

THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ENERGY AND GEO-ENVIRONMENTAL ENGINEERING
GEOEE 408 CHARACTERIZATION OF GROUNDWATER SYSTEMS

Final Examination
1 hour 50 minutes
May 4th, 2000

Name: _____

SSN (last 4 digits): _____

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 in your definitions as possible. Where relevant, include any equations or figures to explain the term.

1. Gaseous retardation coefficient, R_g .

2. Seismic refraction surveying.

3. Shelby tube samples.

4. Straddle packer testing.

5. Electro osmotic remediation.
6. Relative permeability, k_r .
7. Capillary pressure, p_c .
8. Hydrodynamic dispersivity, $D_L = D^* + \alpha_L v$.
9. Capillary rise, h_c .
10. Fick's law.

Question 2

A variety of DNAPL solvents, have been found in surficial soils and within the bedrock at a military site in the arid desert South-west. The site comprises 10 *m* of silty alluvium, overlaying highly fractured basalts. The watertable is 30 *m* below the surface, and the main locations of free product is as discrete lenses in the alluvium, and within the bedrock fractures.

1. Describe an appropriate (direct) site investigation for this site to:

- (a) Evaluate geology and hydrogeology.
- (b) Determine the extent of NAPL (free product) and dissolved product contamination.
- (c) Determine the potential for continued migration within the vadose zone and in the groundwater zone.

Use note form, if you wish, to itemize your choices and explain their relevance.

2. The bulk hydraulic conductivity, of the fractured volcanic rocks is of the order of 10^{-2} cm/s , and the matrix conductivity is very low, of the order of 10^{-10} cm/s , with a porosity of 3%. The unsaturated overlaying alluvium has a porosity of 25%, and a saturated conductivity of 10^{-4} cm/s .

Identify, and describe the operating principles of two remedial techniques that may be applied to this site to remove or contain the bedrock source NAPLS. For each of these two applicable techniques, identify three factors that make the technique particularly applicable to the site. Use note form to answer if you wish.

Question 3

A two component DNAPL cocktail has been spilled into the vadose zone in a sand aquifer. Soil samples are taken from the vadose zone and the fluid assayed to determine aqueous concentrations, c_a . Components are desorbed from the solid grains to define the presumed equilibrium sorbed concentrations, c_s . The porosity of the sand aquifer is $n = 25\%$, the bulk density is $\rho_b = 1200 \text{ kg/m}^3$ and the mean volumetric moisture content in the vadose zone is $\theta = 5\%$. The mean soil temperature is 10°C . The universal gas constant is $\bar{R} = 8.206 \times 10^{-5} (\text{atm.m}^3)/(\text{mol.}^\circ\text{K})$.

Component	c_a mg/l	c_s mg/kg	Henry's law coeff., H' $(\text{atm.m}^3)/\text{mol.}$	Distribution coeff., k_d m^3/kg	Mole fraction, X_i %
Trichloroethene (TCE)	_____	672	9.1×10^{-3}	_____	60
Methylene Chloride	_____	600	2.0×10^{-3}	_____	40

Component	Gaseous concentration, c_g mg/l	Aqueous retardation coeff., R_a —	Gaseous retardation coeff., R_g —
Trichloroethene (TCE)	_____	11.0	_____
Methylene Chloride	_____	1.5	_____

1. Complete the missing entries in the tables above.
2. Evaluate the order of arrival (following the spill) of components sampled by capillary tube from the vadose zone. The monitoring location is 20 m from the spill site and advective gas velocities in the vadose zone are zero. The gaseous diffusion coefficients for the two components are equal.
3. If air stripping is used as a remedial technique in the vadose zone, and throughput of the sparging system is $100 \text{ m}^3/\text{d}$, evaluate the time required to clean a 5000 l spill. Assume that mole fraction approximates mass fraction, and mean density of the NAPL is 1400 kg/m^3 .

