Model Answers to Study Questions

1. See Section 5.3.

   Although determination of the absolute energy level of soil water is difficult, water behavior is governed by the relative energy level at various locations in the soil. By using a standard reference state of water, energy levels can be determined relative to this reference state. Customarily for soil investigations, the reference state is pure water (no osmotic potential), not influenced by soil solids (zero matric potential), and at the bottom of the soil profile or at the water table (gravitational potential defined as 0).

2. See Section 5.3.

   The root must overcome matric forces attracting the water to the soil solids, osmotic forces attracting water to solutes (salts) dissolved in the soil solution, and gravitational forces pulling downward on the water. Compaction would likely increase the matric forces by reducing the size of pores, thus bringing more of the water close to a solid surface.

3. See Section 5.3 plus Box 5.1 and Figures 5.5, 5.6.

   Free water at the water table is attracted by adhesion to the hydrophilic surfaces of soil mineral particles, causing the water to spread out in a thin film with a contact angle of essentially zero. Simultaneously, cohesion among water molecules tends to hold them together. The fact that the cohesion is much stronger than adhesion of water to the air in the soil pore causes a membrane-like surface tension at the air-water interface. However, because the water cohesion is much weaker than the adhesion of the water to the solid surfaces of the pore, a curved meniscus forms at the water-air interface. While atmospheric pressure acts on the water at the water Table, the countervailing pressure of the water under the meniscus is less than atmospheric pressure (because pressure is always lower on the convex side of a curved interface), therefore the water rises in the pore until the difference in pressure is just balanced by the weight of the water pushed above the water Table.

4. See Section 5.4 and Table 5.2.

   Tensiometers are sensitive enough in moist soils for use in the flower beds, but cannot measure beyond about –85 kPa and so could not be used for the rough turf. The resistance blocks are fine for the rough turf, but are not sensitive enough at very high potentials to be useful in the flower beds.

5. See Section 5.4.

   The capacitance method measures the soil water content, while the tensiometer and electrical resistance block methods measure the water potential. Therefore, TDR requires that a calibration be made to allow one to know at which soil water contents the desired potentials stated would pertain for a particular soil.

6. See Section 5.2, especially Figure 5.5.

   The depth of soil in the pot will determine the height of capillary columns possible. Smaller diameter pores can create taller capillary columns. Therefore, near the top of the 30 cm tall pot, larger pores will be air-filled because they cannot create a 30 cm tall capillary column. Fewer pores will be air-filled near the top of a 15 cm tall pot because even relatively large pores can create a 15 cm capillary column. If the same soil is used in both pots, there will be a larger volume of well-aerated soil in the taller pot.

7. See Section 5.9 and Box 5.3, where the density of water (1Mg/m^3) is included for completeness and to show how units cancel. Note that the Bx horizon (a fragipan) does not count in the rooting depth).

   A horizon: $(1.2\ \text{Mg/m}^3/1\ \text{Mg/m}^3) \times (0.28\ \text{kg/kg} - 0.08\ \text{kg/kg}) \times 30\ \text{cm} = 7.2\ \text{cm}$

   Bt horizon: $(1.4\ \text{Mg/m}^3/1\ \text{Mg/m}^3) \times (0.30\ \text{kg/kg} - 0.15\ \text{kg/kg}) \times (70\ \text{cm} - 30\ \text{cm}) = 8.4\ \text{cm}$

   Total (no significant rooting in a Fragipan) = 7.2 cm + 8.4 cm = 15.6 cm

8. See Section 5.4, Box 5.2.

   θ_m = g water/g soil $= [(972 - 300) - (870 - 300)]/ (870 - 300)$

   $= (672 - 570)/(570) = 0.179$ (or <u>17.9%</u>)

   θ_v = cm^3 water/cm^3 soil $= \theta_m \times D_b = \theta_m \times$ (dry mass soil/volume soil)

   $= 17.9\% \times$ (dry mass soil/volume soil)

   $= 17.9\% \times (570\ \text{g}/\pi\, r^2 h)$

   $= 17.9\% \times (570\ \text{g}/3.14 \times 3.25\ \text{cm} \times 3.25\ \text{cm} \times 15\ \text{cm}) =$ <u>20.5%</u>

9. See Section 5.9 and Figures 5.39–5.40.
   a. Compaction increases soil strength and thus limits root penetration to reach more water.
   b. Compaction reduces macropores that would hold water at field capacity.
   c. Compaction will reduce aeration at field capacity, limiting plant ability to take up water.
   d. Compaction creates more micropores which hold more water at potentials below wilting point.

10. See Section 5.10.

    Roots continually extend themselves into new volumes of moist soil, and soil water films conduct water to the root by capillary flow as the root depletes the water adjacent to it.

11. Step one: What is the volume of the compacted soil with bulk density 1.10g/cm^3?

    $0.75\ \text{g}/1\ \text{cm}^3 = 1.10\ \text{g}/\times\ \text{cm}^3$ » $0.75/1.1 = x = 0.68\ \text{cm}^3$

    Step two: What is the water to soil volume ratio in the compacted soil, assuming all the water remained during the compaction process?

    Water in uncompacted soil = $0.25\ \text{cm}^3/\text{cm}^3$ as indicated by ◄ on the bar graph.

After compaction, this same 0.25 cm^3 water is contained in the 0.68 cm^3 of soil calculated in the previous step. Therefore, in the compacted soil $\theta_v = 0.25cm^3$ water/$0.68cm^3$ soil = $0.36cm^3/cm^3$.

This is the value indicated by ◀ on the bar graph for the sandy loam with severe compaction.

12. Unsaturated flow: movement of a wetting front; capillary rise from a water table; movement of water toward a root as the root removes water.

    Vapor movement: moistening of a fertilizer granule in wilting point dry soil; movement and condensation of moisture on the underside of surface rock during a cold night following a warm dat; maintenance of near 100% humidity in soil air.

13. Detailed calculation for first cell:
    a. Convert % to ratio: 27.1% = 27.1 g H_2O/100 g dry soil = 0.271 g/g
    b. From Eq.5.7, but with density of water = 1 added (Box 5.2): $\theta_v = \theta_m * D_b * D_{H20}$:

    1.49 Mg soil/m^3 * 1 Mg H_2O/m^3 * 0.271g H_2O /g soil = 0.403 m^3/m^3

    Water in layer = θ_v * *L, where L = cm layer thickness*

    Water in 0–30 cm layer = 0.403 m^3/m^3 * 30 cm = **12.1 cm**

    and from Eq.5.11 (Box 5.4)

$$\boldsymbol{AWC} = (\theta_{mFC} - \theta_{mWP}) \cdot \boldsymbol{D_b} \cdot \boldsymbol{L}$$

for 0–30 cm layer: AWC = (12.1 – 8.0)= 4.1 cm

for 0–90, $AWC_{0\text{-}120} = AWC_{0\text{-}30} + AWC_{30\text{-}60} + AWC_{60\text{-}90}$ *=4.1+4.3+3.3 = 10.69 cm*

Filled in table. Calculated values in bold type.

		Field capacity		Wilting point		Available water	
Soil depth	Bulk density, ρ_b	θ_m	θ_d	θ_m	θ_d	θ_m	θ_d
cm	(Mg m^{-3})	%	cm	%	cm	%	cm
0–30	1.49	27.1	**12.1**	17.9	**8.0**	9.2	**4.1**
30–60	1.51	27.5	**12.5**	18.1	**8.2**	9.4	**4.3**
60–90	1.55	27.1	**12.6**	20.0	**9.3**	7.1	**3.3**
0–90			**37.2**		**25.5**		**10.7**