Environmental Geology Lab 1 – The Hydrologic Cycle

All water on our planet resides in temporary storage areas called reservoirs. The largest reservoir for water is the oceans, but considerable water is present in the atmosphere (as gaseous water vapor), on land (in lakes, rivers and glacial ice) and under the ground (as groundwater). Reservoirs are considered temporary storage facilities because water is constantly being transferred between them. The Hydrologic Cycle is an attempt by geologists to quantify the exchange of water between the various reservoirs. In its simplest description, the Hydrologic Cycle represents a balance between atmospheric precipitation (as rain, sleet, snow... etc.) and all of the reservoirs that receive this precipitation. A basic equation may be written that summarizes this description.

(1) $$P = ET + Q + I$$

where:

P = the amount of atmospheric precipitation available
ET = loss of precipitation through evaporation (heat from the sun) combined with transpiration; evaporation from the leaves of plants as they utilize the water as part of their metabolic cycle (commonly referred to as evapotranspiration)
Q = discharge; a measure of the amount of surface runoff that flows through rivers and streams
I = infiltration; water that penetrates the ground and may become groundwater.

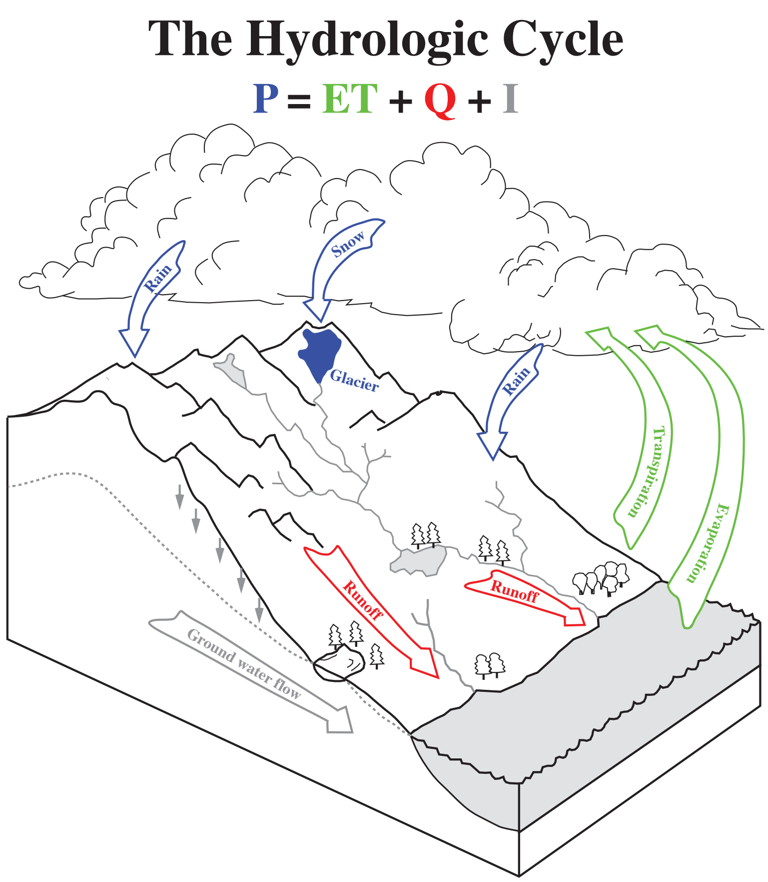


Figure 1. Shows the components of the hydrologic cycle.

QUESTIONS:

1. Do you think that the rate of infiltration (I) will be significant in south Texas? If the infiltration term (I) is negligible then simplify equation 1 below.

$$P = ET + Q + I$$

2. Compare the magnitude of ET versus Q in this region. In general, which term do you think will be larger? Circle the correct answer (greater than or less than).
   Hint: is it common for there to be running water in the streams present in this region?

$$ET \quad > \text{ or } < \quad Q$$

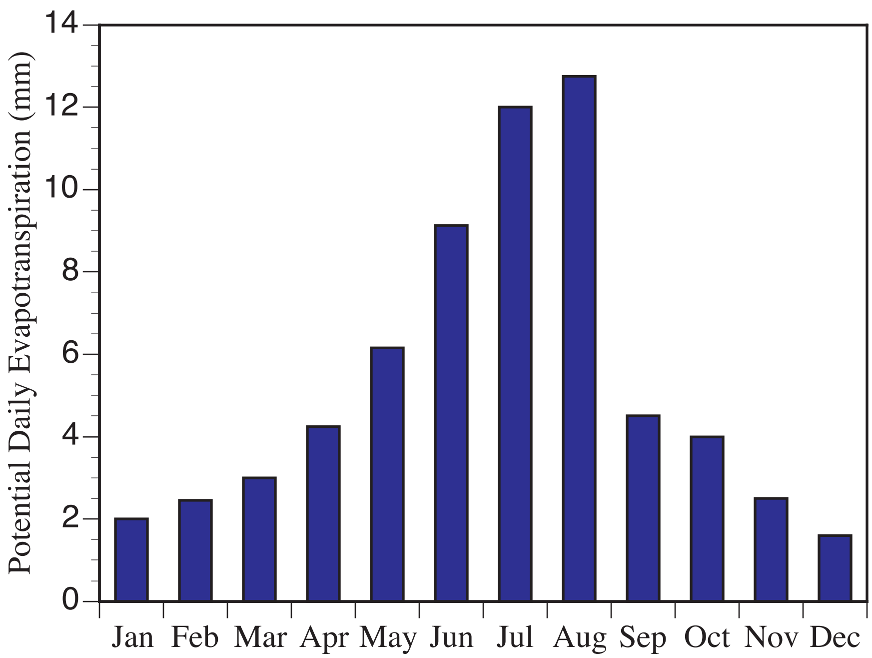


Figure 2. Histogram plotting the average daily PET for each month of the year 2001 from the Texas A&M Agricultural Experiment Station at Uvalde, Texas

NOTE: THIS FIGURE IS REPRESENTATIVE OF PET VALUES IN SOUTH TEXAS!

We must consider the difference between the potential evapotranspiration (PET), which is plotted on Figure 2, and the actual evapotranspiration (ET). Commonly the actual evapotranspiration is much less than the potential evapotranspiration because it is based on having an infinite quantity of water that can be evaporated; certainly not the case in South Texas. There are some simple equations that relate PET with ET.

If **P is greater than PET (P > PET)**, which is true on those rare extremely wet days, the following is true

(2) PET = ET and the excess precipitation becomes runoff (Q) as calculated using **equation 3 below**

(3) Q = P - PET

NOTE: THAT THE ABOVE SITUATION IS LIKELY TO BE TRUE DURING A DAY WITH A PRECIPITATION EVENT.

If **P is less than PET (P < PET)** than the following is true

(4) PET > ET and precipitation equals evapotranspiration (P = ET) and there is **no runoff (Q = 0)**

QUESTIONS:

3. Look at Figure 2. Which months have the highest PET values? The lowest? Is temperature directly correlated with PET in south Texas? Explain!

   Highest ______________ Lowest ____________________

4. How much PET is there during the month of June in Uvalde in mm?

Daily Evapotranspiration (mm) X # of Days in June = Monthly Evapotranspiration (mm)

___________________________ X 30 = _________________________

5. Over a 1 km^2 area 200 mm of rain fell evenly spread out on each day during the month of June (obvious not realistic but ok for this simple example). Describe the relatiionship between P and PET by circling the correct answer (greater than or less than) below.

   P > or < PET

6. Predict how much discharge (Q) is likely to occur in this area in mm duirng June using the relationships on the top of pg. 3.

7. How much PET is there during the month of October in Uvalde in mm?

Daily Evapotranspiration (mm) X # of Days in Oct = Monthly Evapotranspiration (mm)

________________________ X 31 = ________________________

8. Over a 1 km^2 area 200 mm of rain fell evenly spread out on each day during the month of October. Describe the relatiionship between P and PET by circling the correct answer (greater than or less than) below.

P   > or <   PET

9. Predict how much discharge (Q) is likely to occur in this area in mm duirng October using the relationships on the op of pg. 3.

10. Based on the answers to the previous questions would you agree that the potential for evaporation is less in early summer than fall? Justify your answer.

All the rain that falls in a drainage basin ultimately ends up in the trunk stream for that drainage basin. Drainage basins have an irregular shape as defined by the drainage divide (Figure 3). Within a drainage basin many streams flow (Figure 3). These streams ultimately flow downhill into a main (trunk) stream that eventually exits the drainage basin at the mouth One can conveniently measure the discharge (Q) within the entire drainage basin by placing a discharge meter at the mouth in the trunk stream where the water leaves the drainage basin.

As defined earlier in the lab precipitation is the transfer of water from the atmosphere to the earth's surface. There are several types of precipitation depending the state of water of the precipitation when it hits the surface.

Liquid Precipitation
Rain – High intensity liquid precipitation
Drizzle – Low intensity liquid precipitation

Frozen Precipitation
Snow – Solid precipitation in the form of ice crystals
Sleet - Solid precipitation in the form of rounded ice pellets

Freezing Precipitation
Freezing Rain – Liquid precipitation that freezes once it makes contact with a cold ground surface

There are two fundamental approaches to measuring liquid precipitation including ground-based (rain gauge, Figure 4a) and remotely sensed (weather radar; Figure 4b) measurements. Both of these methods have advantages and disadvantages. Rain gauge measurements tend to be more accurate than weather radar estimates but has a problem in that a rain gauge measures the rainfall only in the area immediately around the gauge.

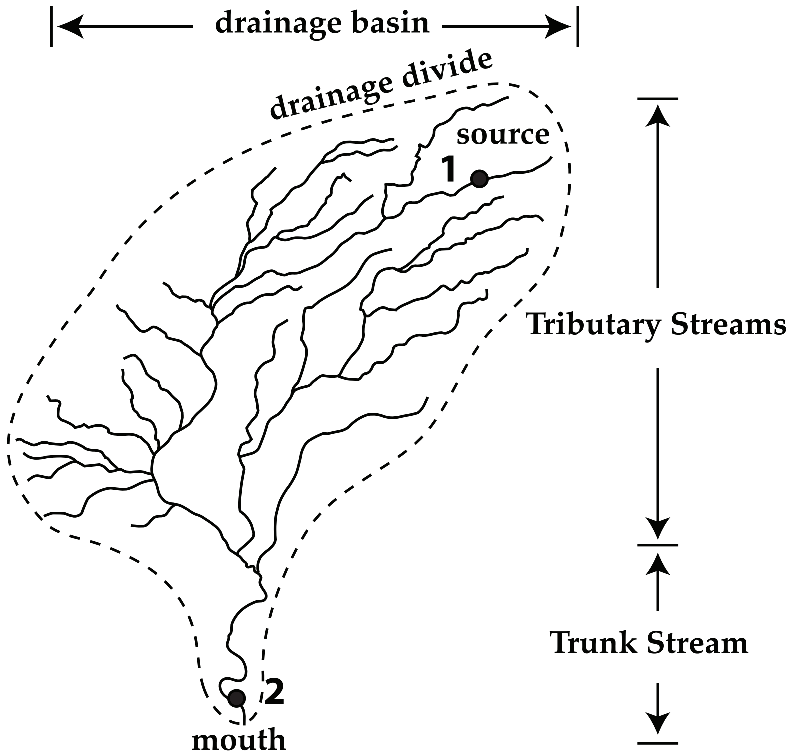
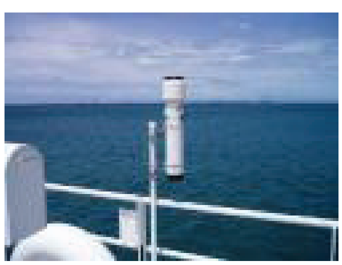


Figure 3. Features within a Drainage Basin

A.



B.

Figure 4. (a) Tipping bucket rain gauge used to measure rainfall on the earth's surface (image from National Weather Service website; http://www.nws.noaa.gov). (b) National Weather Service NEXRAD Type 88 weather radar system surface (image from National Weather Service website; http://www.nosa.noaa.gov.

This can be problematic especially in areas such as South Texas where rainfall is highly localized with situations in which rainfall may be intense in one location but close by there may be no rain. For example, most people have experienced rainfall on one side of the road but not the other side. Weather radars such as the National Weather Service (NWS) NEXRAD Type 88 have the ability to sense rainfall over broad regions, however, provide a less accurate estimate of rainfall. In Laredo, TX the radar estimates precipitation based on activity 10,000 to 12,000 ft above the surface. As precipitation falls it can evaporate (virga) in the dry South Texas air causing radar estimates to overestimate actual rainfall. In other words, it is common for the radar to indicate precipitation when there is no rainfall that reaches the ground.

Parameters like precipitation can be remotely sensed using weather radar within a drainage basin. This weather radar data has a spatial resolution of 1 X 1 km (1 km^2). Therefore, one can quantify precipitation within a drainage basin by dividing the basin into a grid of one square kilometer blocks. Such a simplified drainage basin based on these grids is shown in Figure 5.

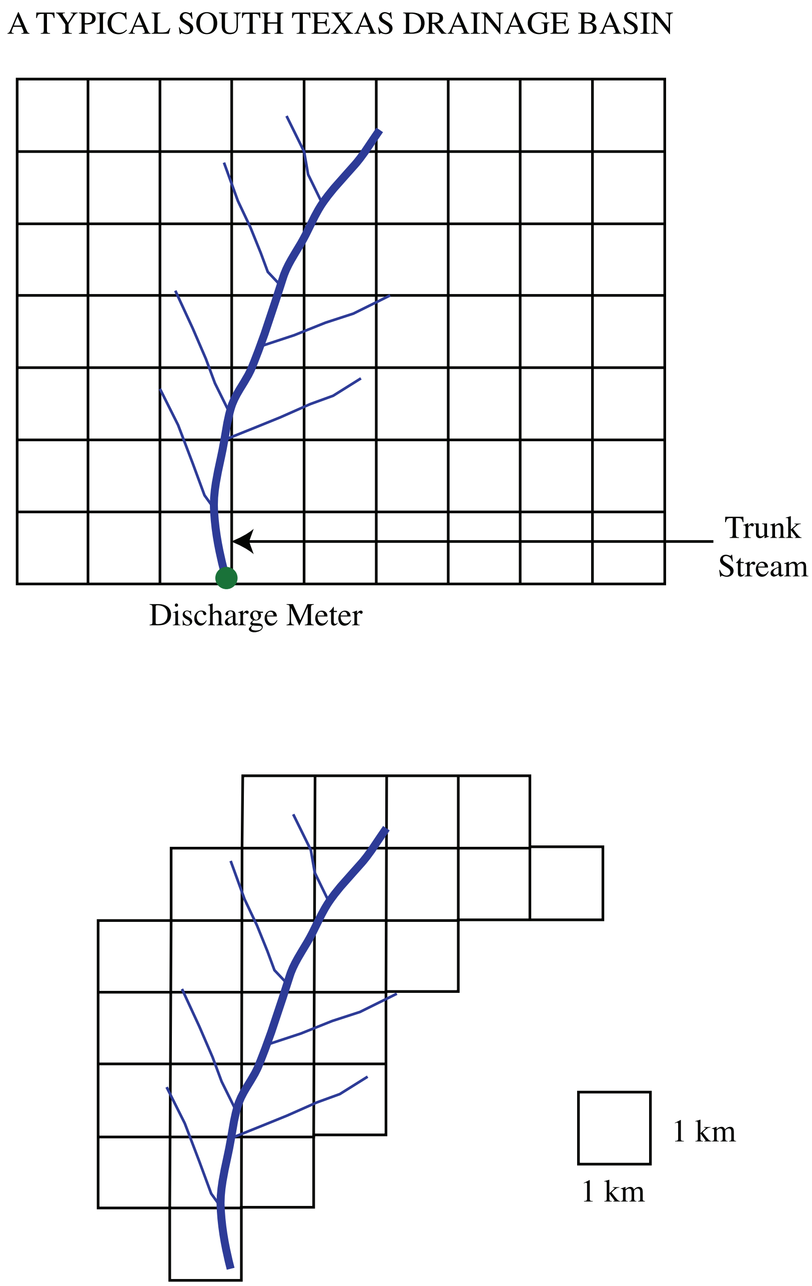


Figure 5. Digitizing a Sample Drainage Basin

QUESTIONS:

11. What is the total area of the basin depicted in Figure 5? Count up the squares in the bottom figure. ____________ km^2

12. How many tributary streams are there that feed water into the trunk stream? (the thinner lines) ________________

13. Consider the result from question 9. Spread discharge over the total area of the basin depicted in Figure 5. Determine how many m^3 is potentially available for discharge.

(a) Convert discharge (Q) value from question 9 from mm to meters

Q (m) = 0.001 X Q (mm) = __________ m

(b) convert answer to question 11 into realizing that 1,000,000 m^2 = 1 km^2

Area (m^2) = 1,000,000 X Area (km^2) = ____________________ m^2

(c) convert Q to a volume measurement (in m^3)

Q (m^3) = Q (m) X Area (m^2) = ____________________ m^3

14. Note that 1 m^3 is equal to 1000 liters. Convert answer from question 13 from m^3 to liters.

Q (liters) = 1,000 X Q (m^3) = ____________________ liters

Bonus: How many 2 liter bottles would this fill!

A TYPICAL SOUTH TEXAS DRAINAGE BASIN:
SOME PRECIPITATION EVENTS

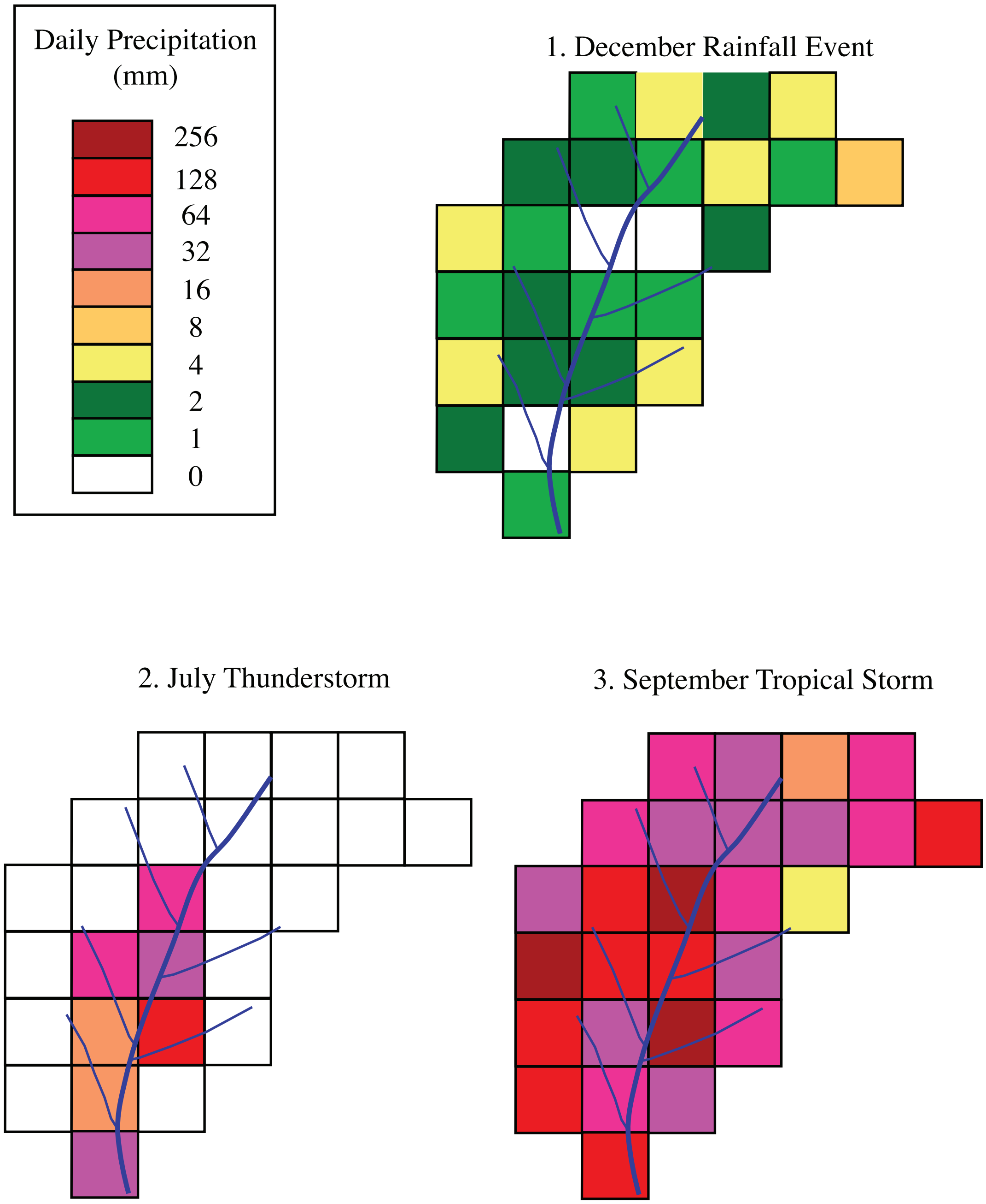


Figure 6. Storm Events and Calculating Discharge. Rainfall represents the total precipitation during one day from each of the three months indicated.

If the rate of PET and the amount of precipitation is known for a given area then this information may be used to calculate how much rainfall is lost during a storm event and how much is available as potential discharge. In this exercise we have chosen a small river drainage basin where the PET is known (using Figure 2) and precipitation data (Figure 6) has been monitored and recorded by weather radar instrumentation. Three types of storm events are considered:

(1) Winter precipitation event:	Widespread; low intensity; associated with stratiform (low-lying) clouds connected with frontal systems; common in winter
(2) Summer convective:	Spatially isolated and small (commonly < 10 km2) high intensity; associated precipitation event with localized episodes of atmospheric instability; common in summer
(3) Tropical storm event:	Widespread; very high intensity; fairly rare; usually in summer and fall

QUESTIONS:

15. Just by visually examining Figure 6 determine which precipitation event (wintertime, summer convective, tropical storm) has the highest intensity rainfall? The lowest intensity?

Highest _____________ Lowest ___________________

16. Which precipitation event is the most geographically isolated? Does this make sense based on the description of rainfall events above? Explain!

17. Determine the average precipitation (P, in mm) for all three events. Sum the precipitation from all grids and divide by 27, the number of grids except for July where you divide by seven (the number of grids that experienced rainfall). Show your work

July

Sept

Dec

18. Determine the daily potential evapotranspiration (PET, in mm) using Figure 2 for all three events. Just carefully read the graph. No calculations are required.

July ______________________ mm

Sept ______________________ mm

Dec ______________________ mm

19. For the three events determine the relationship between P and PET. Circle the correct answers below.

July P > or < PET

Sept P > or < PET

Dec P > or < PET

20. Determine the amount of runoff (in mm) for three events using the relationships on top of page 3. Show your work.

July

Sept

Dec

21. Which precipitation event most likely will cause extensive flooding? Justify your answer.

22. Convert your answers for question 20 as follows.

For Sept Only

(a) Convert discharge (Q) value in mm to meters

Q (m) = 0.001 X Q (mm) = ___________ m

(b) Area is 27,000,000 m^2

(c) convert Q to a volume measurement (in m^3)

Q (m^3) = Q (m^3) X Area (m^2) = ______________________ m^3

Write down runoff value in m^3 for the September event in your notebook for use it in next week's labs.