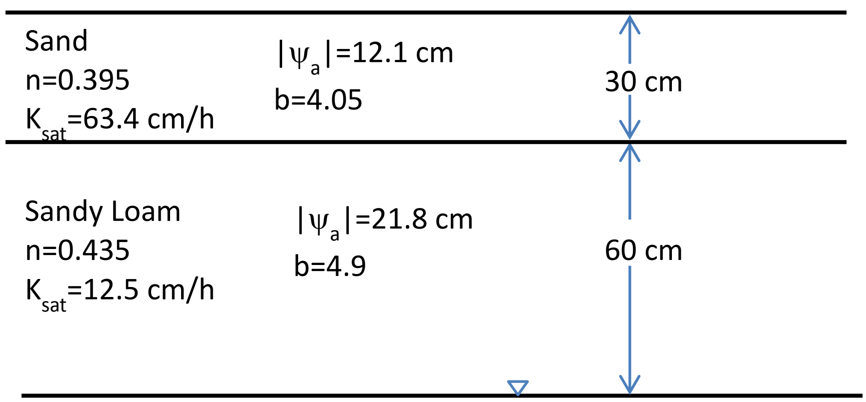
Utah State University
Department of Civil and Environmental Engineering
CEE 6400 Physical Hydrology

Final exam. Date: 12/14/2011
D.G. Tarboton Time: 110 min
[90 points open book portion. 120 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 or printed reference material. Calculator use. You may use a programmable calculator 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. You may use programs that you have written to evaluate quantities commonly used in this class (e.g. saturation vapor pressure). You may not use your calculating device to retrieve stored reference material in any form. You may not send messages or access the internet or communicate in any way with anyone other than the instructor or moderator regarding solutions to these questions.

1. **Water in Soil.** Consider two soils layered in the unsaturated zone under hydrostatic equilibrium. The water table is located at the bottom of the second layer.



The parameters indicated are Clapp and Hornberger (1978) parameters from Table 1, page 4:18 of the Rainfall Runoff Processes workbook.

a. Plot the pressure head (matric potential) versus depth through the soil. [5]
b. Indicate the height of the top of the capillary fringe. [5]
c. Plot the water content versus depth through the soil. Indicate numerical values at the water table, top of capillary fringe, interface between soil types and surface. [5]
d. Calculate the soil moisture deficit (cm). [5]

Assume a rainstorm during which 8 cm falls steadily during 1 day.

e. Calculate the time to ponding. [5]
f. Calculate the depth of runoff generated. [5]

[30 points]

2. **Evaporation by Penman-Monteith.** Consider a coniferous forest with the following information:

Dry gas constant, R_a = 287 J kg^{-1} K^{-1} Latent heat of vaporization, λ_v = 2.46 MJ kg^{-1} Density of water, ρ_w = 1000 kg m^{-3} Air heat capacity at constant pressure, c_a = 1.005 x 10^{-3} MJ kg^{-1} K^{-1} Air density, ρ_a = 1.13 kg m^{-3} Atmospheric pressure, P = 95 kPa Air temperature, T_a = 18 °C Relative humidity, W_a = 0.54 Wind speed, v_a = 3 m s^{-1} at height z_m = 2 m above the top of the vegetation	Incoming solar radiation, K_{in} = 25 MJ m^{-2} day^{-1} Net longwave radiation, L = -5 MJ m^{-2} day^{-1} Albedo, a = 0.14 Maximum leaf conductance C^*_{leaf} = 5.3 mm s^{-1} Leaf area index (LAI) = 6 z_{veg} = 25 m Shelter factor, f_s = 0.5 Soil moisture deficit, $\Delta\theta$ = 5 cm

PenMontX.xls spreadsheet

Vegetation Type, Season:		*zveg* =	25	m		
		fs =	0.5			
		*C*leaf* =	5.30	mm/s Table 7-5, Fig 7-14		
		a =	0.14	See Table 7-5		
		LAI =	6.0	See Table 7-5		
	Weather, Soil:	*P* =	95	kPa		
		clear-sky solar radiation, *Kcs* =	25	MJ/m^2 day; See SolarRad.xls		
		cloud cover, *C* =	0	0 <= *C* <= 1		
		Ta =	18	C		
		Wa =	0.54			
		va =	3	m/s		
		Δθ =	5	cm		
ρ*w* =	1000	kg/m^3	*ea* =		kPa	
ρa =	1.13	kg/m^3	*Kin* =	25.00	MJ/m^2 day; Eqn. (7-26)	
λ*v* =	2.46	MJ/kg	ε*at* =	0.78	Eqn. (7-30)	
K+L =	16.50	MJ/m^2 day	*L* =	-5.00	MJ/m^2 day	
*e*a* =		kPa	Δ*ea* =		kPa	
Δ =	0.130	kPa/K	Δρ*v* =		kg/m^3	
γ =	0.062	kPa/K				
f(*Kin*) =	0.812		*f*(Δρ*v*) =	0.528		
f(*Ta*) =	1.000		*f*(Δθ) =	0.932		
		f(*Kin*)**f*(Δρ*v*)**f*(*Ta*)**f*(Δθ) =	0.399			
Cat =	2.69E+02	mm/s *Cleaf* =		mm/s *Ccan* =	6.34E+00	mm/s
		Penman-Monteith ET rate =		mm/s =		mm/day

Refer to the Penman-Monteith equation in Dingman on page 299 and the PenMontX.xls spreadsheet given on the previous page that you used in your homework. Some of the cells have been blanked out

a. Evaluate the saturation vapor pressure [5]
b. Evaluate the absolute humidity deficit $\Delta\rho_v$ [5]
c. Validate the value for $f_\rho(\Delta\rho_v)$ shown in the spreadsheet [5]
d. Evaluate the Leaf Conductance C_{leaf} [5]
e. Evaluate ET (mm/day) using the Penman-Monteith equation [10]

[30 points]

3. **Infiltration and Runoff Generation.** Consider the following storm

Time (h)	0-2	2-4
Rainfall Intensity (cm/h)	0.5	2

Philip's equation is applicable with K_p = 0.2 cm/h and S_p = 3 cm/$h^{0.5}$

a. Plot a graph of infiltration capacity as a function of infiltrated depth for this soil [10]
b. What it the time that ponding first occurs in this storm [10]
c. Determine the infiltration and runoff generated in each two hour increment [10]

[30 points]