Stormwater Runoff Assignment

When a property is developed, it is important to understand that changes to watershed characteristics (such as land use, slope, soil type, vegetative cover) will change the amount of storm water runoff from the site. Development typically increases runoff and negatively affects water quality, which may impact downstream property owners and the environment as site storm water flows into drainage swales, ponds, creeks, or rivers.

Several different methods are used by civil engineers to assess the hydrology of a site. In this activity, you will calculate peak runoff using the *rational* method.

Part 1: Pre-development Runoff

Calculate the site runoff prior to the construction of a parking lot.
The rainfall intensity can be determined using the Point Precipitation Frequency Estimates chart for Nashville (included in this activity).

i = 2.17 in. (see Point Precipitation Frequency Estimates chart)
A = 3 acres
C = 0.18 (average Rational Runoff Coefficient for farmland, see chart)
$C_f = 1.0$
$Q = C_f CiA = (1.0)\ (0.18)\ (2.17\ in./hr)\ (3\ ac) = 1.2\ cfs$

Part 2: Post-development Runoff

Calculate the site runoff after construction of the impermeable, asphalt parking lot.

i = 2.17 in. (see Rainfall Intensity map or Precipitation Intensity Estimates table)
A_1 = 30,000 sq ft or 0.69 acres (parking lot)
A_2 = 3 acres − 0.69 acres = 2.31 acres (farmland minus parking lot)
C_1 = 0.95 (conservative coefficient for parking lot, see chart)
C_2 = 0.18 (average coefficient for farmland, see chart)
A composite runoff coefficient (C_c) must be calculated that reflects the post-development watershed characteristics before calculating the peak runoff when the parking lot is added to the farmland.
Use the composite runoff coefficient in the rational formula to determine the runoff when the parking lot is added to the farmland.
$Q = C_f CiA = (1.0)\ (0.36)\ (2.17\ in./hr)\ (3\ ac) = 2.3\ cfs$

Part 3: Change in Runoff

As a result of paving over 30,000 square feet (23 percent of the property area) of previously permeable farmland, the peak runoff has increased from approximately 1.2 cfs to 2.3 cfs (nearly double) for a total increase of 1.1 cfs.

The engineer uses this information to create a storm water management plan for the site.

Note that the rainfall (precipitation) intensity is unique for each location. So, you can not confidently use the chart for Nashville to determine the rainfall intensity for other locations. To obtain a Precipitation Intensity Table for locations within the United States, visit the Hydrometeorological Design Studies Center Precipitation Frequency Data Server.

(LINK: https://hdsc.nws.noaa.gov/hdsc/pfds/index.html)

Choose the applicable state. Then choose **Precipitation Intensity** as the Data Type and **Partial Duration** for the Time series type. Next, select the Location and click **Submit**. The Point Precipitation Frequency Estimates for Nashville follow.

Rational Method Runoff Coefficients	
Categorized by Surface	
Forested	0.059–0.2
Asphalt	0.7–0.95
Porous Asphalt (10%–25% void space)	0.25–0.35
Brick	0.7–0.85
Concrete	0.8–0.95
Shingle roof	0.75–0.95
Lawns, well-drained (sandy soil)	
Up to 2% slope	0.05–0.1
2% to 7% slope	0.10–0.15
Over 7% slope	0.15–0.2
Lawns, poor drainage (clay soil)	
Up to 2% slope	0.13–0.17
2% to 7% slope	0.18–0.22
Over 7% slope	0.25–0.35
Driveways, walkways	0.75–0.85
Categorized by Use	
Farmland	0.05–0.3
Pasture	0.05–0.3
Unimproved	0.1–0.3
Parks	0.1–0.25
Cemeteries	0.1–0.25
Railroad yard	0.2–0.40
Playgrounds (except asphalt or concrete)	0.2–0.35
Business Districts	
Neighborhood	0.5–0.7
City (downtown)	0.7–0.95
Residential	
Single-family	0.3–0.5
Multiplexes, detached	0.4–0.6
Multiplexes, attached	0.6–0.75
Suburban	0.25–0.4
Apartments, condominiums	0.5–0.7
Industrial	
Light	0.5–0.8
Heavy	0.6–0.9

Lindeburg, M. R. (1994). *Civil engineering reference manual* (9th ed.). Belmont, CA: Professional Publications, Inc.

Runoff Coefficient Adjustment Factor

Return Period	C_f
1, 2, 5, 10	1.0
25	1.1
50	1.2
100	1.25

Use the rational formula to calculate the answers to each of the following. Show all of your work. Use the rational formula to calculate the change in runoff for each of the following developed sites.

1. What is the change in storm water runoff for a 1.5-acre site near Chicago University in Chicago, IL, that was forested before construction? A 50-ft × 35-ft coffee shop with a 100-ft × 120-ft parking lot was built on the site. The remainder of the site was planted with lawn in well-drained, sandy soil that has a slope of over 7 percent. The design storm is a 25-yr, 1-hr storm. Use average runoff coefficients for forested land and the post-development lawn, but use **conservative values** for the post-development roof and parking lot runoff coefficients. Remember to use the runoff coefficient adjustment factor for a recurrence interval greater than 10 years.
   Note: To estimate the precipitation intensity, use the Hydrometeorological Design Studies Center Precipitation Frequency Data Server (linked earlier in this activity). Be sure to select Precipitation Intensity under Data Type—the default selection will produce the wrong chart. Conversion factor: 1 acre = 43,560 ft^2.

2. What is the estimated change in storm water runoff for the Affordable Home site in Noblesville, IN, using a 100-yr, 1-hr design storm? Assume that the existing site is flat with clay soil and unimproved with a runoff coefficient of C = 0.2.

   When calculating post-development runoff for each of the following options, use the most conservative values (resulting in the greatest volume of storm water runoff) for runoff coefficients. Use your current site plan as a basis for your calculations.
   - Option 1: No storm water management
     - The roof is covered with asphalt shingles.
     - The driveway and sidewalks (and patio, if included) have a concrete surface.
     - The remainder of the site is planted with turf grass (no additional landscaping or plant material).
   - Option 2: Low-impact Affordable Home site design
     - The rainwater from the roof is captured in rain barrels or a cistern (and therefore is not included in the post-development storm water volume) and used for watering the lawn and landscaping.
     - The driveway and sidewalks (and patio, if included) are constructed from permeable pavers.
     - 50 percent of the turf area in Option 1 is instead planted with native plant material.
3. What size water storage tank would you recommend to collect the volume of water that would fall during the 24 hours of a 2-yr, 24-hr storm on the Affordable Home? How would you install sufficient water storage?

   Answer the following questions in your engineering notebook:

   1. What impact does adding an asphalt parking lot have on the site runoff on a farm?
   2. How can you limit the downstream negative effects of storm water runoff?
   3. How could you revise your Affordable Home site plan based on what you have learned about storm water runoff? Explain how the change will improve your design.