National Exams May 2004

98-Geol-B1, Contaminant Hydrogeology

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. Any non-communicating calculator is permitted. This is an Open Book exam. Note to candidates you must indicate the type of calculator being used. i.e. write the name and model designation of the calculator, on the first inside left hand sheet, of the exam work book.

3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.

4. All questions are of equal value.

1. Road salt is leaching from a long ditch into a shallow aquifer. The Darcy velocity in the aquifer is 5 cm/day perpendicular to the axis of the ditch, the aquifer porosity is 0.35, and the concentration of chloride in the aquifer below the ditch is 250 mg/L. It is estimated that the dispersivity appropriate for modeling solute transport in the aquifer is 1 m and the effective diffusion coefficient for chloride is 10^{-10} m^2/sec.

a) If the transport of chloride in the aquifer can be assumed to be one-dimensional, determine the concentration of chloride 20 m away from the ditch in the direction of groundwater flow, after both 125 and 175 days.

b) Discuss the assumptions that are involved in the equations you used to solve part (a) and how reasonable they are for the scenario described.

c) Discuss situations where it is appropriate to use Type 1 (Dirichlet) boundary conditions and where it is appropriate to use Type 3 (Neuman) boundary conditions for modeling solute transport.

2. a) Draw a typical capillary pressure saturation curve for a system containing water and an organic fluid (NAPL), identifying and defining all key features of the curve.

b) Explain why it is necessary to use relative permeabilities when modeling multiphase flow.

c) Describe and explain the differences in behaviour between LNAPLs and DNAPLs spilled into the subsurface.

3. A truck containing a dilute solution of hydrochloric acid (contains 500 mg/L chloride) is involved in an accident and spills 10,000 L of acid into the subsurface. The acid quickly reaches a shallow aquifer just below the ground surface and creates a contaminant plume in the aquifer. The aquifer has a porosity of 0.3, the Darcy velocity in the aquifer is 0.3 m/day, the dispersivity is isotropic and has a value of 2 m, and the effective diffusion coefficient for chloride is 10^{-10} m^2. Assume that the acid spilled initially created a uniform contamination zone (500 mg/L chloride) in the aquifer over an area of 10 m^2, that the acid did not react with the subsurface materials, and that the spill did not significantly alter flow in the aquifer.

a) Determine the maximum concentration of chloride in the aquifer after 100 days and the location of this maximum concentration.

b) Determine the concentration of chloride after 100 days, 120 m from the spill, in the direction of groundwater flow.

4. It is discovered that a drycleaning operation has been losing dry cleaning solvent (perchloroethylene – density = 1600 g/cm^3, water solubility = 150 mg/L, vapour pressure at 20 C approximately 1870 Pa) from a leaking underground storage tank for approximately 5 years. The tank is located above the water table in sandy soil. The water table is approximately 3 m below the ground surface. The unconfined aquifer below the tank is also sandy soil, and is underlain by a clay aquitard at a depth of 20 m below the ground surface.

a) Discuss the processes that govern the movement of the leaking solvent in this system.

b) Describe what steps you would include in a preliminary site investigation aimed at delineating the extent of contamination at the site.

c) Discuss two possible approaches to remediate the solvent contamination at this site.

5. A gasoline station accidentally overfills their underground storage tanks with gasoline, and 10000 L of gasoline is spilled and seeps into the ground. Below the spill the soil consists of a 50 cm layer of gravel, a 1 m layer of silty soil, and a 5 m layer of coarse sand. The water table is located in the middle of the sand layer and dips at an angle of 2° toward a stream that is 100 m from the spill location. The aquifer discharges to the stream.

a) Discuss the movement of the spilled gasoline at this site, and any processes that contribute to the movement of the gasoline or to the spread of contamination in the subsurface.

b) Discuss processes that will attenuate the movement away from the spill site of gasoline components dissolved in groundwater.

c) Outline steps you would take to control and remediate the gasoline contamination at this site.

6. In a laboratory experiment a solution of water containing 10 mg/L of toluene is introduced into a one-dimensional column (5 cm diameter, 60 cm length) containing a sandy soil (porosity of 0.3, dispersivity of 0.05 m, organic carbon fraction of 0.01, bulk density of 1.8 g/cm^3). If toluene has an effective diffusion coefficient of 10^{-10} m^2/sec, and an organic carbon partitioning coefficient, K_{oc}, of 100, estimate the concentration of toluene in the effluent from the column after 2 days and 2.5 days if the volumetric flow rate of water into the column is 1 L/day.

7. a) If groundwater that does not contain any Ba or $SO_4^=$ comes into contact with barite ($BaSO_4$) determine the equilibrium concentration of Ba and $SO_4^=$ in (mg/L). $BaSO_4$ has a solubility product of 10^{-10}, Ba has an atomic weight of 137.3 g/mol, S has an atomic weight of 32.1 g/mol, and oxygen has an atomic weight of 16.0 g/mol.

b) If groundwater that does not contain any Ba, but contains 50 mg/L $SO_4^=$, comes into contact with barite ($BaSO_4$) determine the equilibrium concentration of Ba and $SO_4^=$ in (mg/L).

c) Leachate from a mining tailings pond is seeping into an aquifer. The leachate has a pH of 2.0, is anaerobic and reduced, and contains dissolved iron. As the leachate moves through the aquifer the pH increases and the E_h also increases as oxygen mixes with the leachate. Discuss the chemical processes that affect the movement of the iron in the leachate.

β	erf (β)	erfc (β)
0	0	1.0
0.05	0.056372	0.943628
0.1	0.112463	0.887537
0.15	0.167996	0.832004
0.2	0.222703	0.777297
0.25	0.276326	0.723674
0.3	0.328627	0.671373
0.35	0.379382	0.620618
0.4	0.428392	0.571608
0.45	0.475482	0.524518
0.5	0.520500	0.479500
0.55	0.563323	0.436677
0.6	0.603856	0.396144
0.65	0.642029	0.357971
0.7	0.677801	0.322199
0.75	0.711156	0.288844
0.8	0.742101	0.257899
0.85	0.770668	0.229332
0.9	0.796908	0.203092
0.95	0.820891	0.179109
1.0	0.842701	0.157299
1.1	0.880205	0.119795
1.2	0.910314	0.089686
1.3	0.934008	0.065992
1.4	0.952285	0.047715
1.5	0.966105	0.033895
1.6	0.976348	0.023652
1.7	0.983790	0.016210
1.8	0.989091	0.010909
1.9	0.992790	0.007210
2.0	0.995322	0.004678
2.1	0.997021	0.002979
2.2	0.998137	0.001863
2.3	0.998857	0.001143
2.4	0.999311	0.000689
2.5	0.999593	0.000407
2.6	0.999764	0.000236
2.7	0.999866	0.000134
2.8	0.999925	0.000075
2.9	0.999959	0.000041
3.0	0.999978	0.000022
β	**erf (β)**	**erfc (β)**