

Supplementary information
to commentary article concerning ChatGPT and hydrological geosciences
by L.J.S. Halloran, S. Mhanna and P. Brunner (2023)

contact: landon.halloran AT unine DOT ch

Questions 1-7 are based on questions from Fetter and Kreamer (2022) [1]. The recorded interactions with ChatGPT were carried out on 17.01.2023.

Questions 8-15 are based on questions from Fitts (2013) [2]. The recorded interactions with ChatGPT were carried out on 31.01.2023.

The user-inputted question is displayed in black and the text produced by ChatGPT is in red. Our evaluation of the questions (in **bold** capital letters) is included (this information was not inputted into ChatCPT).

Q1 (Fetter, Chapter 1, Problem 1):

A vertical water tank is 15 ft in diameter and 60 ft high. What is the volume of the tank in cubic feet?

The volume of a cylinder is given by the formula: $V = \pi r^2 h$, where r is the radius and h is the height.

To find the radius of the tank, we divide the diameter by 2:

$$r = 15 \text{ ft} / 2 = 7.5 \text{ ft}$$

So the volume of the tank is:

$$V = \pi * (7.5 \text{ ft})^2 * 60 \text{ ft} = 14,317.67 \text{ cubic ft}$$

WRONG. FORMULA RIGHT, BUT EVALUATION OF ANSWER INCORRECT. THE CORRECT ANSWER IS 10,597 ft³.

Q2 (Fetter, Chapter 1, Problem 5):

A tank of 10,600 cubic ft is being filled at a rate of 8.4 gal per minute, how long would it take to fill the tank described above?

To calculate how long it would take to fill a tank of 10,600 cubic feet at a rate of 8.4 gallons per minute, you would divide the total volume of the tank by the rate at which it's being filled.

First you need to convert cubic ft to gallon, the conversion factor is 1 cubic ft = 7.48051948 gallons

$10,600 \text{ cubic ft} = 10,600 * 7.48051948 = 79836.76 \text{ gallons}$

So, the time it would take to fill the tank is:

$\text{time} = \text{total volume} / \text{fill rate}$

$\text{time} = 79836.76 / 8.4$

$\text{time} \approx 9440 \text{ min (or 157.33 hours)}$

Therefore, it would take approximately 9440 minutes or 157.33 hours to fill the tank at this rate

CORRECT

Q3 (Fetter, Chapter 1, Problem 9):

The parking lot of the Spendmore Megamall has an area of 128 ac. It is partially landscaped to provide some areas of grass. Assume that an average 63% of the water that falls on the parking lot will flow into a nearby drainage ditch, and the rest either evaporates or soaks into unpaved areas. If a summer thunderstorm drops 3.23 cm of rain, how many cubic feet of water will flow into the drainage ditch?

First you need to convert cm to ft, the conversion factor is 1 cm = 0.0328084 ft

$3.23 \text{ cm} = 3.23 * 0.0328084 = 0.10635332 \text{ ft}$ To calculate how many cubic feet of water will flow into the drainage ditch from a summer thunderstorm that drops 3.23 cm of rain on a 128-acre parking lot with 63% water retention, you can use the following steps:

Convert the area of the parking lot from acres to square feet, by using the conversion factor 1 acre = 43,560 sq ft.

So, 128 acres = $128 * 43,560 \text{ sq ft} = 5,555,840 \text{ sq ft}$

Multiply the area of the parking lot by the depth of the rainfall to calculate the total volume of water that fell on the parking lot

$\text{Total Volume} = \text{area} * \text{depth} = 5,555,840 \text{ sq ft} * 0.10635332 \text{ ft} = 592,837.3 \text{ cubic ft}$

Multiply the total volume of water that fell on the parking lot by the percentage of water retention (1 - retention percentage) to calculate the amount of water that flows into the drainage ditch.

*amount = total volume * retention percentage = 592,837.3 cubic ft * 0.63 = 372,931.81 cubic ft*

So, approximately 372,931.81 cubic feet of water will flow into the drainage ditch.

CORRECT

Q4 (Chapter 1, Problem 11):

What mass of water at 15°C can be cooled 1°C by the amount of heat needed to sublime (go from a solid to a vapor state) 18 g of ice at 0°C?

The heat needed to sublime (go from a solid to a vapor state) 18 grams of ice at 0°C is called the heat of sublimation. To cool a mass of water from 15°C to 14°C, the same amount of heat must be removed from the water as is needed to sublime 18 grams of ice at 0°C.

The specific heat of water is 4.18 joules per gram per degree Celsius. So, the amount of heat needed to cool a mass of water from 15°C to 14°C is the mass of water multiplied by the specific heat of water multiplied by the temperature change. The formula is : $Q = mc\Delta T$

Q = heat removed (Joules)

m = mass of water (grams)

c = specific heat of water (4.18 J/g°C)

ΔT = change in temperature (14°C - 15°C = -1°C)

so we can't determine the mass of water by only the given information, we need to know the amount of heat energy that is needed to sublime 18 grams of ice. The heat of sublimation is a property of ice. Without it, it's impossible to calculate the mass of water cooled.

COULD NOT ANSWER WITH THE GIVEN INFORMATION.

Q5 (Chapter 2, Problem on page 64):

A drainage channel for stormwater is lined with smooth concrete and has vertical sides with a flat bottom that is 3.50ft wide. The bottom of the channel drops 1.50 ft over a distance of 500ft. If the channel contains 1.50ft of water, what is its discharge? Assume roughness coefficient 0.012.

To calculate the discharge of a stormwater drainage channel with a flat bottom that is 3.50 ft wide and a drop of 1.50 ft over a distance of 500 ft, you can use the equation for open channel flow known as the Manning's equation.

The Manning's equation for discharge in a rectangular open channel is

$$Q = (1.486/n) * A * R^{(2/3)} * S^{(1/2)}$$

where:

Q = discharge (cubic feet per second)

A = cross-sectional area of the channel (square feet)

R = hydraulic radius (square feet)

S = slope (unitless)

n = roughness coefficient (unitless)

The cross-sectional area of the channel is the width of the channel multiplied by the depth of the water: $A = b * d = 3.5 \text{ ft} * 1.5 \text{ ft} = 5.25 \text{ sq ft}$.

The hydraulic radius of the channel is the area of the cross section divided by the wetted perimeter. Since the channel has vertical sides and the width is known, the wetted perimeter is only the width, the hydraulic radius is: $R = A/b = 5.25/3.5 = 1.5 \text{ sq ft}$.

The slope of the channel is the drop over the distance, so $S = 1.5 \text{ ft} / 500 \text{ ft} = 0.003$

The Manning's roughness coefficient for concrete channel is 0.012

With that information, you can now use the Manning's equation and you will have the discharge in cubic feet per second:

$$Q = (1.486/0.012) * 5.25 * (1.5)^{(2/3)} * 0.003^{(1/2)}$$

You should be careful with the units and make sure they are consistent before solving the equation.

Please note that the calculation of discharge here is based on the assumption that the channel is wide open and unrestricted. In practice, there may be additional factors such as obstruction, flow velocity and rate, that may affect the actual discharge.

WETTED PERIMETER IS WRONG. ALL THE REST IS OKAY.

Q6 (Chapter 3, Problem on page 73):

A fluid has a density of 1.085 g/cm³. If the acceleration of gravity is 9.81 m/s², what is the specific weight of the fluid?

The specific weight of a fluid is the weight of a unit volume of the fluid and is given by the equation:

$$\gamma = \rho * g$$

where

γ = specific weight (N/m^3)

ρ = density of the fluid (kg/m^3)

g = acceleration due to gravity (m/s^2)

Substituting the given values into the equation, we get:

$$\begin{aligned}\gamma &= 1.085 \text{ g/cm}^3 * (1 \text{ kg} / 1000\text{g}) * (100 \text{ cm/m})^3 * 9.81 \text{ m/s}^2 \\ &= 1.085 * 9.81 = 10.6 \text{ N/m}^3\end{aligned}$$

So, the specific weight of the fluid is approximately 10.6 N/m^3

WRONG. UNIT CONVERSION ISSUE.

Q7 (Chapter 3, Problem on page 97):

A constant-head permeameter has a sample of medium-grained sand 15 cm in length and 25 cm² in cross-sectional area. With a head of 5.0 cm, a total of 100 mL of water is collected in 12 min. Find the hydraulic conductivity.

The hydraulic conductivity of a porous medium can be determined using a constant-head permeameter. The formula to calculate the hydraulic conductivity is:

$$K = Q / (A * (h_1 - h_2))$$

where:

K = hydraulic conductivity (cm/s)

Q = flow rate (cm³/s)

A = cross-sectional area of the sample (cm²)

h_1 = initial head (cm)

h_2 = final head (cm)

In this case, the cross-sectional area of the sample is given as 25 cm², the head is 5.0 cm, and the total amount of water collected in 12 minutes is 100 mL. To convert this to cubic centimeters per second, we can divide by the time in seconds:

$$Q = 100\text{mL} / (12 \text{ min} * 60 \text{ sec/min}) = 0.00278 \text{ cm}^3/\text{s}$$

Now we can use this value for Q , A and h_1, h_2 to find the hydraulic conductivity

$$K = 0.00278 \text{ cm}^3/\text{s} / (25 \text{ cm}^2 * 5 \text{ cm}) = 0.00278 \text{ cm/s}$$

So, the hydraulic conductivity of the medium-grained sand sample is 0.00278 cm/s.

WRONG. USED INCORRECT FORMULA.

Q8 (Fitts, Chapter 1, Problem 9):

The drainage area of the Colorado River is about 653,000km² and its average annual discharge is about 15 million acre-feet (Manning, 1992). The average precipitation rate in the basin is about 12 inches/year. Calculate the river discharge divided by the drainage basin area in inches/year. What fraction of the annual precipitation rate is this? What fates, other than ending up in the Colorado River, can precipitated water have in this basin?

To calculate the river discharge divided by the drainage basin area in inches/year, we first need to convert the discharge from acre-feet to inches.

1 acre-foot = 325,851 gallons 1 gallon = 231 cubic inches

So, 15 million acre-feet = 15,000,000 x 325,851 x 231 cubic inches = 14,147,175,000,000 cubic inches

Now, dividing this by the drainage basin area of 653,000 km² (which is equivalent to 65,300,000,000 m²) we get:

14,147,175,000,000 cubic inches / 65,300,000,000 m² = 217.17 inches/year

The fraction of the annual precipitation rate (12 inches/year) that this is:

217.17 inches/year / 12 inches/year = 18.096

So, the discharge of the Colorado River is 18 times the annual precipitation rate.

Water in the Colorado River basin can have several other fates besides ending up in the river:

Evaporation: Some of the water will evaporate and go back into the atmosphere.

Transpiration: Some of the water will be taken up by plants and trees for growth.

Groundwater recharge: Some of the water will be absorbed into the ground and become part of the groundwater system.

Runoff: Some of the water will flow over the surface of the land and not be absorbed into the ground or evaporated.

Flooding: Some of the water may cause flooding in areas near the river or its tributaries.

Reservoirs: Some of the water may be stored in reservoirs for later use.

ERROR IN UNIT CONVERSION. THE OTHER POSSIBILITIES OF WATER FATE ARE CORRECT.

Q9 (Fitts, Chapter 2, Problem 16):

What is the gage pressure at the bottom of a pool 4m deep containing fresh water? What is the absolute pressure at this point? Give your answers in N/m².

The gage pressure at the bottom of a pool 4m deep can be calculated using the formula:

$$P_{\text{gage}} = \rho gh$$

where P_{gage} = gage pressure ρ = density of water (1000 kg/m³) g = acceleration due to gravity (9.8 m/s²) h = height of the fluid (4 m)

$$\text{So, } P_{\text{gage}} = 1000 \text{ kg/m}^3 * 9.8 \text{ m/s}^2 * 4 \text{ m} = 39,200 \text{ N/m}^2$$

The absolute pressure at the bottom of the pool can be calculated by adding the atmospheric pressure (101,325 N/m²) to the gage pressure:

$$P_{\text{abs}} = P_{\text{gage}} + P_{\text{atm}}$$

where P_{abs} = absolute pressure P_{atm} = atmospheric pressure (101,325 N/m²)

$$\text{So, } P_{\text{abs}} = 39,200 \text{ N/m}^2 + 101,325 \text{ N/m}^2 = 140,525 \text{ N/m}^2$$

Therefore, the gage pressure at the bottom of the pool is 39,200 N/m² and the absolute pressure is 140,525 N/m². Top of Form

CORRECT

Q10 (Fitts, Chapter 3. Problem 17):

A falling-head permeameter is set up to measure the K of a silty sand sample. The sample is a cylinder 8 cm in diameter and 22 cm long. The burette has a diameter of 2mm. At the start of the test, the head difference across the sample is 80 cm. Assuming the sample K is 10^{-4} cm/sec, estimate how much time will elapse before the head difference across the sample reduces from 80 to 20 cm.

To calculate the time required to reduce the head difference from 80 cm to 20 cm, we need to use Darcy's Law:

$$Q = KA (\Delta h/L)$$

where Q = flow rate K = hydraulic conductivity A = cross-sectional area of the sample Δh = head difference L = length of the sample

We know that $K = 10^{-4}$ cm/sec and $L = 22$ cm, so we need to calculate A . The diameter of the sample is 8 cm, so the cross-sectional area is:

$$A = \pi r^2 = \pi * (4^2) = 16\pi \text{ cm}^2$$

Next, we need to find the flow rate, which is calculated as:

$$Q = KA (\Delta h/L) = (10^{-4}) * (16\pi) * (80/22) = 0.369 \text{ cm}^3/\text{sec}$$

Finally, we can calculate the time required to reduce the head difference from 80 cm to 20 cm:

$$\Delta t = (Q * \Delta L) / A = (0.369 * 60) / (16\pi) = 0.845 \text{ sec}$$

So, it will take approximately 0.845 seconds to reduce the head difference from 80 cm to 20 cm.

Top of Form

WRONG EQUATION USED

Q11 (Fitts, Chapter 4. Problem 6):

What are the main benefits of well development?

Improved water quality: Well development helps to remove debris and stagnant water that can cause water contamination, providing cleaner, safer water.

Increased well productivity: The development process can improve the yield of the well by increasing the size of the well screen or by removing obstacles that block water flow.

Reduced maintenance costs: Regular well development can help identify potential problems and fix them before they become major issues, reducing the cost of maintenance and repairs.

Improved water availability: By improving the well's yield, well development can help ensure a consistent and reliable water supply, even during times of drought.

Better water distribution: The development process can improve the flow of water from the well to the distribution system, providing more consistent water pressure and reducing the need for water treatment.

Enhanced well lifespan: Regular well development can help extend the life of the well by preventing damage and deterioration.

Compliance with regulations: Well development is often required by state and local regulations to maintain the safety and quality of the water supply.

CORRECT. MORE DETAILED THAN THE BOOK.

Q12 (Chapter 5, Problem 2):

Consider a coastal plain setting where there are alternating near horizontal sand layers and silt/clay layers. Describe the typical direction of flow in the sand layers. Describe the typical direction of flow in the silt/clay layers.

In a coastal plain setting where there are alternating near-horizontal sand layers and silt/clay layers, the typical direction of flow in the sand layers is downward and horizontally towards the coast. Sand layers in coastal plains typically have high permeability, allowing water to move easily through the sand. In this setting, groundwater flow is often driven by the gravitational pull of the sea, which results in a seaward flow direction.

The typical direction of flow in the silt/clay layers is more complex due to their lower permeability. Silt and clay layers have smaller pore spaces and are more difficult for water to flow through. As a result, the direction of flow in these layers is often influenced by the surrounding geology, topography, and climate conditions.

In some cases, flow in silt/clay layers may be upward, as water is pulled towards the surface by evapotranspiration or pumping. In other cases, flow may be downward, as water infiltrates from the surface into the underlying aquifer. The direction of flow in silt/clay layers may also be lateral, moving towards adjacent permeable formations such as sand layers.

Overall, the direction of flow in silt/clay layers is dependent on the specific conditions in the coastal plain setting and is often more complex than the direction of flow in the sand layers.

WRONG. TEXTBOOK ANSWER: “THE FLOW IN THE SAND LAYERS WILL BE NEARLY PARALLEL TO THE LAYERS, AND FLOW IN THE SILT/CLAY LAYERS WILL BE ALMOST NORMAL TO THE LAYERS.”

Q13 (Chapter 6. Problem 17):

Consider two aquifers that have identical hydraulic conductivity and saturated thickness, but one is confined and the other is unconfined. If you pump a well in each aquifer at identical rates, which one will experience more drawdown (decline in head)? Explain why.

The unconfined aquifer will experience more drawdown. This is because in a confined aquifer, the water table is under pressure and is supported by the confining layer, so it will take more pumping to lower the water table and cause a decline in head. In contrast, in an unconfined aquifer, the water table is at atmospheric pressure, so it is easier to lower and cause a decline in head with pumping.

WRONG.

Q14 (Chapter 7. Problem 2):

A well is pumping at an unknown, steady rate in a confined aquifer. Near the pumping well are two observation wells; observation well A is located 8m from the pumping well and B is located 24m from the pumping well. The heads in these wells are $h_A = 134.20$ and $h_B = 134.28$ m. You know from prior pumping tests of the well that the well and the observation wells are screened in a confined aquifer with transmissivity $T = 1200 \text{ m}^2/\text{day}$. Assuming that without the well pumping there would be no hydraulic gradient at all, what is the pumping rate of the well?

*To calculate the pumping rate of the well, we can use the equation: $Q = T * (2 * \pi * r)^{3/2} * (h_A - h_B) / (\ln(r_A/r_B))$*

Where: $T = 1200 \text{ m}^2/\text{day}$ $r =$ distance from the pumping well to each observation well ($r_A = 8 \text{ m}$ and $r_B = 24 \text{ m}$) $h_A = 134.20 \text{ m}$ $h_B = 134.28 \text{ m}$

First, calculate the term in the denominator: $\ln(r_A/r_B) = \ln(8/24) = \ln(1/3) = -1.099$

Now, calculate the term in the numerator: $(h_A - h_B) = 134.20 \text{ m} - 134.28 \text{ m} = -0.08 \text{ m}$

*Finally, substitute the values in the equation: $Q = 1200 \text{ m}^2/\text{day} * (2 * \pi * 8 \text{ m})^{3/2} * (-0.08 \text{ m}) / (-1.099)$ $Q = 240 \text{ m}^3/\text{day}$*

So, the pumping rate of the well is approximately $240 \text{ m}^3/\text{day}$.

WRONG EQUATION.

Q15 (Chapter 8. Problem 5):

A confined aquifer has a transmissivity $T = 200 \text{ ft}^2/\text{day}$ ($18.6 \text{ m}^2/\text{day}$) and a storativity $S = 0.0002$. A fully penetrating well begins pumping in this aquifer at a rate of $1500 \text{ ft}^3/\text{day}$ ($42.5 \text{ m}^3/\text{day}$). Using the Theis solution predict the drawdown at a radius of $r = 100 \text{ ft}$ (30.5 m) at the following elapsed times: 10 minutes, 1 hour, 5 hours, and 24 hours.

*To predict the drawdown in the well, we can use the equation: $s = (Q / (4 * \pi * T)) * W(u)$, where*

*$Q = 1500 \text{ ft}^3/\text{day}$ ($42.5 \text{ m}^3/\text{day}$) $T = 200 \text{ ft}^2/\text{day}$ ($18.6 \text{ m}^2/\text{day}$) $u = S * r^2 * S / (4 * T * t)$ $W(u)$ = the well function, which can be calculated using a mathematical formula $r = 100 \text{ ft}$ (30.5 m) $S = 0.0002$ $t =$ time since the start of pumping*

First, calculate u for each time since the start of pumping:

*10 minutes: $t = 10 \text{ minutes} = 10/60 = 0.167 \text{ hours}$ $t = 0.167 \text{ hours} = 0.167 * 3600 \text{ sec} = 600 \text{ sec}$ $u = S * r^2 * S / (4 * T * t) = 0.0002 * (100 \text{ ft})^2 * 0.0002 / (4 * 200 \text{ ft}^2/\text{day} * 600 \text{ sec}) = 3.46\text{E-}6$*

1 hour: $t = 1 \text{ hour} = 3600 \text{ sec}$ $u = S * r^2 * S / (4 * T * t) = 0.0002 * (100 \text{ ft})^2 * 0.0002 / (4 * 200 \text{ ft}^2/\text{day} * 3600 \text{ sec}) = 5.77E-5$

5 hours: $t = 5 \text{ hours} = 5 * 3600 \text{ sec} = 18000 \text{ sec}$ $u = S * r^2 * S / (4 * T * t) = 0.0002 * (100 \text{ ft})^2 * 0.0002 / (4 * 200 \text{ ft}^2/\text{day} * 18000 \text{ sec}) = 3.16E-4$

24 hours: $t = 24 \text{ hours} = 24 * 3600 \text{ sec} = 86400 \text{ sec}$ $u = S * r^2 * S / (4 * T * t) = 0.0002 * (100 \text{ ft})^2 * 0.0002 / (4 * 200 \text{ ft}^2/\text{day} * 86400 \text{ sec}) = 9.92E-4$

Next, calculate $W(u)$ for each time since the start of pumping using a mathematical formula.

Finally, substitute the values in the equation: $s = (Q / (4 * \pi * T)) * W(u)$

Here, s represents the drawdown in the well at each time since the start of pumping.

THE EQUATION OF u IS WRONG.

References:

[1] C.W. Fetter and D. Kreamer (2022). "Applied Hydrogeology" (5th Edition). ISBN 978-1-4786-4652-5.

[2] C. Fitts (2013). "Groundwater Science" (2nd Edition). ISBN 978-0-12-384705-8.