CE 365K Hydraulic Engineering Design

Spring 2016

Designing a Detention Pond using FlowMaster, ArcGIS and HEC-HMS

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This example follows the pond using in Question 3 of the Second Exam for a pond located in the Boggy Creek Greenbelt with an outlet structure which is a rectangular weir.

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Outlet Structure

Assume a rectangular weir with width 160 ft, and crest elevation 6 ft. Compute discharge for headwater elevation of 11.50 ft (important to use discharge as the variable to be found so that you can get the rating curve later).

	Workshee	et : Recta	ngular Weir - 1		
alculations 🕜 Message	IS				
Solve For: Discharge	~	8			
Discharge:	6948.76	ft³/s	Headwater Height Above Crest:	5.50	ft
Headwater Elevation:	11.50	ft	Tailwater Height Above Crest:	-6.00	ft
Crest Elevation:	6.00	ft	Flow Area:	880.00	ft²
Tailwater Elevation:	0.00	ft	Velocity:	7.90	ft/s
Weir Coefficient:	3.367	US	Wetted Perimeter:	171.00	ft
Crest Length:	160.00	ft	Top Width:	160.00	ft
Number Of Contractions:	0 ~				

Compute a rating curve for the weir



Produce a report on the rating curve



Export the chart as Text (include "Point Index" to get value from both axes)

۵.	Rating Cur	ve Chart Options 🛛 🗖 🗙
Chart	Series Tools Ex	port Print
Picture	Native Data	
Serie For O	es: (all) mat: Text XML	Include: Point Index Point Labels Header
0	HTML Table	Tab
	Excer	
Ca	Save	
		Close

Here is the exported output file

	Α	В
1	Index	0
2	0	0
3	1	538.72
4	2	1523.73
5	3	2799.271
6	4	4309.76
7	5	6023.073
8	6	7917.535

Convert this to an Elevation-Discharge Curve, remembering that the crest elevation of the rectangular weir is at 480 ft above geodetic datum, and that the base elevation of the detention pond is 474 ft above geodetic datum

Elevation	Discharge
474	0
475	0
476	0
477	0
478	0
479	0
480	0
481	539
482	1524
483	2799
484	4310
485	6023
486	7918

Detention Pond

Open the Hydrology Spatial files for the watershed in ArcMap, recolor the themes appropriately and save the ArcMap document in the folder you want to use for the project data. Add a Topographic base map for spatial context.



Right click on the **Subbasin** feature class, select **Properties** and set the Label field as **Subname** with size **12**. Right click on the Subbasin feature class again and select Label Features so you can see which subbasins you are dealing with.

					La	iyer Pr	oper	ties					×
General	Source	Selection	Display	Symbology	Fields	Definitio	on Que	ry Lal	bels	Joins & Relate	s Time	HTML Popup	
Lab	el feature	es in this lay	/er										
Method	d:	Lab	el all the f	eatures the	same w	ay.				~			
All fe Text Lat	atures wil t String bel Field:	l be labeled	l using th Gub_Nam	e options spo ne	ecified.				~	Expres	ssion		
Tex	t Symbol												
		AaBb	YyZz		e	Arial	B <i>I</i>	Ū	 I 	2 V Symbol			
Oth	er Option Placen	s nent Prope	rties	S	cale Ra	inge		Pre-de	efinec	l Label Style Label Styles.	-		

Zoom in to the area where you want to define a detention pond.



In the ArcCatalog tab on the right hand side of the ArcMap display, right click on the folder where your data are stored and select a New Geodatabase and call this **DesignProject**. Right click on the file geodatabase and select New Feature Class and call it **Pond**.

	New Feature Class		×
Name:	Pond		
Alias:			
Type Type of fea	tures stored in this feature class:		
Polygon F	eatures	v	

Use Texas State Plane Central Zone as XY Coordinate System



And click ok to all the rest of the questions to finish creating the feature class. This is just a holder to contain the outline of your pond, which we'll now digitize.

Click on **Customize/Toolbars** and select the **Editor** Toolbar. Start Editing and select the Pond feature class



Click on the "Create Features" icon icon at the right hand end of the Editor toolbar and select the Polygon option.

K	~	Create Features
- ×		ि - Search>
2 🗉 🗛 😰		Pond
- Ser		Pond
od AVE COM		
/		
BOG150		Construction Tools
\sim		Polygon
Jon		Rectangle
		Circle
> AlleSt		Ellipse

In this case, I followed the boundaries of the greenbelt and of the subbasin.



Stop editing and save edits. Now you have a Pond feature. Recolor it so you can see through the outline.



Add the **DEM** file that you got from applying the GetData function in HMSPrePro or from the WatershedData set that I supplied earlier. This elevation dataset has elevations in meters and has cells that are 30m x 30m in size. We'll work in metric units to be consistent with these data and then convert them to feet later.



The next step requires that you have the Spatial Analyst extension of ArcGIS enabled. In ArcMap, use Customize/Extensions to open the Extensions window and then make sure that the box next to Spatial Analyst is checked on.

С	ustomize	Windows	Help
	Extension	s	
M	Select th	e extensions y	ou want to use.
N T N		3D Analyst ArcScan Geostatistical Network Anal Publisher Schematics Spatial Analys Tracking Ana	Analyst yst st lyst

In the Search Tab on the right hand side of ArcMap, search for "Extract by Mask", and enter the inputs as below, storing the result in your DesignProject geodatabase under the title **ElevationMeters.**

<i>₹</i>	Extract by Mask
Input raster	
DEM	
Input raster or feature mask data	
Pond	
Output raster	
C:\Users\maidment\Documents\CE365KSpr16\Tutorial\DesignProject.gdb\ElevationMe	eters

The extracted elevation data are shown below



This is an elevation model with cells that are 30m x 30m in size and elevations in meters. Lets convert the elevations into feet. Search for "Raster Calculator" under the Search Tab in ArcMap, create the expression "DEM" * 3.2808 and store the results as **ElevationFeet**, as shown below.

×		Ras	ster C	Calcul	ator
Map Algebra expression					
Layers and variables					
 ElevationMeters DEM 	7	8	9	1	==
	4	5	6	*	>
	1	2	3	-	<
	()	•	+	(
"ElevationMeters" * 3.2808					
▲Output raster					
C:\Users\maidment\Documents\CE365KSpr16\Tutorial\DesignProject.gdb\Ele	vationF	eet			

Now we have an elevation raster with values from Elevation 471 to 495 ft



Nawajish Noman of ESRI has programmed a special tool for the elevation-area-storage called "Storage Capacity" (Thanks Noman!) Get the Storage Capacity toolkit at http://www.caee.utexas.edu/prof/maidment/CE365KSpr16/Detention/StorageCapacity.zip and unzip it.

Open Arc Toolbox, right click in the clear area to the right hand side of the tool box, select "Add Toolbox" and navigate to where the Storage Capacity v 1.0 toolbox is located.

- 🐌 test_data
- 👗 test_outputs.gdb
- 🗾 README
- 🗊 Storage Capacity v1.0
- Storage Capacity v1.0.pyt
- Storage Capacity v1.0.StorageCapacity.pyt

Add this to Arc Toolbox (it will take a moment or two to show up).



Storage Capacity	
Input DEM	
ElevationFeet	🖻
Output Table	
$C: \label{eq:constraint} C: eq:constr$	2
Input boundary polygon (optional)	
Maximum elevation (optional)	
	486
Minimum elevation (optional)	
	474
Incremental (optional)	-
	1

Open the resulting Storage Capacity table and you'll see Area in m² and Volume in m²-ft as shown below indexed by 1 foot increments of elevation as we need.

Table

🗄 - | 碧 - | 🖫 👧 🛛 🐗 🗙

ElevationFeet_StorageCapacit

	OBJECTID *	Elevation	Area	Volume
•	1	475	9561.750795	20415.831224
	2	476	14342.626193	33072.161006
	3	477	19123.50159	48704.684002
	4	478	21992.026829	68555.378906
	5	479	24860.552067	92191.390569
	6	480	36334.653022	122348.891275
	7	481	43984.053658	163979.716287
	8	482	51633.454294	211777.781049
	9	483	59282.85493	266405.470689
	10	484	66932.255566	329996.844761
	11	485	71713.130964	399179.385111
	12	486	81274.881759	475667.323857

•	Γ	а	k	C	I
	°.		Ŧ		!

Right click on the **Table Options** button **Elev** and select **Export**. Choose export as .txt and store the StorageCapacity.txt file in your project workspace.

	Saving Data	Х
Look in:	🛛 Tutorial 🗸 🗸 🖉 🖉 🕹 🖉	
~\$RatingC ■ RatingCun ■ RatingCun	Curve.xlsx ve.txt ve.xlsx	
Name:	StorageCapacity.txt Save	
Save as type:	Text File Cancel	

Convert the units of square meters to square feet by multiplying by 10.7639 and convert cubic feet to acre-ft by dividing by 43560. This gives the elevation – storage curve for the pond. I have added a set of zero values at elevation 474 ft to indicate that this is the base elevation of the pond. We will use the elevation in ft and area in acres in our analysis.

					Area		
OBJECTID	Elevation	Area	Volume	Area (ft2)	(Ac)	Storage (ft3)	Storage (Ac-ft)
	474	0	0	0	0.00	0	0.00
1	475	9562	20416	102922	2.36	219754	5.04
2	476	14343	33072	154383	3.54	355985	8.17
3	477	19124	48705	205843	4.73	524252	12.04
4	478	21992	68555	236720	5.43	737923	16.94
5	479	24861	92191	267596	6.14	992339	22.78
6	480	36335	122349	391103	8.98	1316951	30.23
7	481	43984	163980	473440	10.87	1765061	40.52
8	482	51633	211778	555777	12.76	2279555	52.33
9	483	59283	266405	638115	14.65	2867562	65.83
10	484	66932	329997	720452	16.54	3552053	81.54
11	485	71713	399179	771913	17.72	4296727	98.64
12	486	81275	475667	874835	20.08	5120036	117.54

Flow Routing in HEC-HMS

Copy the "Hydrology Model" folder for the watershed to your project workspace and open the HEC-HMS project there. Zoom in to the project location at the downstream end of Subbasin Bog_220. You'll see

that there is a Junction there called JBOG230. We are going to replace this junction in the model with a Detention Pond.



Right click on the JB230 junction and select Cut Element. In HEC-HMS select the Create Reservoir Tool

nts Parameters (



And create a new reservoir at the same location.

Create A New Reservoir Elem				
Name : Detention Pond				
Descripti For CE 365K				
	Create Cancel			

To make sure we have this reservoir connected to its downstream element, select Downstream and put in RBOG230 as the reach which is next downstream of the reservoir.

Reservoir Options

Basin Name: BOG_Existing Element Name: Detention Pond				
Description:	For CE 365K	÷		
Downstream:	RBOG230 V	Ľ		
Method:	Outflow Curve 🗸			
Storage Method:	Elevation-Area-Discharge			
*Elev-Area Function:	None 🗸	\simeq		
*Elev-Dis Function:	None 🗸	\simeq		
Primary:	Elevation-Discharge 🗸			
Initial Condition:	Inflow = Outflow			

Similarly, for the BOG220 Subbasin, select Detention Pond as the Downstream Element.

🝰 Subbasin	Loss	Transform	Options		
Basin Name: BOG Existing					
Element I	Name	: BOG220	2		
Descr	ription	:			æ
Downs	tream	: Detention	Pond	×	-
*Area	a (MI2) 0.1173			
Latitude De	egrees	:			

And similarly for the upstream reach RBOG220, select Detention Pond as the Downstream Element.

⇔Reach Routing	Options		
Basin Name: BOG_Existing Element Name: DBOC220			
Description:		Æ	
Downstream:	Detention Pond 🗸 🗸		
Routing Method:	Modified Puls		

Now you have all the upstream elements flowing into the Detention Pond and the Pond discharging into the downstream reach as it should.

Now we have to specify the data describing the Detention Pond

Under **Components** in HEC-HMS, select **Paired Data Manager**, and within this, select **Elevation-Area** functions and create a new table called **Detention Pond**



You'll now have a new Paired Data table called Detention Pond. In the **Component Editor** for this table, make sure that the data source is set for Manual Entry units are set for ft and acres.

File Edit View Components Parameters Compute Results



Then you can copy and paste your data from Excel into the columns of this table

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Table 53 Table 54 Table 6 Table 7 Table 8 Table 9 Elevation-Storage Function Elevation-Area Function Lake Park Pond Elevation-Discharge Function Cross Sections	ons s ctions ons
Components Compute Results	9
Paired Data Table Graph	
Elevation (FT)	Area (AC)
474.0	0.00
475.0	2.36
476.0	3.54
477.0	4.73
478.0	5.43
479.0	6.14
480.0	8.98
481.0	10.87
482.0	12.76
483.0	14.65
484.0	16.54
485.0	17.72
486.0	20.08

File Edit View Components Parameters Compute Results 1

Lets do the same thing for the Elevation-Discharge function that we worked out in FlowMaster. Create an Elevation Discharge function using the Paired Data Manager

Paired Data Manage	er
Data Type: Elevation-Discharge Functions	
Detention Pond Discharge Lake Park Pond	

Set the units to be ft and cfs

Lake Park Pond Elevation-Discharge Functions Detention Pond Discharge Lake Park Pond					
Components	Compute Results				
<mark>≃</mark> Paired Dat	a Table Graph				
Name:	Name: Detention Pond Discharge				
Description: Elevation (ft), Discharge (cfs)					
Data Source: Manual Entry					
Data Source:	Manual Entry 🗸				
Data Source: Units:	Manual Entry FT : CFS				

Add the data by copying and pasting from Excel

Elevation-Discharge Functions				
Components Compute Results				
≥Paired Data Table Graph				
levation (FT)	Discharge (CFS)			
474	0			
475	0			
476	0			
477	0			
478	0			
479	0			
480	0			
481	539			
482	1524			
483	2799			
484	4310			
485	6023			
486	7918			

In your Detention Pond Element, make sure that the appropriate Paired Data Tables have been selected for the Elevation-Area and Elevation-Discharge functions

BOG220 Betention Pond Betention Pond Bog230 Bog230 Bog230a Bog240		
mponents Compute Results		
Reservoir Options		
Basin Name: BOG_Existing Element Name: Detention Pond		
Description:	For CE 365K	Æ
Downstream:	RBOG230	
Method:	Outflow Curve	
Storage Method:	Elevation-Area-Discharge	
lev-Area Function:	Detention Pond 🗸 🗸	\simeq
Elev-Dis Function:	Detention Pond Discharge	\simeq
Primary:	Elevation-Discharge	
Initial Condition:	Inflow = Outflow	

Now if you save the model and run HEC-HMS you can see the effect of the detention pond on various storm intensities. You can change the outlet structure design and see if this has an effect. When I first ran this modified model it did not work but I closed HEC-HMS and reopened it and ran the model and it worked fine.

