Utah State University
Department of Civil and Environmental Engineering
CEE 6400 Physical Hydrology

Final exam.	Date: 12/9/2013
D.G. Tarboton	Time: 110 min
	[100 points total]

Open Book. Answer all questions. **Please answer on separate sheets of paper**. You may refer to the textbook, notes, solutions to homework and any other written, printed or online reference material.

Calculator/Computer use. You may use a programmable calculator or computer. You should limit the use of the calculating device to the performance of calculations or examination of reference material. You may use spreadsheet or other appropriate programs for calculations, but should write your answers down on paper to hand in. For full or partial credit show your work. I need to see how you got your answer as well as the answer. You may not send messages using the computer or communicate in any way with anyone other than the instructor. Email and messaging programs (Facebook, instant messaging etc.) should be turned off for the duration of the exam. If one of these programs is open during the exam it may be grounds for disqualification.

Open Book. Answer all questions. **Please answer on separate sheets of paper**. You may refer to the textbook, notes, solutions to homeworks and any other written or printed reference material that you have brought with you.

Calculator and computer use. You may use a programmable calculator, portable computer or equivalent calculating device (e.g. calculator functionality on a phone). You should limit the use of the calculating device to the performance of calculations or reference to material provided for this class. You may use spreadsheets or programs that you have written to evaluate quantities commonly used in this class (e.g. saturation vapor pressure).

You may not send messages or use the internet to communicate in any way with anyone other than the instructor or moderator regarding solutions to these questions.

1. **Unit Hydrographs.** The six hour unit hydrograph of a watershed is given below. Consider a storm having excess rainfall of 2 cm for the first six hours and 3 cm for the second six hours. This watershed drains into a detention basin that has an area of 10 km^2.

Time (h)	Unit Hydrograph (m^3/s/cm)
0	0
6	1.8
12	30.9
18	85.6
24	41.8
30	14.6
36	5.5
42	1.8
48	0
Sum	182

a) Determine the drainage area (km^2) [10]

b) Determine the peak direct runoff flow rate (m^3/s) [10]

c) Assuming that during the storm there is no outflow from the detention basis determine the change in depth of water in the detention basin (m). [10]

[30 points]

2. In homework 8 you worked with the SOLARRAD spreadsheet. Following is an image of SOLARRAD at a location at 37 °N for June 23.

TOTAL DAILY GLOBAL CLEAR-SKY RADIATION					SolarRad.xls		
ON HORIZONTAL AND SLOPING SURFACES					S.L. Dingman		
See Appendix E for symbol definitions and equations.					*Physical Hydrology*, 2nd Ed.		
		MJ/m^2 hr	MJ/m^2 day	W/m^2	cal/cm^2day		
	Solar Constant (*Isc*) =	4.921	118.1	1367	2821		
		Input data		**Computed values**			
Site:		Location:	-				
		Latitude, *Λ*:	37	degrees =	0.6458	radians	
		Slope Azimuth, α	240	degrees =	4.1888	radians	
		Slope Angle, β:	12	degrees =	0.2094	radians	
Day of Year:		Year Day, *J*:	175	====> Date =	23-Jun		
		Declination, δ =	23.442	degrees =	0.4091	radians	
		Optical Air Mass, *Mopt*:	4.50	**From Figure E-4**			
Weather:		Air Temperature, *Ta*:	20.0	C			
		Relative Humidity, *Wa*:	0.50	0 <= *Wa* <= 1			
		Surface Albedo, *a*:	0.30	0 <= *a* <= 1			
		Dust Attenuation, γ*dust*:	0.05	0 <= γ*dust* <= *0.20*			
Parameters:		Day Angle, *Γ* =	2.9953	radians =	171.62	degrees	
		Eccentricity, (*ro*/*r*)^2 =	0.967				
		Vapor Presssure, *ea* =	1.172	kPa			
		Dew Pt, *Td* =	9.3	C			
		Precipitable Water, *Wp* =	2.0	cm			
	τ*sa* =	0.50006164	τ*s* =	0.62839535			
	τ =	0.45006164	γ*s* =	0.42160465			
			NON-POLAR				
		RADIATION ON HORIZONTAL SURFACE					
	Sunrise, *Thr* =	-7.271	hr	Sunset, *Ths* =	7.271	hr	
		Day Length =	14.543	hr			
	Extraterrestrial, *K'ET* =	41.747	MJ/m^2day	=	483.23	W/m^2	
	Direct, *K'dir* =	18.789	MJ/m^2day	=	217.48	W/m^2	
	Diffuse, *K'dif* =	8.800	MJ/m^2day	=	101.87	W/m^2	
	Global, *K'g* =	27.589	MJ/m^2day	=	319.35	W/m^2	
	Backscatter, *K'bs* =	1.745	MJ/m^2day	=	20.20	W/m^2	
	CLEAR SKY, *K'cs* =	29.334	MJ/m^2day	=	339.54	W/m^2	
		RADIATION ON SLOPING SURFACE					
		Longitude Difference, *ΔΩ* =	-0.21024805	radians =	-12.0463257	degrees	
		Equivalent Latitude, *Λeq* =	0.530124888	radians =	30.37391869	degrees	
	Sunrise, *Thr* =	-6.178	hr	Sunset, *Ths* =	7.271	hr	
		Day Length =	13.450	hr			
	Extraterrestrial, *K'ET* =	41.073	MJ/m^2day	=	475.42	W/m^2	
	Direct, *K'dir* =	18.485	MJ/m^2day	=	213.97	W/m^2	
	Diffuse, *K'dif* =	8.658	MJ/m^2day	=	100.22	W/m^2	
	Global, *K'g* =	27.144	MJ/m^2day	=	314.19	W/m^2	
	Backscatter, *K'bs* =	1.717	MJ/m^2day	=	19.87	W/m^2	
	CLEAR SKY, *K'cs* =	28.860	MJ/m^2day	=	334.06	W/m^2	

a) Report the time of sunrise and time of sunset at this location according to our commonly used am/pm representation of time (e.g. 6:30 am). [5]

b) Draw a diagram that depicts the magnitude and direction of the topographic slope at this location. [5]

c) Calculate the intensity of solar radiation on this sloping surface at noon (W/m^2). [10]

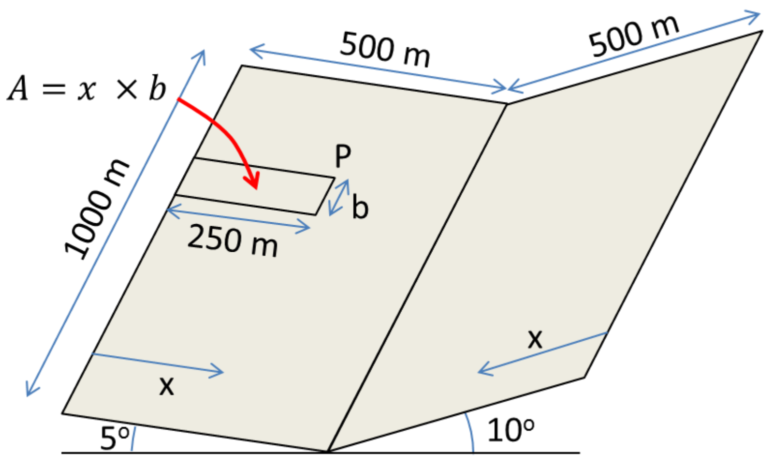
d) This location is at an elevation where the atmospheric pressure is P=95 kPa. Determine the daily total potential evaporation (mm/day) using the Priestly Taylor equation for (i) a horizontal surface at this location and (ii) a sloping surface at this location with slope as given in the spreadsheet above. Report your answers in mm/day. [10]

e) Determine the instantaneous potential evaporation rate (mm/day) at noon on the sloping surface using the Priestly-Taylor equation. [5]

f) Explain the differences between the potential evaporation rates calculated in (d) and (e) above. [5]

[40 points]

3. **TOPMODEL.** Consider an idealized rectangular watershed as shown. (Note: This is an obvious idealization, but you do not want to do a final exam with real topography.). In this diagram flow is from the edges in towards the middle along the direction of the arrows indicated x.



The watershed has the following properties

Surface Hydraulic Conductivity $K_o = 0.5$ m/hr	Area = 1 km^2
Transmissivity $T_o = 0.2$ m^2/hr	Effective porosity $\theta_e = 0.25$
Parameter m = 0.1 m	Baseflow $Q_b = 1.5 \times 10^{-2}$ m^3/s
Parameter f = 2.5 m^{-1}	

a) Recall that specific catchment area is defined based on contributing area and contour width (e.g. Figure 49, p6:3 of the Rainfall-Runoff processes module). Determine the specific catchment area at point P in the diagram above at x = 250 m half way down the slope. [5]

b) Determine the TOPMODEL wetness index at P. [5]

c) Let the distance from the divide on each slope be indicated by x. Determine the wetness index as a function of x on the left and right sides of the watershed. Write your solution as a separate equation giving wetness index as a function of x for the left side and the right side. [5]

d) Determine the threshold wetness index above which the watershed is saturated and draw a diagram showing the saturated areas for the watershed above. [5]

e) Determine the fraction of area that is saturated (before the start of a storm). [5]

f) Determine the soil moisture deficit at point P. [5]

Assume a storm in which 5 cm of precipitation falls.

g) Determine the volume of runoff generated over just the area that is initially saturated (m^3). (i.e. ignore the expansion of the saturated area) [5]

h) Determine the depth of runoff generated at point P (cm). [5]

[40 points]