Problem 3-4

Lay out the storm sewer system shown below in StormCAD and enter the data for the network from the tables below. Calculate the results using Manning's equation and the 10-yr storm event data tables that follow. Inlet I-1 is on grade with a longitudinal slope of 3%, whereas inlet I-2 is in sag. The tailwater condition at the outlet is free outfall. Assume that there is no clogging of the inlets.

Schematic for Problem 3-4

Pipe Data for Problem 3-4

Pipe	Circular Section Size (mm)	Upstream Invert Elevation (m)	Downstream Invert Elevation (m)	Length (m)	Pipe Material (*n*-value)
P-1	300	115.40	115.10	46	Concrete (0.013)
P-2	300	115.05	114.60	61	Concrete (0.013)

Node Data for Problem 3-4

Nodes	Ground Elevation (m)	Sump Elevation (m)	Head Loss Method	Head Loss Coefficient
I-1	117.40	115.40	Standard	0.5
I-2	117.15	115.05	Standard	0.5
O-1	118.00	114.60	-	-

Inlet Catchment Data for Problem 3-4

Inlet	Time of Concentration (min)	Additional Carryover (m^3/s)	Area (ha)	Inlet *C*
I-1	6.3	0	0.45	0.75
I-2	5.2	0	0.22	0.80

Inlet Data for Problem 3-4

Inlet	Inlet Type	Grate Length (m)	Road Cross-Slope (m/m)	Bypass Target	Manning's *n*
I-1	Grate DI-1	1.1	0.02	I-2	0.012
I-2	Grate DI-1	1.1	0.02	-	-

Grate DI-1

(Provided in case missing from inlet library)

Structure Width = 0.67 m
Structure Length = 0.67 m

Grate Type =
P-50 mm x 100 mm

Width = 0.76 m Standard
Length = 0.76 m

Rainfall Data for Problem 3-4

Rainfall Intensities (mm/hr)			
Duration (min)	Return Period		
	5 Year	10 Year	50 Year
5	69.8	78.7	99.6
10	54.6	61.0	77.5
20	40.6	45.2	56.6
30	31.7	36.2	45.7

Fill out an answer table like the one below for each of the following situations:

a) Assume uniform gutters with a slope of 0.02 m/m.

Inlet	Gutter Spread (m)	Total Flow to Inlet (m^3/s)	Intercepted Inlet Flow (m^3/s)	Bypassed Inlet Flow (m^3/s)	Efficiency (%)
I-1	2.25	0.0694	0.0498	0.0197	71.7
I-2	2.84	0.0588	0.0588	0.0000	100

b) Assume continuously depressed gutters with a road cross-slope of 0.02 m/m, a gutter cross-slope of 0.04 m/m, and a gutter width of 0.8 m.

Inlet	Gutter Spread (m)	Total Flow to Inlet (m^3/s)	Intercepted Inlet Flow (m^3/s)	Bypassed Inlet Flow (m^3/s)	Efficiency (%)
I-1	2.01	0.0694	0.0578	0.0116	83.3
I-2	1.76	0.0503	0.0503	0.0000	100.0

c) Assume continuously depressed gutters as described in (b), as well as inlet lengths increased from 1.1 m to 1.6 m.

Inlet	Gutter Spread (m)	Total Flow to Inlet (m^3/s)	Intercepted Inlet Flow (m^3/s)	Bypassed Inlet Flow (m^3/s)	Efficiency (%)
I-1	2.01	0.0694	0.0596	0.0099	85.8
I-2	1.42	0.0485	0.0485	0.0000	100.0

d) Explain the reasons for the differences between the three resulting tables.

At I-1, the most pronounced change in both spread width and efficiency results from the addition of the gutter depression in (b). The spread width decreases because the added gutter depression increases the cross-sectional area of the gutter over the gutter in part (a). The efficiency increases because the steeper gutter cross-slope increases the frontal flow, which is captured more efficiently than side flow.

There was no change in spread at I-1 with the longer grate because spread is only a function of gutter shape for inlets on grade. The relatively small change in efficiency results from the slight increase in side flow captured. The longer the grate, the greater the opportunity for side flow to be captured before it becomes bypass flow. The velocity in the gutter is small compared to the splash-over velocity. So, the frontal flow is already completely captured by the smaller grate, and the increase in grate length adds no benefit in that regard.

For inlet I-2, the decrease in spread width from part (a) to part (b) results from the increase in the cross-sectional area of the gutter for a given spread width due to the added gutter depression. Capacity is directly proportional to depth, and the added gutter depression increases the depth for a smaller spread.

The decrease in spread width at I-2 from part (b) to part (c) occurs because of the greater capacity of the longer inlet to capture flow while acting either as a weir or an orifice.

Test Inlet Data	
Structure width and length	1.2 m
Grate type	P-50 mm
Grate width	1 m

Grate lengths start at 1 m and are available in increments of 0.5 m

A grate length of 1.5 m is required to satisfy the design spread length of 4.0 m. This length results in a spread of 3.7 m.

c) Using the same data and inlet designed in (b), calculate the spread at I-2 assuming 50% clogging.

Gutter Spread = 5.38 m, which fails to satisfy the design spread.

This may be a good time to reiterate that grate inlets are generally not considered acceptable for operating in sag because of the increased likelihood of clogging.

Problem 3-6

The data that follows describes the existing storm sewer system shown below. For runoff calculations, assume $C = 0.3$ for pervious land cover and $C = 0.9$ for impervious cover. The ground elevation at the system discharge point is 17.0 m. All pipes are concrete (n = 0.013) and circular. Apply a standard head loss coefficient of 0.5 to inlet I-3. Assume all inlets are *Generic Default 100%*, which means that they are assumed to capture 100% of the surface flow.

a) Analyze the system for a design return period of 10 years. Assume a free outfall condition. Provide output tables summarizing pipe flow conditions and hydraulic grade lines at the inlets. How is this system performing?

There is flooding in the system at I-1, and pipe P-3 appears to have the steepest hydraulic grade line.

b) Increase the size of pipe P-3 to 450-mm. Rerun the analysis and present the results. How does the system perform with this improvement?

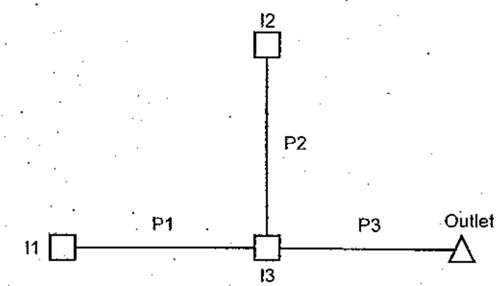
There is no flooding in the system, and the hydraulic grades are lower throughout. A hydraulic jump forms in P-2. Pipes P-1 and P-2 are under pressure.

c) Local design regulations require that storm sewer systems handle 25-year return periods without flooding. Rerun the analysis for the improved system in (b). Does the system meet this performance requirement?

The requirement is met, but there is an increase in velocity over part (b), and pipes P-1 and P-2 are flowing under pressure. A hydraulic jump forms in P-2.

d) The above analyses are run using a default Manning's n of 0.013. Many drainage design manuals propose a less conservative design roughness of 0.012. Reanalyze the improved system under 25-year flows using $n = 0.012$. How does this change influence the predicted performance of the system?

The decrease in n-value lowered the HGL in the pipes slightly. The pipes, however, are operating under flow conditions similar to those in parts (b) and (c).



Schematic for Problem 3-6

Rainfall Data for Problem 3-6

Duration (min)	Rainfall Intensity (mm/hr)		
	5 year	10 year	25 year
5	165	181	205
10	142	156	178
15	123	135	154
30	91	103	120
60	61	70	80

Inlet Information for Problem 3-6

Inlet	Ground Elevation (m)	Impervious Area (ha)	Pervious Area (ha)	Time of Concentration (min)
I-1	17.9	0.13	0.32	6.0
I-2	18.0	0.15	0.58	5.0
I-3	17.6	0.08	0.36	5.0

Pipe Information for Problem 3-6

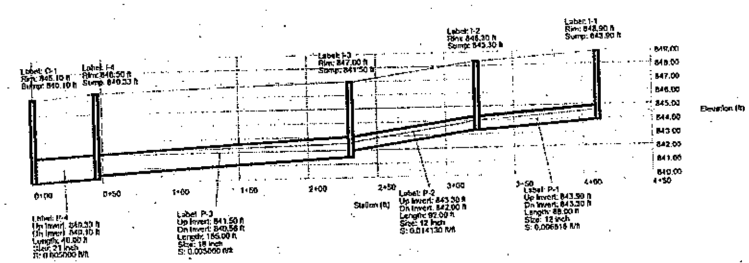
Pipe	Upstream Invert (m)	Downstream Invert (m)	Diameter (mm)	Length (m)
P-1	16.7	16.15	300	56
P-2	16.8	16.1	375	46
P-3	16.1	15.3	375	54

Problem 3-7

You have been asked by the lead project engineer for a water supply utility to design the stormwater collection system for the proposed ground storage tank and pump station facility shown in the layout. Pipe lengths for P-1, P-2, P-3, and P-4 are 88, 92, 185, and 46 feet, respectively. See the CAD drawing and data for the system layout. Assume C = 0.3 for pervious areas and C = 0.9 for impervious areas.

a) Using the StormCAD program's Automatic Design feature, size the system using the following design data. Use concrete pipe (n = 0.013) and the 25-year intensity-duration-frequency data provided in problem 3-6 (Hint: StormCAD can mix SI and U.S. customary units). The top of bank elevation at the outfall ditch is 846.1 ft. The outfall pipe invert must be located at or above elevation 838.0 ft. Assume that the water surface elevation at the outfall is 842.0 ft, and that the pipes should have matching soffit (crown) elevations at every structure. Present your design in tabular form and provide a profile plot of your design.

Pipe	Section Size	Upstream Invert Elev. (ft)	Downstream Invert Elev. (ft)	Discharge (cfs)	Upstream HGL (ft)	Downstream HGL (ft)
P-1	12 inch	843.90	843.30	2.38	844.58	844.04
P-2	12 inch	843.30	842.00	2.99	844.04	842.62
P-3	18 inch	841.50	840.58	5.51	842.52	842.11
P-4	21 inch	840.33	840.10	7.75	842.11	842.00



Note that text can be dragged and dropped in the profile view, just as it can in the plan view. Layers (HGL, ground, etc.) can also be turned on and off to create the desired profile.

b) During agency review, the county engineer requests that the water utility and the county work cooperatively to accommodate the planned construction of an elementary school nearby by increasing the size of the proposed storm system so that it can handle the design runoff from the school. The county engineer performs his own calculations and asks that you increase the size of pipes P-3 and P-4 to handle an external CA of 9.5 acres with a time of concentration of 12 min. Using StormCAD, introduce the additional flow at inlet I-3 and revise the facility design using the Automatic Design functionality of the program. Are all of the design constraints met? What can you say about the flow conditions in pipe P-3 and pipe P-4? In the rest of the pipes?

All design constraints are met. The new design is documented in part (c).

c) If necessary, manually fine-tune and revise the design to meet all design criteria. Document your design as in part (a).

Pipe	Section Size	Upstream Invert Elev. (ft)	Downstream Invert Elev. (ft)	Discharge (cfs)	Upstream HGL (ft)	Downstream HGL (ft)
P-1	12 inch	843.90	843.30	2.38	844.58	844.04
P-2	12 inch	843.30	842.00	2.99	844.04	842.54
P-3	48 inch	839.00	838.08	76.48	842.54	842.13
P-4	48 inch	838.08	837.85	77.72	842.13	842.00