CE 3372 Water Systems Design
Fall 2016

1. The hydraulic radius in a conduit containing a flowing liquid is
   (A) the mean radius from the center of flow to the wetted side of the conduit
   (B) the ratio of the cross-sectional area of the conduit and the wetted perimeter
   (C) the ratio of the wetted perimeter and the cross-sectional area of the conduit
   (D) the ratio of the cross-sectional area of flow and the wetted perimeter
2. The rational runoff coefficient for a 14.81 acre parcel property is 0.35. The rainfall intensity is 4.56 inches per hour. The peak discharge from this property is anticipated to be about
   (A) 22 ft^3/s
   (B) 24 ft^3/s
   (C) 38 ft^3/s
   (D) 70 ft^3/s
   (E) 22 ft^3/s
   (F) 24 ft^3/s
   (G) 38 ft^3/s
   (H) 70 ft^3/s
3. A storm sewer (reinforced concrete pipe) is 400-feet long and 30-inches in diameter. The sewer flows partially full (not-surcharged) between a personnel access shaft (invert elevation 101.00 feet) and a lift station sump (invert elevation 100.00 feet). Assuming Manning's roughness coefficient is 0.013 for all flow depths, the sewer capacity is about
   (A) 4.2 cfs
   (B) 9.8 cfs
   (C) 20.5 cfs
   (D) 32.6 cfs
   (E) 22 ft^3/s
   (F) 24 ft^3/s
   (G) 38 ft^3/s
   (H) 70 ft^3/s

4. The storm sewer in the question above is flowing at $\frac{3}{4}$ full. What is the discharge in the sewer?

   (A) 3.6 cfs

   (B) 8.1 cfs

   (C) 12.5 cfs

   (D) 18.1 cfs

   (E) 22 ft^3/s

   (F) 24 ft^3/s

   (G) 38 ft^3/s

   (H) 70 ft^3/s

5. A pipe with a diameter of 2.4 meters is depicted in Figure 1. The pipe is flowing partially full.

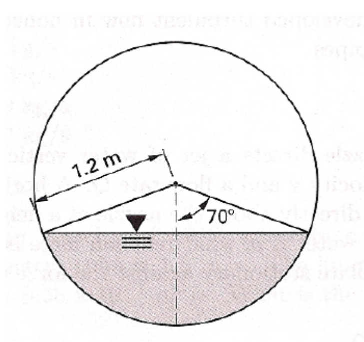

Figure 1: Circular channel flowing partially full.

   What is the hydraulic radius of flow in the circular section?

   (A) 0.44 m

   (B) 0.88 m

   (C) 1.30 m

   (D) 1.80 m

   (E) 0.44 m

   (F) 0.88 m

   (G) 1.30 m

   (H) 1.80 m

14. A smooth concrete channel is depicted in Figure 2. The channel's dimensionless slope in the direction of flow is 0.005. If the flow width at the surface is 2-meter, what is the flow rate in the channel using the Hazen-Williams friction formula?

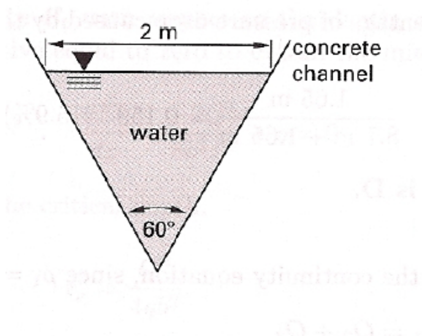

Figure 2: Triangular channel.

(A) 0.80 m^3/sec

(B) 1.30 m^3/sec

(C) 1.45 m^3/sec

(D) 2.20 m^3/sec

(E) 22 ft^3/s

(F) 24 ft^3/s

(G) 38 ft^3/s

(H) 70 ft^3/s

6. A 24-inch diameter sewer pipe, with Manning's n of 0.015 is laid on slope $S_0 = 0.01$ as shown in Figure 3.

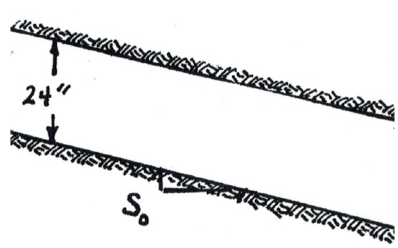

Figure 3: Sewer pipe sketch

Equation 1 is the depth-area equation and Equation 2 is the depth-perimeter equation for a circular conduit where the flow area is A, the flow depth is y, the diameter is D. and the wetted perimeter is P_w. Use Manning's equation and Equations 1 and 2 to complete Table 1.

$$A = \frac{D^2}{4}\{[cos^{-1}(1-\frac{2y}{D})] - [sin(cos^{-1}(1-\frac{2y}{D}))] \times [cos(cos^{-1}(1-\frac{2y}{D}))]\} \tag{1}$$

$$P_w = D \times cos^{-1}(1-\frac{2y}{D}) \tag{2}$$

Table 1: Depth-Area, Depth-Perimeter, Depth-Hyd. Radius, and Discharge for Circular Sewer

y (ft)	A (ft^2)	P_w (ft)	R_h (ft)	Q (ft^3/sec)
1.00				
2.00				

7. Figure 4 is a sketch of a 24 inch line with Manning's n of 0.015, laid on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The flowlines (invert elevations) match at the junction box. The downstream boundary conditions cause the flow depth in the 48 line to be 12 inches deep.

   a) What is the likely flow depth in the 24 inch line (at the junction box)?

   b) What is the discharge in the 24 inch line, assuming normal flow at the flow depth in the junction box?

   c) What is the discharge in the 24 inch line, assuming normal flow, when the pipe (24 inch) is full?

   d) What is the unused flow capacity in the 24 inch line?

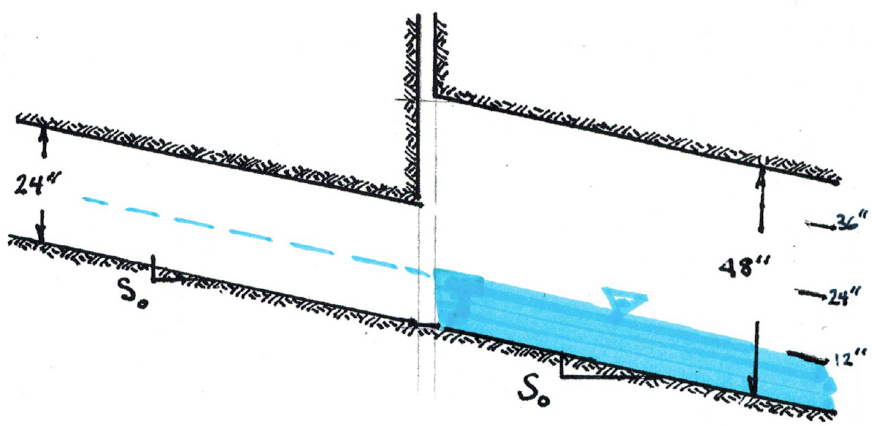

Figure 4: Sewer pipes connected at a junction box. Matching flow line elevations.

8. Figure 5 is a sketch of a 24 inch line with Manning's n of 0.015, laid on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The soffit(crown) elevations match at the junction box. The downstream boundary conditions cause the flow depth in the 48 line to be 36 inches deep.

   a) What is the likely flow depth in the 24 inch line (at the junction box)?

   b) What is the discharge in the 24 inch line, assuming normal flow at the flow depth in the junction box?

   c) What is the discharge in the 24 inch line, assuming normal flow, when the pipe (24 inch) is full?

   d) What is the unused flow capacity in the 24 inch line?

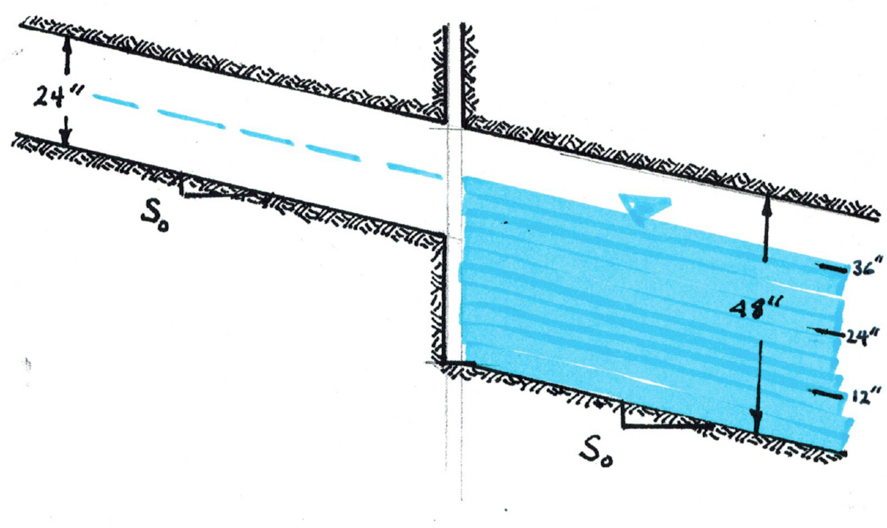

Figure 5: Sewer pipes connected at a junction box. Matching soffit elevations.

9. Figure 6 is a sketch of a 24 inch line with Manning's n of 0.015, laid on a slope of 0.01, connecting to a 48 inch line (also at 0.01) at a junction box. The soffit(crown) elevations match at the junction box. The downstream boundary conditions cause the flow depth in the 48 line to be 36 inches deep.

   a) What is the likely flow depth in the 24 inch line (at the junction box)?

   b) What is the discharge in the 24 inch line, assuming normal flow at the flow depth in the junction box?

   c) What is the discharge in the 24 inch line, assuming normal flow, when the pipe (24 inch) is full?

   d) What is the unused flow capacity in the 24 inch line?

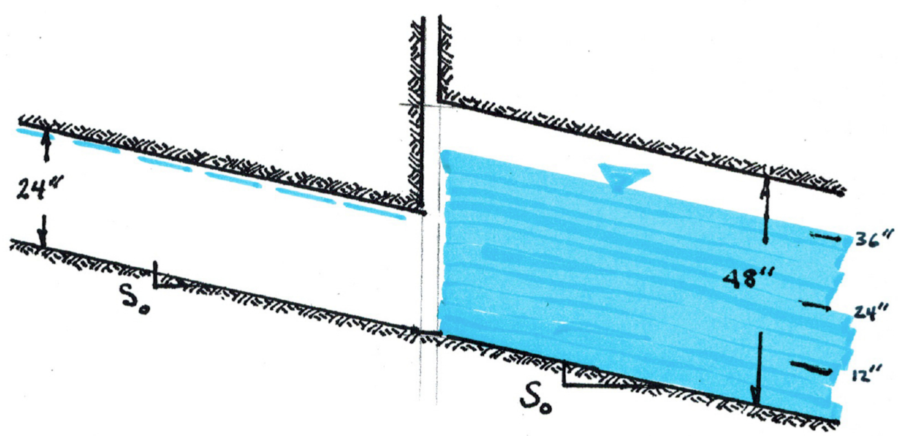

Figure 6: Sewer pipes connected at a junction box. Matching flow line elevations.

10. A circular, 60-inch diameter, reinforced concrete sewer pipe ($n = 0.013$)carries 50 MGD of wastewater to a lift station wet well. Average slope along the flow path is 1.0%.

    (a) Sketch the cross section, indicate the pipe diameter.

    (b) For the conditions in the problem statement, what is the flow rate in cubic feet per second?

    (c) What is the diameter of the pipe, in feet?

    (d) Use Manning's equation ($Q = \frac{1.49}{n} AR^{(2/3)} S^{(1/2)}$) and determine the **pipe-full** discharge in cubic feet per second?

(e) What is the pipe-full discharge (Q_f) in million gallons per day (MGD)?

(f) Compute the ratio of actual flow ($\frac{Q}{Q_f}$) to full pipe flow.

(g) What is the ratio of depth of actual flow to full flow ($\frac{d}{D}$) using the hydraulic element chart in Figure 7? Use the highlighted curve.

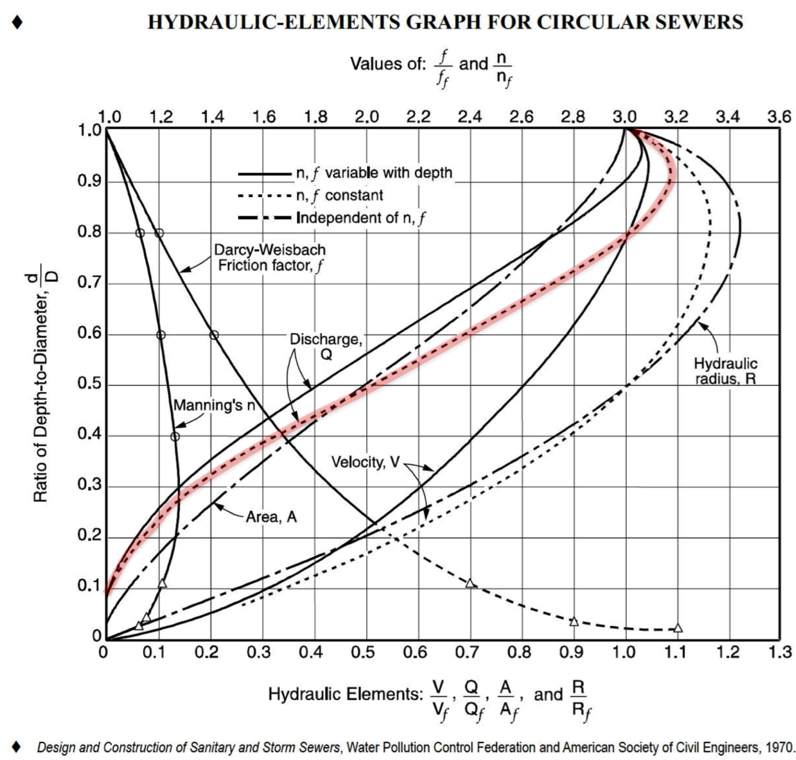

Figure 7: Hydraulic Elements Chart

(h) What is the depth of actual flow in feet?

(i) What is the depth of actual flow in inches?

(j) Modify your sketch to include the water surface position and the approximate flow depth.

(k) Is this portion of sewer close to surcharging?

11. An EPA-NET simulation model for a reservoir-pump-network was constructed and operated for four (4) different operational scenarios. Figure 8 is a depiction of the network. The numbers next to the nodes are Node_ID values in the reports that follow, and the numbers next to the pipes are the Link_ID values. The network is supplied from a reservoir through a booster pump, both are depicted on Figure 8.

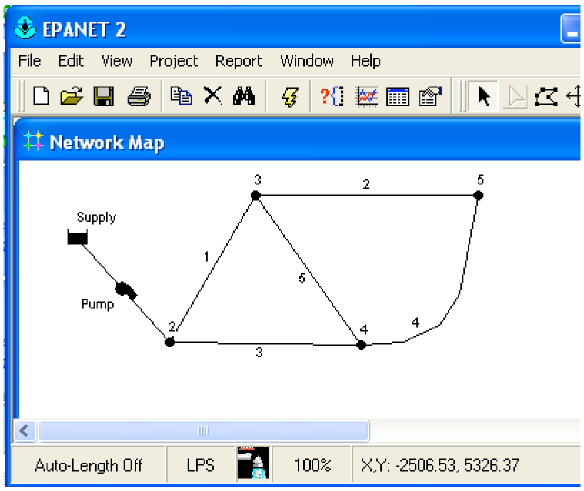

Figure 8: EPA-NET system topology.

Figure 9 is the a portion of the summary report for simulation 1. Figure 10 is the a portion of the summary report for simulation 2. Figure 11 is the a portion of the summary report for simulation 3. Figure 12 is the a portion of the summary report for simulation 4.

These four simulation represent different demand scenarios for the same system.

Interpret these reports, to answer the following questions:

(a) Complete the table below. Q_{pump} is the discharge in liters-per-second through the pump station, H_{Supply} is the head at the supply reservoir, H_{Node2} is the head at Node 2, and ΔH_{pump} is the added head supplied by the pump.

Table 2: Pump Discharge and Supplied Head

Simulation #	Q_{pump}	H_{Supply}	H_{Node2}	ΔH_{pump}
1				
2				
3				
4				

(b) Complete the table below. Q_{pump} is the discharge in liters-per-second through the pump station, $\Delta H_{Node2-to-5}$ is head loss in the system from Node 2 to Node 5.

Table 3: System Discharge and Head Loss

Simulation #	Q_{pump}	H_{Node2}	H_{Node5}	$\Delta H_{Node2-to-5}$
1				
2				
3				
4				

(c) If the pump performance curve has the mathematical structure:
$H_{pump} = H_{shutoff} - K_{pipe} \times Q^2$, estimate the values of $H_{shutoff}$ and K_{pipe}.

(d) If the system frictional loss curve has the mathematical structure: $H_{pipe} = K_{loss} \times Q^2$, estimate the value of K_{loss}

(e) What effect would removing the pipe joining nodes 3 and 4 have on the system performance? Explain your reasoning.

(f) Estimate the flow distribution and head losses the the system if the the pipe joining nodes 3 and 4 are removed, and the pipe joining node 4 and 5 is removed if the nodal demands are the same as SIMULATION 2.

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  Page 1                                               10/4/2010 2:27:47 PM
  **********************************************************************
  *                             E P A N E T                            *
  *                  Hydraulic and Water Quality                       *
  *                  Analysis for Pipe Networks                        *
  *                            Version 2.0                             *
  **********************************************************************
  Input File: SIMULATION #1
Link - Node Table:
  ----------------------------------------------------------------------
  Link             Start            End                 Length  Diameter
  ID               Node             Node                     m        mm
  ----------------------------------------------------------------------
  1                2                3                     1000       124
  2                3                5                     1000       124
  3                2                4                     1000       124
  4                4                5                     1000       124
  5                3                4                     1400       124
  7                6                2                     #N/A      #N/A Pump
Node Results:
  ----------------------------------------------------------------------
  Node                  Demand      Head  Pressure   Quality
  ID                       LPS         m         m
  ----------------------------------------------------------------------
  2                       0.00     20.00     20.00      0.00
  3                       0.00     20.00     20.00      0.00
  4                       0.00     20.00     20.00      0.00
  5                       0.00     20.00     20.00      0.00
  6                       0.00      0.00      0.00      0.00 Reservoir
Link Results:
  ----------------------------------------------------------------------
  Link                    Flow  VelocityUnit Headloss    Status
  ID                       LPS       m/s      m/km
  ----------------------------------------------------------------------
  1                       0.00      0.00      0.00      Open
  2                       0.00      0.00      0.00      Open
  3                       0.00      0.00      0.00      Open
  4                       0.00      0.00      0.00      Open
  5                       0.00      0.00      0.00      Open
  7                       0.00      0.00    -20.00      Open Pump
```

Figure 9: EPA-NET Summary Report, Simulation #1

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Page 1                                          10/4/2010 2:28:15 PM
**********************************************************************
*                            E P A N E T                             *
*                    Hydraulic and Water Quality                     *
*                    Analysis for Pipe Networks                      *
*                          Version 2.0                               *
**********************************************************************
Input File: SIMULATION 2
Link - Node Table:
----------------------------------------------------------------------
Link           Start          End                  Length  Diameter
ID             Node           Node                      m        mm
----------------------------------------------------------------------
1              2              3                      1000       124
2              3              5                      1000       124
3              2              4                      1000       124
4              4              5                      1000       124
5              3              4                      1400       124
7              6              2                      #N/A      #N/A Pump
Node Results:
----------------------------------------------------------------------
Node                 Demand      Head  Pressure   Quality
ID                      LPS         m         m
----------------------------------------------------------------------
2                      0.00     19.28     19.28      0.00
3                      1.00     19.03     19.03      0.00
4                      1.00     19.03     19.03      0.00
5                      1.00     18.99     18.99      0.00
6                     -3.00      0.00      0.00      0.00 Reservoir
Link Results:
----------------------------------------------------------------------
Link                   Flow  VelocityUnit Headloss    Status
ID                      LPS       m/s      m/km
----------------------------------------------------------------------
1                      1.50      0.12      0.25      Open
2                      0.50      0.04      0.03      Open
3                      1.50      0.12      0.25      Open
4                      0.50      0.04      0.03      Open
5                      0.00      0.00      0.00      Open
7                      3.00      0.00    -19.28      Open Pump
```

Figure 10: EPA-NET Summary Report, Simulation #2

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 Page 1                                                  10/4/2010 2:29:00 PM
**********************************************************************
*                            E P A N E T                             *
*                  Hydraulic and Water Quality                       *
*                  Analysis for Pipe Networks                        *
*                        Version 2.0                                 *
**********************************************************************
Input File: SIMULATION 4
Link - Node Table:
----------------------------------------------------------------------
Link           Start          End                 Length  Diameter
ID             Node           Node                     m        mm
----------------------------------------------------------------------
1              2              3                     1000       124
2              3              5                     1000       124
3              2              4                     1000       124
4              4              5                     1000       124
5              3              4                     1400       124
7              6              2                     #N/A      #N/A Pump
Node Results:
----------------------------------------------------------------------
Node                 Demand      Head  Pressure   Quality
ID                      LPS         m         m
----------------------------------------------------------------------
2                      0.00     17.12     17.12      0.00
3                      2.00     16.16     16.16      0.00
4                      2.00     16.16     16.16      0.00
5                      2.00     16.04     16.04      0.00
6                     -6.00      0.00      0.00      0.00 Reservoir
Link Results:
----------------------------------------------------------------------
Link                   Flow  VelocityUnit Headloss    Status
ID                      LPS       m/s      m/km
----------------------------------------------------------------------
1                      3.00      0.25      0.96      Open
2                      1.00      0.08      0.12      Open
3                      3.00      0.25      0.96      Open
4                      1.00      0.08      0.12      Open
5                      0.00      0.00      0.00      Open
7                      6.00      0.00    -17.12      Open Pump
```

Figure 11: EPA-NET Summary Report, Simulation #3

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  Page 1                                              10/4/2010 2:29:46 PM
  **********************************************************************
  *                            E P A N E T                             *
  *                   Hydraulic and Water Quality                      *
  *                   Analysis for Pipe Networks                       *
  *                         Version 2.0                                *
  **********************************************************************
  Input File: SIMULATION 3
Link - Node Table:
  ----------------------------------------------------------------------
  Link           Start          End                 Length  Diameter
  ID             Node           Node                     m        mm
  ----------------------------------------------------------------------
  1              2              3                     1000       124
  2              3              5                     1000       124
  3              2              4                     1000       124
  4              4              5                     1000       124
  5              3              4                     1400       124
  7              6              2                     #N/A      #N/A Pump
Node Results:
  ----------------------------------------------------------------------
  Node                  Demand      Head  Pressure   Quality
  ID                       LPS         m         m
  ----------------------------------------------------------------------
  2                       0.00     13.52     13.52      0.00
  3                       3.00     11.40     11.40      0.00
  4                       3.00     11.40     11.40      0.00
  5                       3.00     11.15     11.15      0.00
  6                      -9.00      0.00      0.00      0.00 Reservoir
 Link Results:
  ----------------------------------------------------------------------
  Link                    Flow  VelocityUnit Headloss    Status
  ID                       LPS       m/s      m/km
  ----------------------------------------------------------------------
  1                       4.50      0.37      2.12      Open
  2                       1.50      0.12      0.25      Open
  3                       4.50      0.37      2.12      Open
  4                       1.50      0.12      0.25      Open
  5                       0.00      0.00      0.00      Open
  7                       9.00      0.00    -13.52      Open Pump
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Figure 12: EPA-NET Summary Report, Simulation #4