53:078 Principles of Hydrology
Exam 2
Spring 2004

Name: KEY

Equations and constants you may (or may not) find useful:

$$f^* = \phi \qquad P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

$$I_a = 0.2S \qquad S = \frac{1000}{CN} - 10$$

$$Q(t) = Q(t_0)K^{(t-t_0)} \qquad V_d = Ar_d$$

$$t_l = 0.6t_c \qquad T_p = \frac{t_r}{2} + t_l$$

$$Q_p = \frac{CA}{T_p} \qquad R_{k+1} = \alpha R_k + \frac{(1+\alpha)}{2}(Q_{k+1} - Q_k)$$

$$F(x) = \exp\left[-\exp\left(-\frac{x-b}{a}\right)\right] \qquad q(p) = b - a\ln(-\ln(1-p))$$

$$a = \frac{\sqrt{6}\sigma}{\pi} \qquad b = \mu - 0.5772a$$

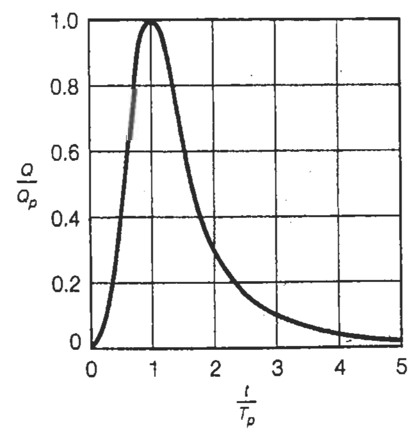
$$y = -\ln(-\ln(1-p)) \qquad P(X \ge x_m) = \frac{m}{N+1}$$

$$T = \frac{1}{p}$$

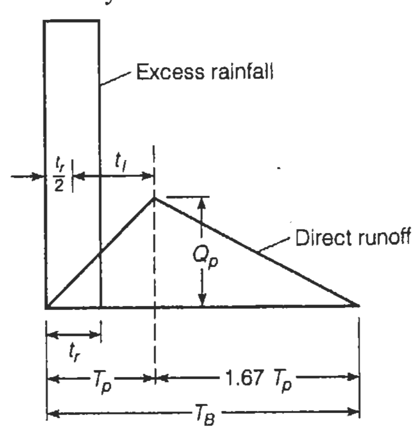
1 in = 25.4 mm　　1 ft = 12 in

1 mi² = 640 ac　　1 acre = 43560 ft²

1 hr = 3600 s　　1 day = 86400 s



(a) Dimensionless Unit Hydrograph



(b) Triangular Unit Hydrograph

(25) 1. Miscellaneous

6 a) The SCS runoff curve number (CN) is determined based on the following three factors:

land use/land cover

hydrologic soil group

antecedent moisture condition

5 b) The baseflow today is 50 cfs. The baseflow one week ago was 67 cfs. Assuming this baseflow-only period continues, the estimated baseflow one week from today is 37.3 cfs.

$Q(t) = Q(t_0)K^{(t-t_0)}$

$50 = 67K^7$

$\therefore K^7 = \frac{50}{67}$

In one week

$Q(7) = 50K^7$

$= 50(50/67)$

$= 37.3$

c) List three (unique) properties of a unit hydrograph:

P_e is 1 unit (in or cm)

$P_e = 1 = i_e t_r$

r_d is 1 unit ($P_e = r_d$)

$V_d = Ar_d = A(1 \text{ unit})$

d) Define the time of concentration (t_c):

travel time from the farthest point (hydraulically) to the basin outlet

e) List the two assumptions made in flood frequency analysis:

Independence – flood data are a random sample

Stationarity – flood distribution does not change with time

(25) 2. Streamflow Prediction

Predict the direct runoff hydrograph for the Mays Creek watershed (1.16 mi^2). The storm rainfall (P) and the 2-hour unit hydrograph for the watershed are shown below. The SCS curve number (CN) for the watershed at the time of the storm is 80.

Time (hours)	P (inch)	ΣP (in)	ΣP_e (in)	P_e (in)
0		0	0	
	0.2			0
2		0.2	0	
	2.6			1.1
4		2.8	1.1	
	1.4			1.1
6		4.2	2.2	

Time (hours)	2-hour UH (cfs)
0	0
1	150
2	300
3	200
4	100
5	0

Use this information to determine the following:

22 a) The direct runoff hydrograph (in cfs). *CLEARLY INDICATE YOUR ANSWER.*

b) The peak discharge of the direct runoff hydrograph is <u>440</u> cfs at time <u>6</u> hour.

Use SCS method:

$$S = \frac{1000}{CN} - 10 = \frac{1000}{80} - 10 = 2.5^{in}$$

$$I_a = 0.2S = 0.2(2.5^{in}) = 0.5^{in}$$

$$\therefore P_e = \frac{(P-I_a)^2}{P-I_a+S} = \frac{(P-0.5)^2}{P-0.5+2.5} = \frac{(P-0.5)^2}{P+2}, \quad P \geq I_a$$

@ $t = 2\text{hr} \quad P = 0.2 < I_a \rightarrow P_e = 0$

@ $t = 4\text{hr} \quad P = 2.8, \quad P_e = \frac{(2.8-0.5)^2}{2.8+2} = 1.10^{in}$

@ $t = 6^{hr} \quad P = 4.2, \quad P_e = \frac{(4.2-0.5)^2}{4.2+2} = 2.21^{in} \sim 2.2^{in}$

Need 2-hr UH:

t	2-hr UH (cfs)	1.1× UH DRH_1	1.1× UH DRH_2	(a) ΣDRH
0	0	--	--	--
1	150	--	--	--
2	300	0	--	0
3	200	165	--	165
4	100	330	0	330
5	0	220	165	385
6		110	330	440 ← Q_p @ $t = 6^{hr}$
7		0	220	220
8			110	110
9			0	0

(25) 3. Hydrograph Analysis

Shown below are the storm rainfall (P) and resulting streamflow (Q) for a flood event on a 12.4 mi^2 watershed.

Time (hour)	P (in)	Q (cfs)	Q_b (cfs)	DRH (cfs)	i (in/hr)
0		300	300	--	
	0.60				0.20
3		300		0	
	2.16				0.72
6		1200		900	
	1.89				0.63
9		1500		1200	
	1.11				0.37
12		1200		900	
15		900		600	
18		300		0	
21		300	300	--	

Σ 3600 cfs

Use hydrograph analysis techniques, with the horizontal line method for baseflow separation, to answer the following:

11 a) The depth of direct runoff (r_d) is 1.35 inches.

b) The rainfall excess (P_e) hyetograph (in inches). *CLEARLY INDICATE YOUR ANSWER.*

3 **c) The effective duration (t_r) is** 6 hours.

a) $V_d = (\Sigma DRH)\Delta t = (3600 \text{ cfs})(3 \text{ hr}) = 10{,}800 \text{ cfs-hr}$

$$r_d = \frac{V_d}{A} = \frac{10{,}800 \frac{ft^3}{s} \cdot hr\,(3600 s/hr)(12 in/ft)}{12.4(640)(43560 ft^2)} = 1.35 \text{ in}$$

b) Assume $\phi > 0.63$, then

$r_d = 1.35 = (0.72 - \phi)(3)$

$\phi = 0.72 - \left(\frac{1.35}{3}\right) = 0.27 \text{ in/hr} < 0.63 \text{ in/hr}$ (Not ok)

Assume $0.37 \le \phi \le 0.63 \text{ in/hr}$, then

$r_d = 1.35 \text{ in} = (0.72 - \phi)(3) + (0.63 - \phi)(3)$

$2\phi = 0.72 + 0.63 - \left(\frac{1.35}{3}\right) = 0.90$

$\phi = 0.45 \text{ in/hr}$ [OK]

$i_e = i - \phi \qquad i > \phi$

Hence,

t	i (in/hr)	i_e (in/hr)	(b) P_e (in)
0			
	0.20	--	0
3			
	0.72	0.27	0.81
6			
	0.63	0.18	0.54
9			
	0.37	--	0
12			

Σ 1.35 ✓

6-hr

(25) 4. Flood Frequency Analysis Using Sample Data

Recent record flooding on the Big Bad River has motivated the town of Burgeville to consider building a flood levee. A nearby streamgage on the river has a 60-year record. The ranked sample of annual maximum peak discharges and the sample moments are:

Rank	Peak Discharge (cfs)
1	5850
2	4120
3	4000
..	..
..	..
58	410
59	390
60	200

↑ flood

$\bar{x} = 1704$ cfs

$\hat{\sigma} = 1112$ cfs

$$\hat{a} = \frac{\sqrt{6}}{\pi}\hat{\sigma} = \frac{\sqrt{6}}{\pi}(1112)$$

$$= 867.0 \text{ cfs}$$

$$\hat{b} = \bar{x} - 0.5772\hat{a}$$

$$= 1704 - 0.5772(867)$$

$$= 1203.6 \text{ cfs}$$

a) Assume that a peak discharge of 4000 cfs or greater is a *damaging flood event*. The estimated return period for a damaging flood is 25.7 years based on a fitted EV1 distribution (parametric method) and 20.3 years based on its plotting position (nonparametric method).

b) The city decides to build a flood levee for a design life of 30 years. The *risk of failure* that they are willing to accept during the design life is 1 chance in 5 (or 0.20). The city should design the levee for a ______________ -year return period flood, which has an estimated discharge of ______________ cfs based on a fitted EV1 distribution.

a) Parametric

$$\hat{p} = P\{X \geq 4000\} = 1 - P\{X < 4000\} = 1 - \hat{F}(4000)$$

$$= 1 - \exp\left[-\exp\left(-\left\{\frac{4000 - 1203.6}{867.0}\right\}\right)\right]$$

$$= 1 - 0.96104 = 0.03896$$

$$\hat{T} = 1/\hat{p} = 1/0.03896 = 25.7 \text{ yr}$$

Nonparametric

$$\hat{p} = P(X \geq x_{(m)}) = \frac{m}{N+1} \qquad \hat{T} = \frac{N+1}{m} = \frac{60+1}{3} = 20.3 \text{ yr}$$

b) $R = 1-(1-p)^m$

$1-R = (1-p)^m$

$(1-R)^{1/m} = 1-p$

$p = 1-(1-R)^{1/m} = 1-(1-0.20)^{1/30}$

$= 0.00741$

$T = 1/p = 1/0.00741 = 134.9 \text{ yr}$

$\hat{q}(p) = 1203.6 - 867 \ln(-\ln(1-0.00741))$

$= 5453 \text{ cfs}$