Final Exam 2025-3

This exam is comprised of a multiple-choice section, short answers, and some worked problems. The worked problems are encoded as file-uploads; intent is single file per question or screen capture to .png, then upload the .png

1 Multiple Choice 1 point

What is the primary advantage of MODFLOW 6 compared to earlier versions such as MODFLOW-2005?

- ◯ It replaces the need for separate solute transport models such as MT3D
- ◯ It runs only on Windows systems
- ◯ It uses fewer input files and requires manual entry
- ◯ It is a modular framework designed to integrate multiple model types (flow, transport, exchanges)

2 Multiple Choice 1 point

Why is Python considered essential for modern groundwater modeling workflows?

- ◯ It replaces MODFLOW and solves groundwater flow directly
- ◯ It forces users to write models using low-level machine code
- ◯ It eliminates the need to understand hydraulic or transport processes
- ◯ It automates creation, modification, and visualization of model input and output

3 Multiple Choice 1 point

What is FloPy primarily used for in MODFLOW 6 modeling?

- Solving groundwater flow using commercial cloud resources
- Replacing all MODFLOW packages
- Editing MODFLOW source code
- Creating, running, and post-processing MODFLOW-based models via Python

4 Multiple Choice 1 point

Why is visualization important in solute transport modeling?

- Because simulation results can only be interpreted graphically
- Because visualization automatically fixes model errors
- Because raw output files cannot be read by any software
- Because visualization helps interpret transport and flow behavior more effectively than reviewing raw outputs

5 Multiple Choice 1 point

What does combining MODFLOW 6 and Python ultimately enable users to focus on?

- Connecting cloud servers to model outputs
- Scientific decision-making instead of manual data handling
- Debugging file formats instead of understanding the model
- Eliminating the need for field data

6 Multiple Choice 1 point

Why is MT3DMS Example 9 used when introducing MF6–GWT?

- It only tests sorption and decay processes.
- It is the fastest transport model ever developed.
- It is a widely used benchmark for verifying numerical transport solutions.
- It requires no dispersion or advection setup.

7 Multiple Choice 1 point

In the MF6 advection setup, how is the flux-limiter option selected in the example(s)?

- By assigning mixelm = 0 to disable advection completely.
- By assigning mixelm = 2 to apply pure central differences.
- By assigning mixelm = +1 to force upstream weighting.
- By assigning mixelm = −1 to enable TVD flux limitation.

8 Multiple Choice 1 point

What does the SSM (Source–Sink Mixing) package do in MF6–GWT?

- Assigns concentrations to sources/sinks such as wells and constant head boundaries.
- Generates concentration color maps during postprocessing.
- Controls mass storage and porosity settings.
- Calculates decay reactions in the aquifer matrix.

9 Multiple Choice 1 point

According to the instructor's notes, which MF6 workflow pattern is emphasized as repeatable?

- Conceptualize → Linearize → Iterate → Export
- Import USGS data → Export MT3DMS input → Animate → Print
- Mesh design → Solve → Visualize → Publish
- Build model → Run simulation → Postprocess → Verify

10 Multiple Choice 1 point

In transport modeling, why is a TVD (Total Variation Diminishing) method desirable when simulating contaminant plumes?

- It forces the plume to remain symmetric around the source.
- It reduces non-physical oscillations near sharp concentration gradients.
- It eliminates the need for specifying dispersivities.
- It speeds up model runtime by skipping mass balance checks.

11 Multiple Choice 1 point

What characterizes the unsaturated (vadose) zone beneath the land surface?

- It exists only in sandy soils
- Pore spaces contain a mixture of air and water
- It transports only vapor, not liquid water
- Pore spaces are entirely filled with groundwater

12 Multiple Choice 1 point

Movement of fluids in the unsaturated zone is influenced by which combination of forces?

- Only gravity, because water drains downward
- Earth tides and magnetic forces
- Gravity, capillary forces, and pressure gradients
- Only pressure gradients caused by contamination

13 Multiple Choice 1 point

Why is the unsaturated zone important for groundwater protection?

- It filters contaminants and affects their transport to deeper layers
- It plays no measurable role in hydrology
- It prevents any contaminants from reaching groundwater
- It only stores water for plant root uptake

14 Multiple Choice 1 point

Which process is directly linked to the interaction between rainfall, soil moisture, and plant activity in the vadose zone?

- Radioactive decay of minerals
- Complete evaporation of stored soil water
- Soil moisture replenishment and root water uptake
- Flash distillation of water near the surface

15 Multiple Choice 1 point

Why must groundwater sampling locations be chosen carefully?

- Because results depend on hydrogeology and proximity to contamination sources
- To minimize the number of samples required
- Because only surface locations provide reliable results
- To avoid sampling near monitoring wells

16 Multiple Choice 1 point

Why is it necessary to collect groundwater samples at different depths?

- To obtain water for mixing and dilution tests
- Because shallow water is always more contaminated
- Because groundwater quality can vary vertically
- To reduce laboratory costs

17 Multiple Choice 1 point

Which item below is a key laboratory quality control measure for groundwater data?

- Avoiding chemical preservatives
- Using blank samples and duplicates
- Changing containers between each step
- Increasing sample size

18 Multiple Choice 1 point

What role does GIS mapping play in groundwater contamination studies?

- It produces spatial representations of contaminant plumes
- It applies chemical corrections to concentration data
- It reduces costs by replacing laboratory testing
- It is used only when field work is unavailable

19 Multiple Choice 1 point

What is the purpose of trend analysis in groundwater monitoring?

- To reduce the number of required sampling events
- To calibrate laboratory equipment
- To estimate pumping rates for all wells
- To track changes in contamination levels over time

20 Multiple Choice 1 point

Which technology involves pumping contaminated groundwater to the surface for treatment?

- Permeable Reactive Barriers
- Electrokinetic Remediation
- Pump-and-Treat Systems
- In-Situ Bioremediation

21 Multiple Choice 1 point

In-situ bioremediation primarily relies on:

- Pumping groundwater to the surface for aeration
- Using plants to absorb heavy metals
- Microorganisms breaking down organic contaminants
- Injecting oxidizing chemicals to destroy contaminants

22 Multiple Choice 1 point

Permeable Reactive Barriers (PRBs) remediate groundwater by:

- Using electric currents to mobilize contaminants above ground
- Physically filtering water at the surface
- Extracting contaminated soil and heating it
- Reacting with contaminants as groundwater flows through a subsurface barrier

23 Essay 3 points

Distinguish between the application of a numerical groundwater transport model as a predictive tool and as a screening tool. Which type (predictive or screening) of model use takes more effort by a model user?

24 Essay 3 points

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

25 Essay 3 points

Explain how MODFLOW6 and FloPy allows the user to establish the initial concentration distribution in a similation domain. Is the approach generic to where it can be applied for other initial conditions or parameters?

26 Essay 4 points

Describe how one could determine particle travel times from an initial location or the particle until its exit point from the solution domain? Does MODFLOW6 and FloPy have necessary tools to make such calculations?

27 Essay 4 points

What are the four types of transport processes that MODFLOW6 readily simulates?

28 Essay 4 points

What four types of site characterization information can be obtained from construction and use of a monitoring well?

29 Essay 4 points

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

30 Essay 3 points

Explain the concept of capillary pressure head for water in the unsaturated zone. Why is it negative?

31 Essay 3 points

Identify and describe three categories of groundwater and soil remediation, including approaches for containment, source control, and mass reduction.

32 Essay 3 points

Explain the concept of entry pressure as it applies to DNAPL movement through the capillary fringe.

33 Essay 3 points

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

34 Essay 3 points

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

35 File Upload 4 points

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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 0.37 and bulk density of 130 $\frac{lb}{ft^3}$ (2080 $\frac{kg}{m^3}$). 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.

Determine:
(a) The thickness of the free phase LNAPL in the formation in feet.
(b) The volume of LNAPL in the free phase in gallons.

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36 File Upload 4 points

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Continuing with the previous scenario. 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.

Determine:
(a) The mass of TPH in the unsaturated zone in kg.
(b) The volume of TPH in gallons

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37 Essay 4 points

Continuing with the previous scenario. A plume of contaminated groundwater has also been delineated. 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.

Determine:
(a) The mass of TPH in the saturated zone in kg.
(b) The volume of TPH (not the water) in gallons.

38 Essay 4 points

Continuing with the previous scenario. The site owner estimates from inventory checks, that 3500 gallons of fuel are lost.

Determine:
(a) If this estimate compares well with your results.
(b) What other fates of hydrocarbons have not been accounted for in the estimates above.

39 Essay 4 points

Groundwater samples have been collected quarterly for the last 18 months and analyzed for TCE in parts per billion. The table lists the results for one monitoring well.

Table 1: TCE Observations in an Aquifer

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

Determine:
a) An appropriate method to detect and quantify a trend for small sample sizes.
b) If the data show a trend.
c) If the trend is increasing or decreasing.

40 File Upload 5 points

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Consider the concentration profiles in Figure 1. The elapsed time, 10 days, is the time since the injection of a constituent mass. Assuming the porosity is 0.50 and the initial mass of constituent is 200 mg.

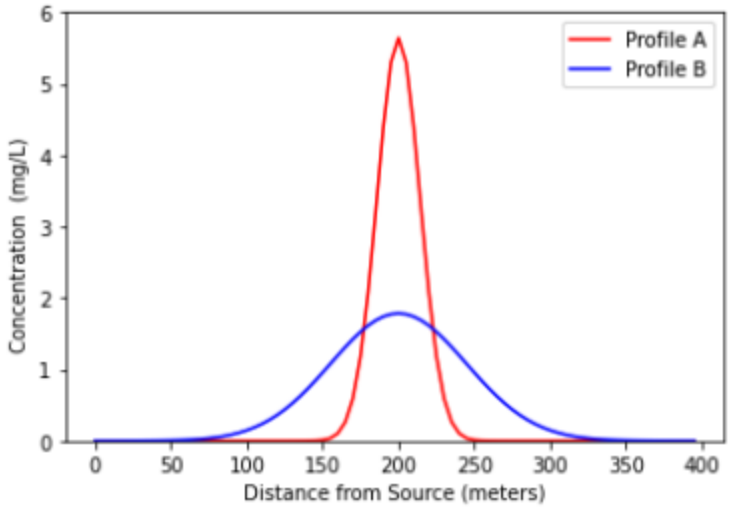

Figure 1: Concentration profile(s)

Determine:
(a) The profile (A) or (B) that indicates greater dispersive behavior.
(b) The model that describes the type of transport indicated by the profile.
(c) The pore velocity and apparent dispersion for each profile.

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41 File Upload 5 points

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Consider the concentration histories in Figure 2. The elapsed time is the time since the release of the constituents. The observation location is 100 meters away from the source zone.

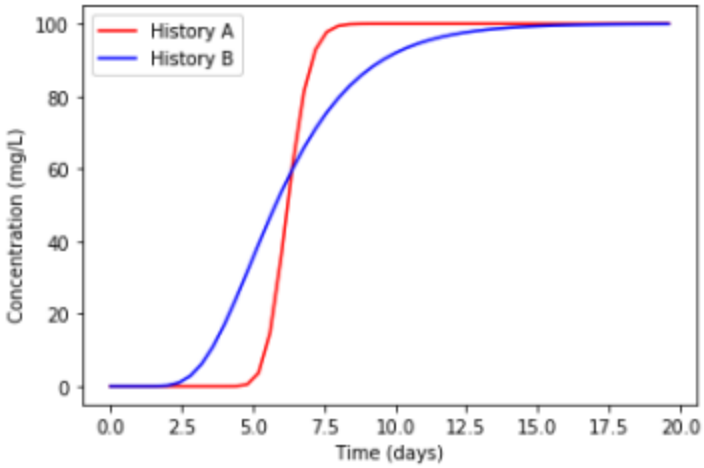

Figure 2: Concentration histories

Determine:

(a) The history (A) or (B) that indicates greater dispersive behavior.
(b) The model that describes the type of transport indicated by the history.
(c) The pore velocity and apparent dispersion for each histor

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42 File Upload 8 points

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Figure 4 is a plot of concentration histories of constituients introduced into a 1-meter long column at t = 0 minutes, x = 0 cm. Species 1 is known to be conservative and non-reactive (with the aquifer solids).

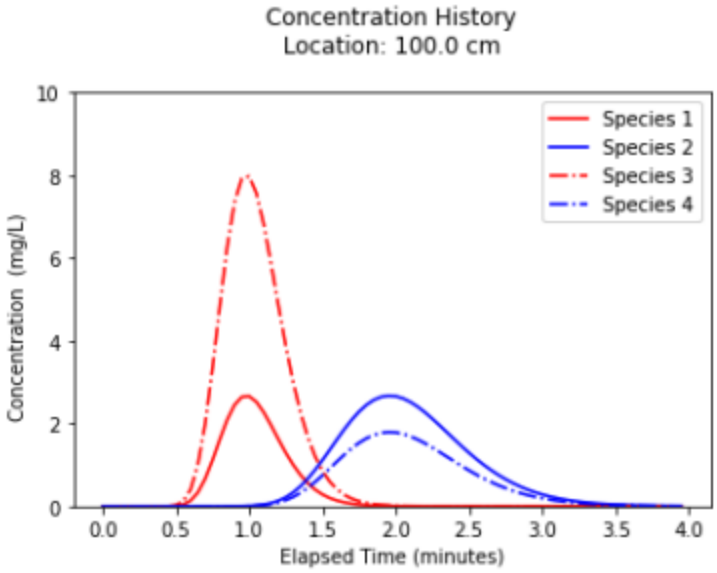

Figure 4: Concentration histories in a porous column

Determine:
a) The specific discharge if the porosity is 0.30.
b) The distribution coefficients (assume linear, instantaneous, equilibrium adsorbtion isotherms) for species 2, 3, and 4, if the solids density is 2.97 g/cc.
c) An estimate of the dispersion coefficient for species 3
d) Predict the concentration history for species 3 at x = 50 cm

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