIONS

1. Open a browser and go to https://www.arcgis.com/home/index.html and sign in with your ArcGIS Online account.

2. Once signed in, click "Map" on the menu to create a new map.



BEFORE YOU MOVE ON click on "Open in Map Viewer Classic"

You can find it in the top right, next to the bell icon

3. Next, you will search for a DEM layer and add it to your map for observation. On the menu click "Add" ==> "Search for Layers".

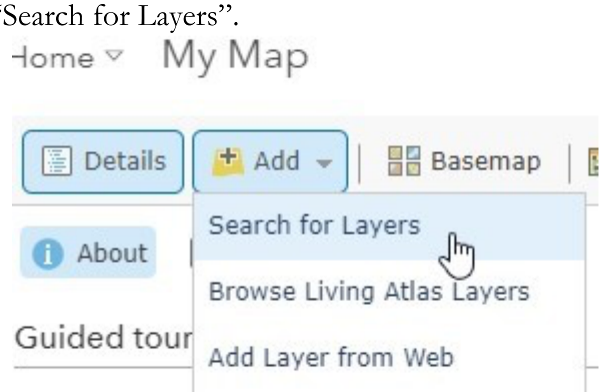


Figure 1. Search for layers

4. From the "Search for Layer" window (Figure 2), find "Tinted Hillshade", in "ArcGIS Online" and add "Terrain: Elevation Tinted Hillshade" by Esri to your map.

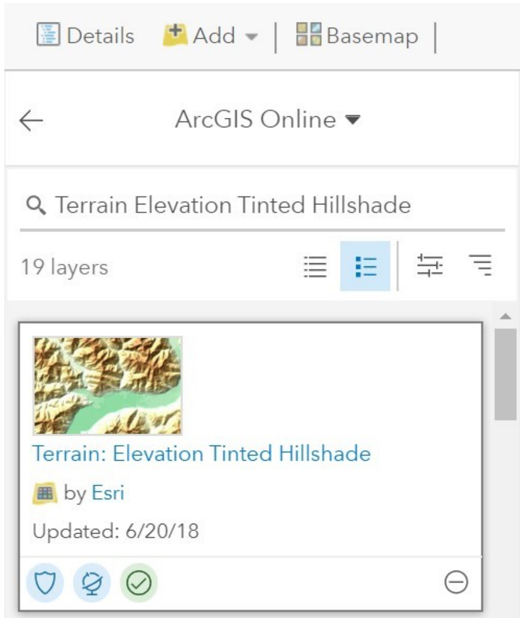


Figure 2. Search elevation data in ArcGIS Online

5. You will see the map (Figure 3) with the color scheme representing the distinct elevations across the world. To have a better understand of this elevation layer, you can click under the layer name for more options, and click "Show Item Details" for more information.

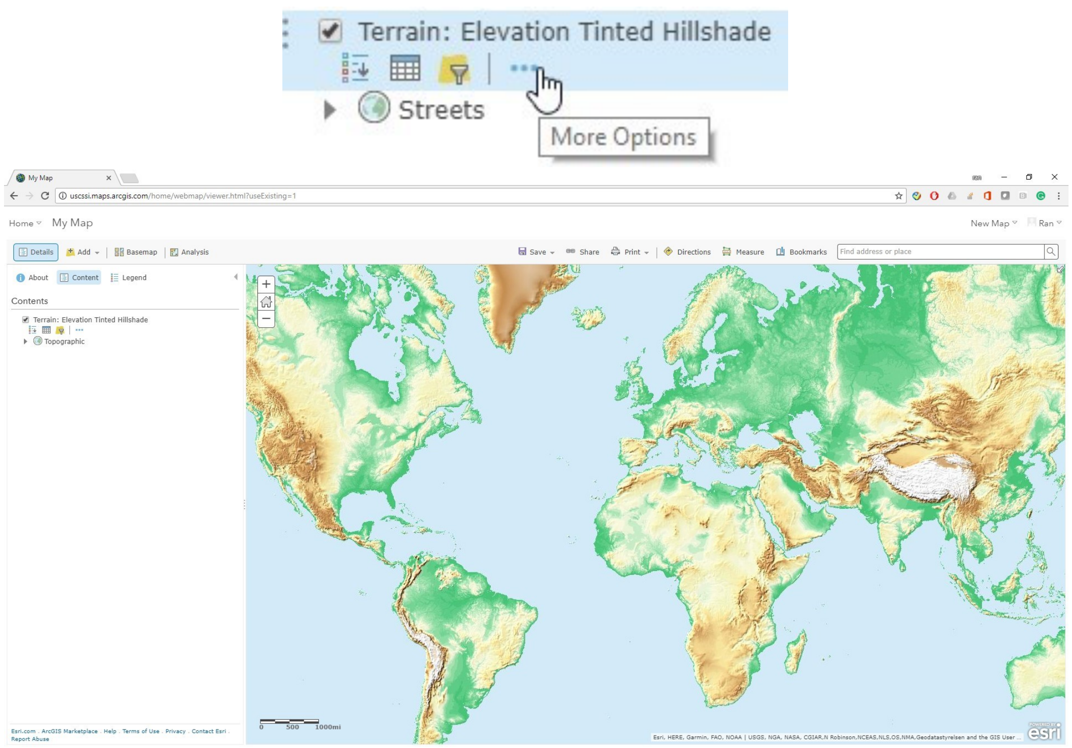


Figure 3. Terrain: elevation tinted hillshade

6. On the menu click “Add” ==> “Search for Layers”. Find “world rivers” in “ArcGIS Online.” Add the layer on the list called “Rivers_World_Natural_Earth” by: uscssi_research.

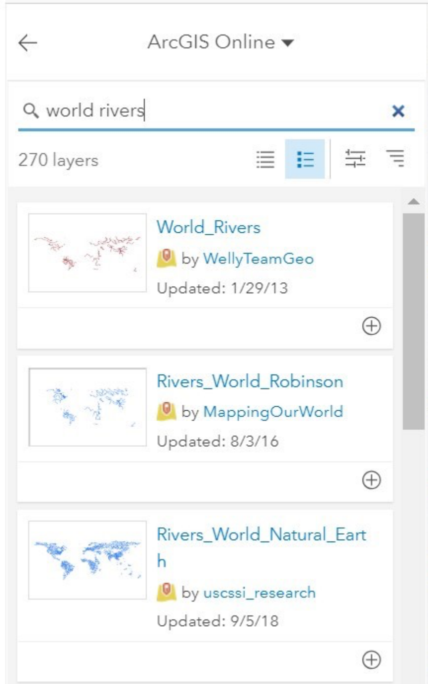


Figure 4. Search for river layer

7. You will see the major rivers in the world shown on top of the terrain layer (Figure 5). Explore the map by zooming to the largest river systems such as the Nile, Amazon, Yangtze, or Mississippi Rivers. Observe the elevation of the origin and destination of the river and see the how the elevation changes along the river path.

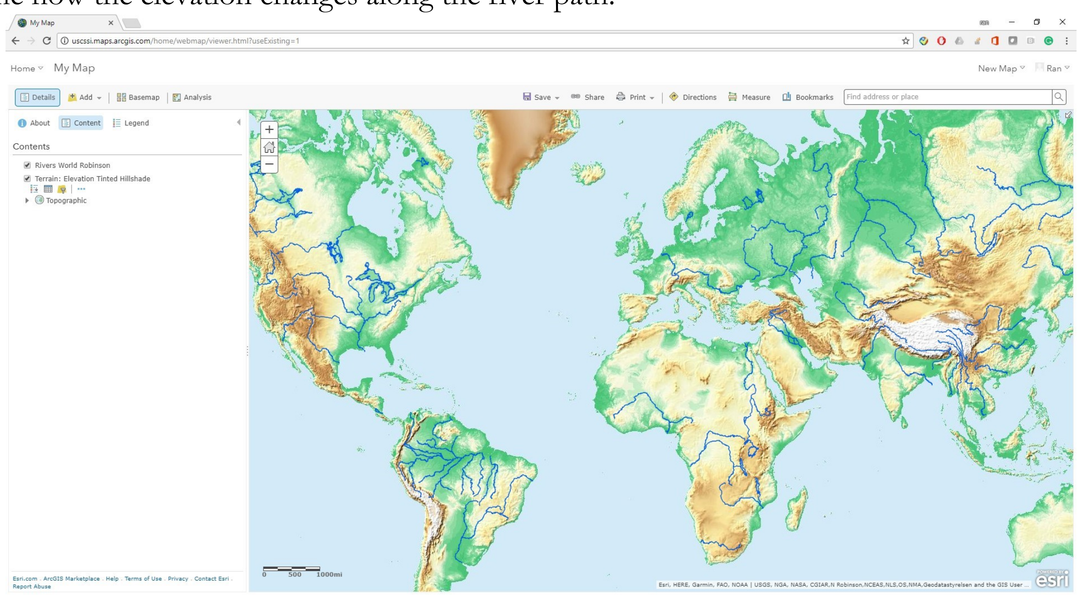


Figure 5. Major rivers in the world

8. Click 

on the top and change the basemap to “Streets”.

9. Click the layer name of “Terrain: Elevation Tinted Hillshade” on the left panel, and click ··· for more options. In the drag-down window select “Transparency” and set it as 50% transparent so you can see both the elevation layer and the basemap at the same time.

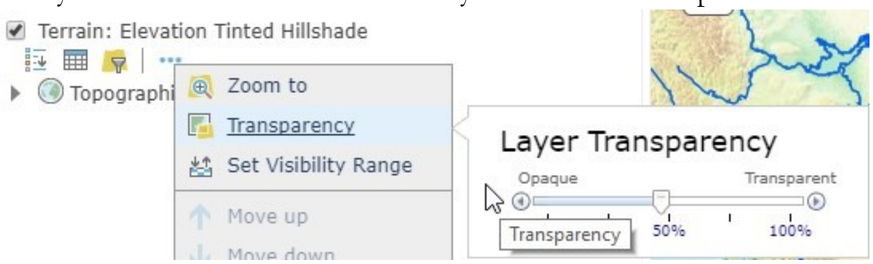


Figure 6. Set transparency

10. Next, we will learn what is watershed and how to create a watershed in ArcGIS Online. As mentioned in the overview, a watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. Every location on the Earth surface belongs to a watershed. The map provided by USDA illustrates the boundaries of major watersheds in the U.S. https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs143_021556.jpg Check out which watershed that your home/school belongs to. Watersheds should be thought of as **nesting**: Larger watersheds such as those identified in the map are composed of many small watersheds.

11. Using ArcGIS Online, you can identify the watershed that certain locations belong to. On the menu click “Add” ==> “Search for Layers”. Search “USA River and Stream” in “ArcGIS Online” and add “USA Rivers and Streams” by Esri.

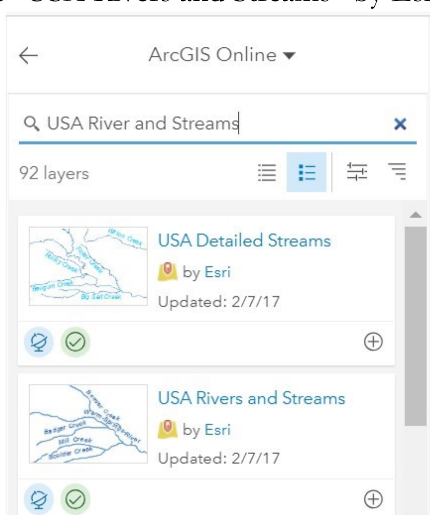


Figure 7. Search for USA rivers and streams

12. Use your mouse to navigate and zoom to the mountainous region east of Seattle, WA, in the northwest corner of the continental US. As in Figure 8 below, you can see not only the varying elevation of the Earth's surface, but the rivers and streams that have helped to shape the terrain. (Note: the river and stream layer may take a few seconds to load and it may disappear if you zoom too close.)

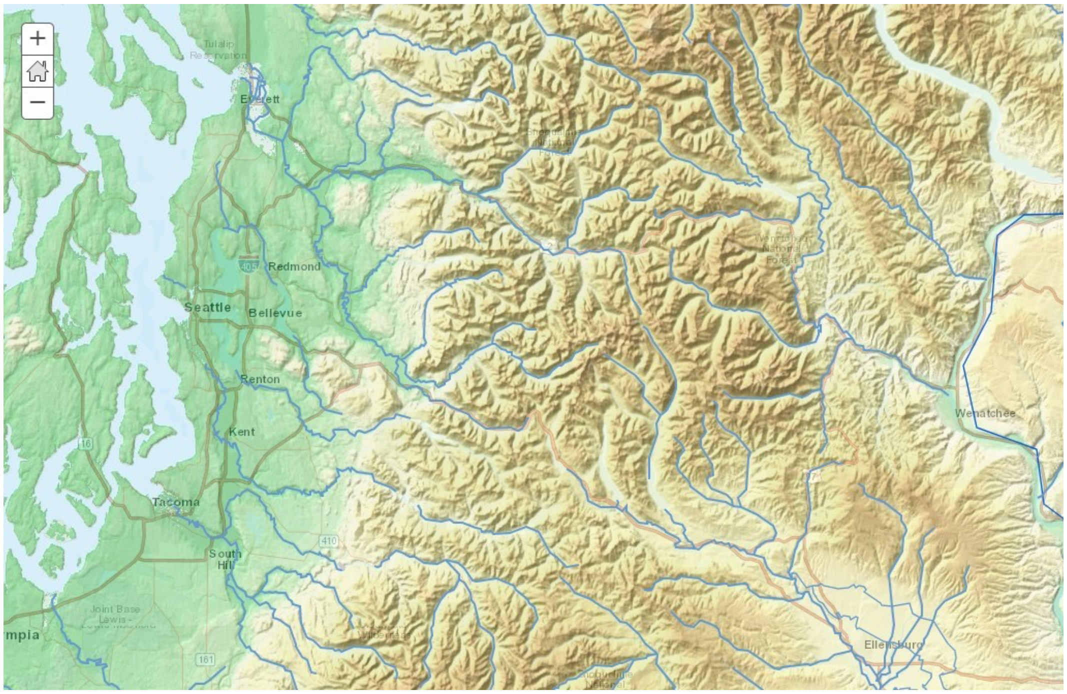


Figure 8. Rivers and terrain in the region near Seattle, WA

13. To better understand the relationships between watersheds, let's find a fork-like stream or river system in the mountains east of Seattle, and create three correlated watersheds. Below are a couple examples for you to consider (feel free to find your own).

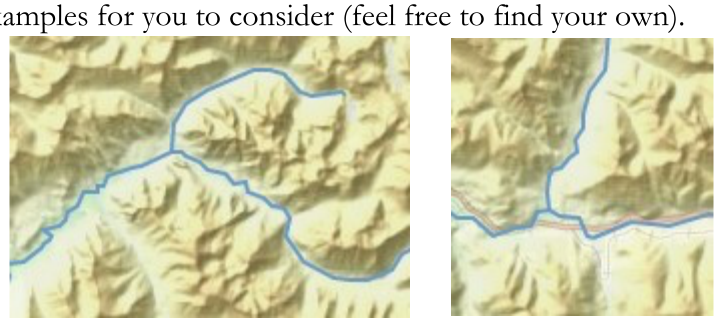
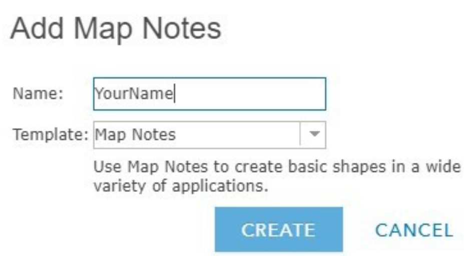


Figure 9. Fork-like streams and rivers

14. On the top menu click "Add" ==> "Add Map Notes". Then rename it as your name, and click "CREATE". Choose (click) one of the three pinpoint styles, then you will be able to click on the map to add points.



15. Press the Ctrl button on your keyboard, then click on the fork-like river to add a point. Name the "Title" as "Point1", then "CLOSE".

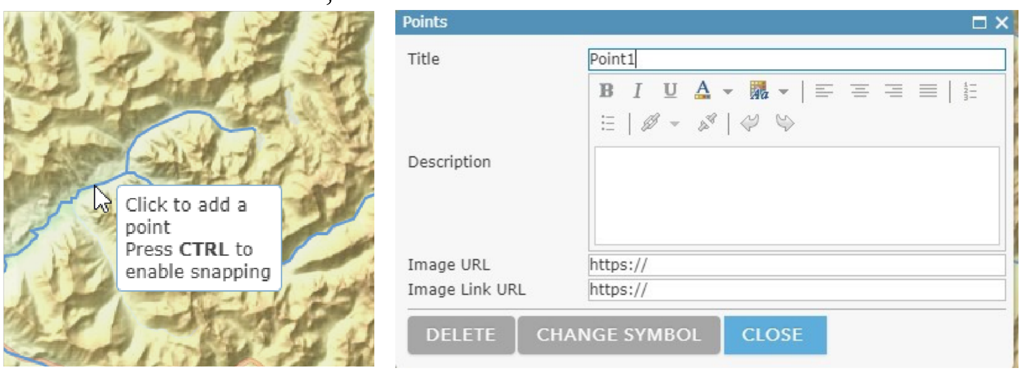


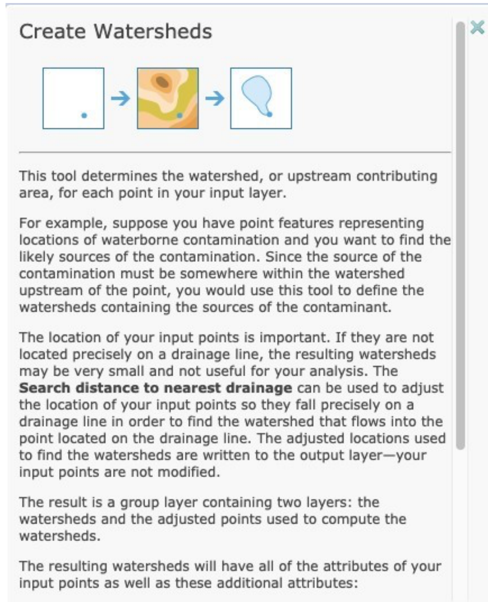
Figure 10. Add a point on river path

16. Repeat the step above to create another two points (Title as Point2 and Point3). Make sure that each of the point locates at a branch of the "fork" and have them be close to the branch-off point as possible (see Figure 11 below).

Figure 11. Three points on river path

17. On the top menu click "Analysis" ==> "Find Locations" ==> "Create Watersheds". Click the information icon on the right for function explanations. Read carefully about how this "Create Watersheds" works. It is important to understand the functionality before you actually run it. You will need to explain this for the Lab Report.

After clicking the information icon, you should see the following pop-up window:



18. Set the parameters as Figure 12 below: “YourName (Points)” that you just created as the “Point features for calculating watersheds”; “Search distance” as “5,000 Feet”; leave the “Result layer name” as default; however, if you run this analysis again you will have to give the result a different name; uncheck “Use current map extent”, then hit “RUN ANALYSIS”. This analysis may take up to one minute, so be patient!

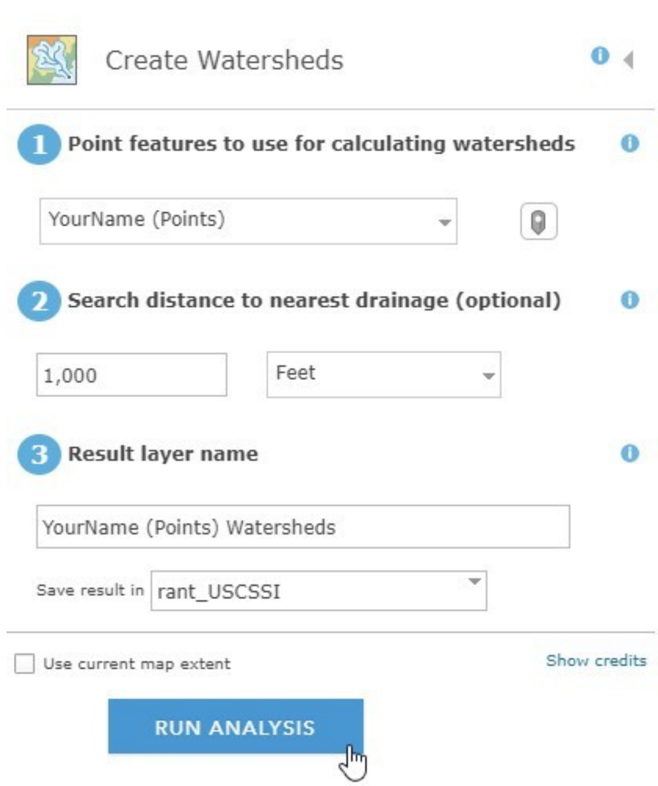


Figure 12. Set parameters for creating watersheds

19. After you successfully create the watersheds, you will see three watersheds on your map. If you cannot see all three watersheds, it is because a large watershed "blocks" the small ones. Don't worry, you will see them after you change the symbology in the next step.

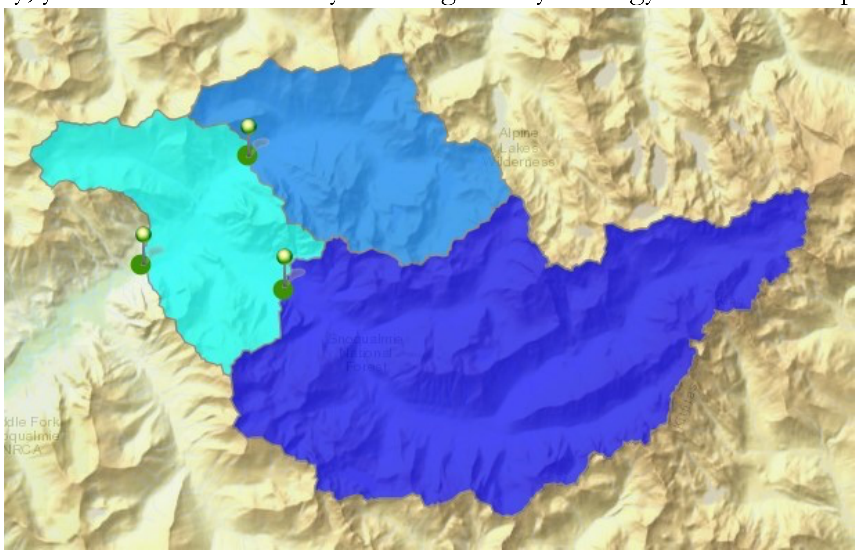


Figure 13. Watersheds corresponding to three points

20. Click the layer name of the watersheds and click Change Style. Under Choose an attribute to show, choose "show location only", and "Select drawing style" click "OPTIONS".

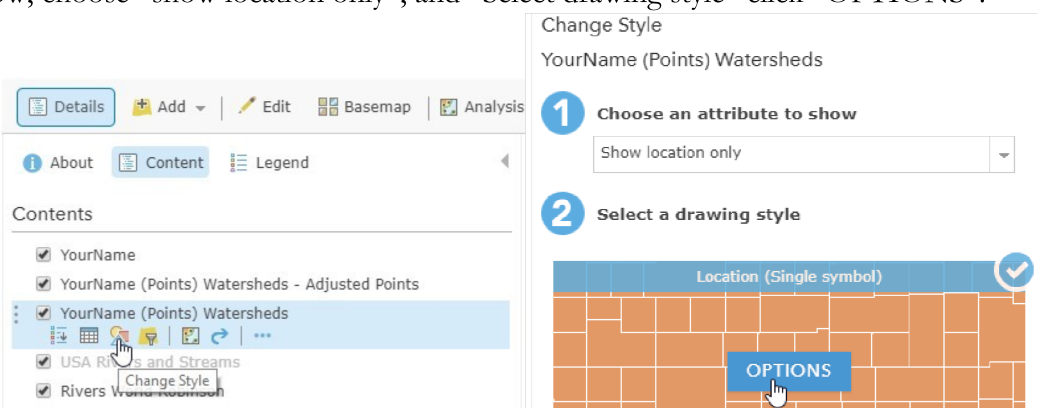
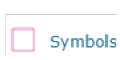
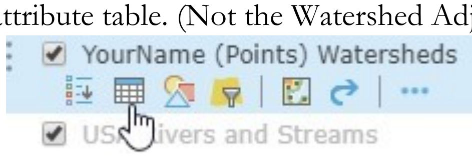


Figure14. Changing the symbology of the watersheds

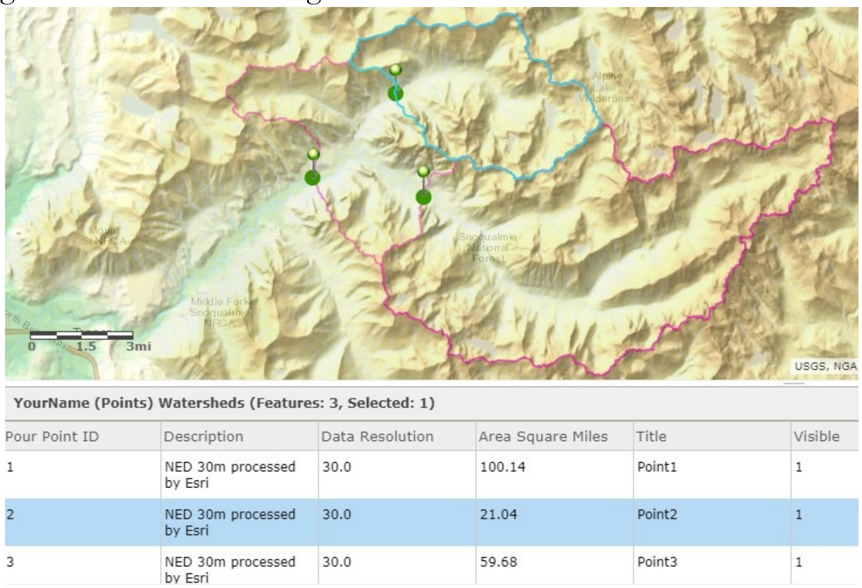
21. Click "Symbols" 

and set the "FILL" to "No Color" and "OUTLINE" to magenta. Then click "OK" ==> "OK" ==> "Done".

22. Now click the table icon under the "YourName (Points) Watersheds" layer to open the attribute table. (Not the Watershed Adjusted Points.)



23. In the table you can see the details of each watershed polygon. Click a row of the table to select one of the watersheds, the selected one will be highlighted in blue color on the map. Observe all three watersheds. When you close the attribute table, then the outline color of all three polygons would return to magenta.

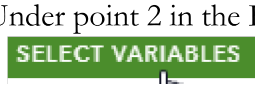


YourName (Points) Watersheds (Features: 3, Selected: 1)

Pour Point ID	Description	Data Resolution	Area Square Miles	Title	Visible
1	NED 30m processed by Esri	30.0	100.14	Point1	1
2	NED 30m processed by Esri	30.0	21.04	Point2	1
3	NED 30m processed by Esri	30.0	59.68	Point3	1

Figure 15. Selecting watersheds to observe

24. Evapotranspiration is an important water-related concept introduced in the previous lab. With the watersheds data, we can quantitatively assess evapotranspiration in your study area. On the top menu, click "Analysis" ==> "Data Enrichment" ==> "Enrich Layer". Click on the information icon on the right side of the "Enrich Layer" icon. Basically, this analysis function retrieves information about the people, places, and business in a specific area, or within a selected travel time or distance from a location.

25. Under point 2 in the Enrich Layer menu, find and click "SELECT VARIABLES" 

. This will open a Data Browser window. Use the side arrow to scroll to the second page of the menu and find "Landscape" (Figure 16). Click to open "Landscape" and use the side arrows again to find the blue box labeled "Water and Wetlands". Click "Water and Wetlands" to find a list of variables. Select "Mean Evapotranspiration (0.1 mm/year)",click the box next to it and then hit "APPLY" (Figure 16).

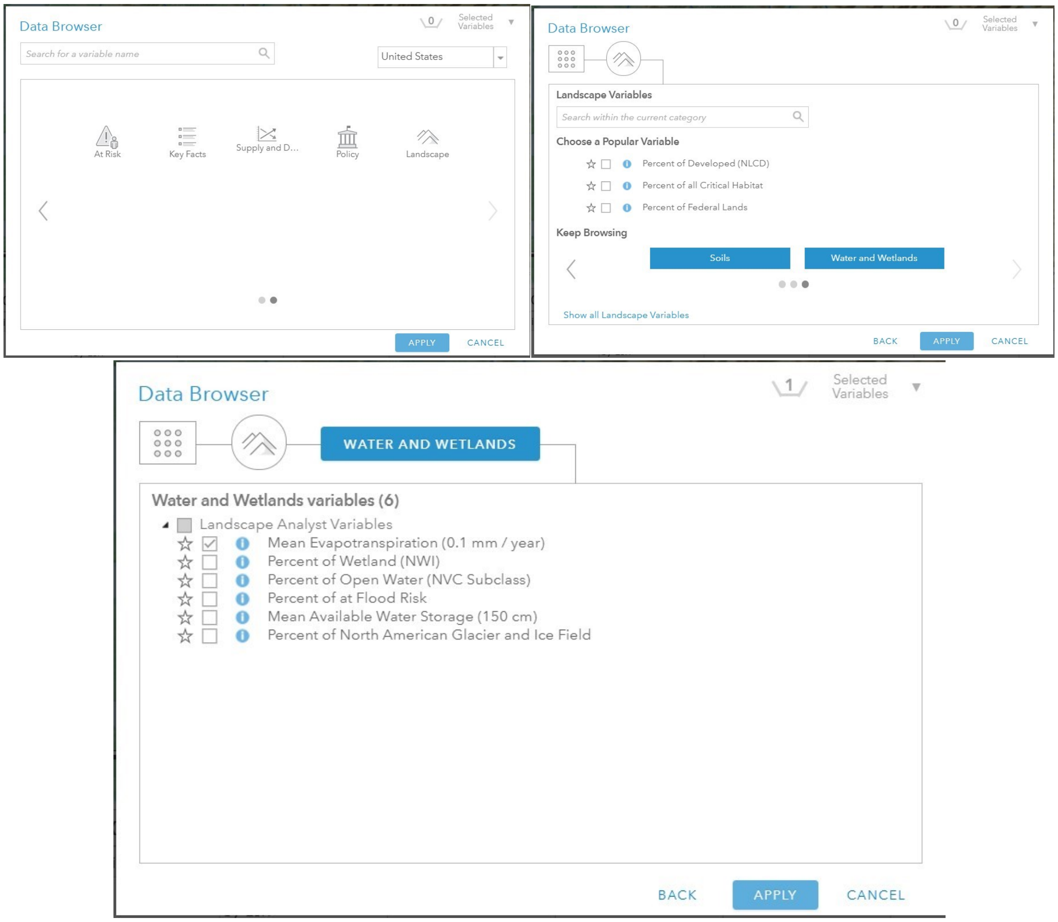


Figure 16. Select variable to enrich layer

26. Set the other input parameters as follows: 1. "Choose Layer to enrich with new data" as "YourName (Points) Watersheds"; 2. The "Mean Evapotranspiration" you selected in the last step; uncheck "use current map extent", and hit "RUN ANALYSIS".

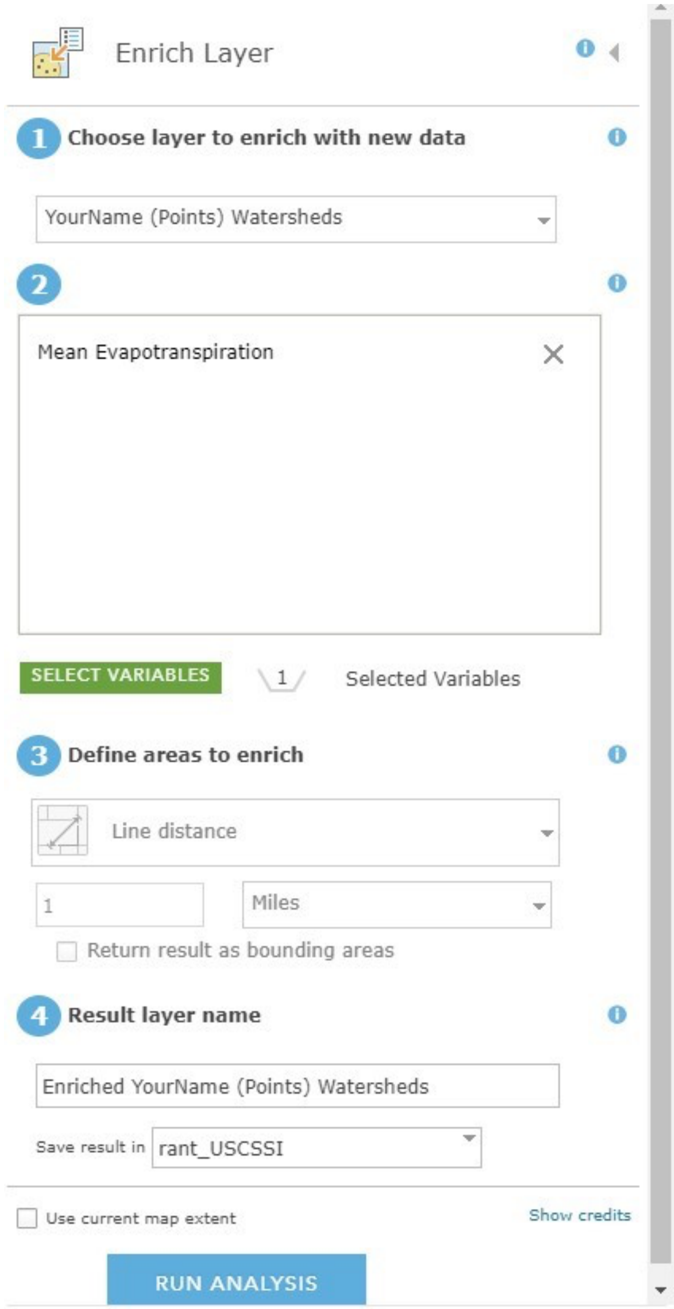
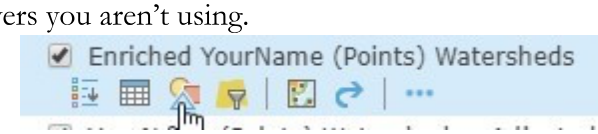


Figure 17. Enrich layer settings

27. This will create a new layer of polygons with the same spatial extent as your watersheds. Refer to Steps 19 and 20 to change the style of the new layer as you did before (no fill color; outline color as magenta). At this point your map will be getting quite busy, so turn off the visibility for the layers you aren't using.



28. **The difference of this enriched watershed layer is in the attribute table**. Open its attribute table. Drag it to the far right and you will see the value of "Mean Evapotranspiration" of each watershed.

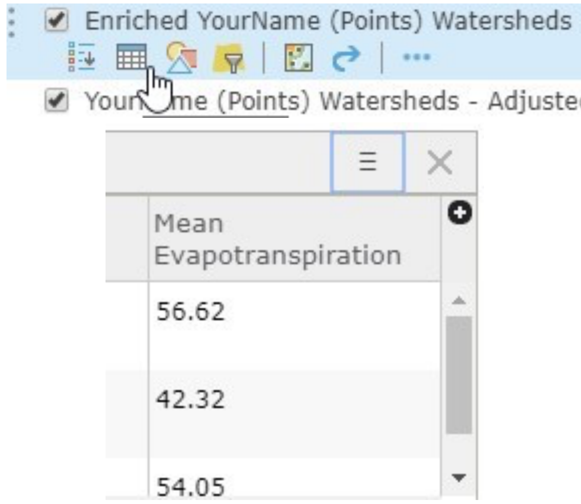


Figure 18. Mean evapotranspiration in attribute table

29. On the menu click "Add" ==> "Search for Layers". Find "USA rainfall" in "ArcGIS Online" and add "USA Mean Rainfall" by Esri.

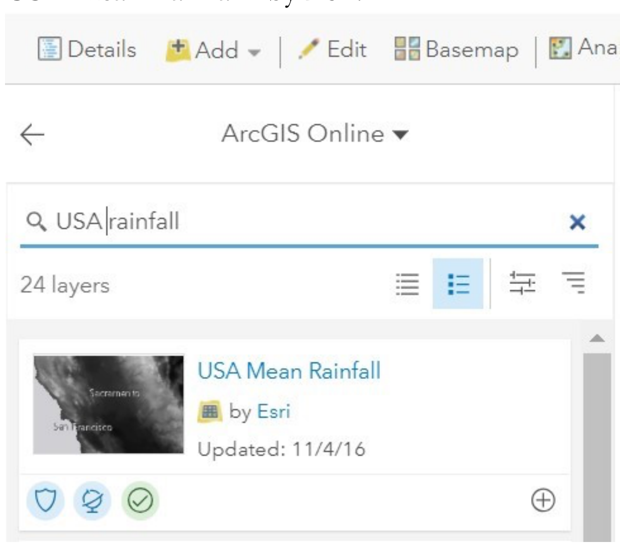


Figure 19. Add rainfall layer

30. Click the layer name of "USA Mean Rainfall" and click ••• for more options. In the dragdown window select "Transparency" and set it at about 25% transparent.

31. Now you can compare your watersheds with the rainfall background. **A brighter background represents more rainfall while a darker background means less rainfall**. (Note: the amount of rainfall varies rapidly across this whole region, so the watersheds you created may fall in a wet or dry area or even a mix of both.)

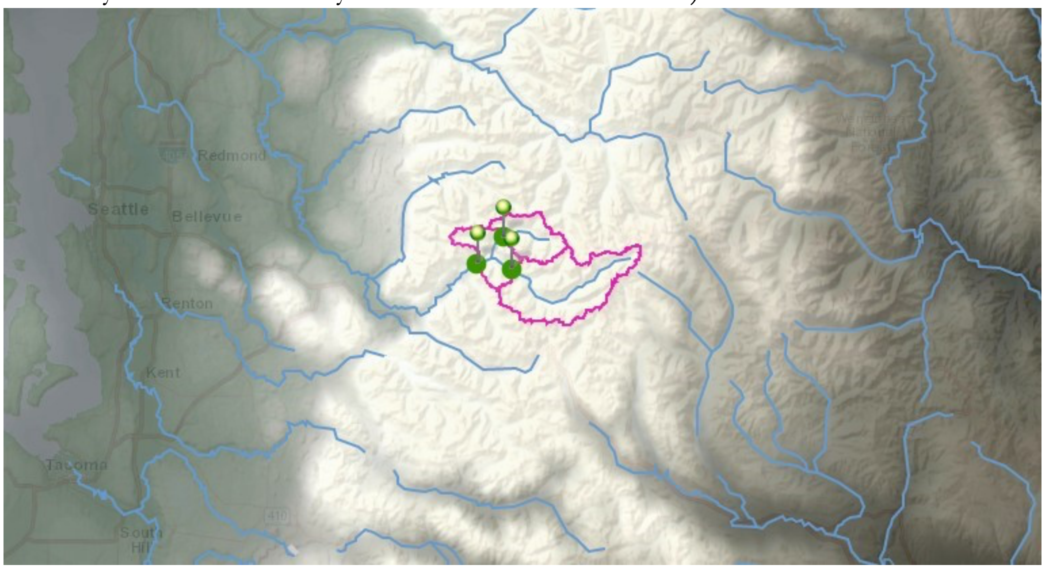


Figure 20. Watershed and rainfall

32. Save your map as "SSCI265 Lab 2 Watersheds and Water Resources". You can view your saved content, such as maps and map layers, on the Content page of ArcGIS.com. From the Home page, you access this on the top menu (Fig. 21 left), and from the Map, you access it from the Home drop-down menu (Fig. 21 right).

Figure 21. Accessing your saved content from the Home page (L) and from the Map (R).

LAB REPORT

Open a blank Word document and answer the following four questions (each question is equivalent to 1% of the total course credit and in total this lab is worth 4%). Your report will be graded on accuracy, thoroughness, and effort. Your name and lab meeting time should be on the first page, and in the header of your lab report. Make it clear which question you are answering by numbering it on the left hand side. When you have completed the lab report, upload it to the class Blackboard site.

Due date: 11:59 p.m. the day before your next lab session. Your name and lab meeting time should be in the header of your lab report.

1. Based on what you have observed in Step 7, use your own words to describe the relationship between elevation and the characteristics of a river system (direction, structure, origin, and destination). Take the example of one of the four longest rivers in the world, namely the Nile, Amazon, Yangtze, or Mississippi Rivers. Insert screenshots as support and refer to them in your answer. (1 paragraph)

2. In your own words, define what a watershed is.
   Describe what the "Create Watershed" tool does **in ArcGIS** and what the watershed polygons you created represent.
   What is the difference between the watersheds shown in the USDA map and the polygons that you created? (1 paragraph)

3. What is the relationship between the three watersheds you created? If the smallest watershed gets polluted, does that mean all of them will suffer the same pollution? Why or why not? Include a screenshot of your three watershed polygons. (1 paragraph)

Remember: Water can only flow downhill!

4. Insert a screenshot of rainfall across your watersheds from Step 31.
   Describe the pattern of rainfall amount in your watersheds. Relate this to what you've learned about precipitation in previous lectures (The Global Water Cycle lecture).
   Explain the reasons behind your observed pattern.
   Imagine you are assigned to protect the water resources in your watersheds.
   Considering the mean evapotranspiration value you calculated in step 27 and the rainfall amount in that area, what steps might you take and why? Will you take the same strategy for all your watersheds and why?
   (1-2 paragraphs, insert screenshots if needed)

Think: Why is there rain on one side of the mountains but not the other?

REFERENCES

[1] Digital Elevation Models https://learn.arcgis.com/en/related-concepts/digitalelevationmodels.htm

[2] Li, Z., Zhu, Q. and Gold, C. (2005): title=Digital terrain modeling: principles and methodology|. CRC Press. Boca Raton.

[3] The USGS Water Science School https://water.usgs.gov/edu/watershed.html

[4] Mississippi River Facts https://www.nps.gov/miss/riverfacts.htm