Water Resources, Sustainability and Climate Change
22CVC109

Semester 2 2023 | In-Person Exam Paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **FOUR** questions.

All questions carry equal marks.

Refer to table and formula sheet included with the paper.

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1) a) The one-dimensional equation for describing non-conservative contaminant transport in an aquifer is given by:

$$\frac{\partial c}{\partial t} + \frac{\rho_b}{n}\frac{\partial c^*}{\partial t} = D_L\frac{\partial^2 c}{\partial x^2} - v\frac{\partial c}{\partial x}$$

(i) What is the physical meaning of c*? [2 marks]

(ii) It is common for a constant dispersion coefficient to be used. Discuss if this is a valid or physically correct assumption. You must use physical arguments to justify your answer. [4 marks]

(iii) Physically explain the different types of adsorption processes, and how one would go about determining which type was applicable to measured breakthrough data. [5 marks]

(iv) Give the equations for $\partial c^*/\partial t$ for (a) reversible kinetic Langmuir adsorption and desorption and (b) irreversible kinetic Freundlich sorption. [3 marks]

b) Two contaminant transport experiments are carried out in the laboratory. In both experiments we have used the same soil, the same flow velocity *v* and the same flow length *L*. However, each experiment uses a ***different*** chemical pollutant. Figure (1b) below shows the plots of both breakthrough curves, i.e. plots of the measured concentration at *x* = *L* through time *t*. Given that the chemical curve 1 corresponds to conservative transport, what type of transport could be occurring for chemical 2? You must provide a physical explanation to support your answer. [5 marks]

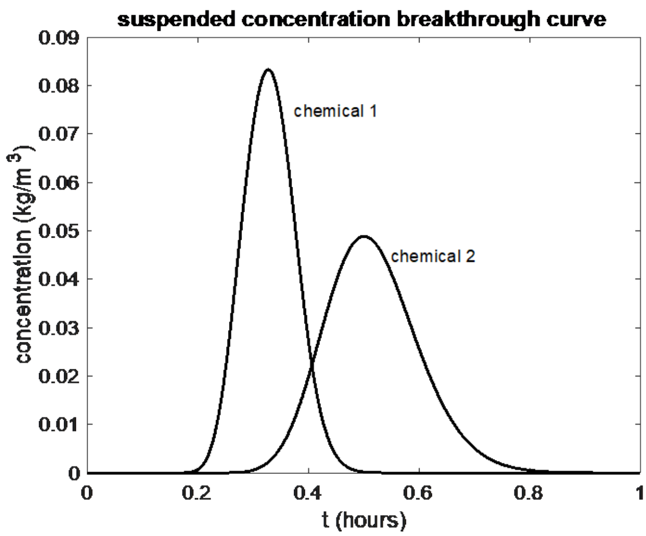

Figure Q1b

c) Briefly explain the causes of mechanical dispersion in the transport of contaminants in an aquifer. [6 marks]

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2) a) For the secondary stage of wastewater treatment, explain the difference between the treatment processes using attached or suspended growth. Give examples for each attached or suspended growth treatment process. [3 marks]

b) Pick one of the examples from part (a) and provide a detailed discussion of how it operates (include schematics, parts, and details of how the treatment works). [2 marks]

c) Explain the nitrogen cycle. [5 marks]

d) Discuss how the rise of temperature due to global warming affects aquatic life. Describe underlying causes. [3 marks]

e) An AD plant receives new organic feedstock. Analysis of the material indicates 25% dry solids and 96% volatile solids. The operator proposes a feeding regime of 70 tonnes of feedstock per day for AD reactor which is 900 m^3 in volume. Assuming the above feeding regime, calculate:

(i) the organic loading rate in terms of volatile solids per cubic metre of digester. [3 marks]

(ii) hydraulic retention time for the reactor assuming that the operator removes a total of 30 m3 of digestate on a daily basis. [3 marks]

(iii) projected daily biogas production, knowing that $0.8m^3$ biogas is expected to be produced per 1kg of volatile solids fed to the reactor. [3 marks]

(iv) discuss how the type of feedstock affects hydraulic retention time. Based on the above calculated HRT (as per ii)), what is the feedstock most likely to be- agricultural waste, or brewery waste? Give a reason for your answer. [3 marks]

3) a) State and explain two criteria for a suitable indicator organism that can be cultured to test for potential faecal contamination. [4 marks]

b) Give an example of a water-borne pathogen and describe its transmission pathway. [6 marks]

Question 3 continues/…

…/question 3 continued

c) You have been tasked with selecting an appropriate form of household water treatment for a low-income community which relies on open deep wells which are often contaminated from the containers used to draw water. The results of a field analysis of a water sample from one of the wells were as follows:

Turbidity:	<5 NTU
pH:	6.8
TDS:	157 mg/l
E. coli:	58 CFU/100 ml

Choose **three** potential methods of household water treatment which you might consider selecting in this context and list the pathogen removal and/or inactivation mechanisms which may be present for each. Compare the advantages and disadvantages of the potential methods, making sure you consider other factors as well as treatment efficacy. [15 marks]

4) a) Discuss the advantages and disadvantages of in-situ measurements and satellite observations for water quality monitoring. [5 marks]

b) Remote sensing provides a synoptic view of the earth surface that can provide spatial and temporal trends and characteristics necessary for comprehensive water quality monitoring and assessment. What factors need to be considered when deciding what satellite imagery to use? How can water quality parameters for surface water bodies be quantitatively evaluated? [6 marks]

c) Serious algae blooms occurred in one specific lake in 2015. We would like to map the potential input areas of nonpoint source pollution for the lake. How could this be achieved and what tools could be used? [4 marks]

Question 4 continues/…

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d) Figure Q4d shows groundwater levels from two nearby boreholes and river flow data for one of the locations. The data are from the UK.

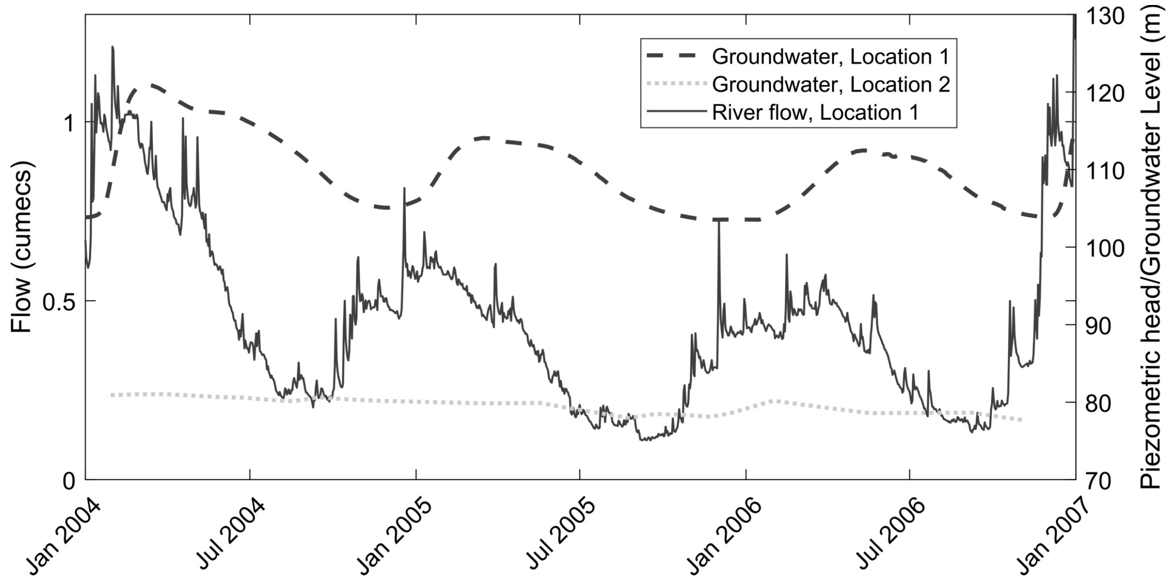

Figure Q4d

(i) For Location 1, using the groundwater and river flow data provided, what can you infer about the river catchment and geology? [6 marks]

(ii) What does the trend in groundwater levels at Location 2 (which is geographically close to Location 1) suggest about the aquifer type at Location 2 and why? [2 marks]

(iii) For each borehole (Locations 1 and 2), briefly describe one issue you might expect if you were to use the borehole for water supply. [2 marks]

5) a) Name the three pillars of IWRM and describe what each means [5 marks]

b) To what extent is the Water Framework Directive an example of IWRM? [8 marks]

c) Discuss which drivers of supply and demand, and other related factors must be considered in long-term water resource planning? [7 marks]

d) Briefly explain five sources of uncertainty that must be accounted for when modelling the regional hydrological impacts of climate change under different emissions scenarios. [5 marks]

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Error Function Values

VALUES OF THE COMPLEMENTARY ERROR FUNCTION, erfc(X),
FOR POSITIVE VALUES OF X

X	erfc(X)	X	erfc(X)
0	1.0	1.1	0.120
0.5	0.944	1.2	0.090
0.1	0.889	1.3	0.066
0.15	0.832	1.4	0.048
0.2	0.777	1.5	0.034
0.25	0.724	1.6	0.024
0.3	0.671	1.7	0.016
0.35	0.621	1.8	0.011
0.4	0.572	1.9	0.0072
0.45	0.525	2.0	0.0047
0.5	0.480	2.1	0.0030
0.55	0.437	2.2	0.0019
0.6	0.396	2.3	0.0011
0.65	0.358	2.4	0.00069
0.7	0.322	2.5	0.00041
0.75	0.289	2.6	0.00024
0.8	0.258	2.7	0.00013
0.85	0.229	2.8	0.000075
0.9	0.203	2.9	0.000041
0.95	0.179	3.0	0.000022
1.0	0.157		

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Formula Sheet

$$c(x,t) = c_o \, erfc\left(\frac{x}{2\sqrt{D_s t}}\right) \qquad \frac{M(t)}{A} = 2nc_0\sqrt{\frac{D_s t}{\pi}}$$

$$c(x,t) = \frac{c_o}{2}\left[erfc\left(\frac{x - vt}{2\sqrt{D_L t}}\right) + e^{\frac{vx}{D_L}} erfc\left(\frac{x + vt}{2\sqrt{D_L t}}\right)\right]$$

$$c(x,t) = \frac{c_o}{2}\left[erfc\left(\frac{x - vt}{2\sqrt{D_L t}}\right) + \sqrt{\frac{4v^2 t}{\pi D_L}} e^{\frac{-(x-vt)^2}{4D_L t}} - \left(1 + \frac{vx}{D_L} + \frac{v^2 t}{D_L}\right) e^{\frac{vx}{D_L}} erfc\left(\frac{x + vt}{2\sqrt{D_L t}}\right)\right]$$

$$c(x,t) = \frac{c_o}{2}\left[erfc\left(\frac{x - vt}{2\sqrt{D_L t}}\right) - e^{\frac{vx}{D_L}} erfc\left(\frac{x + vt}{2\sqrt{D_L t}}\right)\right]$$

$$c(x,t) = \frac{c_o}{2} erfc\left(\frac{x - vt}{2\sqrt{D_L t}}\right) \qquad \alpha_L = 0.83\left(\log_{10} L\right)^{2.414}$$

$$c(x,y,t) = \frac{c_o A}{4t\pi\sqrt{D_L D_T}} * \exp\left[-\frac{(x - vt)^2}{4D_L t} - \frac{y^2}{4D_T t}\right]$$

$$c_{\max} = \frac{c_o A}{4t\pi\sqrt{D_L D_T}} \qquad \sigma_x = \sqrt{2D_L t} \quad \sigma_y = \sqrt{2D_T t}$$

$$erfc(-z) = 2 - erfc(z)$$