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

Mid-term Examination – Tuesday February 26th, 2002 – 75 minutes
Answer all three questions.
For water (in contact with air): $\sigma = 7.3 \times 10^{-2}$ *N/m*; γ=9.8 kN/m³; $\mu = 1.12 \times 10^{-3}$ *N.s/m²*
For TCE (in contact with water): $\sigma = 3.5 \times 10^{-2}$ *N/m*; γ=15.6 kN/m³; μ= 0.96 x 10⁻³ *N.s/m²*

Name: _____

Include extra sheets, as needed, and return entire packet

Question	Points	Score
1	100	
2	100	
3	100	
Total	300	

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. Retardation coefficient, R

2. Coefficient of transverse hydrodynamic dispersion $D_T = D^* + \alpha_L v$

3. van Genuchten parameter, α

4. Imbibition

5. Relative permeability, k_r

6. Capillary pressure, p_c

7. Volumetric moisture content, θ

8. Darcy's law.

9. Tension saturated zone.

10. Irreducible non-wetting saturation, S_{nw0}

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 $\left[P_e = \dfrac{v.L}{D_L}; \quad t_R = \dfrac{v.t}{L} \right]$

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 $10^{-9}\,\text{m}^2/\text{s}$, 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.
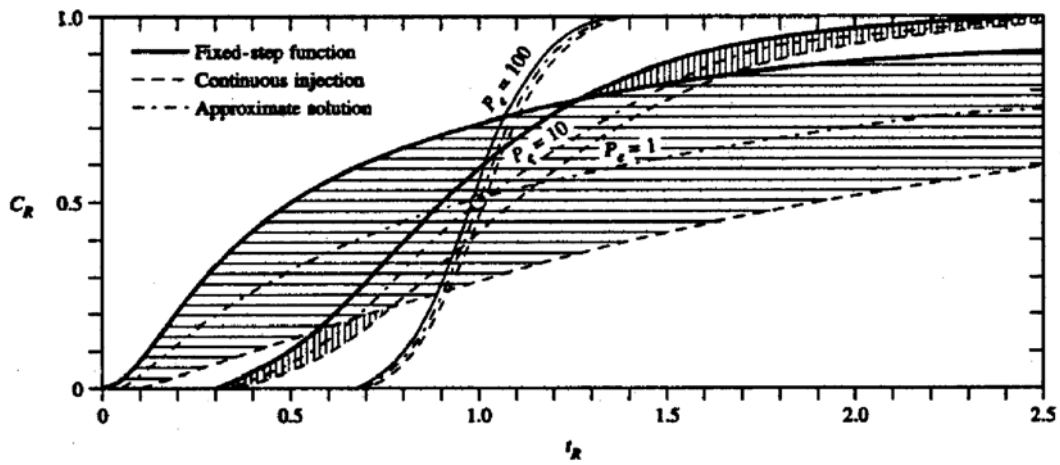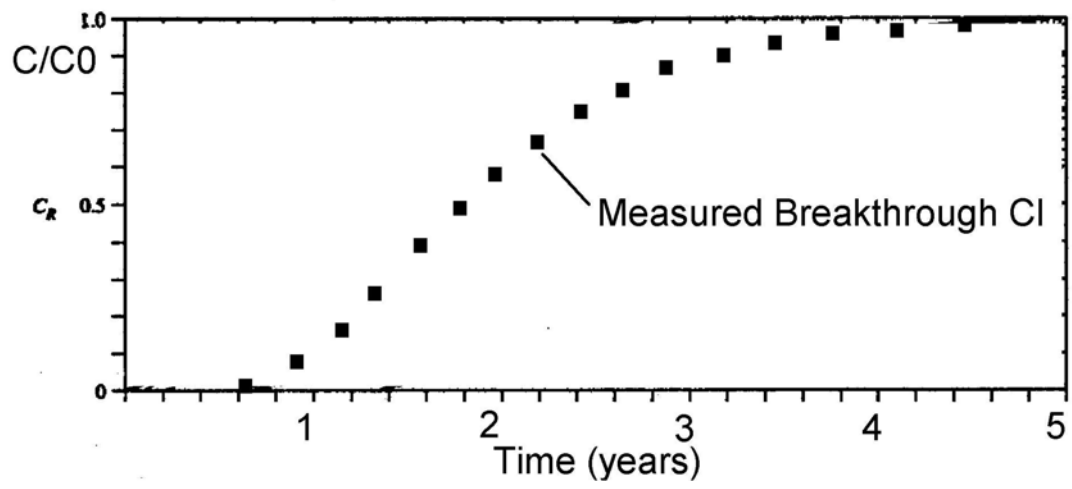
Question 3

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

Capillary Pressure (kPa)

Water Saturation, S

0   100%

SILT

Capillary Pressure (kPa)

100

80

60

40

20

0

Water Saturation, S

0   100%

SAND

Relative permeability, k_r

1.0

0.0

Water Saturation, S

0   100%

SILT

Relative permeability, k_r

1.0

0.0

Water Saturation, S

0   100%