Hydrology Homework Problems

1. Using the Figure, calculate the maximum precipitation for a 4 day storm.

\[ h_r = 455 \text{cm} \]

2. Calculate the soil texture, cumulative infiltration depth and infiltration rate at time equals 2 hours. The soil is composed of 15% silt, 25% clay and 60% sand. The effective saturation (Se) is 50%.

Texture Triangle \rightarrow \text{sandy clay loam}.

From table \( \theta_s = 0.398 \), \( \rho_e = 0.330 \), \( h_p = 2.85 \text{cm} \), \( K = 0.15 \text{ cm/hr} \)

\[ \Delta \theta_e = 0.165 \]

\[ F(+) = 1.67 \text{cm} \]

\[ f(+) = 0.47 \text{cm/hr} \]

3. Assume that the effective saturated hydraulic conductivity is zero. Use figure 3.5 to determine the cumulative infiltration and infiltration rate. Explain why your results are different in question 2 and 3.

\[ F(+) = 2.3 \text{cm} \]

\[ f(+) = 0.6 \text{ cm/hr} \]
4. Using the rational method calculate the 100-year discharge caused by a 25-year rainfall storm which lasted 2 hours. The watershed is 50 acres. A detailed analysis has been performed to determine that 45% of the land area is concrete/roofs, 25% is good grass areas with flat slopes, 15% is cultivated agricultural area with flat slope and the remaining 15% is forested lands with steep slopes.

\[ Q = CIA \]

Composite runoff coefficient

\[ C = 0.675 \]

\[ i = \frac{14.5 \text{ mm}}{\text{hr}} \]

\[ Q = 19 \text{ cy} \]

5. Using the Figure on extreme discharge fill in the following table.

<table>
<thead>
<tr>
<th>Area (m^2)</th>
<th>Specific Discharge (ft^3/m^2)</th>
<th>Discharge (ft^3/s)</th>
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<tr>
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</table>

How does the specific discharge and discharge vary with increased area?
Sample Problems on Hydraulics

1. You are given the following rectangular channel.

\[ R_h = \frac{W}{4h} \]

a. Calculate the hydraulic radius for the given channel.

b. If the velocity within the channel is measured to be 5 feet/sec determine the discharge and unit discharge.

c. If the slope is \( S = 0.001 \), determine Manning \( n \).

\[ n = 0.024 \]

2. You are given a wide rectangular channel. The channel is a clean, straight, full stage, no riffs or deep pools (Hint uses Table 2.1 in HIRE to determine the Manning n). Given the following, \( Q = 1000 \) cfs, \( W = 100 \) feet, \( S_0 = 2 \) ft/mile, calculate the following in English units.

a. Calculate the normal depth. (Hint: check the formula in English units)

b. Calculate the critical depth

c. Calculate the minimum specific energy.

d. Define whether the channel slope is mild or steep.

e. If the flow depth is 110% of the normal depth, calculate the friction slope.

f. Determine the Froude number and define whether the flow is critical, supercritical or subcritical.

g. Calculate the specific energy for the actual flow depth.

h. If the reach is long describe and draw the water surface profile.

\[ E_{min} = 2.19 \text{ ft} \]

\[ h_{n} = 4.06 \text{ ft} \]

\[ h_s = 1.46 \text{ ft} \]

\[ Fr = 0.19 \]

\[ S_0 = 1.46 \text{ ft/mile} \]

i. Explain in words how you would solve this problem differently if told that the rectangular channel is not wide.

\[ M1 \text{ profile} \]

\[ \text{Use } R_h \text{ not } h \]
3. You are given a straight mountain channel with $ds = 300 \text{ mm}$, $n = 0.04$ and a slope of $S_0 = 0.07$. Calculate the following in SI at a discharge $Q = 20 \text{ cms}$ and width $W = 15 \text{ m}$.

   j. Calculate the normal depth.
   k. Calculate the critical depth and minimum energy.
   l. Define whether the channel is mild or steep.
   m. If water flows at normal depth, calculate the hydraulic radius.
   n. Determine the Froude number and define whether the flow is critical, supercritical or subcritical.
   o. Determine the friction slope.
   p. Determine the bed shear stress.

\begin{align*}
\text{j} & \quad 0.46m = h_n \\
\text{k} & \quad h_c = 0.57m \\
\text{l} & \quad h_c > h_n \rightarrow \text{steep slope} \\
\text{m} & \quad h = h_n \quad R_h = 0.44m \\
\text{n} & \quad F_r = 1.35 \quad \text{supercritical} \\
\text{o} & \quad S_f = S_0 - 0.07 \\
\text{p} & \quad T_0 = \left( \frac{1000 \times 9.81}{m^2} \right) \frac{N}{m^2} \times 0.144m \times 0.07 \\
\text{ } & \quad T_0 = 300 \frac{W}{m^2}
\end{align*}
1. Calculate the velocity head and sketch the curve of grade line for the entire reach.

2. Sketch the hydraulic grade line of the entire reach.

3. Identify where the hydraulic grade is for each section and determine the boundary conditions.

4. Draw the critical depth above the reach. The critical depth is defined as the depth below which the flow is subcritical. Calculate the following in English units:

   \[ V = Q / A \]
   \[ T = V / e \]
   \[ D_c = (2g)^{1/2}A^{1/2} \]
   \[ h_c = V^2 / 2g + T + D_c \]
   \[ y_c = h_c / D_c \]

   Where:
   - \( Q \): discharge
   - \( A \): cross-sectional area
   - \( e \): wetted perimeter
   - \( V \): velocity
   - \( T \): total head
   - \( D_c \): critical depth
   - \( h_c \): critical water depth
   - \( y_c \): relative depth

The given point is 10 m/s and consider throughout the entire reach. Calculate the...
Turbulent Velocity Profiles and Resistance to Flow

**Problem # 1 (100 %)**
Field measurements along a vertical profile of the Rhine River are shown below. The navigable channel width covers 260 m. Consider a rectangular section to determine the hydraulic radius. The bed material is typically $d_{10} = 0.4$ mm, $d_{50} = 1.3$ mm and $d_{90} = 10$ mm. The measured slope of the Energy Grade Line was 13.12 cm per km on Nov. 3. Show the velocity profile on linear scale, and also provide a semi-log plot with a fitted line to the data to graphically determine the value of kappa.

Determine the following parameters in SI:

a) flow depth
b) hydraulic radius
c) ratio of hydraulic radius to flow depth
d) shear stress in Pascals
e) shear velocity
f) von Kármán constant
g) mean flow velocity in m/s (3 points)
h) Froude number
i) Manning n
j) laminar sublayer thickness in mm

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(a) \( n = 9.4 \text{m} \)

(b) \( R_n = \frac{h}{\delta} = 9.2 \text{m} \)

(c) Ratio of \( R_n \) to \( h \)

(d) \( \varepsilon = 8R_n \sqrt{f} = 1.8 \text{Pa} \)

(e) \( u* = \sqrt{\frac{\varepsilon}{f}} = 0.11 \text{m/s} \)

(f) Velocity Profile (based on log law)

\[ y = 3.375x + 11.301 \]

\[ R^2 = 0.9561 \]

\[ (x) \quad n = \frac{R^2 \sqrt{f t}}{V} = 0.027 \]

\[ (x) \quad \frac{11.6V}{V_m} = 0.11 \text{mm} \]