# Solutions Manual

Developed by

Sukru Ozger and Larry W. Mays

To

Accompany

# Groundwater Hydrology, 3rd Edition

By

David Keith Todd

And

Larry W. Mays

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2.2.1 Cubic Packing

Let's assume a cube containing $n \times n \times n$ number of uniform spheres. Then, the porosity of this representative volume is given by

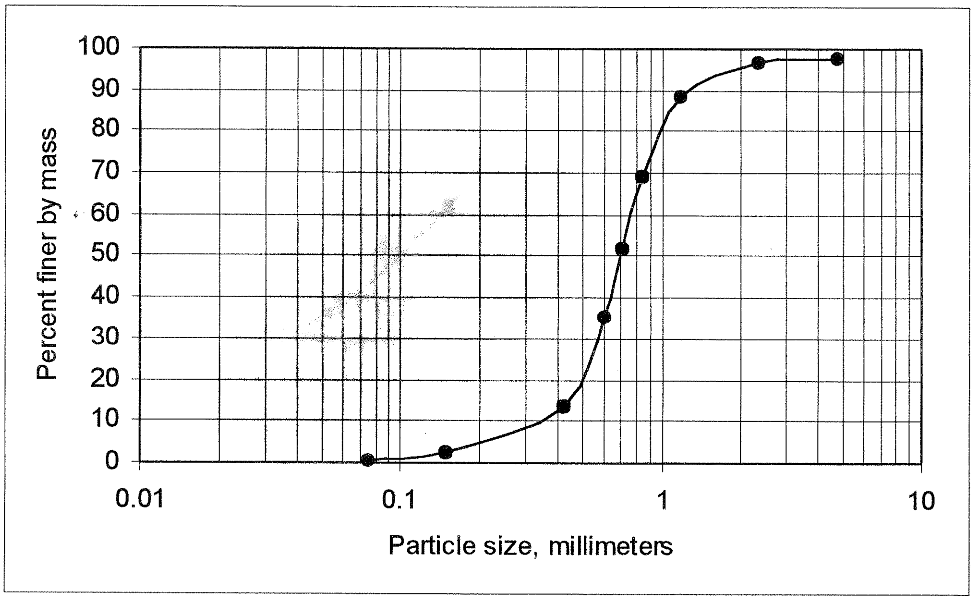
$$\alpha = \frac{v_i}{V} = \frac{(nD)^3 - \left(n^3\right)\left(\frac{4}{3}\pi\left(\frac{D}{2}\right)^3\right)}{(nD)^3} = 1 - \frac{\pi}{6} = 0.4764 = 47.64\%$$

The porosity for this type of grain packing does not depend on the grain size, *D*.

2.2.2 It may seem like porosity tends to increase with decreasing grain size from Table 2.1 and Table 2.2. On the other hand, there is a much stronger relationship between porosity and gradation. Poorly graded (well-sorted) sediments have high porosities. If, also, the individual grains are well-rounded in such deposits, the porosity does not depend on the grain size. On the other hand, well-graded sediments have low porosities since small grains fill interstices between the larger ones.

2.2.3 The analysis of the given data and the resulting grain size distribution curve are shown below.

| U.S. Standard Sieve Number | Grain Size (mm) | Mass Retained (g) | Percent finer by mass |
|---|---|---|---|
| 4 | 4.75 | 11.92 | 97.35 |
| 8 | 2.36 | 2.66 | 96.76 |
| 16 | 1.18 | 37.30 | 88.47 |
| 20 | 0.84 | 87.53 | 69.02 |
| 25 | 0.71 | 78.07 | 51.67 |
| 30 | 0.6 | 72.95 | 35.46 |
| 40 | 0.425 | 98.82 | 13.50 |
| 100 | 0.15 | 50.85 | 2.20 |
| 200 | 0.075 | 8.10 | 0.40 |
| Pan | <0.075 | 1.80 | 0.00 |
| Total sample weight | | 450 | |




From the given grain size distribution curve,

$$d_{60} \cong 0.75\ mm \qquad \text{and} \qquad d_{10} \cong 0.33\ mm$$

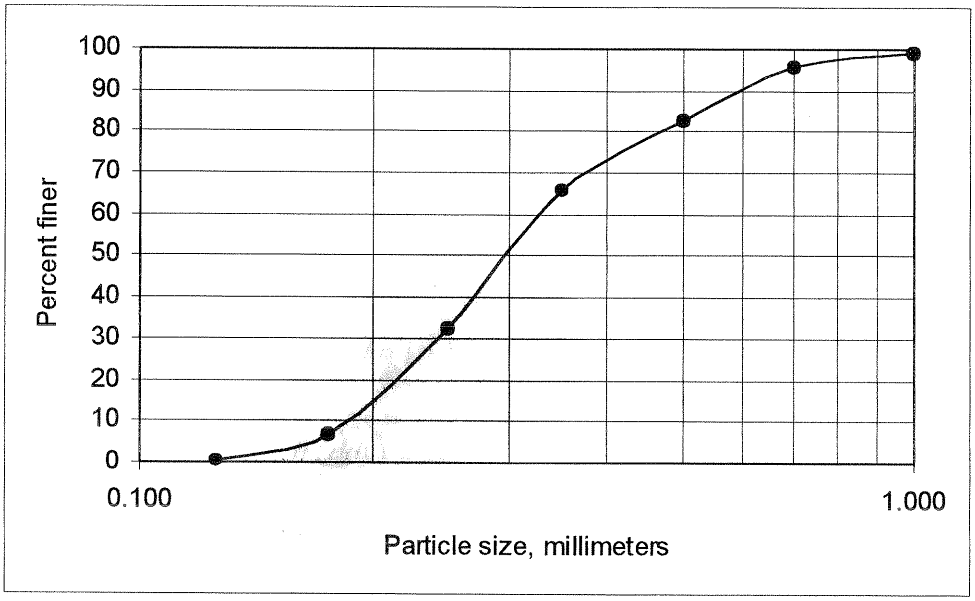
Thus, the uniformity coefficient is given by equation 2.5

$$U_c = \frac{d_{60}}{d_{10}} = \frac{0.75\ mm}{0.33\ mm} \approx 2.3$$

Since $U_c < 4$, the sample can be described as poorly-graded (i.e., highly uniform).

Again from the grain size distribution curve, approximately 60% of the sample consists of coarse sand. The expected porosity of the sample would be around 40% based in this classification.

2.2.4 The grain size distribution for the given data is shown below.




$$d_{60} \cong 0.32\ mm \qquad \text{and} \qquad d_{10} \cong 0.19\ mm$$

Thus, the uniformity coefficient is given by equation 2.5

$$U_c = \frac{d_{60}}{d_{10}} = \frac{0.32\ mm}{0.19\ mm} \approx 1.68$$

Since $U_c < 4$, the sample is poorly-graded (i.e., highly uniform).

From the given test data, the sample is composed of approximately

16% coarse sand

50% medium sand

32% fine sand

while the remaining 2% is a mix of finer and coarser sediments than the above.

2.4.1 The specific yield of the aquifer can be found using equation 2.10

$$S_y = \alpha - S_r = 0.20 - 0.09 = 0.11$$

and the water level rise can be found from equation 2.9

$$V = (A)(\Delta h) = \frac{w_y}{S_y} = \frac{(4\ inches)(A)}{0.11}$$

$$\Delta h = 36.4\ inches \approx 3\ ft$$

2.4.2 The volume of water released per day is

$$w_y = (222\ acres)(0.5\ ft/day) = 111\ acre - ft$$

$$or$$

$$w_y = (222\ acres)(3\ ft/day) = 666\ acre - ft$$

The bulk volume of formation needed to absorb this volume of water can be calculated from equation 2.9

$$V = \frac{w_y}{S_y} = \frac{111\ acre - ft}{0.20} = 555\ acre - ft$$

$$or$$

$$V = \frac{w_y}{S_y} = \frac{666\ acre - ft}{0.20} = 3330\ acre - ft$$

Thus, the average groundwater level rise can be found by dividing the bulk volume of formation by the aerial extent of the effect of leakage. The results are summarized in the following table.

| Aerial extent | GW level rise (ft/day) |
|---|---|
| | |
| 222 acres | 2.5 - 15 |
| 1 $mile^2$ = 640 acres | 0.87 - 5.20 |
| 5 $mile^2$ = 3200 acres | 0.17 - 1.04 |
| 25 $mile^2$ = 16000 acres | 0.035 - 0.21 |

2.4.3 The specific yield of the aquifer is given by

$$S_y = \alpha - S_r = 0.38 - 0.15 = 0.23$$

Then, equation 2.9 can be used to estimate the volume of water released:

$$w_y = S_y V = (0.23)(7\ ft \times 1\, mile^2)$$
$$= (0.23)(7\ ft \times 2.788 \times 10^7\ ft^2) = 4.5 \times 10^7\ ft^3$$

2.8.1 Assuming water at 15 °C,

$$\gamma = 9798\ N/m^3$$

$$\beta = 4.673 \times 10^{-10}\ m^2/N$$

$$\theta = 0.25$$

Then,

$$S = \gamma\theta\beta b = (9798\ N/m^3)(0.25)(4.673 \times 10^{-10}\ m^2/N)(50\ m) = 5.72 \times 10^{-5}$$

is the storage coefficient of the aquifer considering the expansion of water only.

Thus,

$$\frac{5.72\times10^{-5}}{1.8\times10^{-4}}\times100 = 32\%$$ of the storage coefficient is attributable to the expansibility of water and the remaining 68% is attributable to the compressibility of the aquifer skeleton.

2.8.2 The relationship between specific storage and storage coefficient is

$$S_s = \frac{S}{b}$$ where $b$ is the aquifer thickness.

Thus, $S = S_s b = (3\times10^{-5}\ m^{-1})(45\ m) = 1.35\times10^{-3}$ and the volume of water released is given by

$$V = (A)(\Delta h)(S) = (1\times10^{6}\ m^{2})(10\ m)(1.35\times10^{-3}) = 13{,}500\ m^{3}$$