CE 3354 Engineering Hydrology

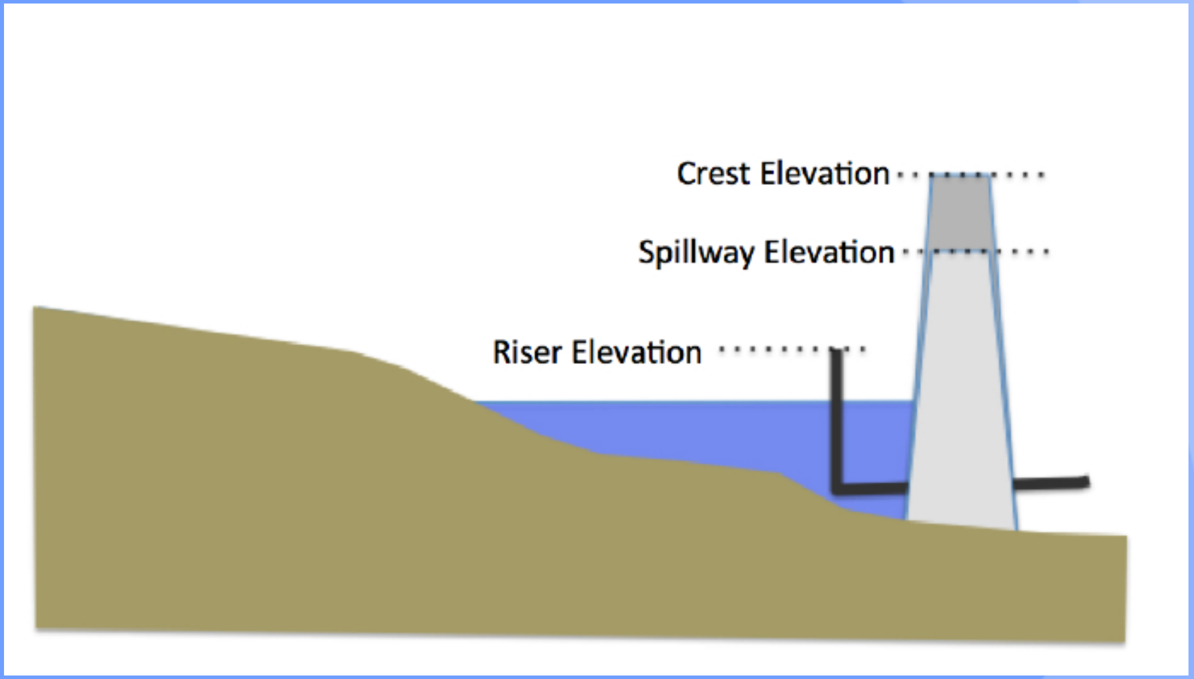
Lecture 20: Reservoir Storage and Discharge

Outline

- Elevation-Discharge Concepts
- Elevation-Discharge Tables

Elevation Discharge

- Elevation-Discharge
  - Determine pool area at different elevations
  - Use hydraulic outlet features to estimate discharge



Elevation Discharge

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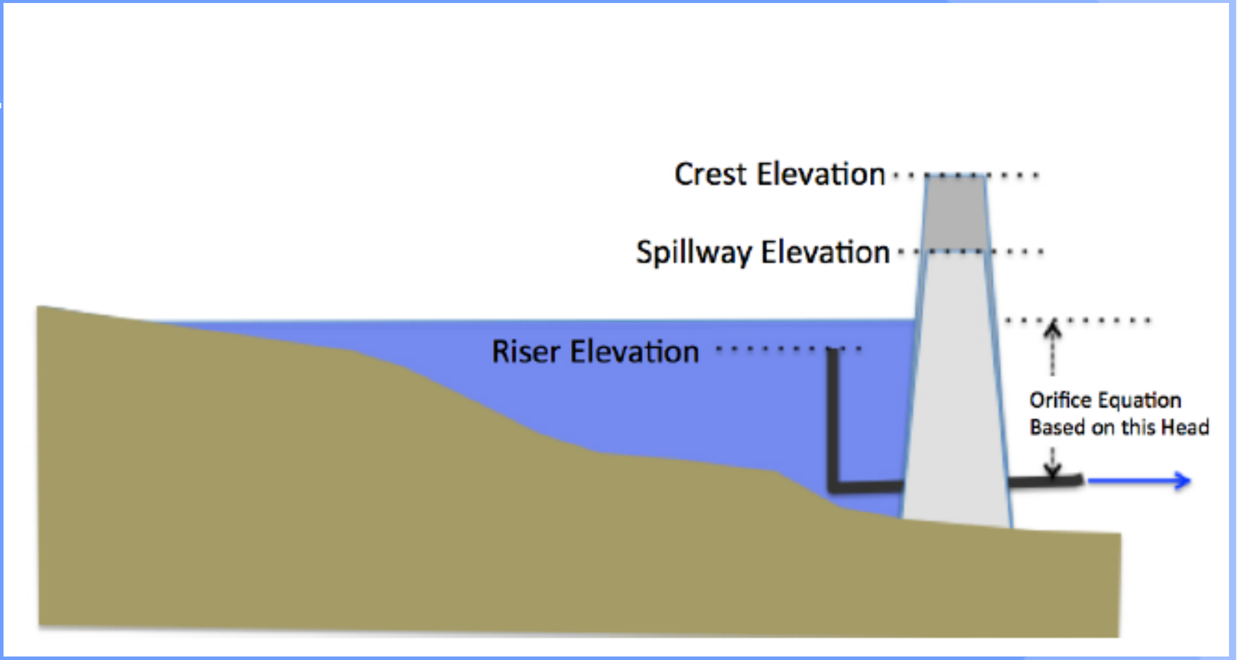

Elevation Discharge

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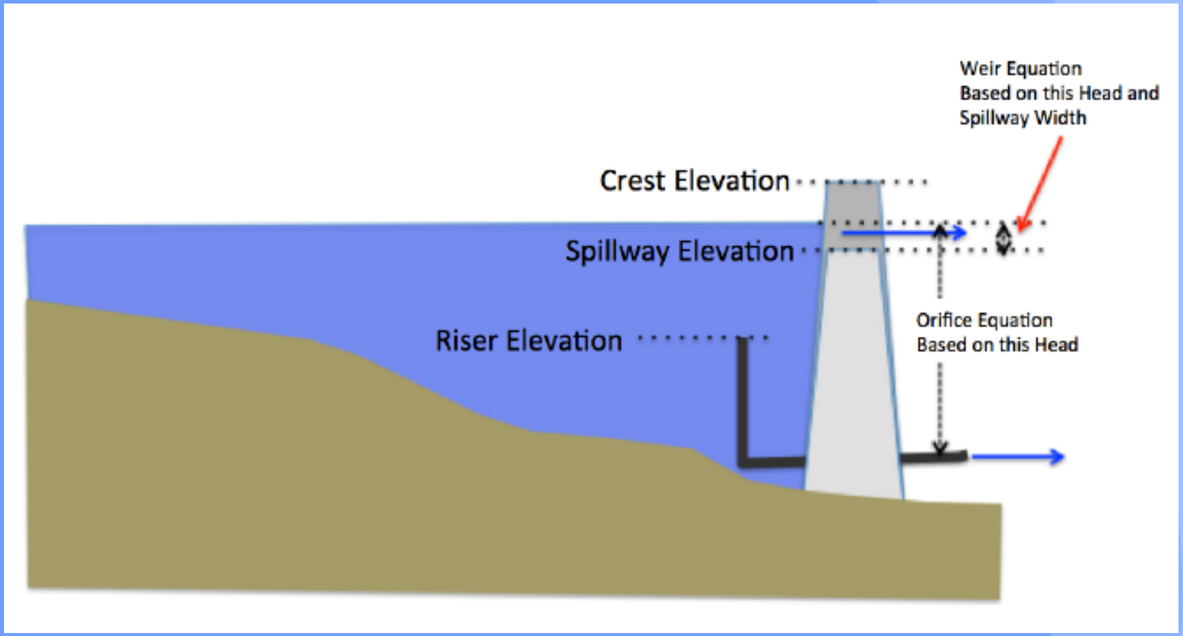

Elevation Discharge

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  - Determine pool area at different elevations
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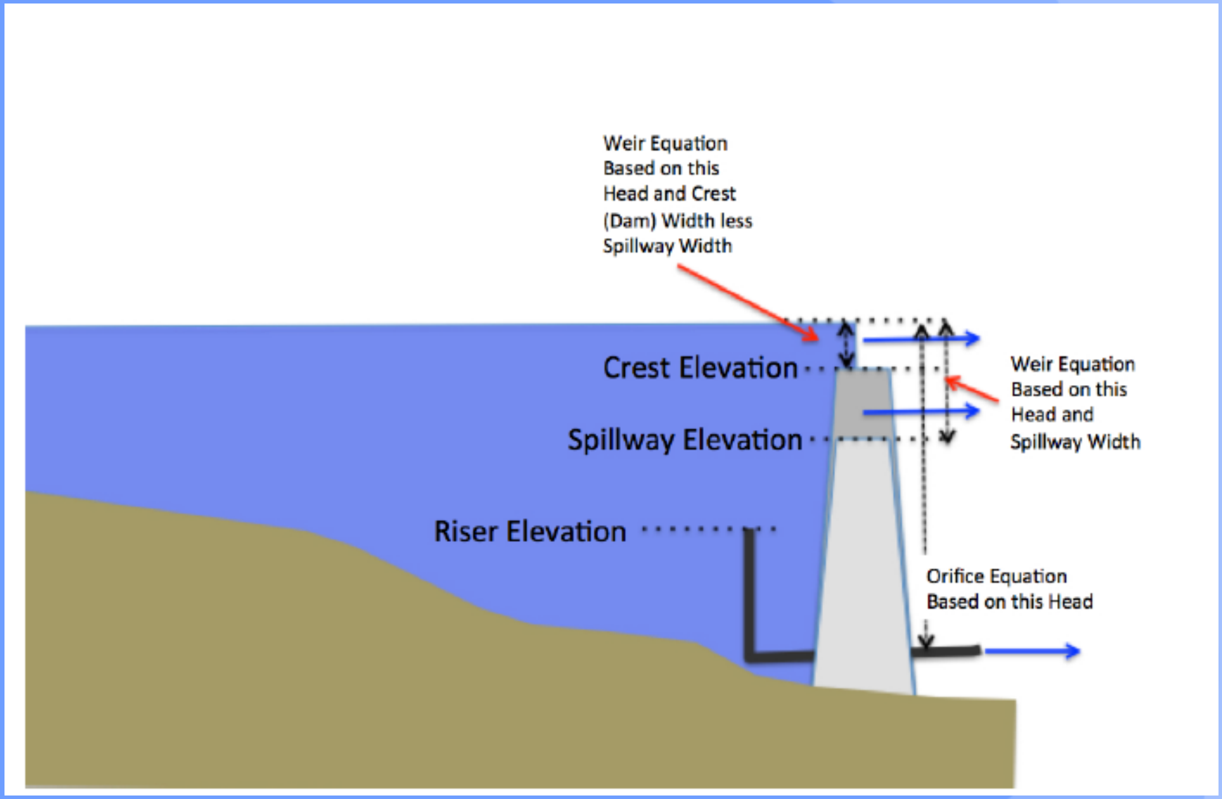
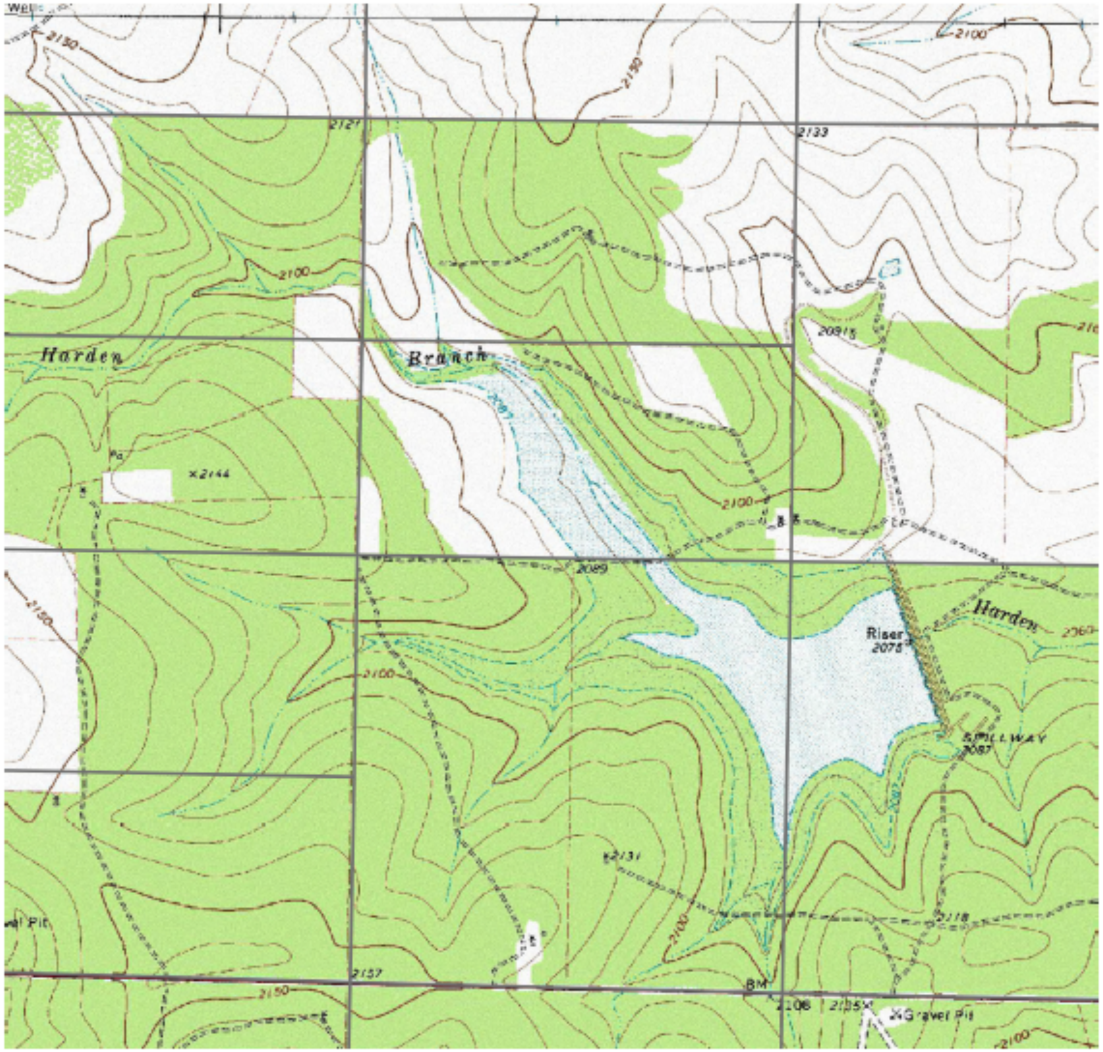


Elevation Determination

- Use map (or design drawings
- Reservoir:
  - Bottom = 2065 ft.
- Riser:
  - Invert= 2075 ft.
  - Soffit = 2077 ft.
- Spillway
  - Invert = 2087 ft.
  - Width = 100 ft.
- Dam Crest
  - Invert = 2090 ft.
  - Width = 2500 ft



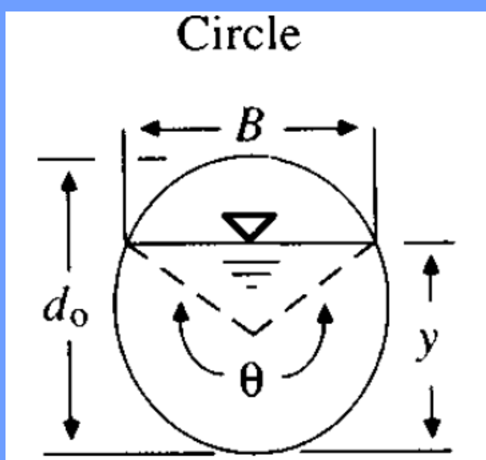
Riser (Culvert) Structure

- Riser:
  - Build an elevation-discharge table
    - From elevation 2065 to 2067 ft. use Manning's equation in a circular conduit (2 ft. diameter)
      - We are assuming the riser is a horizontal culvert
    - From 2067 to 2090 feet deep use orifice equation (neglecting frictional losses)
  - Save the table in a spreadsheet for building composite elevation-discharge table for all hydraulic elements

Riser (Culvert) Structure

- Modify Manning's Calculator

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$



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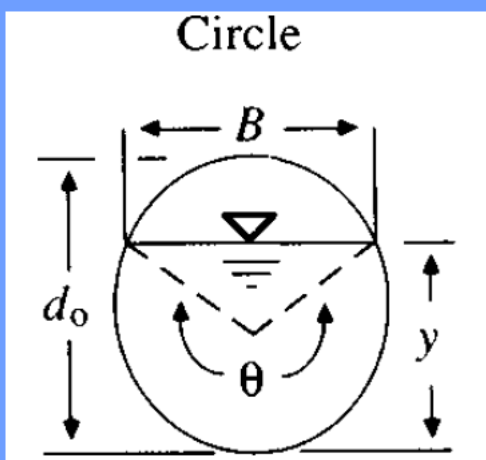
	A	B	C	D	E
1	Circular Pipe Flow Computations				
2	US Customary Units Version				
3	INPUT DATA				
4	Manning's n	0.013			
5	Invert Elev.	2065	<=Feet		
6	Soffit Elev.	2067	<=Feet		
7	Pool Elev.	2065.001	<=Feet		
8	Depth	0.001	<=Feet		
9	Diameter	2	<=Feet		
10	Slope	0.003	<=Dimensionless		
11	INTERMEDIATE COMPUTATIONS				
12	Angle	0.0447251	<=Radians		
13	Area	5.962E-05	<=Feet Squared		
14	Perimeter	0.0894502	<=Feet		
15	Radius	0.0006665	<=Feet		
16	DISCHARGE AND VELOCITY				
17	Discharge	2.856E-06	<=Cubic Feet per Second		
18	Velocity	0.0479007	<=Feet per Second		

Riser (Culvert) Structure

- Modify Manning's Calculator

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$



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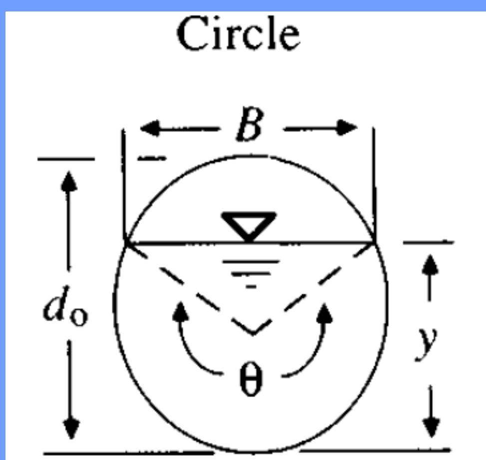
	A	B	C	D	E
1	Circular Pipe Flow Computations				
2	US Customary Units Version				
3	INPUT DATA				
4	Manning's n	0.013			
5	Invert Elev.	2065	<=Feet		
6	Soffit Elev.	2067	<=Feet		
7	Pool Elev.	2065.5	<=Feet		
8	Depth	0.5	<=Feet		
9	Diameter	2	<=Feet		
10	Slope	0.003	<=Dimensionless		
11	INTERMEDIATE COMPUTATIONS				
12	Angle	1.0471976	<=Radians		
13	Area	0.6141848	<=Feet Squared		
14	Perimeter	2.0943951	<=Feet		
15	Radius	0.2932517	<=Feet		
16	DISCHARGE AND VELOCITY				
17	Discharge	1.7018827	<=Cubic Feet per Second		
18	Velocity	2.7709618	<=Feet per Second		

Riser (Culvert) Structure

- Modify Manning's Calculator

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$



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B17 fx =(1.49/B4)*B13*B15^(2/3)*B10^(1/2)

	A	B	C	D	E
1	Circular Pipe Flow Computations				
2	US Customary Units Version				
3	INPUT DATA				
4	Manning's n	0.013			
5	Invert Elev.	2065	<=Feet		
6	Soffit Elev.	2067	<=Feet		
7	Pool Elev.	2067	<=Feet		
8	Depth	2	<=Feet		
9	Diameter	2	<=Feet		
10	Slope	0.003	<=Dimensionless		
11	INTERMEDIATE COMPUTATIONS				
12	Angle	3.1415927	<=Radians		
13	Area	3.1415927	<=Feet Squared		
14	Perimeter	6.2831853	<=Feet		
15	Radius	0.5	<=Feet		
16	DISCHARGE AND VELOCITY				
17	Discharge	12.424152	<=Cubic Feet per Second		
18	Velocity	3.9547304	<=Feet per Second		

Riser (Culvert) Structure

- Now Switch to Modified Orifice Equation Calculator

$$Q = C_d A\sqrt{2gh}$$

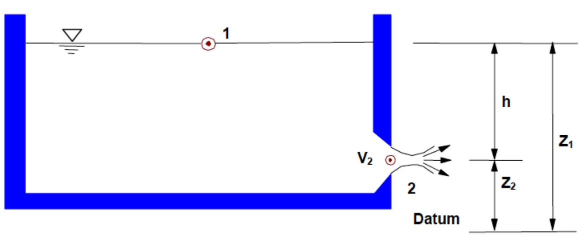

Figure 8.4. Schematic diagram of the flow through an orifice

This can be simplified by making the following assumptions: (1) the pressure at both points is atmospheric, therefore $p_1 = p_2$; (2) the surface area of the pool A_1 is very large relative to the

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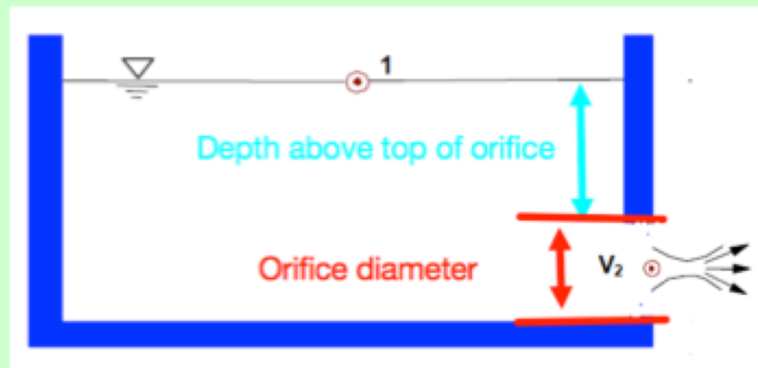
	A	B	C	D
1	Horizontal Orifice Discharge Calculator -- US Customary Units			
2				
3	---- INPUT VALUES -----			
4	Invert Elev.	2075	FT	
5	Soffit Elev.	2077	FT	
6	Pool Elev.	2078	FT	
7	Orifice Diameter	2	FT	
8	Depth above top of Orifice	0.5	FT	
9	Orifice Coefficient	0.5	Dimensionless	
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20	----- COMPUTED VALUES -----			
21	Depth to Orifice centerline	1.5	FT	
22	Orifice Circular Area	3.142	FT^2	
23	Discharge	15.44	CFS	
24				
25				
26				



Riser (Culvert) Structure

- Now Switch to Modified Orifice Equation Calculator

$$Q = C_d A \sqrt{2gh}$$

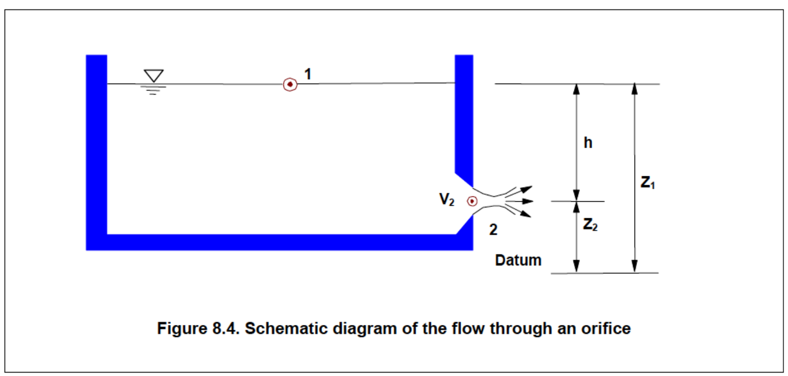


Figure 8.4. Schematic diagram of the flow through an orifice

This can be simplified by making the following assumptions: (1) the pressure at both points is atmospheric, therefore $p_1 = p_2$; (2) the surface area of the pool A_1 is very large relative to the

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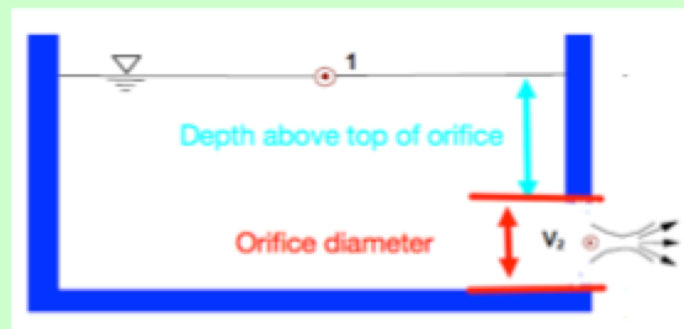
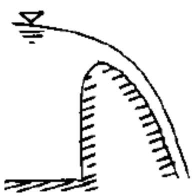
B7 fx =B5−B4

	A	B	C
1	Horizontal Orifice Discharge Calculator -- US Customary Units		
2			
3	---- INPUT VALUES -----		
4	Invert Elev.	2075.00	FT
5	Soffit Elev.	2077.00	FT
6	Pool Elev.	2086.00	FT
7	Orifice Diameter	2	FT
8	Depth above top of Orifice	9	FT
9	Orifice Coefficient	0.5	Dimensionless
10–19			
20	----- COMPUTED VALUES -----		
21	Depth to Orifice centerline	10	FT
22	Orifice Circular Area	3.1415927	FT^2
23	Discharge	39.862342	CFS
24			

Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.
  - Need to select a spillway equation:

TABLE 8.2.1
Spillway discharge equations

Spillway type	Equation	Notation
Uncontrolled over-flow ogee crest 	$Q = CLH^{3/2}$	Q = discharge, cfs C = variable coefficient of discharge L = effective length of crest H = total head on the crest including velocity of approach head.

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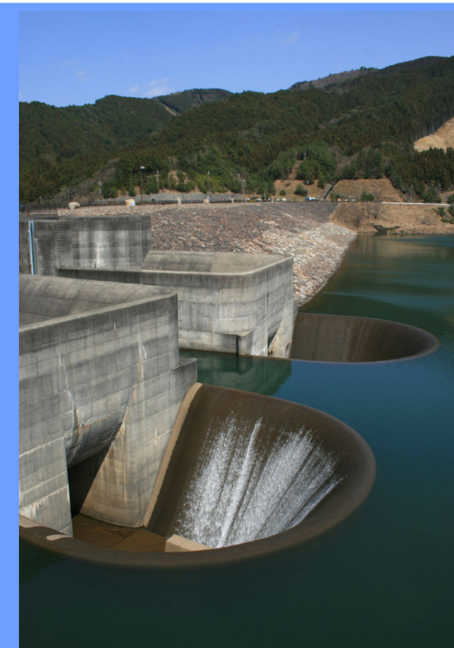
Spillway Types



Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.
  - Definitions of weir terms – namely approach depth

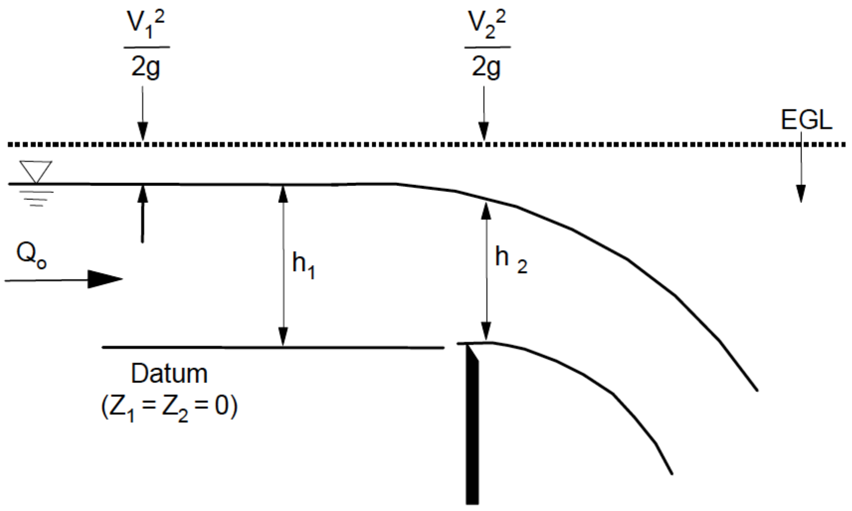


Figure 8.5. Schematic diagram of flow over a sharp-crested weir

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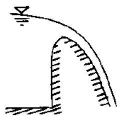
Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.
  - Need to select a spillway equation:

TABLE 8.2.1
Spillway discharge equations

Spillway type	Equation	Notation
Uncontrolled overflow ogee crest 	$Q = CLH^{3/2}$	Q = discharge, cfs C = variable coefficient of discharge L = effective length of crest H = total head on the crest including velocity of approach head.

$$Q = C\,LH^{3/2}$$

- Use H = Pool Elev. – Spillway Invert Elev. for the head on the spillway

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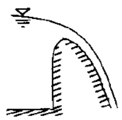
Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.
  - Need to select a spillway equation:

TABLE 8.2.1
Spillway discharge equations

Spillway type	Equation	Notation
Uncontrolled over-flow ogee crest 	$Q = CLH^{3/2}$	Q = discharge, cfs C = variable coefficient of discharge L = effective length of crest H = total head on the crest including velocity of approach head.

$$Q = C\ LH^{3/2}$$

  - Use H = Pool Elev. – Spillway Invert Elev. for the head on the spillway
  - Need a weir coefficient

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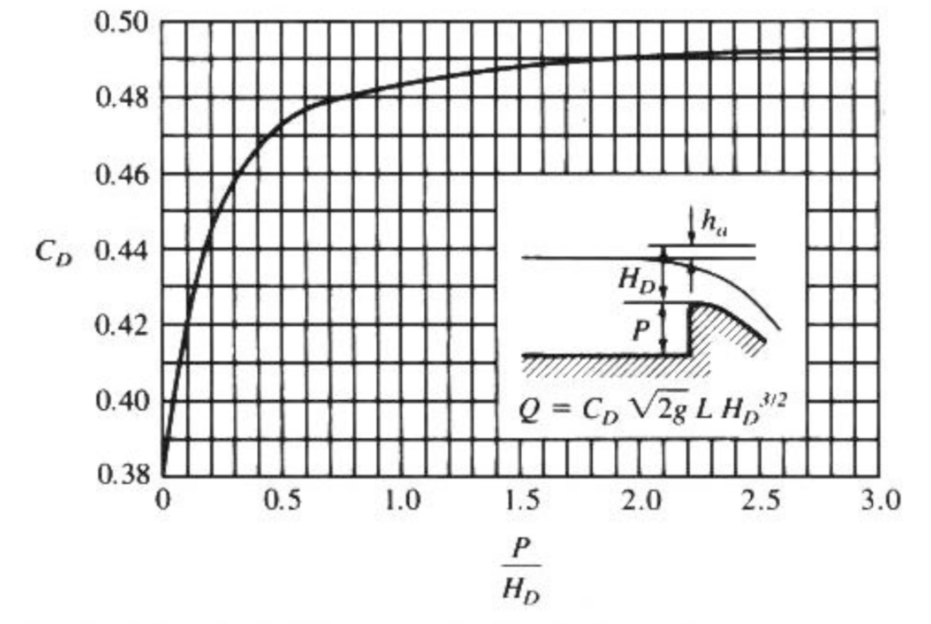
Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.



$$Q = 0.49 \cdot \sqrt{2 * 32.2} \cdot LH^{3/2}$$

$$\therefore C = 3.93$$

- Now build a calculator for the spillway

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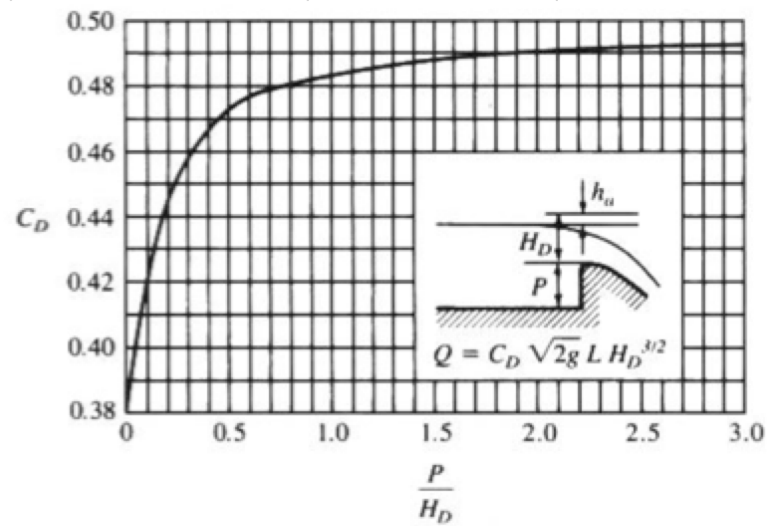
Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.

  - Spillway Calculator
  - Supply:
    - Bottom Elev.
    - Spillway Invert Elev.
    - Pool Elev.
    - Length
  - Computes:
    - P
    - P/H
    - C
    - Q

Ogee Spillway Calculator

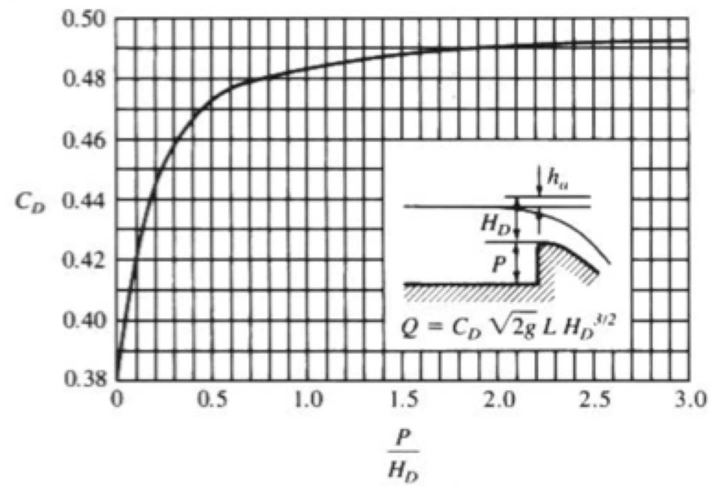


Bottom Elev	2065.00	<=FT
Spillway Invert	2078.00	<=FT
Pool Elevation	2079.00	<= FT
No Flow Depth (P)	13.00	<=FT
P/H	13.00	<=X-AXIS ON CHART
C_D	0.49	<=USE CHART
C	3.93	<=COMPUTED
Head	1.00	<= FT
Length	100.00	<=FT
Discharge	393.22	<=CFS

Spillway Structure

- Now Add Spillway starting at z = 2087+ ft.
  - Systematically apply in 0.5 foot intervals (like all the rest) to build the spillway portion of the table.
  - Use 2500 foot spillway width for the dam crest with a H = 0.5 feet

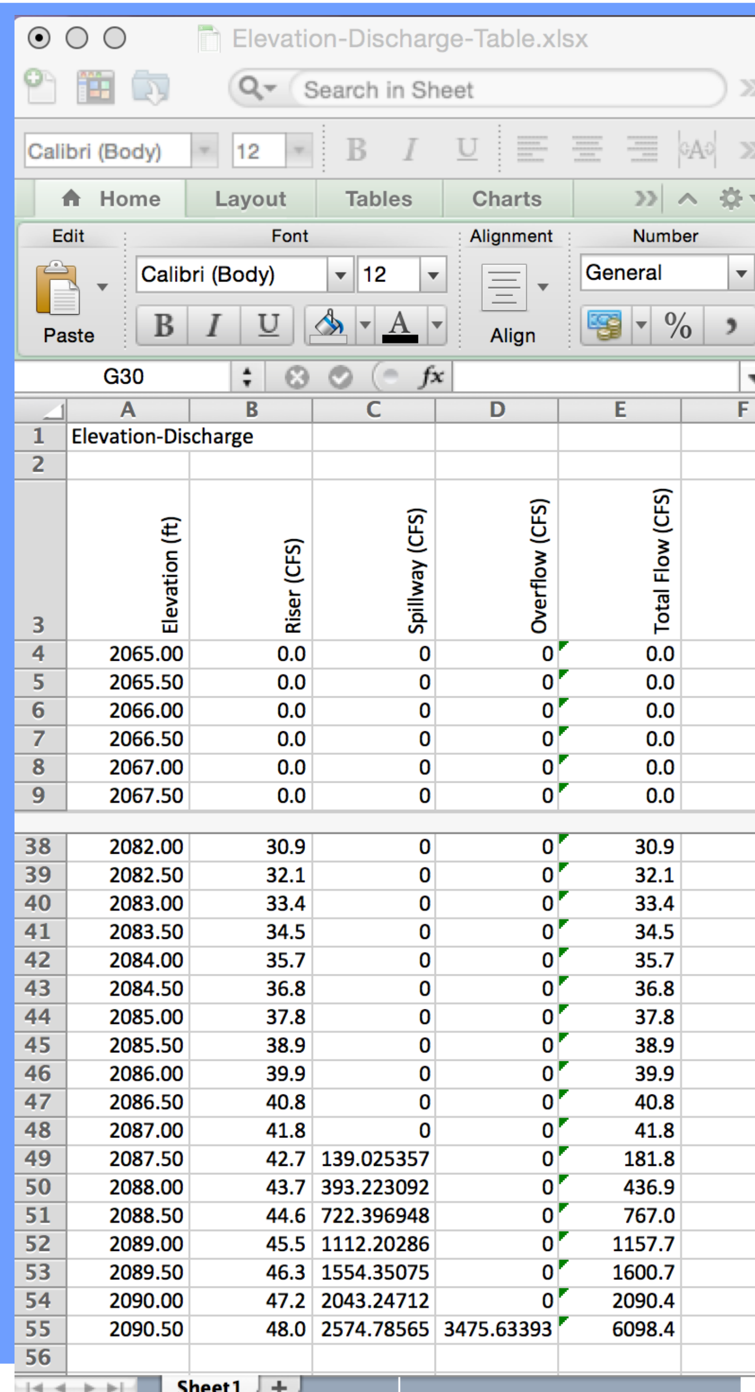
Ogee Spillway Calculator



Bottom Elev	2065.00	<=FT
Spillway Invert	2078.00	<=FT
Pool Elevation	2079.00	<= FT
No Flow Depth (P)	13.00	<=FT
P/H	13.00	<=X-AXIS ON CHART
C_D	0.49	<=USE CHART
C	3.93	<=COMPUTED
Head	1.00	<= FT
Length	100.00	<=FT
Discharge	393.22	<=CFS

Combined Structures

- Elevation-Discharge Table
  - Ready for HEC-HMS or for homebrew level pool routing
  - Use same method for the crossing
    - Multiple culverts (multiply Q by how many culverts
    - Road surface is the spillway



	A	B	C	D	E
1	Elevation-Discharge				
2					
3	Elevation (ft)	Riser (CFS)	Spillway (CFS)	Overflow (CFS)	Total Flow (CFS)
4	2065.00	0.0	0	0	0.0
5	2065.50	0.0	0	0	0.0
6	2066.00	0.0	0	0	0.0
7	2066.50	0.0	0	0	0.0
8	2067.00	0.0	0	0	0.0
9	2067.50	0.0	0	0	0.0
38	2082.00	30.9	0	0	30.9
39	2082.50	32.1	0	0	32.1
40	2083.00	33.4	0	0	33.4
41	2083.50	34.5	0	0	34.5
42	2084.00	35.7	0	0	35.7
43	2084.50	36.8	0	0	36.8
44	2085.00	37.8	0	0	37.8
45	2085.50	38.9	0	0	38.9
46	2086.00	39.9	0	0	39.9
47	2086.50	40.8	0	0	40.8
48	2087.00	41.8	0	0	41.8
49	2087.50	42.7	139.025357	0	181.8
50	2088.00	43.7	393.223092	0	436.9
51	2088.50	44.6	722.396948	0	767.0
52	2089.00	45.5	1112.20286	0	1157.7
53	2089.50	46.3	1554.35075	0	1600.7
54	2090.00	47.2	2043.24712	0	2090.4
55	2090.50	48.0	2574.78565	3475.63393	6098.4
56					

Next Time

- Elevation-Discharge Functions
- HEC-HMS Workshop (if needed)