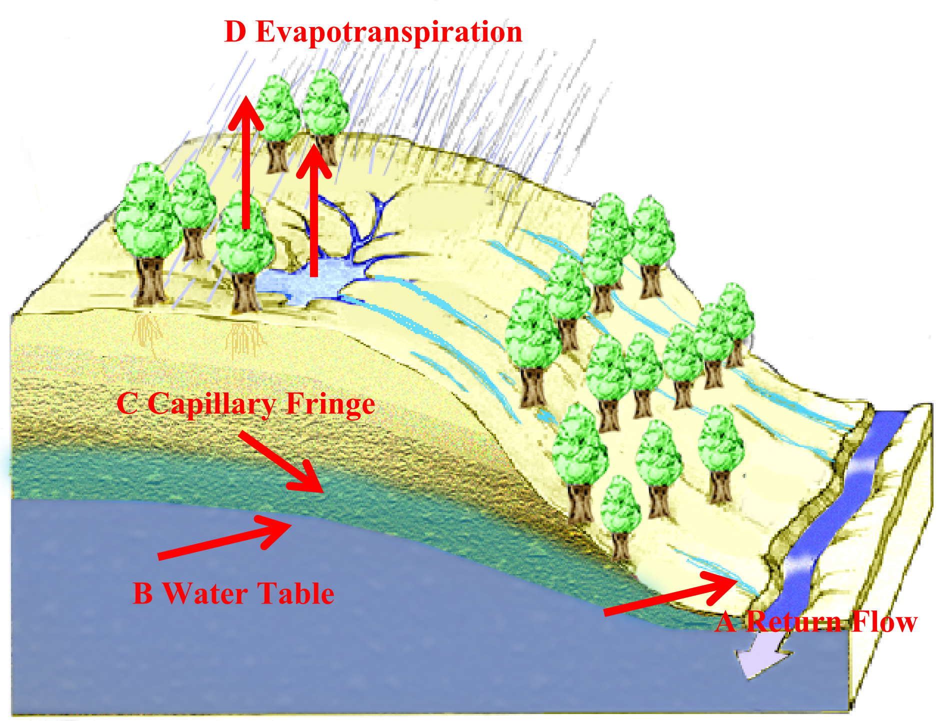
Utah State University **Name:___Solution________________**
Department of Civil and Environmental Engineering
CEE 6400 Physical Hydrology Midterm

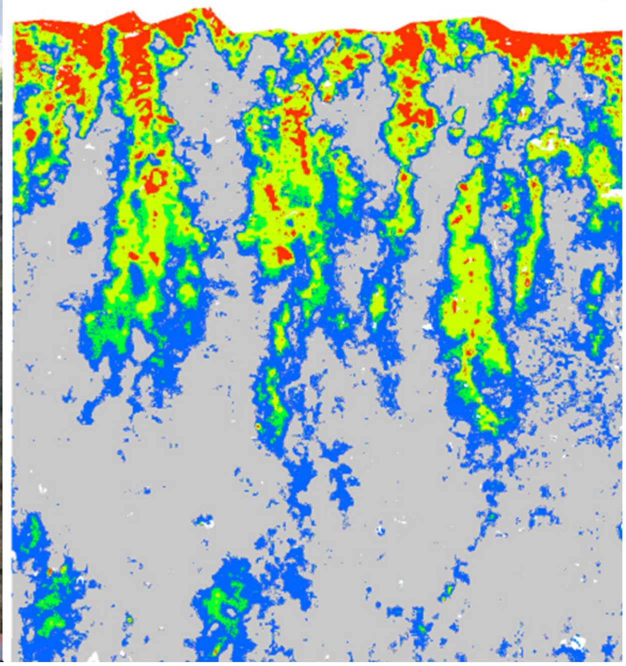
Closed book portion. Answer all questions. Please answer on this paper.
20 min [25 points closed book portion. 100 points total.]

1. For each of the following hydrologic phenomena provide a brief definition and label/depict it on the diagram below

Return flow A	Subsurface flow that returns to the surface and contributes to overland flow or streamflow. Thus usually occurs near a stream
Water table B	The surface where subsurface water is at atmospheric pressure that divides saturated (below) and unsaturated (above) subsurface water
Capillary fringe C	The area immediately above the water table where moisture content is near saturation due to water being held there by capillary forces.
Evapotranspiration D	The transfer of water from the surface to the atmosphere originating either from open water, the soil, or from the leaves of plants (transpiration)



2. The pictures below have been shown in this class. Describe what they are and the hydrologic significance of the process they depict.

The picture to the left shows soil exposed following an infiltration experiment using dye. The picture to the right highlights the preferential pathways followed by infiltrating water obtained from the dye. These pictures show that during infiltration water follows preferential pathways with lower conductivity, a rather complex process. Water can reach depth without the shallow soil being saturated. Understanding and representing this in our equations is important to properly quantify infiltration and changes in soil moisture that affect many hydrologic processes.

3. In an unsaturated soil, porosity is defined as (circle one):
   A. Volume of voids/Total volume
   B. Volume of voids/Volume of solids
   C. Volume of water/Volume of solids
   D. Volume of air/Volume of water
   E. Mass of Water/Density of soil

4. Volumetric moisture content is defined as (circle one):
   A. Volume of air/Volume of water
   B. Mass of Water/Density of soil
   C. Volume of water/Volume of solids
   D. Volume of water/Total volume
   E. Volume of voids/Total volume

5. Relative humidity is defined as (circle one):
   A. The dew point temperature divided by the air temperature as long as absolute (Kelvin) temperature unit are used
   B. The ratio of the saturated adiabatic lapse rate to dry adiabatic lapse rate
   C. The ratio of specific humidity to dew point
   D. The ratio of actual vapor pressure to saturation vapor pressure
   E. 0.622 e/P

6. Describe and explain the differences between infiltration excess and saturation excess runoff generation mechanisms

Infiltration excess runoff occurs when the rainfall rate exceeds the rate at which water can be absorbed in to the soil surface. This limiting rate is the infiltration capacity and depends on soil moisture conditions related to how much water has infiltrated. Infiltration still occurs during infiltration excess runoff generation and the runoff generated is the difference between rainfall rate and infiltration capacity. Saturation excess runoff occurs when the soil profile is completely saturated and there is no pore space into which water can infiltrate. This is associated with the water table rising to the surface. All rainfall becomes runoff once saturation occurs and saturation excess runoff is generated.

7. Describe what the Thiessen Polygon Method is used for:

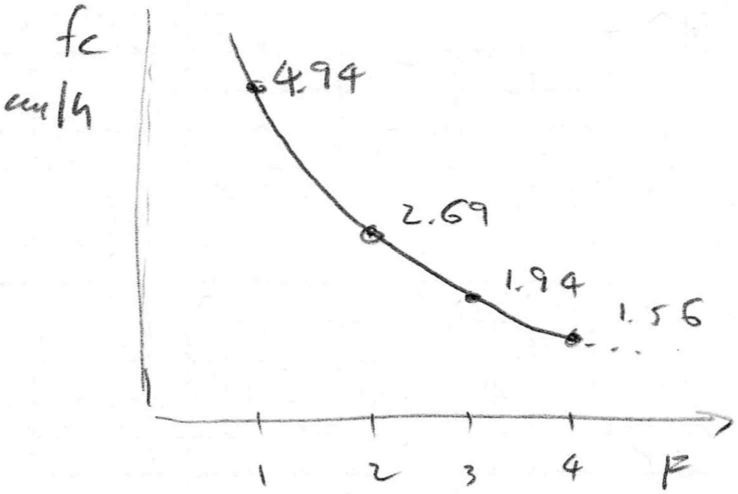
To estimate area average rainfall from measurements at points.

1. a) $f_c(F) = K_p + \dfrac{K_p S_p}{\sqrt{S_p^2 + 4K_p F} - S_p}$

$K_p = 0.3$ cm/h

$S_p = 3$ cm/h$^{0.5}$

F	1	2	3	4	cm
f_c	4.94	2.69	1.94	1.56	cm/h



b) Based on the above no ponding in first hour with w = 1 cm/h

In second hour

$$F_p = \frac{S_p^2 (w - K_p/2)}{2(w - K_p)^2}$$

$$= \frac{9(3 - 0.3/2)}{2(3 - 0.3)^2} = 1.75 \text{ cm}$$

1 cm infiltrates in first hour

∴ In second hour

$$\Delta t' = \frac{1.75 - 1}{3} = 0.25 \text{ hr}$$

∴ Time to ponding = 1.25 hr

c) Runoff generated $t_s = 1.25$

$$t_o = 1.25 - \frac{1}{4(0.3)^2}\left(\sqrt{9 + 4 \times 0.3 \times 1.75} - 3\right)^2$$

$$= 0.944 \text{ hr}$$

∴ at 2 hr

$$F = 3(2 - 0.944)^{1/2} + 0.3(2 - 0.944)$$

$$= 3.40 \text{ cm}$$

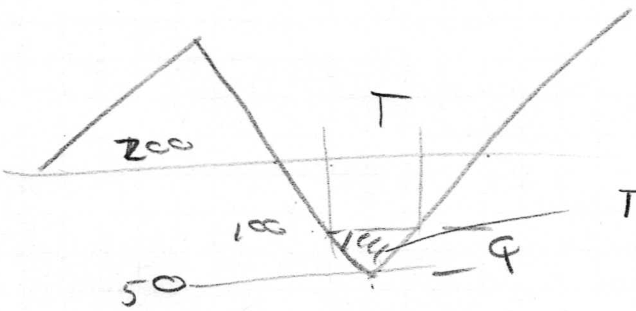
cumulative rainfall = 4 cm

∴ Runoff generated = 4 − 3.4 = 0.6 cm

1st hour No runoff

2nd hour 0.6 cm runoff

2. a) To support yield of 100 cfs



Taken from storage filled in high flows

$$S = \frac{T \times q}{2}$$

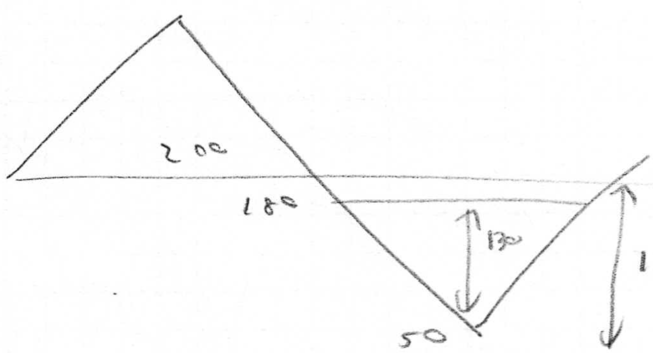
$$T = \frac{1}{3} \times \frac{1}{2} \times 365 \text{ days} \times 24 \times 3600 \text{ s}$$

$$= 5.256 \times 10^6 \text{ sec}$$

$$q = 50 \text{ ft}^3/\text{s}$$

$$\therefore S = 1.314 \times 10^8 \text{ ft}^3$$

b)



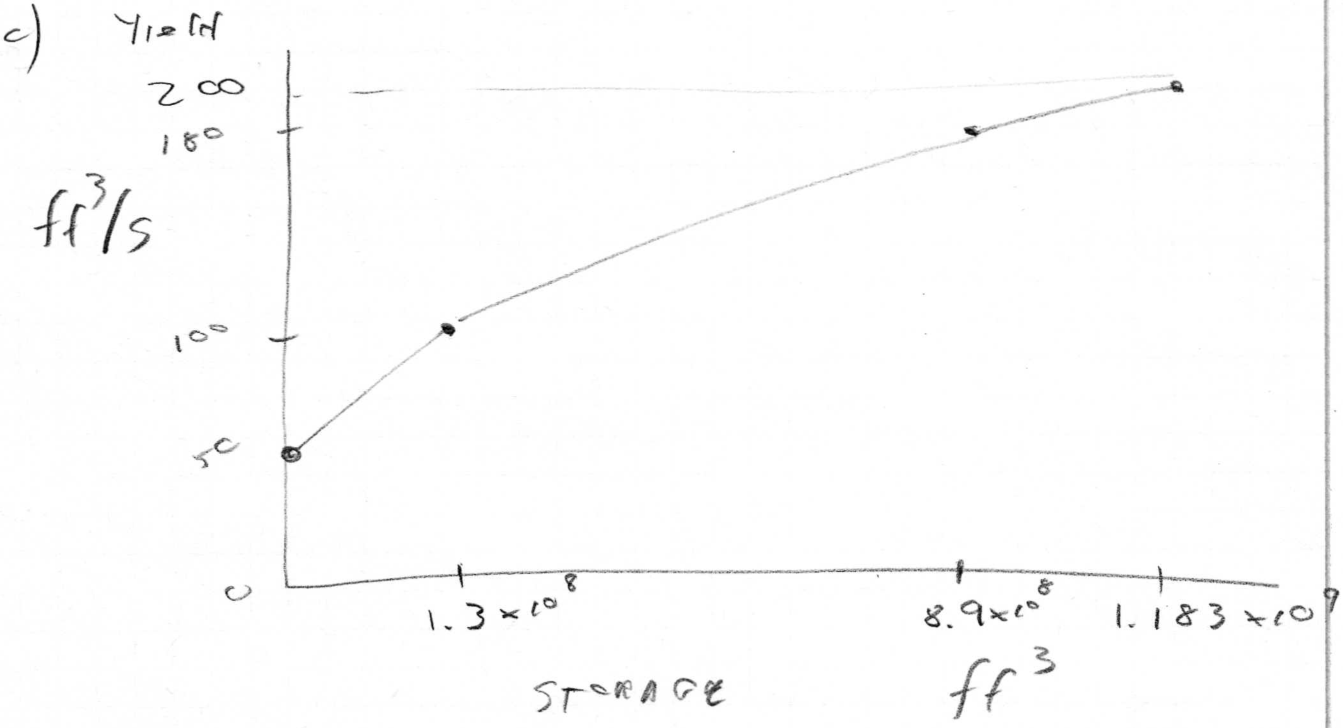
$$T = \frac{130}{150} \times \frac{1}{2} \times 365 \times 3600 \times 24$$

$$= 13.67 \times 10^6 \text{ s}$$

$$q = 130$$

$$\therefore S = 8.88 \times 10^8 \text{ ft}^3$$

c)



For yield @ 200

$$S = \frac{1}{2} \times 365 \times 3600 \times 24 \times \frac{150}{2}$$

$$= 1.183 \times 10^9 \ ft^3$$

3 - a) $e_s = 6.11 \exp\left(\frac{17.27\ T}{237.3 + T}\right)$ $T = 5°C$

$e_s = 8.73$ hPa

$e = 0.8 \times e_s = 6.98$ hPa

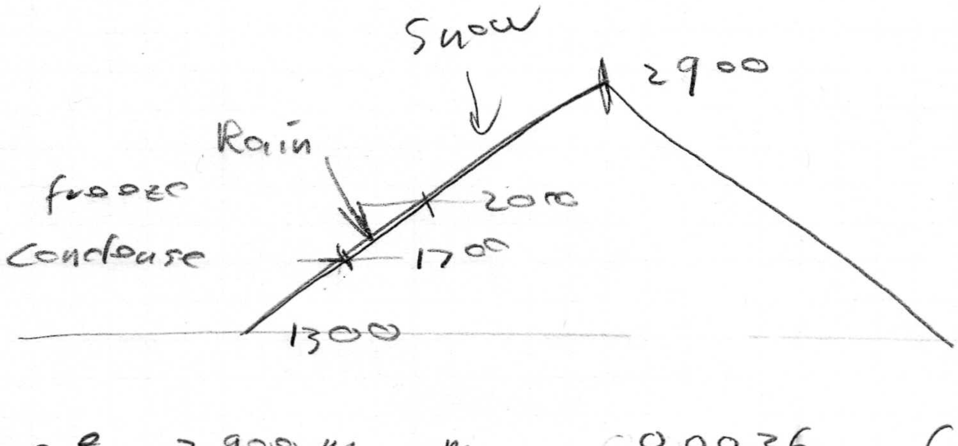
$m = \frac{0.622 e}{p - e} = \frac{0.622 \times 6.98}{850 - 6.98}$

$= 0.00515$ kg/kg

b) From diagram
Cloud level = 1700 m

c) Freezing level = 2000 m

d)



e) at 2900 m $m = 0.0036$ (Mixing ratio)

f) Fraction condensed $= \frac{0.00515 - 0.0036}{0.00515}$

$= 0.30$

g) T of top = $-6^\circ C$

By ambient lapse rate

$$T = 5 - 8(2.9 - 1.3) = -7.8^\circ C$$

Since lifted parcel T > ambient T
$-6^\circ C$ > $-7.8^\circ C$

the air is conditionally unstable and the potential for convection is high

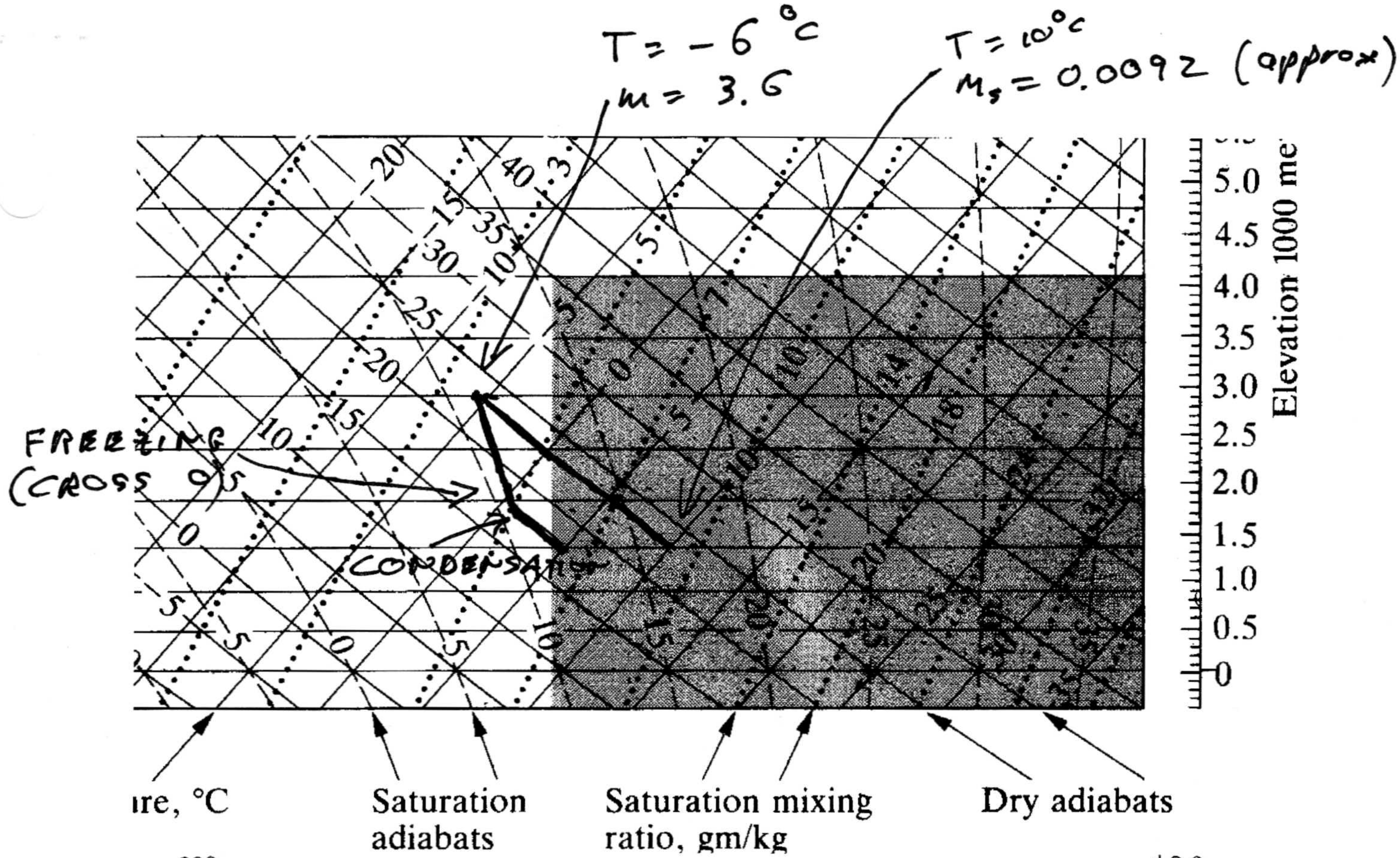
h) Back at base T = $10^\circ C$

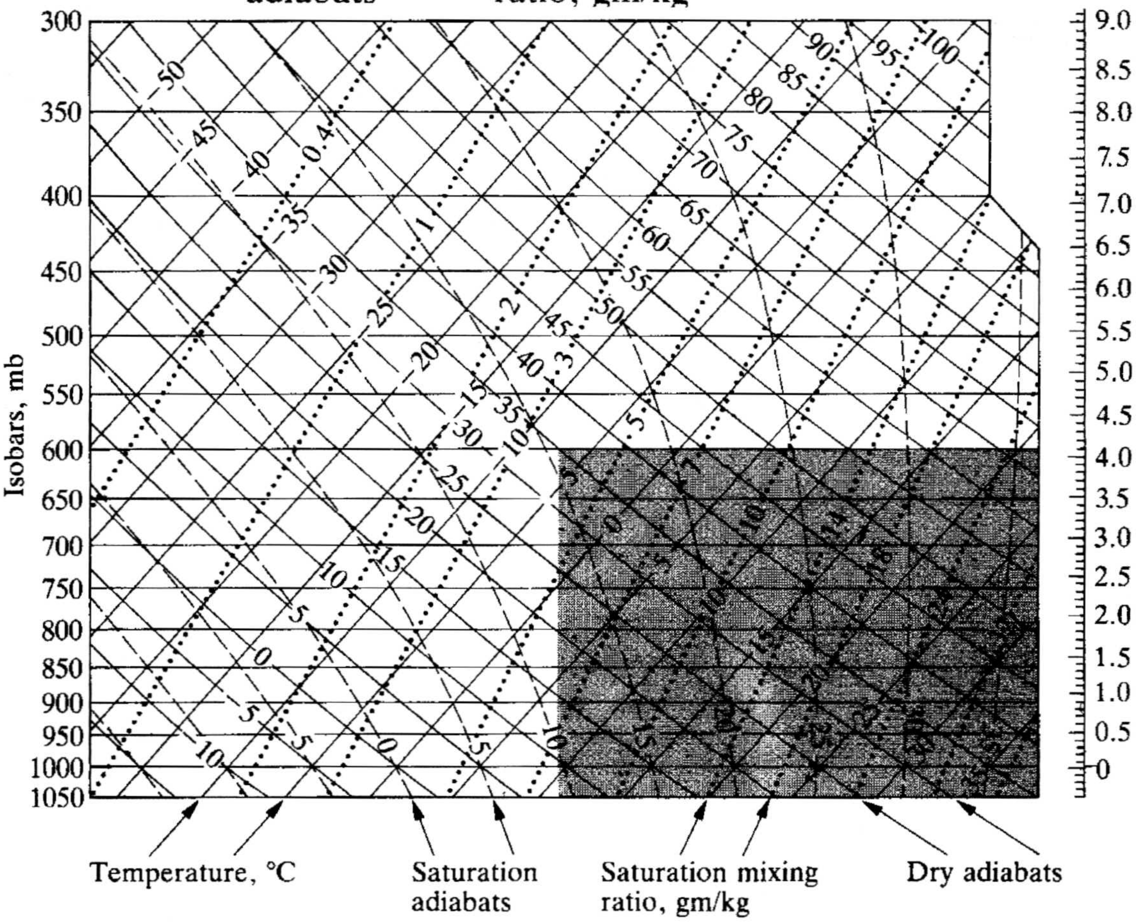
i) at base $m_s = 9.2$ g/kg $= 0.0092$

$$m = 0.0036$$

$$RH = \frac{0.0036}{0.0092}$$

$$= 0.4 = 40\%$$


T = −6 °C
m = 3.6
T = 10°C
Ms = 0.0092 (approx)
FREEZING (CROSS 0)
CONDENSATION
Elevation 1000 me
ire, °C
Saturation adiabats
Saturation mixing ratio, gm/kg
Dry adiabats


Isobars, mb
Elevation 1000 meters
Temperature, °C
Saturation adiabats
Saturation mixing ratio, gm/kg
Dry adiabats