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CE 365K Hydraulic Engineering Design **Second Exam** **Spring 2016**

There are four questions on this exam. They are of equal credit. Please do all four questions.

Question 1: Concepts

(a) How do you determine whether the waters of a particular stream satisfy the Texas Water Quality Standards for E. Coliform bacteria?

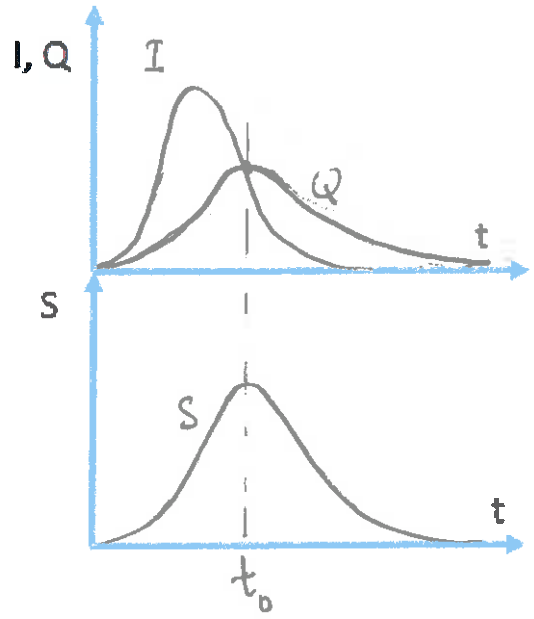
6 · Sample E. Coli in the stream for a period of years.
· Compute geometric mean of data
· If GM ≤ 126 CFU/100mL it satisfies the criteria

(b) The Austin Drainage Criteria Manual contains a number of rules that define how a hydraulic design must be performed. Choose one of these rules and describe how it is used in the design of a particular kind of hydraulic structure

6 For bridges and culverts, the rule is to not have more than 6" on the street for a 100 yr flood

Design bridge or culvert openings to achieve flow

(c) Draw on the diagram below the inflow, I, outflow, Q, and storage, S, for a detention pond. Beginning with the equation $dS/dt = I - Q$, explain why the outflow from the pond is maximized when the inflow and outflow are equal.



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$\frac{dS}{dt} = I - Q$

for a level pool, $Q = f(S)$ or elevation

∴ when S is maximized, so is Q

∴ at max S, $\frac{dS}{dt} = 0$

∴ $I = Q$ at this point

and since S is maximized, so is Q at time t_0

Question 2: Bridge Capacity

The data on the following two pages are for Bridges over Boggy Creek at Highway 183 and Delwau Rd. Make a comparison between the two bridges and the passage of a 100 year flow through them. Where different values are given for Inside BR US and Inside BR DS, use the Inside BR US values.

Characteristic	Highway 183	Delwau Rd
Bed Elevation (Ft)	415	404
Water Surface Elevation (ft)	433.46	432.04
Water Depth (ft)	18.46	28.04
Energy Grade Line Elevation (ft)	438.19	433.14
Velocity (ft/s)	17.46	6.77
Velocity head (ft)	4.63; $\frac{V^2}{2g}$ = 4.73	1.10 $\frac{V^2}{2g}$ = 0.711
Flow Through Bridge (cfs)	23,052	4012.1
Flow Over the Bridge (cfs)	0	19039.9
Total Flow (cfs)	23,052	23,052.0
Flow Area (ft^2)	1320.59	3404.29
Top Width (ft)	107.55	469.81
Shear Stress (lb/ft^2)	6.78	2.75

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Discuss and compare the flow conditions at the two bridges

5

Depth Water is deeper at Delwau Rd

Velocity Velocity is higher at Highway 183

Discharge At 183 all flow goes through bridge, at Delwau Rd, most goes over top of bridge

Flow Top Width Top width > 4 times wider at Delwau Rd than 183

Shear Stress about 3 times higher at 183

Make a summary comparison between these two bridges. What characteristics does a successful bridge crossing have?

8

At 183, the bridge is elevated above the creek and flow stays in channel

At Delwau Rd, bridge is sunk into the channel itself and forces flow out onto the floodplain

Boggy Creek at Highway 183

Bridge Output

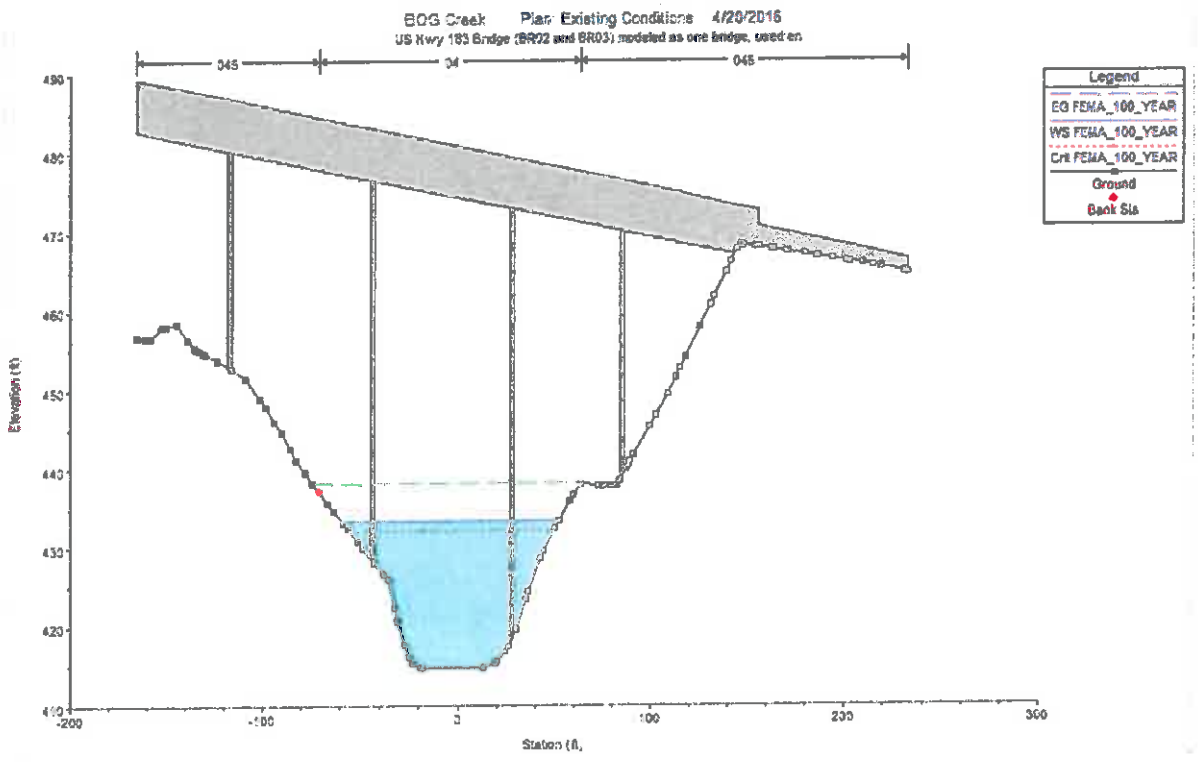
File Type Options Help

River: Boggy Profile: FEMA_100_YEAR

Reach 1 RS: 4756 Plan: Existing

Plan: Existing Boggy 1 RS: 4756 Profile: FEMA_100_YEAR

		Element	Inside BR US	Inside BR DS
E.G. US. (ft)	438.78	E.G. Elev (ft)	438.19	436.46
W.S. US. (ft)	435.61	W.S. Elev (ft)	433.46	433.98
Q Total (cfs)	23052.00	Crit W.S. (ft)	432.13	428.43
Q Bridge (cfs)	23052.00	Max Chl Dpth (ft)	18.74	21.25
Q Weir (cfs)		Vel Total (ft/s)	17.46	12.64
Weir Sta Lft (ft)		Flow Area (sq ft)	1320.59	1823.37
Weir Sta Rgt (ft)		Froude # Chl	0.88	0.59
Weir Submerg		Specif Force (cu ft)	23082.97	25590.79
Weir Max Depth (ft)		Hydr Depth (ft)	12.28	14.43
Min El Weir Flow (ft)	466.51	W.P. Total (ft)	157.42	201.55
Min El Prs (ft)	482.73	Conv. Total (cfs)	202536.0	294079.1
Delta EG (ft)	2.67	Top Width (ft)	107.55	126.37
Delta WS (ft)	1.90	Frictn Loss (ft)	0.60	0.31
BR Open Area (sq ft)	10936.99	C & E Loss (ft)	1.12	0.04
BR Open Vel (ft/s)	17.46	Shear Total (lb/sq ft)	6.78	3.47
Coef of Q		Power Total (lb/ft s)	-165.77	-154.09
Br Sel Method	Energy only			



Boggy Creek at Delwau Rd

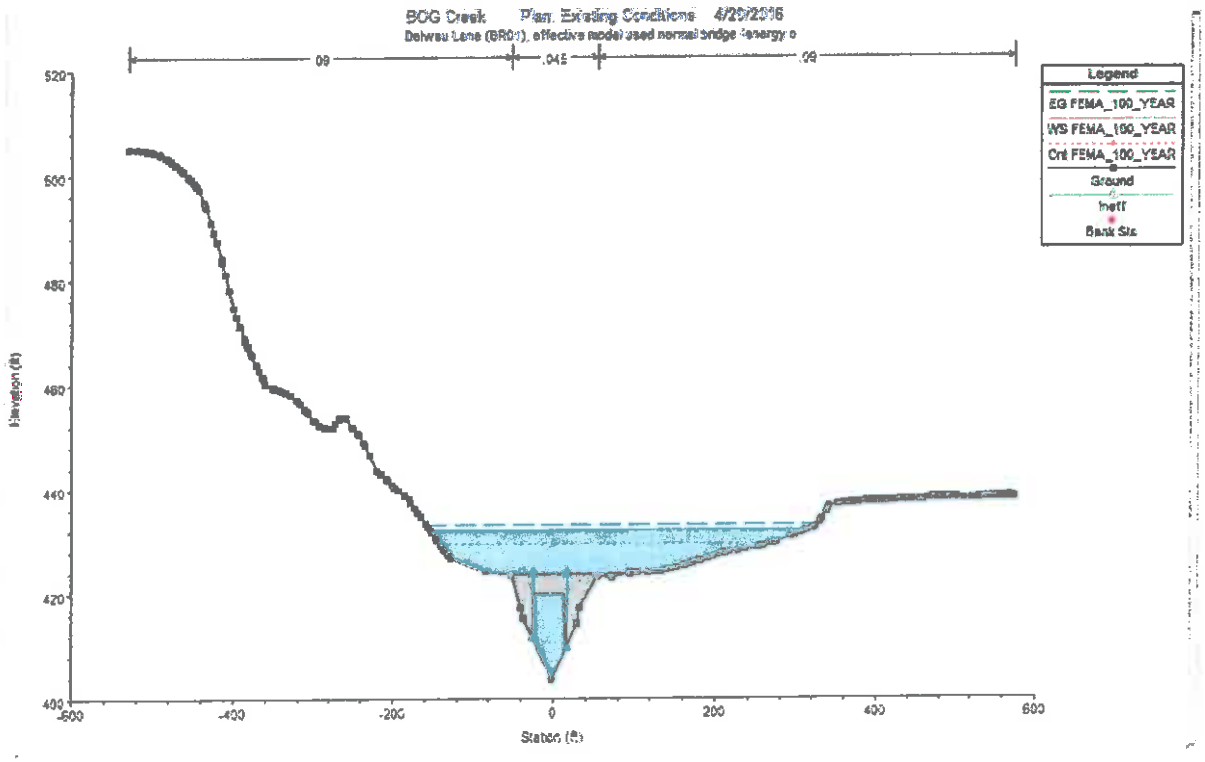
File Type: Options Help

River: Boggy Profile: FEMA_100_YEAR

Reach 1 RS: 3163 Plan: Existing

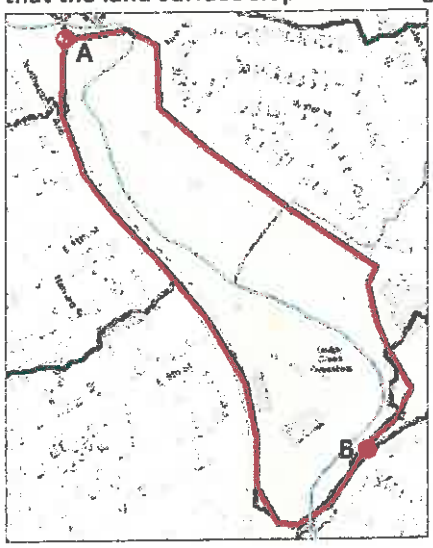
Plan: Existing Boggy 1 RS: 3163 Profile: FEMA_100_YEAR

		Element	Inside BR US	Inside BR DS
E.G. US. (ft)	433.24	E.G. Elev (ft)	433.14	432.92
W.S. US. (ft)	432.18	W.S. Elev (ft)	432.04	431.82
Q Total (cfs)	23052.00	Crit W.S. (ft)	429.31	429.10
Q Bridge (cfs)	4012.10	Max Chl Dpth (ft)	28.25	28.50
Q Weir (cfs)		Vel Total (ft/s)	6.77	6.79
Weir Sta Lft (ft)		Flow Area (sq ft)	3404.29	3394.92
Weir Sta Rgt (ft)		Froude # Chl	0.28	0.28
Weir Submerg		Specif Force (cu ft)	25449.29	27044.13
Weir Max Depth (ft)		Hydr Depth (ft)	7.25	7.46
Min El Weir Flow (ft)	423.69	W.P. Total (ft)	569.19	563.30
Min El Prs (ft)	419.86	Conv. Total (cfs)	268420.1	270638.8
Delta EG (ft)	0.43	Top Width (ft)	469.81	454.97
Delta WS (ft)	0.43	Frctn Loss (ft)	0.22	0.09
BR Open Area (sq ft)	493.48	C & E Loss (ft)	0.00	0.02
BR Open Vel (ft/s)	8.13	Shear Total (lb/sq ft)	2.75	2.73
Coef of Q		Power Total (lb/ft s)	-530.04	-529.77
Br Sel Method	Energy only			



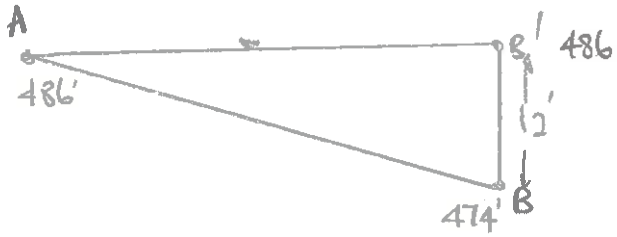
Question 3 Detention Pond Design

A detention pond is being designed in the Boggy Creek Greenbelt. Its outer boundary is shown below. Approximate the shape of the pond as a rectangle whose principal axis is along the line AB and assume that the land surface slopes in a straight line from A to B. 1 acre = 43,560 ft^2.



Average width = $24 \times 43{,}560 / 2000 = 522'$

Length AB = 2000 ft
Elevation at A = 486 ft
Elevation at B = 474 ft
Area = 24 acres



$BB' = 12' = 486 - 474$

$\therefore$ average depth of water = 6'

3 (a) Calculate the average depth of water in the pond (ft)

(b) Calculate the total volume of storage in the pond (acre-ft)

3 Storage volume = 24 acres × 6' = 144 acre-ft

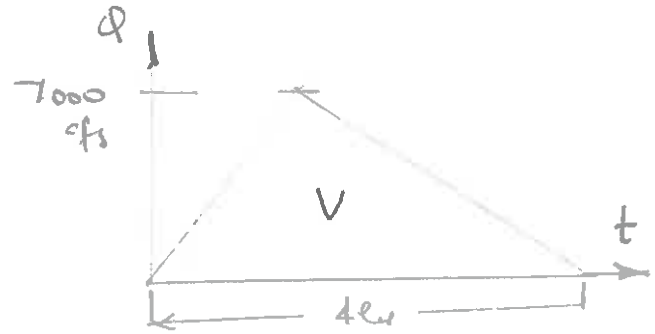
(c) The 100 year flood at this location has a peak discharge of 7000 cfs. If the flood hydrograph is triangular and has a base time of 4 hours, calculate the volume of water in the flood hydrograph (acre-ft). 1 acre = 43,560 ft^2.

6 $V = \frac{1}{2} \times 7000 \text{ cfs} \times 4 \text{ hr} \times \frac{3600 \text{ s}}{\text{hr}}$

$= 5.04 \times 10^8 \text{ ft}^3$

$= \frac{5.04 \times 10^8}{43560} \text{ ac-ft}$

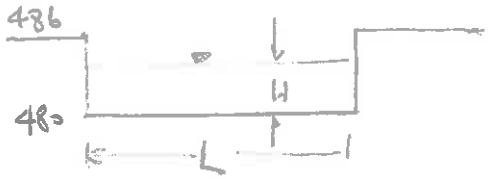
$V = 11571 \text{ ac-ft}$



(d) What percentage of the 100 year flood hydrograph volume can be stored in this pond?

3 $\therefore$ percentage $= \frac{144}{1157} \times \frac{100}{1} = 12.4\%$

(e) The 100 year discharge in this location in Boggy Creek is approximately 7000 cfs. Design a weir at location B whose crest elevation is 480 ft which will convey this flow without overtopping the berm at that location. A table of standard weir equations and coefficients is attached.



For rectangular weir

$Q = C L H^{3/2}$

assume $H = 6'$

$\therefore 7000 = 3.367 \times L \times 6^{3/2}$

$\therefore L = \frac{7000}{3.367 \times 6^{3/2}}$

$L = 141.5'$

Need a factor of safety

($H = 5'$ gives $L = 186'$)

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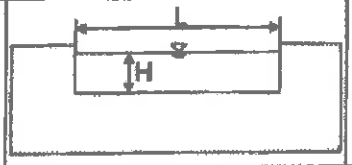
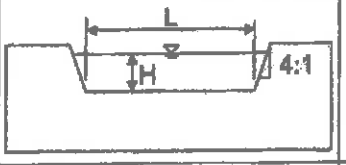
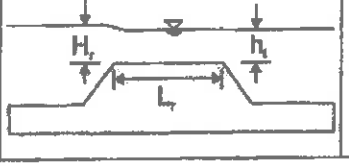
Suppose $L = 160'$

$\therefore 7000 = 3.367 \times 160 \times H^{3/2}$

$\therefore H = \left(\frac{7000}{3.367 \times 160}\right)^{2/3}$

$= 5.52'$

	Weir Type	Figure	Equation	Coefficients
Sharp Crested	Rectangular		Contracted $Q = C(L - 0.1iH) H^{3/2}$ Suppressed $Q = CLH^{3/2}$ i = Number of Iterations	Metric $C = 1.84$ English $C = 3.367$
	V-Notch		$Q = C\left(\frac{8}{15}\right)\sqrt{2g}\tan\theta\left(\frac{H}{2}\right)^{5/2}$	C varies between 0.611 and 0.570 depending on H and Q*
	Cipolletti		Metric $Q = CLH^{3/2}$ English $Q = CLH^{3/2}$	Metric $C = 1.86$ English $C = 3.367$
Non-Sharp-Crested	Broad (Side View)		$Q = C_d L H_t^{3/2}$	C_d is a function of H_t, h_t and L_t ranging between 1.25 and 3.1*

*Refer to FlowMaster help documentation for more information.

FIGURE 1-9: Standard Weirs

V-Notch Weir

$$Q = C\left(\frac{8}{15}\right)\sqrt{2g}\tan\left(\frac{\theta}{2}\right)H^{5/2} \qquad \text{assume } C = 0.6$$

If $\theta = 90°$

$$7000 = 0.6\left(\frac{8}{15}\right)\sqrt{2\times 32.2}\tan\left(\frac{90}{2}\right)H^{5/2}$$

$$= 0.6 \times 4.28 \tan 45° \, H^{5/2}$$

$$= 2.57 \times 1 \times H^{5/2}$$

$$\therefore H = \left(7000/2.57\right)^{2/5}$$

$$= 23.67 \text{ ft}$$

however $BB' = 12$ ft, so not enough height for this solution

From flowmaster, notch angle = 160° for headwater elevation = 12'

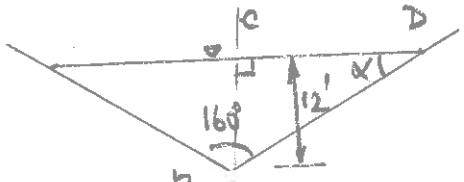
& crest elevation = 0

∴ if notch angle is 160° & headwater elevation = 12'

top width = $2 \times CD$

$= 136'$

Allow for a factor of safety to say 150' width



$$\tan\alpha = \frac{12}{CD}$$

$$\alpha = 180 - 90 - 80$$

$$= 10°$$

$$CD = \frac{12}{\tan 10°}$$

$$= \frac{12}{0.176327}$$

$$= 68.05$$

This is not a bad solution compared to rectangular weir at 6' crest elevation

for $H_W = 12'$, crest = 6', $C = 0.6$

Flowmaster gives $\theta = 176.3°$

Question 4 Design Methods

In this class, we have examined a number of methods for designing hydraulic engineering components. Suppose you are in professional practice, describe how you would go about doing the following tasks: +1

(a) Designing an open channel whose flow capacity whose flow capacity, roughness and slope are known and whose dimensions are to be determined

Q, n, S_o known – get channel shape & size

6 – use FlowMaster for constructed channels with regular geometry

– use HEC-RAS for channel in natural terrain

(b) Designing a culvert under a road whose flow capacity is known and whose dimensions are to be determined.

Q known – need size of conveyance elements so that road is not overtopped

6 – use Culvert Master for straightforward culvert design

– use HEC-RAS if it is more complex in stream system

(c) Designing a bridge over a stream whose flow capacity is known and whose elevation and length are to be determined.

– use HEC-RAS to design elevation of deck & size of

6 bridge piers so that water is just going over the top during design flood

(d) Designing the outlet structure for a detention pond that consists of both an outlet pipe for regular flows and a spillway for very high flows.

Use Flow master to get flow through weir or orifice independently

6 and then add them together to get relationship between elevation and discharge. Put these into HEC-HMS and use this to do routing through the pond.