# Detention Pond Channel Restriction Outlet: Multiple Modeling Approach Case Study

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## Agenda

- Overview
- Modeling Approach
- Outlet 1 – Rectangular Section
- Outlet 2 – Trapezoidal 6 ft Bottom Width Section
- Outlet 3 – Trapezoidal 2 ft Bottom Width Section
- Conclusion

## Overview

## Overview

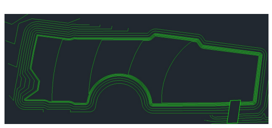
- Background
- Weir vs Channel
- Expectations
- Limitations
- Goals

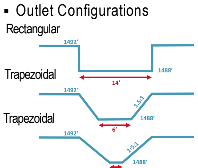
## Modeling Approach

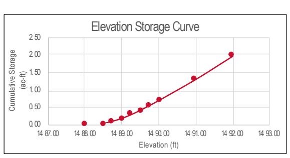
HDR

## Pond Configuration

- Earthen Detention Pond
  - 3:1 side slopes
  - Surface Area = 0.70 ac
- Stage-Storage Rating Curve developed
- Outlet Configurations





## Basic Equations

- Weir Equation: $Q_{Weir} = CLH^{\frac{3}{2}}$

| Measured Head, H[1] (ft) | Breadth Of The Crest Of Weir (ft) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.50 | 0.75 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 4.00 | 5.00 | 10.00 | 15.00 |
| 0.2 | 2.80 | 2.75 | 2.69 | 2.62 | 2.54 | 2.48 | 2.44 | 2.38 | 2.34 | 2.49 | 2.68 |
| 0.4 | 2.92 | 2.80 | 2.72 | 2.64 | 2.61 | 2.60 | 2.58 | 2.54 | 2.50 | 2.56 | 2.70 |
| 0.6 | 3.08 | 2.89 | 2.75 | 2.64 | 2.61 | 2.60 | 2.68 | 2.69 | 2.70 | 2.70 | 2.70 |
| 0.8 | 3.30 | 3.04 | 2.85 | 2.68 | 2.60 | 2.60 | 2.67 | 2.68 | 2.68 | 2.69 | 2.64 |
| 1.0 | 3.32 | 3.14 | 2.98 | 2.75 | 2.66 | 2.64 | 2.65 | 2.67 | 2.68 | 2.68 | 2.63 |
| 1.2 | 3.32 | 3.20 | 3.08 | 2.86 | 2.70 | 2.65 | 2.64 | 2.67 | 2.66 | 2.69 | 2.64 |
| 1.4 | 3.32 | 3.26 | 3.20 | 2.92 | 2.77 | 2.68 | 2.64 | 2.65 | 2.65 | 2.67 | 2.64 |
| 1.6 | 3.32 | 3.29 | 3.28 | 3.07 | 2.89 | 2.75 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 1.8 | 3.32 | 3.32 | 3.31 | 3.07 | 2.88 | 2.74 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 2.0 | 3.32 | 3.31 | 3.30 | 3.03 | 2.85 | 2.76 | 2.27 | 2.68 | 2.65 | 2.64 | 2.63 |
| 2.5 | 3.32 | 3.32 | 3.31 | 3.28 | 3.07 | 2.89 | 2.81 | 2.72 | 2.67 | 2.64 | 2.63 |
| 3.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.20 | 3.05 | 2.92 | 2.73 | 2.66 | 2.64 | 2.63 |
| 3.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.19 | 2.97 | 2.76 | 2.68 | 2.64 | 2.63 |
| 4.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.70 | 2.64 | 2.63 |
| 4.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.74 | 2.64 | 2.63 |
| 5.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.64 | 2.63 |
| 5.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.64 | 2.63 |

[1]Measured at least 2.5H upstream of the weir.

Reference: Brater and King (1976).

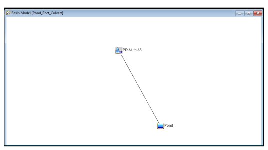
- Orifice Equation: $Q_{Orifice} = CA\sqrt{2gh}$

  Where C = 0.62

  *Also used for Culvert Inlet Control Condition*

- Manning's Equation: $Q_{Channel} = \left(\frac{1.49}{n}\right)AR^{\frac{3}{2}}\sqrt{S_o}$

## HEC-HMS

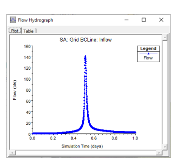


- Setup
- Hydrology Parameters
  - CN, SCS Transform
- Detention Pond
  - Elev-Area Storage Method
  - Inflow = outflow (no tailwater condition)
  - Outlet Structures
    - Outlets
    - Spillways
    - Dam Tops

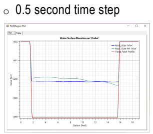
$$I_{avg} - O_{avg} = \frac{\Delta S}{\Delta t}$$

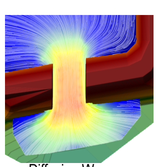
1D Modified Puls (Level-Pool Routing)

## HEC-RAS 2D

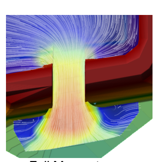



- Geometry
  - Grid - 5'x5' max
  - Landuse (Concrete Structure, DS Roadside Ditch)
- Boundary Conditions
  - 2 inflows applied on north and west sides (Internal BC)
  - DS BC set to normal depth
- Solution Method – Full Momentum
  - 0.5 second time step





Diffusion Wave

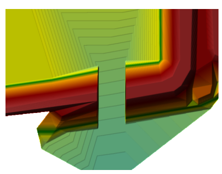


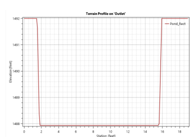
Full Momentum

## Outlet 1
### Rectangular Section

## Outlet Configuration

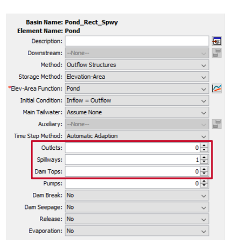
- Typical section
  - 14' wide rectangle section
  - Vertical Walls 4' high
    - Toe - 1488'
    - Top of Berm – 1492'
  - Concrete-Lined
- 0.5% slope through outlet structure





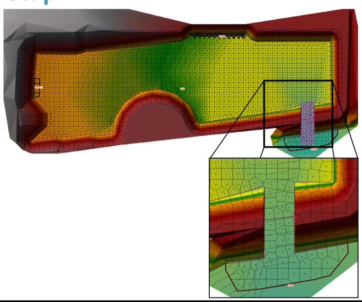

## HEC-HMS Model Setup

- Outflow Structure Approach
  - Spillway - Weir Approach
    - Weir Length = 14'
    - Crest set at flowline
    - $C_{weir}$ = 2.63
  - Outlet - Orifice Approach
    - Area for 14' x 4' opening
    - C = 0.62 (typical)
  - Outlet - Culvert Approach
    - 14' x 4' SBC, L = 31'
    - Typical entrance/exit losses
    - Slope = 0.5%



## HEC-RAS Model Setup

- Geometry
  - Breakline Refinements
- Solution Method
  - Full Momentum
  - Check Courant Condition



## Results

- Inflows:
  - $Q_2$ = 78.55 cfs
  - $Q_{25}$ = 167.38 cfs
  - $Q_{100}$ = 214.4 cfs

| Solution | $Q_2$ | $D_2$ | $Q_{25}$ | $D_{25}$ | $Q_{100}$ | $D_{100}$ |
|---|---|---|---|---|---|---|
| Weir Eq. | 72.1 | 1.57 | 155.3 | 2.61 | 200.0 | 3.09 |
| Manning's Eq. | 210.3 | 1.57 | 454.5 | 2.61 | 582.9 | 3.09 |
| HEC-HMS | | | | | | |
| -Weir | 72.1 | 1.57 | 155.3 | 2.61 | 200.0 | 3.09 |
| -Orifice | | | | | | |
| -Culvert | | | | | | |
| HEC-RAS | | | | | | |
| -Full Moment | | | | | | |
| -Diffusion Wave | | | | | | |

## Results

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| -Weir | 72.1 | 1.57 | 155.3 | 2.61 | 200.0 | 3.09 |
| -Orifice | 78.3 | 2.08 | 165.6 | 2.35 | 210.7 | 2.57 |
| -Culvert | 71.4 | 1.63 | 154.3 | 2.72 | 198.0 | 3.22 |
| HEC-RAS | | | | | | |
| -Full Moment | | | | | | |
| -Diffusion Wave | | | | | | |

## Results

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| -Culvert | 71.4 | 1.63 | 154.3 | 2.72 | 198.0 | 3.22 |
| HEC-RAS | | | | | | |
| -Full Momentum | 74.5 | 1.27 | 158.6 | 2.13 | 203.5 | 2.50 |
| -Diffusion Wave | | | | | | |

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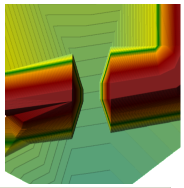
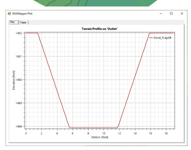
| -Culvert | 71.4 | 1.63 | 154.3 | 2.72 | 198.0 | 3.22 |
| HEC-RAS | | | | | | |
| -Full Momentum | 74.5 | 1.27 | 158.6 | 2.13 | 203.5 | 2.50 |
| -Diffusion Wave | - | - | - | - | 211.3 | 2.10 |

## Outlet 2
### Trapezoidal Section
### (6 ft Bottom Width)

## Outlet Configuration

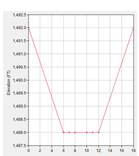
- Typical section
  - Trapezoidal Section
  - 6' bottom width
  - 3.5:1 horizontal transition
  - 1.5:1 side slopes
    - Toe - 1488'
    - Top of Berm – 1492'
  - Concrete-Lined
- 0.5% slope through outlet structure

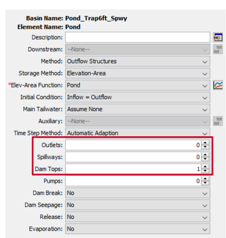




## HEC-HMS Model Setup

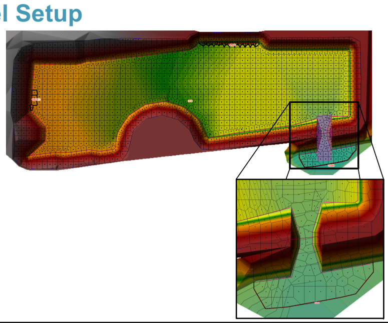
- Outflow Structure Approach
  - Dam Top- Weir Approach
    - Weir Top Width= 14'
    - Bottom Width = 6'
    - 1.5:1 Side Slopes
    - Crest set at flowline
    - $C_{weir}$ = 2.63
  - Outlet - Orifice Approach
    - Area for section opening
    - C = 0.62 (typical)






## HEC-RAS Model Setup

- Geometry
  - Breakline Refinements
- Solution Method
  - Full Momentum
  - Check Courant Condition



## Results

- Inflows:
  - $Q_2$ = 78.55 cfs
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| Solution | $Q_2$ | $D_2$ | $Q_{25}$ | $D_{25}$ | $Q_{100}$ | $D_{100}$ |
|---|---|---|---|---|---|---|
| Manning's Eq. | 199.3 | 2.12 | 472.1 | 3.32 | 624.8 | 3.82 |
| HEC-HMS | | | | | | |
| -Weir | 67.2 | 2.12 | 151.5 | 3.32 | 197.4 | 3.82 |
| -Orifice | | | | | | |
| HEC-RAS | | | | | | |
| -Full Momentum | | | | | | |
| -Diffusion Wave | | | | | | |

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| HEC-HMS | | | | | | |
| -Weir | 67.2 | 2.12 | 151.5 | 3.32 | 197.4 | 3.82 |
| -Orifice | 78.2 | 2.11 | 164.4 | 2.47 | 208.4 | 2.76 |
| HEC-RAS | | | | | | |
| -Full Momentum | | | | | | |
| -Diffusion Wave | | | | | | |

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| HEC-HMS | | | | | | |
| -Weir | 67.2 | 2.12 | 151.5 | 3.32 | 197.4 | 3.82 |
| -Orifice | 78.2 | 2.11 | 164.4 | 2.47 | 208.4 | 2.76 |
| HEC-RAS | | | | | | |
| -Full Momentum | 70.5 | 1.71 | 154.0 | 2.7 | 199.5 | 3.15 |
| -Diffusion Wave | | | | | | |

## Results

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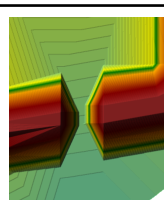
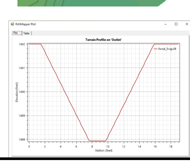
| -Orifice | 78.2 | 2.11 | 164.4 | 2.47 | 208.4 | 2.76 |
| HEC-RAS | | | | | | |
| -Full Momentum | 70.5 | 1.71 | 154.0 | 2.7 | 199.5 | 3.15 |
| -Diffusion Wave | - | - | - | - | 212.8 | 1.43 |

## Outlet 3
### Trapezoidal Section
### (2 ft Bottom Width)

## Outlet Configuration

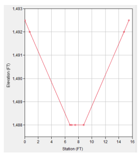
- Typical section
  - Trapezoidal Section
  - 2' bottom width
  - 2.33:1 horizontal transition
  - 1.5:1 side slopes
    - Toe - 1488'
    - Top of Berm – 1492'
  - Concrete-Lined
- 0.5% slope through outlet structure

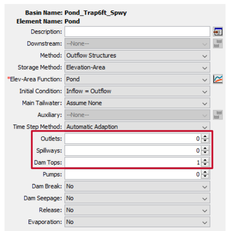




## HEC-HMS Model Setup

- Outflow Structure Approach
  - Dam Top- Weir Approach
    - Weir Top Width= 14'
    - Bottom Width = 2'
    - 1.5:1 Side Slopes
    - Crest set at flowline
    - $C_{weir}$ = 2.63
  - Outlet - Orifice Approach
    - Area for section opening
    - C = 0.62 (typical)






## HEC-RAS Model Setup

- Geometry
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- Solution Method
  - Full Momentum
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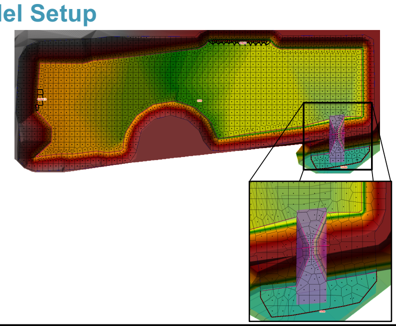

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| Solution | $Q_2$ | $D_2$ | $Q_{25}$ | $D_{25}$ | $Q_{100}$ | $D_{100}$ |
|---|---|---|---|---|---|---|
| Manning's Eq. | 178.5 | 2.80 | > 403.5 | 4.00 | > 403.5 | 4.00 |
| HEC-HMS | | | | | | |
| -Weir | 61.4 | 2.80 | * | * | * | * |
| -Orifice | | | | | | |
| HEC-RAS | | | | | | |
| -Full Momentum | | | | | | |
| -Diffusion Wave | | | | | | |

***Exceeded top of berm elevation.***

## Results

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| HEC-HMS | | | | | | |
| -Weir | 61.4 | 2.80 | * | * | * | * |
| -Orifice | 76.9 | 2.23 | 157.5 | 2.98 | 195.79 | 3.51 |
| HEC-RAS | | | | | | |
| -Full Momentum | | | | | | |
| -Diffusion Wave | | | | | | |

**Exceeded top of berm elevation.*

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| HEC-RAS | | | | | | |
| -Full Momentum | 65.5 | 2.30 | 151.8 | 3.30 | 197.5 | 3.70 |
| -Diffusion Wave | | | | | | |

**Exceeded top of berm elevation.*

## Results

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| HEC-RAS | | | | | | |
| -Full Momentum | 65.5 | 2.3 | 151.8 | 3.3 | 197.5 | 3.70 |
| -Diffusion Wave | - | - | - | - | 212.5 | 1.80 |

**Exceeded top of berm elevation.*

## Conclusion

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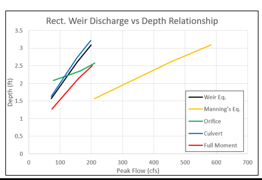
## Conclusion

- Goals
- Results showed similar trends between all three scenarios (weir types)
- Rectangular Weir Discharge vs Depth Relationship
  - Weir eq. (black) vs Culvert eq. (blue) → produce similar results
  - Weir eq. (black) vs Full Momentum (red) → FM shows constriction to be more efficient for a given depth.
    - $C_{weir}$ = 3.6 required to get similar Q vs D from FM results

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## Questions?