OLLSCOIL NA hÉIREANN, GAILLIMH
NATIONAL UNIVERSITY OF IRELAND, GALWAY

(International Postgraduate Hydrology Courses)

Postgraduate Higher Diploma in Hydrology
Spring Examinations 1999

APPLIED HYDROLOGY III

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Time allowed is *three* hours. Attempt any *five* questions.

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1. Answer any *eight* of the following. (*Each answer is worth 2.5 marks.*)

(i) What is the difference between the *water table* and the *potentiometric surface*?
(ii) There are *six* basic properties of fluids and porous media that must be known to properly describe groundwater flow. List the six properties.
(iii) What is the difference between *specific storage* and *storativity* in confined aquifers?
(iv) What is the difference between *trending heterogeneity* and *discontinuous heterogeneity* in reference to the distribution of hydraulic conductivity?
(v) Are (i) *permeability* and (ii) *hydraulic conductivity* affected by changes in groundwater temperature? Briefly explain your answer.
(vi) The water level change in an aquifer at some distance from a pumping well is a function of what?
(vii) What is the difference between a *recharge* and a *discharge boundary*?
(viii) What is the *Tan Law* and what is its use in understanding groundwater flow?
(ix) Is the *moisture content* of a soil sample the same as its *percentage saturation*? *Briefly* explain your answer.
(x) The following equation describes groundwater flow under what flow conditions?

$$\frac{d}{dx}(T_x \frac{dh}{dx}) + \frac{d}{dy}(T_y \frac{dh}{dy}) + q_s(x,y,t) = S\frac{dh}{dt}$$

2. Answer *both* (i) *and* (ii) below.

(i) Answer *all* parts of the question.

(a) What is the *limiting condition* for use of the Cooper-Jacob modified Theis method? *(2 marks.)*

(b) What *field conditions* determine the use of the Cooper-Jacob methods? *(2 marks.)*

(c) A well is cased into a confined aquifer and pumped at the rate of 1500 m^3/day. An observation well is located 350 metres from the pumping well where drawdown is recorded.

The drawdown per log cycle is determined to be 0.7 metres, and $\mathbf{t_0}$ is determined to be 1.1 minutes.

What are the values of *Transmissivity* and *Storativity* for the aquifer? *(6 marks.)*

(ii) Answer *both* parts of the question.

(a) Give two advantages and two disadvantages of using pumping tests. *(4 marks.)*

(b) A production well is installed in an aquifer, and pumped at a rate of 1100 m^3/day. The aquifer is 12.5 metres thick and has a hydraulic conductivity of 10 m/day. The storativity is estimated to be 0.001. A fault is located 50 metres from the well.

What is the drawdown at the midpoint between the well and the fault after pumping for all of May and June? *(6 marks.)*

3. Answer *both* parts of the question.

(i) **A confined aquifer has a uniform thickness of 25 metres and is 12 kilometres wide. Two observation wells are located 800 metres apart in the direction of flow. The aquifer is homogeneous and isotropic, with a hydraulic conductivity of 1.04 m/day. Hydraulic head at Well 1 is measured to be 68 metres, and hydraulic head at Well 2 is measured to be 57 metres.**

What is the *total daily flow* through the entire width of the aquifer? *(4 marks.)*

(ii) The hydraulic conductivity of an unconfined, homogeneous aquifer is estimated to be 10^{-4} m/second. The effective porosity is 0.22. The sand and gravel deposit in which the aquifer is found has a uniform thickness of 40 metres. Two wells are installed 200 metres apart in the direction of flow. The water level in Well 1 is five metres below the land surface and the water level in Well 2 is 7.5 metres below the surface.

(a) What is the discharge per unit width of the aquifer? *(2 marks.)*

(b) What is the average linear groundwater velocity at Well 2? *(2 marks.)*

(c) What is the elevation of the water table at 170 metres from Well 1 (and 30 metres from Well 2)? *(2 marks.)*

4. *Indicate*, on your answer sheet, legibly and unambiguously, the symbols (e. g. (i)-(a), (ii)-(c), etc.) corresponding to the appropriate answers to each of the following multiple-choice questions (with only *one* answer to each question):

(i) Groundwater always flows:

(a) from the places where the hydraulic head is high towards the places where it is low,

(b) from the places where the pressure of water is high towards the places where it is low,

(c) from more permeable parts of the aquifer towards its less permeable parts.

(ii) If water is flowing through a saturated sand column, 1 m long and 1 m^2 in cross-section, the volumetric flux being 0.5 m/day, then:

(a) the average time of travel of a pollutant or a tracer through the column is 2 days,

(b) the daily amount of water having flown through the column is 0.5 m^3,

(c) the hydraulic conductivity of the sand must be 0.5 m/day.

(iii) If the flow of groundwater through a *horizontally-layered saturated formation* is exclusively *vertical*, then:

(a) the magnitude of the hydraulic head gradient in a less permeable layer must be higher than in a more permeable layer,

(b) the total loss of the hydraulic head in a less permeable layer must be higher than in a more permeable layer,

(c) the vertical volumetric flux in a less permeable layer must be smaller than in a more permeable layer.

(iv) Comparing two unconfined aquifers from which water is being abstracted at the same rate and all conditions other than those mentioned below are the same for both aquifers, we can say that:

(a) the speed of groundwater table fall in aquifer A will be higher than that in aquifer B if the specific yield of A is higher than the specific yield of B,

(b) the speed of groundwater table fall in aquifer A will be higher than that in aquifer B if the recharge rate of A is lower than the recharge rate of B,

(c) the drawdown at or near to the pumping wells will be larger in aquifer A than in aquifer B if the transmissivity of A is higher than the transmissivity of B.

(v) During a *non-steady pumping test* when water is being pumped from a single well at a *constant rate* and the aquifer recharge rate is negligible:

(a) the hydraulic head is increasing with time everywhere in the aquifer,

(b) the drawdown is increasing with time everywhere in the aquifer,

(c) the drawdown at a given time instant increases with the increasing distance from the well.

(vi) In order to define *initial conditions* for a groundwater flow problem, we have to specify:

(a) the values of hydraulic head at all points of the flow region boundary at the time zero,

(b) the values of hydraulic head at all points of the flow region interior at all times,

(c) the values of hydraulic head at all points of the flow region interior at the time zero.

(vii) The *base flow* in a stream that drains an adjacent territory, provided that there is no other inlet or outlet of water:

(a) is higher if the adjacent groundwater table depths are larger,

(b) equals, on a multi-annual average, the difference between the precipitation and the actual evapotranspiration,

(c) equals the difference between the net recharge rate (from which the evapotranspiration rate has already been subtracted) and the rate of increase of groundwater storage.

5. *Examine* the figure below, taken from Anderson, M. P., and Woessner, W. W, 1992: *Applied groundwater modelling*. Academic Press, San Diego, pp. 104, and *answer* the following questions:

(i) *Explain* in which direction the groundwater is flowing (refer to both parts of the figure) and where it is coming from.

(ii) *Suggest* the type of a boundary condition that should be applied at the river side of the flow region depicted in the right-hand part of the figure.

(iii) *Make sketches* of typical vertical cross-sections (a) perpendicular to the river, and (b) parallel to the river, of the flow region which is depicted in the right-hand part of the figure.

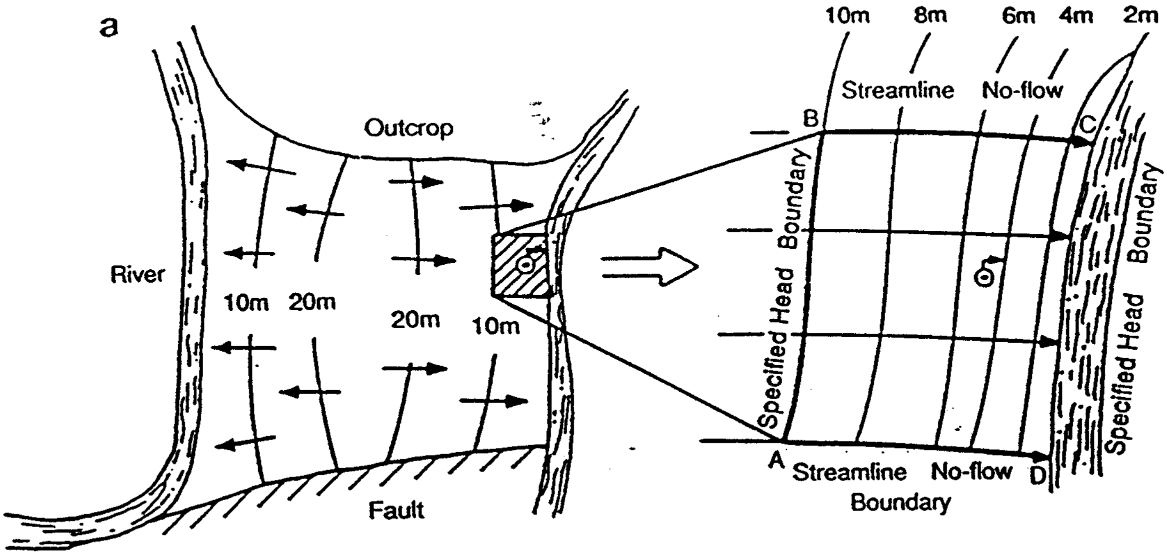
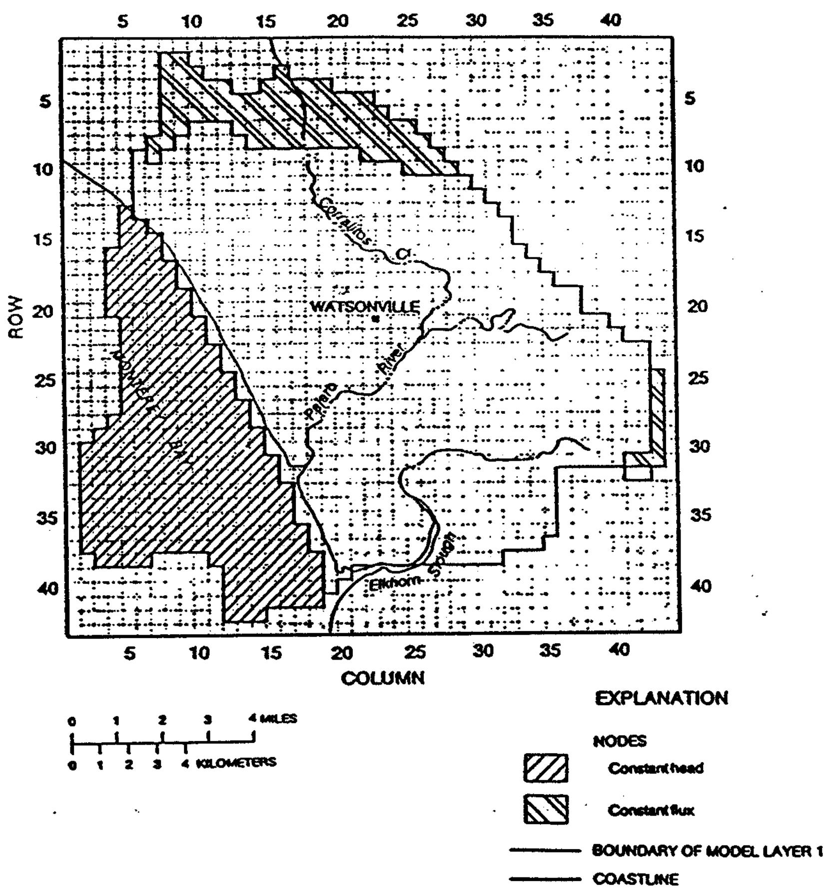


Fig. 4.4 Hydraulic boundaries.
(a) Water table contour maps showing a regional problem domain on the left with physical boundaries and a local problem domain on the right with three hydraulic boundaries (Townley and Wilson, 1980).

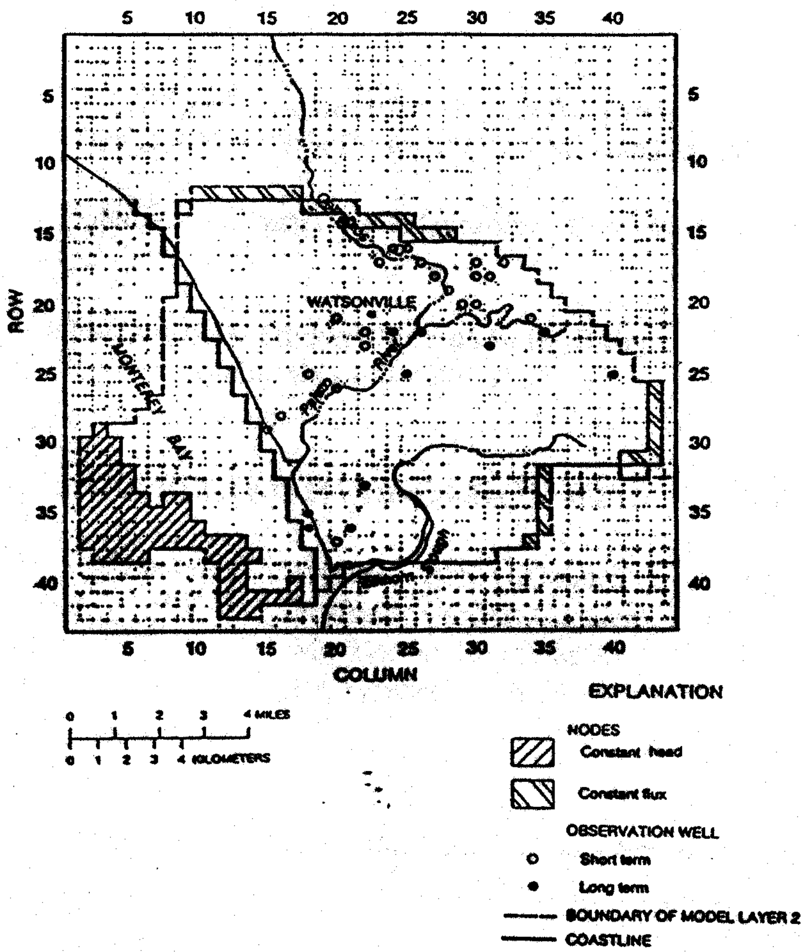
6. *Examine* the following three figures taken from Anderson, M. P., and Woessner, W. W, 1992: *Applied groundwater modelling.* Academic Press, San Diego, pp. 109-111. The figures represent three consecutive layers of an aquifer.

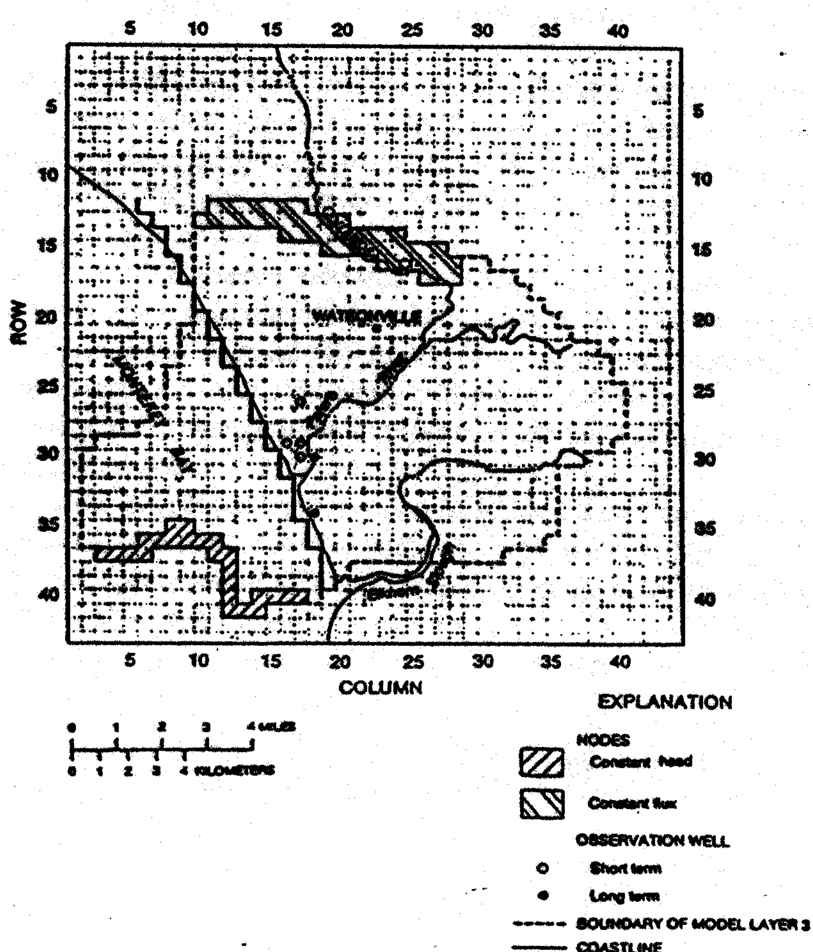
(i) *Explain* why the constant head cells in Monterey Bay are defined in the way depicted, i.e., differently in different layers.

(ii) *Make a sketch* showing what a typical vertical cross-section of the flow region, taken perpendicularly to the shore of Monterey Bay, would look like.



(b) Specified head boundary nodes used to represent Monterey Bay in a three-layer model. The number of inactive cells outside the boundary varies depending on the configuration of the boundary between the aquifer and the bay. Layer 1 is the top layer; aquifers in layers 2 and 3 crop out in the walls of the Monterey submarine canyon (Johnson et al., 1988).


WATSONVILLE
MONTEREY BAY
PAJARO RIVER
ROW
COLUMN
0 1 2 3 4 MILES
0 1 2 3 4 KILOMETERS
EXPLANATION
NODES
Constant head
Constant flux
OBSERVATION WELL
Short term
Long term
BOUNDARY OF MODEL LAYER 2
COASTLINE


WATSONVILLE
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0 1 2 3 4 MILES
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EXPLANATION
NODES
Constant head
Constant flux
OBSERVATION WELL
Short term
Long term
BOUNDARY OF MODEL LAYER 3
COASTLINE