such as HEC-1 Flood Hydrograph ... (HEC 1998), HEC-RAS to simulate flood plain hydraulics (HEC, 1995), the EPA SWMM (Huber and Dickinson, 1988), and the SCS TR-20 (SCS, 1984). They simulate single storm responses for a given rainfall and watershed data. UH methods are used to generate storm hydrograp... which are routed within stream channels (see Chapter 7). All o... models are now available for WINDOWS and come with a ni... graphical interface. Excellent reviews of models in hydrolo... published, including Kibler (1982), Stephenson and Mea... Maidment (1993), DeVries and Hromadka (1993), Hoggan ... and James (1998), and McCuen (1998). One of the best intro...ons to HEC-HMS and HEC-RAS with illustrative application examples is given in Bedient and Huber (2002).

With the advent of Geographic Information Systems (GIS), the availability of digital terrain data has been added to several hydrologic simulation models. The lack of extensive data to field validate the output from complex simulation models has resulted in skepticism. The prevailing view now is to select the simplest simulation model that would satisfy the project objectives. Our approach in this book has been to provide the reader with the fundamental understanding and basic tools to develop his or her own small model. If the use of a specialized model is required, the literature cited in this section may be useful.

PROBLEMS

6.1 Go to the USGS site (http://water.usgs.gov), choose surface water data, select a streamflow station, choose tab-delimited data as an option, and display on your browser the daily streamflow in ft^3/s for the last year. Highlight a portion of the data, copy it, paste it in Notepad, and save it as a text file. Modify the Maple program in Example 6.1 to read the data, fit it to a smooth function and plot the hydrograph. Calculate the total annual water yield in ft^3.

Table 6.10: Rainfall and Runoff Data for Problem 6.3

t (hour)	p (mm/hour)	Q (m^3/s)
7		4.24
8		4.01
9	0.0	3.78
10	10.0	3.55
11	17.0	6.70
12	15.0	11.85
13	8.0	15.10
14	0.0	12.40
15		9.80
16		8.00
17		6.80
18		5.90
19		5.12
20		4.68
21		4.32
22		4.02
23		3.76
24		3.54

6.2 Modify the program in problem 6.1 to enter time versus flow rate coordinates $[[t_1, Q_{g1}], [t_2, Q_{g2}],...]$ that define the groundwater hydrograph, fit them to a smooth curve, and plot it with the total hydrograph. Calculate the total groundwater flow volume for the year in ft^3. Write your observations on the relative importance of overland flow subsurface flow and groundwater flow in the watershed.

6.3 A watershed has a drainage area of 15 km^2. In May, 2009, a storm produced the rainfall-time distribution and the streamflow rate distribution given by Table 6.10. (1) Assuming that equation (6.4) is valid, find the inflection points on the recession limb of the hydrograph. (2) Calculate the groundwater recession constant, k. (3) Plot the streamflow hydrograph and locate the first and last inflection points.

[illegible]	4.68
21	4.32
22	4.02
23	3.76
24	3.54

6.2 Modify the program in problem 6.1 to enter time versus flow rate coordinates $[[t_1, Q_{g1}], [t_2, Q_{g2}],...]$ that define the groundwater hydrograph, fit them to a smooth curve, and plot it with the total hydrograph. Calculate the total groundwater flow volume for the year in ft^3. Write your observations on the relative importance of overland flow subsurface flow and groundwater flow in the watershed.

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6.4 In problem 6.3, (1) calculate the SRV (m^3), and (2) the effective precipitation depth (mm).

6.5 In problem 6.3, (1) calculate the watershed-wide infiltration depth due to the storm. (2) Assuming that all infiltration became groundwater recharge, and an average specific yield of 0.35, estimate the mean increase in water table elevation due to the storm.

Table 6.11: Streamflow Data for Problem 6.6

t (*hour*)	Q (m^3/s)
9	13.7
10	12.5
11	11.2
12	50.0
13	120.0
14	156.0
15	172.0
16	144.0
17	125.0
18	107.0
19	88.0
20	68.0
21	55.0
22	41.0
23	28.0
24	20.0
1	12.0
2	6.5
3	6.0

6.6 The streamflow hydrograph of Table 6.11. was produced by a rainfall of an unknown intensity that lasted for a period of three hours. If the Watershed area is 250 km^2, (1) the effective precipitation depth in *mm*, and (2) derive the 3-*hour* UH. Assume that the last inflection point occurs at t_2=24*hour*

6.7 Assume that the streamflow data given in Example 6.6 (Table 6.3) was actually produced by a rainfall intensity of 7.5*mm/hour* la... five hours. Assume the same m=5.5...

1	12.0
2	6.5
3	6.0

6.6 The streamflow hydrograph of Table 6.11. was produced by a rainfall of an unknown intensity that lasted for a period of three hours. If the Watershed area is 250 km^2, (1) the effective precipitation depth in *mm*, and (2) derive the 3-*hour* UH. Assume that the last inflection point occurs at t_2=24*hour*

6.7 Assume that the streamflow data given in Example 6.6 (Table 6.3) was actually produced by a rainfall intensity of 7.5*mm/hour* lasting for the same five hours. Assume the same φ=5.5*mm/hour* index and that the last inflection point is at t_2=75*hour*. Derive the 5-*hour* UH.

6.8 Change the 2-*hour* UH of Example 6.5 (Table 6.2) into a 6-*hour* UH.

6.9 Change the 5-*hour* UH of Example 6.6 (Table 6.3) into a 15-*hour* UH

6.10 Modify the program in Example 6.8 to produce a 15-*min* (0.25-*hour*) UH using the S-hydrograph method.

6.11 Modify the program in Example 6.8 to produce a 2-*hour* UH using the S-hydrograph method. Hint: now $nt_s > t_s$ and the 2-*hour* UH time base is greater than the original 1-*hour* UH. The corresponding "if" statements in the calculation of the new time base must be changed.

6.12 Using the UH of Example 6.6, Table 6.3, predict the total streamflow rate at the same watershed due to the following storm: at 3:00 PM it started to rain with an intensity of 8*mm/hour*; it continued raining with the same intensity until at 8:00 PM it abruptly increased to 20*mm/hour*; it continued raining with the same intensity until it abruptly ended at 1:00 AM of the following day. Then at 6:00 AM started to rain again with an intensity of 16*mm/hour*; it continued raining with the same intensity until it ended at 11:00 AM. Assume a φ index of 2*mm/hour* and a nominal groundwater flow rate of $1.8 m^3/s$.