CE 3372 Water Systems Design
Fall 2016

1. (1 pts.) 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. (5 pts.) The rational runoff coefficient for a 14.31 acre parcel property is 0.35. The rainfall intensity is 6.54 inches per hour. The peak discharge from this property is anticipated to be about
   (A) 23.82 cfs
   (B) 28.41 cfs
   (C) 33.01 cfs
   (D) 48.18 cfs
   (E) 57.86 cfs
   (F) 65.90 cfs
   (G) 80.18 cfs

3. (8 pts.) A storm sewer (reinforced concrete pipe) is 400-feet long and 30-inches in diameter. The sewer flows from a junction box (invert elevation 101.00 feet) to a lift station sump (invert elevation 100.00 feet). Assuming Manning's roughness coefficient is 0.015 for all flow depths, the sewer maximum flow capacity without surcharge is about[1]
   (A) 17.8 cfs
   (B) 19.2 cfs
   (C) 20.6 cfs
   (D) 22.1 cfs
   (E) 28.9 cfs
   (F) 31.2 cfs
   (G) 33.4 cfs
   (H) 35.9 cfs

[1] For partial credit show work

4. (8 pts.) The storm sewer in the question above is flowing at $\frac{3}{4}$ full. What is the discharge in the sewer?

   (A) $Q_{75\%} = 16.2$ cfs

   (B) $Q_{75\%} = 18.7$ cfs

   (C) $Q_{75\%} = 22.6$ cfs

   (D) $Q_{75\%} = 23.6$ cfs

   (E) $Q_{75\%} = 24.3$ cfs

   (F) $Q_{75\%} = 26.4$ cfs

   (G) $Q_{75\%} = 29.9$ cfs

   (H) $Q_{75\%} = 30.4$ cfs

5. (11 pts.) A pipe with a diameter of 2.4 meters is depicted in Figure 1. The pipe is flowing partially full.

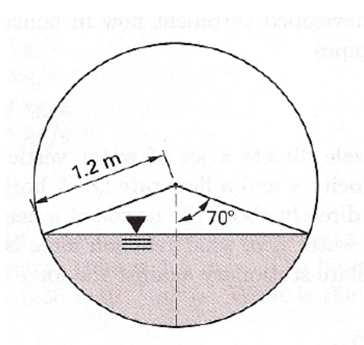

Figure 1: Circular channel flowing partially full.

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

   (A) 0.21 m

   (B) 0.44 m

   (C) 1.30 m

   (D) 1.39 m

   (E) 1.44 m

   (F) 1.68 m

   (G) 1.80 m

   (H) 2.80 m

6. (12 pts.) A smooth concrete channel (n=0.015) 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 Manning's equation?

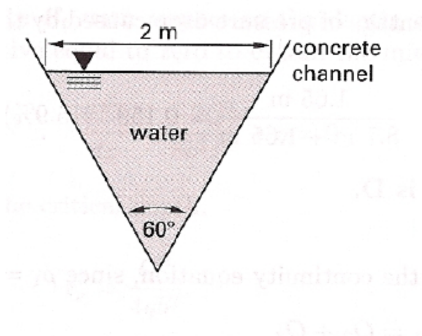

Figure 2: Triangular channel.

(A) 0.24 cms (cubic meters per second)

(B) 0.31 cms

(C) 3.52 cms

(D) 3.91 cms

(E) 4.41 cms

(F) 4.45 cms

(G) 5.83 cms

(H) 6.66 cms

7. (19 pts.) 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.

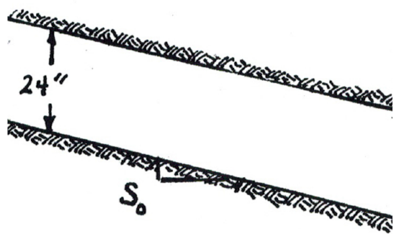

Figure 3: Sewer pipe sketch

Use Manning's equation and the depth-area, and the depth-perimeter equations on the equation sheet to complete Table 1.

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				

8. (8 pts.) Figure 4 is a sketch of a 24 inch line with Manning's n of 0.015, 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-inch line to be 12-inches deep.

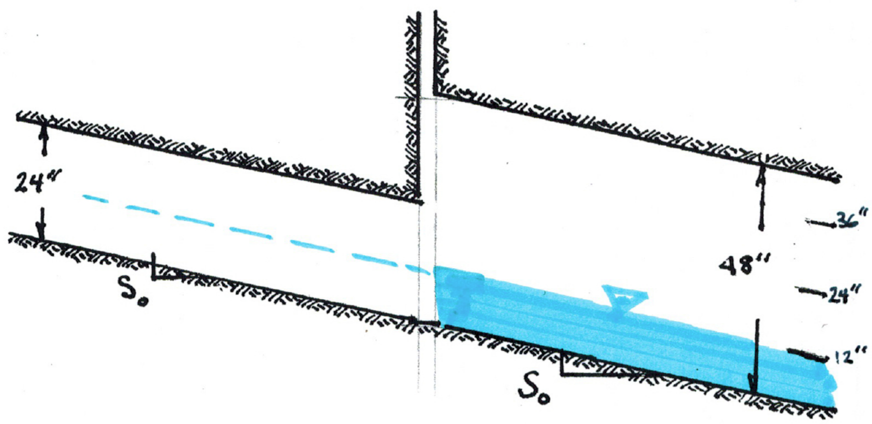

Figure 4: Sewer pipes connected at a junction box. Matching flow line elevations.

(A) The likely flow depth in the 24 inch line (at the junction box) is

i) 12.0-inches
ii) 18.0-inches
iii) 24.0-inches
iv) 36.0-inches
v) 48.0-inches

(B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the pipe is

i) 0.00 cfs
ii) 2.45 cfs
iii) 4.92 cfs
iv) 9.83 cfs
v) 19.66 cfs
vi) 39.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

i) 0.00 cfs

ii) 2.45 cfs

iii) 4.92 cfs

iv) 9.83 cfs

v) 19.66 cfs

vi) 39.32 cfs

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

9. (8 pts.) Figure 5 is a sketch of a 24 inch line with Manning's n of 0.015, 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.

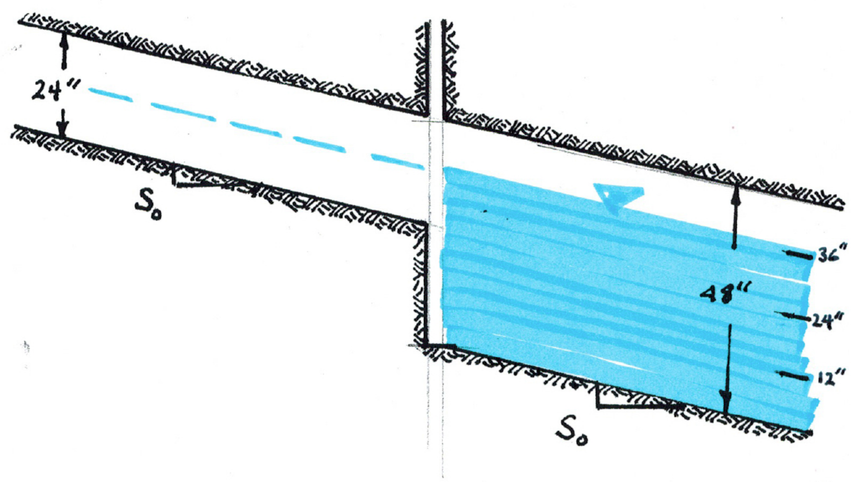

Figure 5: Sewer pipes connected at a junction box. Matching soffit elevations.

(A) The likely flow depth in the 24 inch line (at the junction box) is

i) 12.0-inches

ii) 18.0-inches

iii) 24.0-inches

iv) 36.0-inches

v) 48.0-inches

(B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the pipe is

i) 0.00 cfs

ii) 2.45 cfs

iii) 4.92 cfs

iv) 9.83 cfs

v) 19.66 cfs

vi) 39.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

i) 0.00 cfs

ii) 2.45 cfs

iii) 4.92 cfs

iv) 9.83 cfs

v) 19.66 cfs

vi) 39.32 cfs

(D) What is the unused flow capacity (in cfs) in the 24 inch line?

10. (8 pts.) Figure 6 is a sketch of a 24 inch line with Manning's n of 0.015, 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.

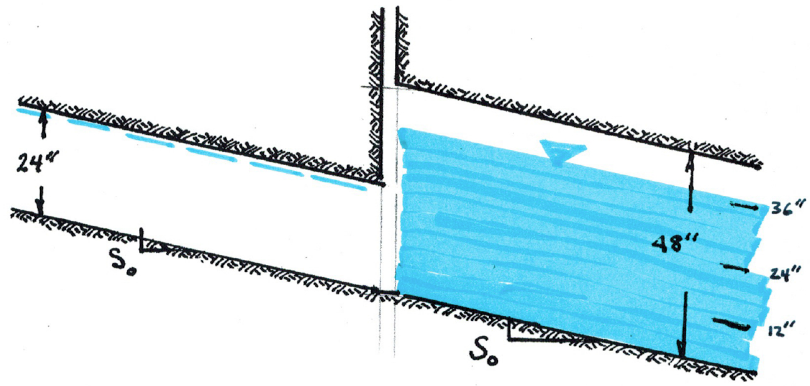

Figure 6: Sewer pipes connected at a junction box. Matching flow line elevations.

(A) The likely flow depth in the 24 inch line (at the junction box) is

i) 12.0-inches

ii) 18.0-inches

iii) 24.0-inches

iv) 36.0-inches

v) 48.0-inches

(B) The discharge in the 24 inch line, assuming normal flow at the flow depth in the pipe is

i) 0.00 cfs

ii) 2.45 cfs

iii) 4.92 cfs

iv) 9.83 cfs

v) 19.66 cfs

vi) 39.32 cfs

(C) The full-pipe discharge in the 24 inch line, assuming normal flow, is

i) 0.00 cfs

ii) 2.45 cfs

iii) 4.92 cfs

iv) 9.83 cfs

v) 19.66 cfs

vi) 39.32 cfs

(D) What is the unused flow capacity (in cfs) in the 24 inch line?

11. (46 pts.) An EPA-NET simulation model for a reservoir-pump-network was constructed and operated for four (4) different operational scenarios. Figure 7 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 7.

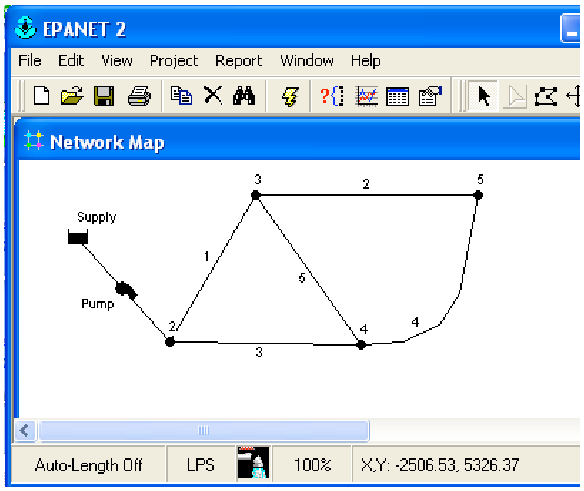

Figure 7: EPA-NET system topology.

Figure 8 is the a portion of the summary report for simulation 1. Figure 9 is the a portion of the summary report for simulation 2. Figure 10 is the a portion of the summary report for simulation 3. Figure 11 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:
$H_{pump} = H_{shutoff} - K_{system} \times Q^2$, estimate the values K_{system}.

(d) If the frictional loss from Node 2 to Node 5 has the mathematical structure:
$\Delta H_{Node\ 2-to-5} = K_{loss} \times Q^2_{pump}$, 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 in 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 8: 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 9: 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 10: 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 11: EPA-NET Summary Report, Simulation #4