THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ENERGY AND GEO-ENVIRONMENTAL ENGINEERING
GEOEE 408 CONTAMINANT HYDROLOGY

Mid-term Examination – Tuesday March 2nd, 2004 – 75 minutes
Answer all three questions.

For water (in contact with air): $\sigma = 7.3 \times 10^{-2}$ *N/m*; γ=9.8 kN/m^3; $\mu = 1.12 \times 10^{-3}$ *N.s/m^2*
For TCE (in contact with water): $\sigma = 3.5 \times 10^{-2}$ *N/m*; γ=15.6 kN/m^3; μ= 0.96 x 10^{-3} *N.s/m^2*

Name: ______________________________

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

Include extra sheets, as needed, and return entire packet

Question 1

Define the following terms, and identify the units [MLT] of the quantity, where relevant. Be as specific and as exhaustive in your definitions as possible.

1. Relative permeability, k_r

2. Capillary pressure-saturation relations, p_c-S_w

3. Coefficient of longitudinal dispersion, α_L

4. Diffusion coefficient, D.

5. Non-dimensional Henry's law coefficient, H.

6. Advective velocity, v_a

7. Total dissolved and sorbed mass mobilized within a plume.

8. Critical ganglion height, h_{min}

9. Sorption.

10. Retardation factor for saturated flow, R.

Question 2

The breakthrough curve of the chloride plume (*Cl* is a conservative tracer) at a compliance well, 2 km downstream of a landfill, is as shown. The aqueous chloride concentration in the landfill is 200 ppm, which acts as a constant concentration or fixed step source at the head of a one-dimensional flowfield.

Use the attached chart, defining theoretical breakthrough curves, in terms of advective velocity, v, dispersion coefficient, D_L, distance to measuring point, L, and time since the commissioning of the landfill, t, to determining the following $\left[P_e = \frac{v.L}{D_L};\quad t_R = \frac{v.t}{L} \right]$

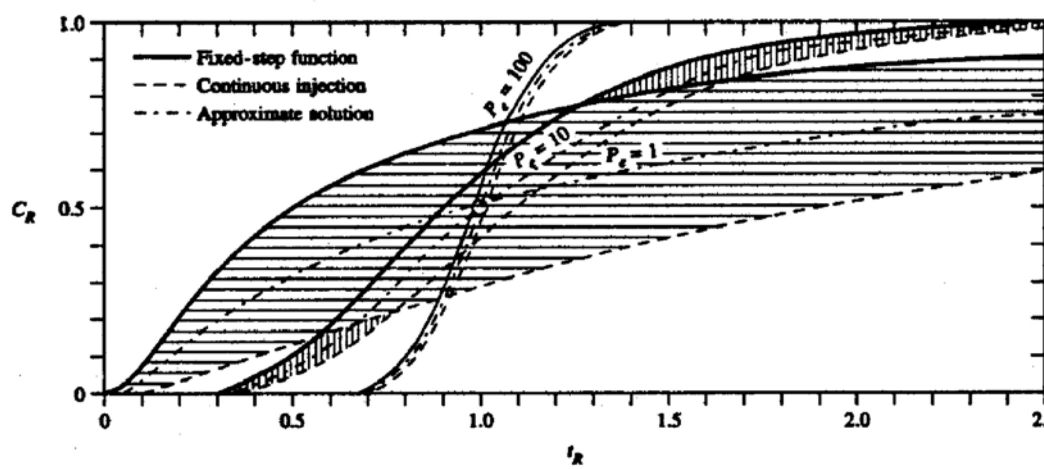
1. If *Cl* is a conservative tracer, determine the advective velocity of the flow field.

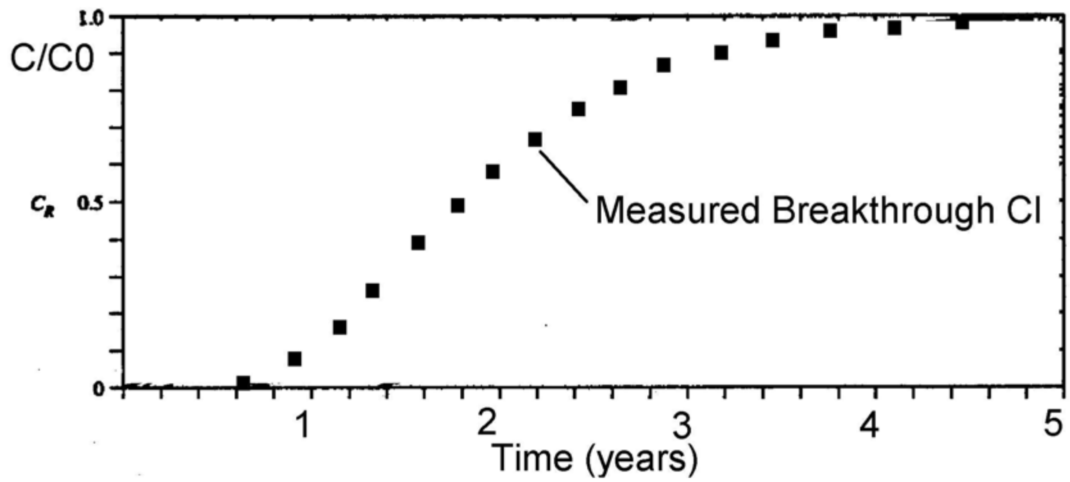
2. What is the longitudinal dispersion coefficient D_L, for *Cl* from the system.

3. If the effective diffusion coefficient of salt in water is 10^{-9} m^2/s, what is the longitudinal dispersion coefficient, α_L.

4. If TCE is also moving through the aquifer, from the same source, that is retarded by a factor of 10 (R=10), when will the breakthrough occur at the same compliance point, equal to 80% of its upstream concentration. Consider the same compliance point.

5. For a more mildly retarded species, PCE, present upstream at 500ppb breaks through at the compliance point at a concentration of 400ppb after 4.2 years. What is the retardation factor for PCE.




1.0
C/C0
C_R 0.5
0
Measured Breakthrough Cl
1
2
3
4
5
Time (years)

Question 3

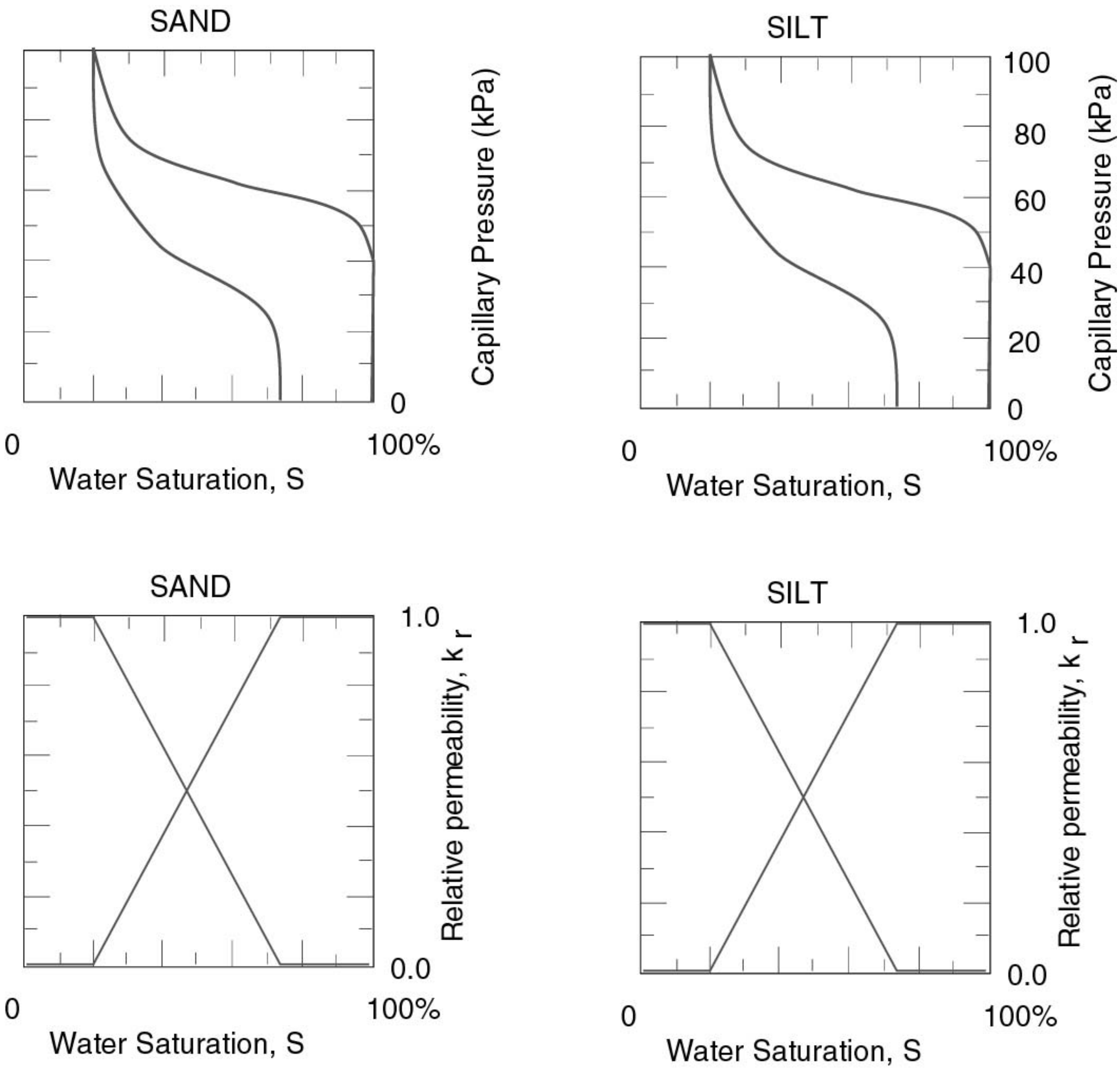
At a given site, the stratigraphy comprises 10m of sand, underlain by a capillary barrier of silt. The porosities of the silt and the sand are identical. Unit weights are as given on page 1. The water table is present at the ground surface, and the groundwater flow-field is static.

1. From knowledge of the capillary pressure curve for the silt, invaded by TCE, label the capillary pressure curve for sand, with the appropriate magnitudes of capillary pressure, if the permeability of sand is 4 orders-of-magnitude (x 10,000) higher than that of the silt.

2. Determine the effective saturation of TCE in the sand immediately above its interface with the underlying silt layer, if a large volume of TCE has been spilled in the sand.

3. What is the saturation in the silt immediately below the overlaying sand.

4. What is the ratio between the <u>effective</u> permeability in the sand and silt to TCE, i.e. k_{silt}/k_{sand}


SAND
0
100%
Water Saturation, S
Capillary Pressure (kPa)
SILT
100
80
60
40
20
0
0
100%
Water Saturation, S
Capillary Pressure (kPa)
SAND
1.0
0.0
0
100%
Water Saturation, S
Relative permeability, k r
SILT
1.0
0.0
0
100%
Water Saturation, S
Relative permeability, k r