ENVS 3060 Groundwater, Final Exam 2013

Name _____ ID# _____

Part A. Select the most correct answer. Answer the questions on the exam sheet and on the computer card. Each question is worth one mark, for a total of 100.

1. True or false, groundwater almost always flows through underground rivers and lakes?
a) True.
b) False.

2. Which of the following are the six most basic physical properties which must be measured to quantify groundwater flow?
a) fluid density, fluid viscosity, hydraulic conductivity, solid material compressibility, fluid compressibility, porosity.
b) fluid density, fluid viscosity, permeability, solid material compressibility, fluid compressibility, porosity.
c) fluid density, fluid viscosity, hydraulic conductivity, solid material compressibility, fluid compressibility, gravity.
d) none of the above

3. Specific storage is defined as
a) the amount of groundwater below the water table.
b) the volume of water that discharges from a spring per day.
c) the volume of water released from storage per unit decline in hydraulic head per unit volume of saturated formation.
d) the volume of water released from storage per unit decline in elevation head per unit volume of saturated formation.

4. Hydraulic conductivity depends on
a) fluid density and viscosity
b) pore size, tortuosity, and degree of pore connections
c) acceleration due to gravity
d) all of the above.

5. True or false, all materials with a high porosity always have a high hydraulic conductivity?
a) True.
b) False.

6. Pressure head is expressed as energy per unit
a) mass of water
b) volume of water
c) weight of water
d) length of water.

7. The effective hydraulic conductivity for flow parallel to layers is
a) the weighted geometric mean of hydraulic conductivities of each layer.
b) the weighted arithmetic mean of hydraulic conductivities of each layer.
c) the weighted harmonic mean of hydraulic conductivities of each layer.
d) the weighted lognormal mean of hydraulic conductivities of each layer.

8. An aquifer of thickness 1000 cm has a specific storage of 8.3×10^{-6} m^{-1} and a porosity of 0.30. What is the storativity of this aquifer?
a) 8.3×10^{-3}
b) 8.3×10^{-4}
c) 8.3×10^{-5}
d) none of the above

9. True or false, a tensiometer must be sealed from atmospheric pressure to function properly?
a) True.
b) False.

10. Hydraulic conductivity is directly proportional to permeability in
a) clay.
b) sand.
c) gravel.
d) all of the above.

11. True or false, hydraulic conductivity is best measured at the microscopic scale?
a) True.
b) False.

12. Water release mechanisms from a confined aquifer are
a) fluid expansion due to decrease in fluid pressure.
b) reduction in n (porosity) due to an increase in effective stress.
c) a and b
d) none of the above

13. Select (in order) the most appropriate hydrogeological terms for glaciofluvial, glaciolacustrine, and till.

a) aquitard, aquifer, aquitard.
b) aquifer, aquitard, aquitard.
c) aquitard, aquitard, aquifer.
d) aquifer, aquifer, aquitard.

14. Name the developer of the following equation: $v = R^2 \Delta P/(8L\mu)$
a) Poiseuille.
b) Theis.
c) Cooper.
d) Neuman.

15. Which of the following is used to map areas of recharge and discharge?
a) topographic maps.
b) a piezometer network.
c) tritium concentration in groundwater.
d) all of the above.

16. To calculate the average groundwater velocity, which of the following is not required?
a) hydraulic conductivity.
b) hydrodynamic diffusion coefficient.
c) effective porosity.
d) hydraulic gradient.

17. Three common types of glacial sediments in southwestern Ontario are:
a) till, glaciolacustrine, glaciofluvial
b) till, dolostone, glaciofluvial
c) glaciofluvial, granite, till
d) glaciolacustrine, till, glacial lake sediments.

18. True or false, the average groundwater velocity in a fractured granite ($n_e = 0.01$) is less than in a silt sediment ($n_e = 0.3$)? (Assume that the hydraulic conductivity and hydraulic gradient are the same for both materials.)
a) True
b) False.

19. True or false, the average groundwater velocity is always less than the groundwater flow rate, q?
a) True
b) False.

20. True or false, the $^3H/^3He$ ratio can be used to calculate an apparent age of groundwater from a single water sample?
a) True
b) False.

21. True or false, variation in land topography can significantly affect local and regional groundwater flow patterns?
a) True
b) False.

22. True or false, bulk density is defined as the mass of dry particles per volume of soil particles?
a) True.
b) False.

23. Particle size and mineral composition control:
a) pore shape
b) porosity
c) compressibility
d) all of the above

24. Which particle size class includes particles of 0.05 – 2.0 mm in diameter?
a) gravel
b) sand
c) silt
d) clay

25. True or false, Dupuit developed an equation for groundwater flow in an unconfined aquifer?
a) True.
b) False.

26. True or false, flow lines are always perpendicular to equipotential lines?
a) True.
b) False.

27. Which of the following is not usually considered an assumption of hand drawn flow nets?
a) Darcy's law is valid.
b) Steady state.
c) Three-dimensional flow system.
d) All boundary conditions are known.

28. True or false, in the following equation p represents the number of drops in hydraulic head across a flow net? $q' = K\ p\ H\ /f$
a) True.
b) False.

29. True or false, for estimating groundwater flow direction in anisotropic materials, $1/(K_z)^{1/2}$ is always less than $1/(K_x)^{1/2}$?
a) True.
b)False.

30. True or false, to determine the degree of refraction of flow lines across a layer boundary, the following equation is applied?

$$K_2/K_1 = \tan \sigma_1/\tan \sigma_2$$

a)True.
b)False.

31. Groundwater flow is parallel to which of the following boundary conditions?
a) constant hydraulic head
b) impermeable
c) open
d) none of the above

32. Which set of conditions best describes this groundwater flow equation?

$$K\left(\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2}\right) = S_s \frac{\partial h}{\partial t}$$

a) One-dimensional, Homogeneous, Steady-state
b) Two-dimensional, Homogeneous, Transient
c) Two-dimensional, Homogeneous, Steady-state
d) One-dimensional, Heterogeneous, Steady-state

33. True or false, the water table is always an equipotential line?
a) True.
b) False.

34. Name the person that applied this equation: q' = -K h dh/dx.
a) Poiseuille.
b) Dupuit.
c) Cooper.
d) Neuman.

35. The equation of continuity is
a) an expression of conservation of mass of groundwater
b) an expression of solute distribution between solid and liquid (water) phases
c) an expression relating K and K_i
d) an expression used to calculate continuous groundwater flow

36. Groundwater flow is perpendicular to which of the following boundary conditions?
a) constant hydraulic head
b) impermeable
c) open
d) a and c

37. True or false, in 1935 Theis developed a pumping test for ideal unconfined aquifers?
a) True
b) False.

38. Which of the following is not an assumption of the Theis pumping test solution?
a) horizontal layers of infinite extent.
b) uniform hydraulic properties.
c) horizontal and vertical flow to the well.
d) constant pumping rate.

39. Select the developers of this equation (Leakage = K' $(h_0 - h)/b'$) for leakage through an aquitard.
a) Hantush and Jacob.
b) Neuman and Witherspoon.
c) Darcy and Poiseuille.
d) Theis and Jacob.

40. True or false, an impermeable boundary across a confined aquifer increases the amount of drawdown in an observation well during a pumping test?
a) True.
b) False.

41. Which of the following is not an advantage of slug tests?
a) measure parameters in situ.
b) measure hydraulic conductivity and storativity simultaneously.
c) only one well is required.
d) none of the above.

42. Which of the following is a stage in drawdown versus time when pumping water from an unconfined aquifer?
a) initially reacts as a confined aquifer.
b) water table begins to decline.
c) drawdown follows Theis with S = Sy
d) all of the above.

43. True or false, when pumping water from an unconfined aquifer, only horizontal flow of water occurs?
a) True.
b) False.

44. The Cooper-Jacob straight-line method of analyzing pumping test data is most applicable to
a) long times.
b) early times.
c) unconfined aquifers.
d) slug tests.

45. To account for a constant-head boundary when estimating drawdown using the Theis solution the two terms are
a) subtracted.
b) added.
c) multiplied.
d) divided.

46. For the Hvorslev test
a) water is pumped from a well.
b) a steel slug is added to the well.
c) soil and water are both assumed to be incompressible.
d) all of the above.

47. Which of the following is not an assumption of the Hantush-Jacob method?
a) upper aquitard is leaky
b) aquifer is incompressible
c) flow through aquitard is vertical
d) none of the above.

48. When pumping water from an unconfined aquifer, which of the following applies?
a) have both horizontal and vertical flow.
b) lower the water table.
c) drain pores.
d) all of the above.

49. True or false, for the Neuman and Witherspoon formula, both vertical and horizontal flows are accounted for?
a) True
b) False

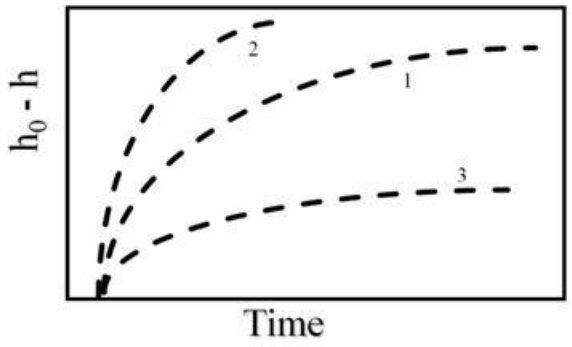
50. What are the disadvantages of pumping tests?
a) $$ High cost.
b) Non-uniqueness of T and S results.
c) Disposal of potentially contaminated water.
d) All of the above.

51. True or false, when calculating the impact of an impermeable boundary across a confined aquifer, the two distances between the observation well and the real and imaginary pumping wells are always equal?
a) True
b) False

52. True or false, Reynolds' number is used to determine the validity of Darcy's Law for low velocity groundwater flow systems?
a) True
b) False.

53. A slug test is performed by lowering a metal slug into a piezometer of inside diameter 5 cm and screen length = 50 cm. If the time for water level to recover to 37% of the initial change is 12 minutes, the value of the hydraulic conductivity is
a) 1.6×10^{-1} cm/min
b) 1.6×10^{-2} cm/min
c) 1.6×10^{-3} cm/min
d) none of the above

54. In the diagram shown below, which is the correct order for curves labelled 1, 2, and 3?
a) impermeable boundary, ideal, constant head boundary
b) constant head boundary, impermeable boundary, ideal,
c) ideal, impermeable boundary, constant head boundary
d) ideal, constant head boundary, impermeable boundary



55. Land subsidence due to over-pumping of groundwater is a serious problem in Mexico City, why?
a) pumping increases fluid pressure and reduces total stress leading to consolidation
b) pumping drains pores and solid grains compress
c) pumping reduces fluid pressure, then effective stress increases leading to consolidation
d) fluid compressibility is much greater than solid material compressibility.

56. What is the distance travelled (in m) in one year of a non-reactive contaminant in groundwater if the effective porosity is 0.28, the hydraulic conductivity is 1 cm/hr, and the hydraulic gradient is 0.03?
a) 0.0011
b) 939
c) 9.39
d) none of the above.

58. In terms of investigating a site with contaminated groundwater,
a) the site history is not important.
b) the nature and behaviour of contaminants must be known.
c) the geology of the site is not important information.
d) installation of monitoring wells is always the first step.

59. An objective of installing monitoring wells is
a) to measure the hydraulic head below the water table.
b) to measure the hydraulic head above the water table.
c) to obtain unrepresentative groundwater samples.
d) none of the above.

60. In terms of groundwater monitoring well material selection,
a) carbon steel is the most expensive.
b) PTFE has the highest strength.
c) stainless steel is the least susceptible to corrosion.
d) carbon steel is the least expensive.

61. Bentonite
a) has a low CEC and a high pH.
b) is a low permeability material when exposed to water.
c) is a low permeability material when it is dry.
d) is only available in a liquid state.

62. Groundwater monitoring well screens
a) permit free flow of water into the well pipe.
b) prevent fine particles from plugging the well pipe.
c) can be made from slotted plastic pipe.
d) all of the above.

63. True or false, sand (or gravel) filter packs are used in non-collapsing cohesive sediments?
a) True.
b) False.

64. The two main solute transport processes in flowing groundwater are:
a) advection and dispersion.
b) diffusion and advection.
c) diffusion and dispersion.
d) none of the above.

65. Which of the following is not one of the causes of pore-scale dispersion?
a) velocity profile across a pore.
b) pore pathway tortuosity.
c) different pore sizes.
d) none of the above.

66. Which of the words given below best fills the blank in the following sentence? The product of _____and groundwater velocity can be used to estimate hydrodynamic dispersion.
a) dispersivity.
b) diffusion.
c) hydraulic conductivity.
d) porosity.

67. True or false, contaminant concentration decreases away from a source in flowing groundwater due to hydrodynamic dispersion?
a) True.
b) False.

71. Processes that attenuate a contaminant in groundwater may include
a) biological degradation.
b) precipitation.
c) oxidation.
d) all of the above.

72. True or false, for a sloping water table the capture zone will be elongated in the up-gradient direction?
a) True.
b) False.

73. To assess the vulnerability of a region to groundwater contamination, which of the following must be determined?
a) depth to the water table.
b) geology of aquifers.
c) groundwater flow direction.
d) all of the above.

74. A definition of the term safe yield is
a) maximum groundwater pumping volume without lowering long-term reserves.

b) minimum groundwater pumping volume required to increase long-term reserves.
c) maximum groundwater pumping volume according to the size of the well.
d) maximum groundwater pumping volume according to the size of the pump.

75. In reference to capture zone analysis, which statement given below is most correct?
a) the stagnation point is located up-gradient from the pumping well
b) the stagnation point is located down-gradient from the pumping well
c) the stagnation point is located above the pumping well
d) none of the above.

76. A funnel and gate groundwater remediation system has a
a) high permeability cut-off wall with a wide gate.
b) low permeability cut-off gate with a wide wall.
c) low permeability cut-off wall with a narrow gate.
d) high permeability cut-off wall with a narrow gate.

77. Which of the following statements is false?
a) DNAPLS are not generally found near the water table
b) LNAPLS are generally found near the water table
c) Tritium is never used in water treatment
d) Guelph drinking water source is Lake Ontario.

78. True or false, natural attenuation can be an effective contaminated groundwater remediation strategy?
a) True.
b) False.

79. An in situ groundwater remediation method is
a) air sparging.
b) funnel and gate.
c) reactive wall.
d) all of the above.

80. True or false, under rapid groundwater flow, diffusion is more important than dispersion in reducing peak concentration of a groundwater contaminant?
a) True.
b) False.

81. The main type of groundwater contaminant at the Seymour recycling site is
a) heavy metals
b) gasoline
c) organic chemicals
d) none of the above.

82. The main advantage of multi-level wells is
a) water samples can be obtained from sediments above the water table
b) bentonite sand is never required
c) groundwater samples can be obtained from more than one depth
d) they have built-in water pumps

84. Which well pipe material is least desirable in a groundwater contamination study near a mine with acidic groundwater?
a) carbon steel
b) stainless steel
c) PVC plastic
d) Teflon

85. The main components of a groundwater monitoring well are
a) the non-ventilated well cap
b) the bentonite seal around the well screen
c) the sand filter pack around the screen
d) the sand filter pack above the screen

86. True or false, bentonite swelling is inhibited by high TDS and organic matter concentrations?
a) True
b) False

87. Monitoring well design criteria include:
a) type of material in the ground
b) biogeochemistry of groundwater
c) both a and b
d) none of the above.

88. True or false, Teflon (PTFE) has a higher leaching potential than carbon steel?
a) True
b) False

89. True or false, the Guelph Ring Infiltrometer is a device used to measure soil volumetric water content?
a) True
b) False

90. True or false, air gaps between TDR rods and soil will lead to errors in soil water content measurements with TDR?
a) True
b) False

91. Name the person who developed the following equation: $K(h_p) = K_{fs} \exp(\alpha h_p)$.
a) Darcy
b) Theis
c) Gardner
d) Dupuit

92. Using the equation given in question 91, if the ratio of $K(h_p)/ K_{fs} = 0.5$ and $h_p = -30$ cm, α is
a) 0.023 m^{-1}
b) 0.023 cm^{-1}
c) 0.023 m
d) none of the above

93. True or false, an assumed value of α in the Guelph Ring Infiltrometer equation is larger for clay than sand?
a) True
b) False

94. True or false, a lysimeter is a device used to measure deep drainage?
a) True
b) False

95. If 1 litre of water was collected in a square pan lysimeter with each side 60 cm long, the amount of deep drainage is:
a) 2.8 cm
b) 2.8 litres
c) 2.8 mm
d) none of the above

96. If the soil water pressure head is -30 cm, the maximum pore size (radius) filled with water is:
a) 0.005 cm
b) 1 cm
c) 0.005 m
d) none of the above

97. True or false, the traditional definition of available water is water content at field capacity (hp = -15,000 cm) minus water content at plants' permanent wilting point (hp = -300 cm)?
a) True
b) False

98. True or false, in the case study presented in last week of classes, the transport of phosphorus was investigated at a field site in southern Ontario?
a) True
b) False

99. In the case study presented in last week of classes, the decrease in nitrate concentration beneath the buffer strip was due to
a) dilution
b) plant uptake of nitrate
c) denitrification
d) all of the above

100. True or false the dominant flow directions of soil water and groundwater are vertical and horizontal, respectively?
a) True
b) False

Part B. Answer each question in the space provided. Show all steps used in deriving the answer. Marks for each question are given in brackets after the question number.

1(5). Use the following information and the Guelph ring infiltrometer equation to determine α for a sandy soil. Calculate the contribution of gravity to the 35 cm^3/min flow rate.
Q = 35 cm^3/min; h_p = 10 cm
K_{fs} = 0.16 cm/min
Ring radius = 5 cm. Depth of ring insertion = 5 cm.

2(5). A capture well is pumping at a rate of 1500 m^3/day from a confined aquifer with a hydraulic conductivity of 425 m/day, an initial hydraulic gradient of 0.00098, and a saturated thickness of 22 m. What is the maximum width of the capture zone? What is the distance from the well to the stagnation point?

/100 + /10 = /110