CE 5364 Groundwater Transport Phenomena
Summer 2020
Exam 2

You have 2.5 hours (150 minutes) to complete your work on this exam except as modified by a disability. That time does not count the time required to print out the exam pages for you to write on or to scan your work into a single pdf file to email back to Dr. Rainwater. If you don't print out the exam to write your answers, write your answers on your own paper, making sure you identify which answer goes with which question. You can also supplement your own paper if the exam printout is too short for you. Please don't waste time copying the entire problem statement or question, just make sure you show where you are like this, spacing them out on the pages wo you can complete your work. If I can't figure it out, it's wrong.

Format if you provide all your own paper for the exam, and don't write your solutions on your printout of the exam

Verbal Questions

1. *followed by your answer*
2. *followed by your answer*
   and so on

Problems

1. *[a] followed by your answer*
   [b] followed by your answer
   [c] followed by your answer
2. *followed by your answer*
3. *followed by your answer*

The verbal part of the exam is to be completed without any books, notes, old homework, or electronic access to anything or anybody. For the problems, you can use your notes, homeworks, and the provided text pdfs on your computer. You are not allowed to use any other digital or paper aids beyond that list. You can use the typical NCEES calculator that you are used to in our courses. You are also prohibited from making the downloaded exam file available to anyone else at any time or selling it to a coursework collection service like Chegg. You must also sign this academic honor pledge and record the clock time for your beginning and ending of the exam. Once you start the exam, you must continue until you finish, with only short interruption for bathroom needs. I hope you will put it behind you during the 10:00 a.m.-12:30 p.m. time slot so you can get on with your other responsibilities.

Pledge (copy this by hand if you don't print out the exam) Absolutely required!

On my honor, I have neither given nor received any aid on this exam. I followed all the given instructions as required.

Signature_____ Start time_____ Stop time_____

CE 5364 Groundwater Transport Phenomena Exam 2 August 7, 2020

Name SOLUTION

I. Verbal questions (60 points total, 4 points each). Answer 15 of the following 18 questions briefly and concisely. Use complete English sentences when appropriate (Explain, Distinguish). Clearly mark the questions that you omit.

1. Distinguish between the application of a numerical groundwater transport model as [1] a predictive tool and [2] a screening tool. Which type of model uses takes more effort by the model user?

As a predictive tool, User must know all parameters to sufficiently describe system & predict concentration change. This is more complex.
As a screening tool, User doesn't know many parameters of system, just wants a quick general idea of possibilities

2. Explain why it is so important to have a proper conceptual model of the system to be simulated before moving forward to discretization and selection of parameters.

We need to understand the sub surface conditions for unsaturated zone, saturated zone, & aquifers to simulate the right problem.

3. Explain how the Groundwater Vistas preprocessor for MT3D allows the user to establish the initial concentration distribution in a simulated domain. Can you use a similar approach for other initial conditions or parameters?

Initial concentrations are set up as properties, and can be assigned as individual cell values or with zones. This approach works for all other properties like, K, S, transmissivity, porosity, & top/bottom elevations.

4. Explain how Modpath can be used to show the particle travel times values from the initial location of the particle to its exit point from the solution domain.

It is possible to show the travel times with arrow heads and time labels. You have to specify these in GWV.

5. List the four solute transport processes that you simulated in your project using MODFLOW and MT3D.

Advection
Dispersion
Sorption
Decay

6. List four types of site characterization information we can get through construction and use of a monitoring well.

Subsurface materials – lithology
Subsurface Contamination – analyze soil samples
Depth to water
Water samples – analyze
NAPL thickness
Slug tests for K

7. Why is approval of the site investigation work plan required before the investigation begins? Who has to approve the plan for it to be acceptable?

Approval is necessary to make sure the scope of work is appropriate. Regulators must approve the work, as does the client.

8. List four possible sources of soil characteristic curve data that may be used when describing flow and transport in the unsaturated zone.

Technical literature
Lab tests with soil
Mathematical estimates from texture
Field measurements

9. Explain the concept of capillary pressure head for water in the unsaturated zone. Why is it negative? Use words, not a picture.

Water is held in the unsaturated zone by capillary forces, and the pressure felt by the water is less than atmospheric → soil suction. It is negative because atmospheric is set as 0 gage.

10. List the three main categories of groundwater and soil remediation used to clean up contaminated sites..

Source control
Containment
Mass reduction — pump&treat, biodegrade

11. Explain how the ability of a soil to accept infiltration from a steady rainfall event is affected by the initial moisture content based on your Chemflo experience. What two forces are acting to bring the water into the soil?

If initial moisture content is high, there's less room for the water to enter the soil so less influx is allowed.

Gravity & capillary forces.

12. Explain the concept of the entry pressure as applied to DNAPL movement through the capillary fringe.

DNAPL fluid lens must build up sufficient head/thickness at top of capillary fringe to overcome surface tension and push the water and air out of the way.

13. Distinguish between the conditions for DNAPL residuals in the unsaturated zone, saturated zone, and free phase zone. Which one tends to have the highest DNAPL saturation? Which tends to have the lowest?

In the unsaturated zone, the residuals can be separate ∈ Lowest immobile blobs attached to drier soil or soil moisture.
In the saturated zone, the DNAPL residuals are smaller blobs as water dominates the pore space.
In the free phase zone, the DNAPL is continuous & mobile. ← Highest

14. Explain how a LNAPL smear zone can develop near the water table. Don't just draw a picture by itself, use words.

Up & down movement of water table moves the LNAPL lens up & down. Residual LNAPLs can be trapped below water table & in capillary fringe.

15. Describe a possible groundwater contaminant situation in which the application of a structural containment barrier would be appropriate. State which type of barrier you would use.

The lower confining layer must be relatively shallow with source zone & plume limited in extent.
Can use slurry wall, piling, grout curtains

16. List four remediation technologies that use injection or production of gases in the unsaturated or saturated zones, including identifying the target type of contaminant.

Soil vapor extraction
Bioventing
Air sparging
} VOCs

DO - biodegradation

H_2 Cl-HCs

17. What type of contaminated sites was RCRA (1976) set up to target? Where does the money for the clean up come from?

Hazardous waste sites at active commercial facilities
Waste disposal/handling/storage
Money is from active site owner.

18. What type of contaminated sites was CERCLA (Superfund) set up to target? How was the money to pay for the clean ups to be obtained?

CERCLA was intended for orphan sites contaminated by hazardous materials, but the owners had left the site.
The money was to come from those who owned & managed the waste, pursued legally since they had left the sites.

Name SOLUTION

II. Problems (50 points total). Do all three problems. Show all work clearly for full credit. Clearly identify the answers, and show all your units!

1. (28 total) An LPST site has been characterized for subsurface total petroleum hydrocarbons contamination in the soil and groundwater. The impacted aquifer is unconfined, and the subsurface sediments have an average porosity of 0.38 and bulk density of 130 lb/ft^3 (2080 kg/m^3).

[a] (8) The free phase LNAPL (specific gravity = 0.80) has been found in several monitoring wells, and the average thickness of LNAPL in the monitoring wells was 1.50 ft. The estimated extent of the LNAPL lens is about 40 ft by 60 ft, and the average LNAPL saturation in the lens is estimated at 0.75. **Find (i) the thickness of the free phase LNAPL in the formation in ft and (ii) the volume of LNAPL in the free phase in gallons.**

[4] (i) $h_f = h_w \cdot \frac{(\rho_w - \rho_{LNAPL})}{\rho_{LNAPL}} = h_w \frac{(SG_w - SG_{LNAPL})}{SG_{LNAPL}} = 1.5ft \frac{(1-0.8)}{0.8}$

$h_f = 0.375 ft$

(ii) $\forall_{FP} = S_{FP}\, n\, \forall_{LNAPL\,Lens} = 0.75(0.38)(40ft)(60ft)(0.375ft)$

$= 257 ft^3 \left(\frac{7.48 gal}{ft^3}\right)$

[4] $\forall_{FP} = 1920$ gal

[b] (8) Residual TPH concentrations in the soil beneath the leaking tank pit were found to average 2500 mg TPH/kg soil. These residuals lie beneath the pit area of 20 ft by 40 ft and extend from the bottom of the pit downward 25 ft to the capillary fringe/water table. **Find the (i) mass of TPH in the unsaturated zone in kg and (ii) the volume of TPH in gallons.**

(i) $M_{UZ_{TPH}} = C_{UZ}\, \rho_{UZ}\, \forall_{UZ} = 2500 \frac{mg}{kg}\left(\frac{1\,kg\,TPH}{10^6 mg}\right)(20ft)(40ft)(25ft)\left(\frac{130 lb}{ft^3}\right)\left(\frac{0.454 kg}{lb}\right)$

[4] $M_{UZ_{TPH}} = 2950$ kg TPH

$\forall_{UZ} = \frac{M_{UZ\,TPH}}{\rho_{UZ\,TPH}} = \frac{2950 kg}{0.8\left(1 \frac{kg}{L}\right)} = 3690 L \left(\frac{1 gal}{3.785 L}\right)$

[4] $\forall_{UZ} = 974$ gal

[c] (8) A plume of contaminated groundwater has been delineated also. The plume is 200 ft long, 80 ft wide, and extends across the saturated thickness of the aquifer, which is 80 ft. The average concentration in the plume is 0.50 mg/L. Find (i) the mass of TPH in the saturated zone in kg and (ii) the volume of TPH (not the water) in gallons.

(i) $M_{SZ\,TPH} = C_{SZ}\, \forall_{SZ}$

$\forall_{SZ} = 0.38(200\,ft)(80\,ft)(80\,ft) = 486400\,ft^3$

4

$M_{SZ\,TPH} = 0.5\,\frac{mg}{L}\left(486400\,ft^3\right)\left(\frac{1\,m}{3.28\,ft}\right)^3\left(\frac{1\,kg}{10^6\,mg}\right)\left(\frac{1000\,L}{m^3}\right)$

$M_{SZ\,TPH} = 6.88\,kg$

(ii) $\forall_{SZ_{TPH}} = \frac{M_{SZ\,TPH}}{\rho_{SZ\,TPH}} = \frac{6.09\,kg}{0.8\,kg/L} = 8.60\,L\left(\frac{1\,gal}{3.785\,L}\right)$

4

$\forall_{SZ_{TPH}} = 2.27\,gal$

[d] (4) The site owner estimates from inventory checks that 3500 gallons of fuel were lost. Does this estimate compare well with your results? What other fates of the hydrocarbons have not been yet accounted for by parts [a], [b], and [c]?

Total HCs $= 1920 + 974 + 2.27\,gal$

3

$= 2900\,gal < 3500\,gal$

1 Volatilization, decay/biodegradation

2. (12) A soil gas characterization at a contaminated site has found the measured concentration of benzene in the soil atmosphere to be 12000 mg/m^3. Assume that the benzene is part of a fuel mixture that is in equilibrium with the soil atmosphere. The temperature of the soil gas was 20°C. Useful information about benzene can be found in the textbook. **Find the mole fraction of benzene in the liquid mixture.**

[4] $C\frac{mg}{L} = \frac{X_a P_o^a MW_a}{RT}$

$$X_a = \frac{C RT}{P_o^a MW_a}$$

[1] $T = 273 + 20 = 293\ ^oK$

[1] $R = 0.0821 \frac{L\ atm}{mole\ ^oK}$

[1] $MW_a = 78.11 \frac{g}{mole}$

[1] $P_o^a = 60\ mm\ Hg\left(\frac{1\ atm}{760\ mm\ Hg}\right) = 0.079\ atm$

$$X_a = \frac{12000 \frac{mg}{m^3}\left(\frac{m^3}{1000L}\right)\left(0.0821 \frac{L\ atm}{mole\ ^oK}\right)(293\ ^oK)\left(\frac{1g}{1000mg}\right)}{(0.079\ atm)\left(78.11 \frac{g}{mole}\right)}$$

[2]

$$X_a = 0.047$$

3. (10) Groundwater samples have been collected quarterly for the last 18 months and analyzed for TCE in ppb. The table below shows the results for one monitoring well. **Use the Mann-Kendall test to determine if there is a trend and if the trend is increasing or decreasing. Show all the work below.**

Date	TCE (ppb)
3/2019	15
6/2019	12
9/2019	28
12/2019	16
3/2020	10
6/2020	30

	1	2	3	4	5	6	Sum #No-#Yes
	15	12	28	16	10	30	
Event 1 > Event n?		Y	N	N	Y	N	3-2 = 1
Event 2 > Event n?			N	N	Y	N	3-1 = 2
Event 3 > Event n?				Y	Y	N	1-2 = -1
Event 4 > Event n?					Y	N	1-1 = 0
Event 5 > Event n?						N	1 = 1

9

+3 = S

Goto Figure |S| = 1+17.27

So no trend

1