Section 5: Pond Outlets

Defining and calculating pond outlet devices
85 Minutes

Press Space, PageDown, or Click to advance.
Press PageUp to reverse. Esc to exit.
Right-Click for other options.

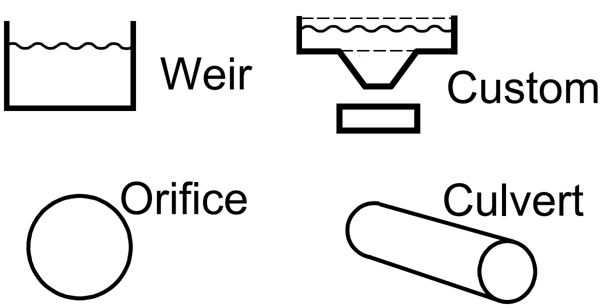
Outlets Introduction

What role do outlets play?

- Outlet devices define the stage-discharge relationship for any pond
- HydroCAD provides a range of outlet calculations...

Pond Outlet Calculations

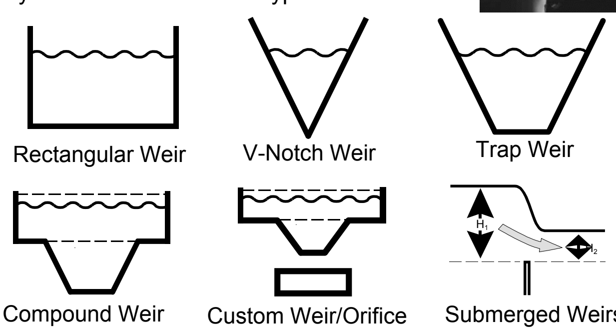
A wide range of built-in hydraulics solutions



Let's review each of these groups...

Weir Calculations

HydroCAD handles most types of weir flow

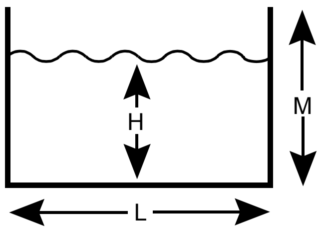


Let's review each of these options...

Sharp-Crested Rectangular Weir

For most rectangular weirs

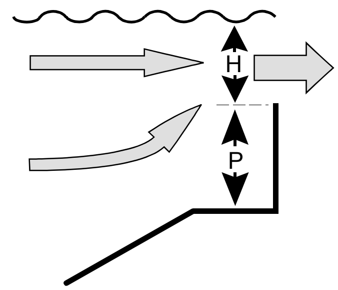
- By default, a weir has no height limit
  - M=Infinity
- HydroCAD 7.1 will implement a “Weir Rise” parameter M
- When H>M, orifice flow occurs
  - Earlier versions must avoid weir “overlap”



What is the Crest Height?

Fine-tuning the basic weir equation

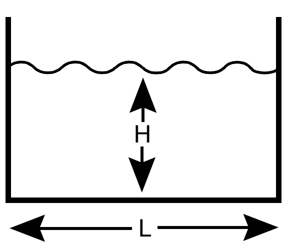
- Crest height P = height of crest above approach channel
- P is used to make slight adjustments to the C value to allow for approach velocity
  - Click Help for details
  - Or see manual



Broad-Crested Rectangular Weir

Adjusting for the “thickness” of the spillway

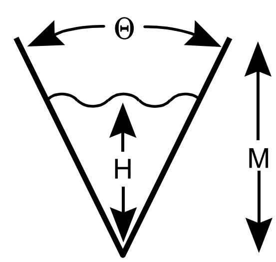
- Same equation as SCRW, but allows C to vary with head
- Automatic C-value lookup for square-edged weirs
  - Values may also be entered manually
  - Special profiles listed in Owner’s Manual Appendix D2



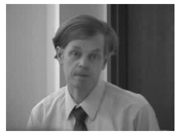
V-Notch Weir

Commonly used for low flows and flow measurements

- Theta is total included angle, not from vertical
- HydroCAD 7.1 will implement the “weir rise” parameter M
  - Uses orifice flow if H>M
  - Otherwise, M=Infinity

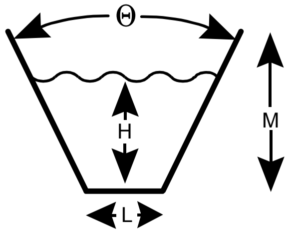


Trapezoidal Weir



A combination of Vee and Rectangular weir flow

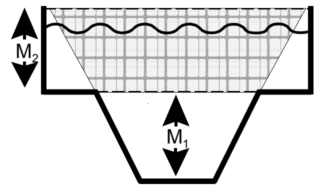
- Theta is total included angle, just like v-notch
- HydroCAD 7.1 will implement rise M
  - Otherwise weir has no height limit!



Compound Weirs

Using the Weir Rise to avoid overlap

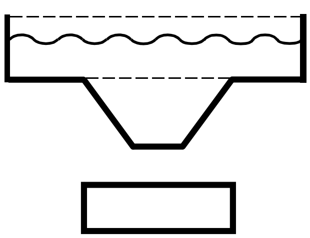
- By default, all outlets are independent, and are added together
- A compound weir (shown) will double-count the overlap area
- Setting the weir rise M_1 will switch to orifice flow and prevent overlap!



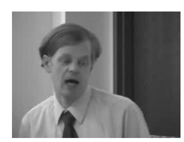
Custom Weir/Orifice

Used to model arbitrary weir and orifice shapes!

- Opening is defined by a stage-width table
  - Each segment is evaluated using trapezoidal weir or orifice flow
- A single device table may define multiple openings, as shown here:

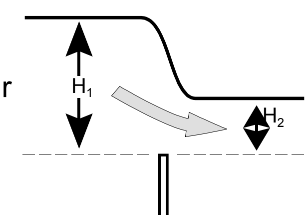


Submerged Weirs



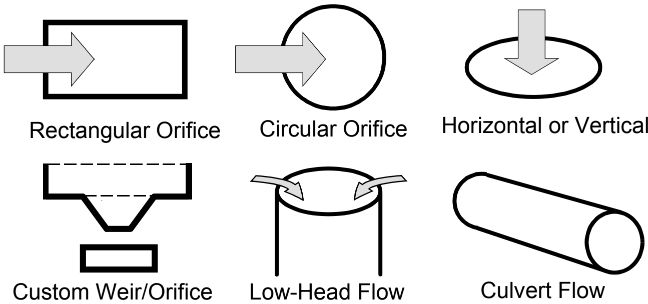
What happens when tailwater is present?

- Normal weir equations assume free discharge
- If tailwater exceeds weir crest, discharge is automatically reduced
  - See Owner's Manual for specific discharge equations



Orifice & Culvert Flow

Complete orifice & culvert calculations



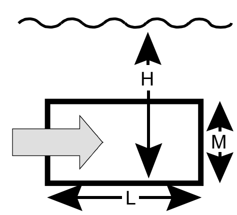
Let's review each of these options...

5-120

Rectangular Orifice - Vertical Plane

For openings in the sides of a vertical riser or dam wall

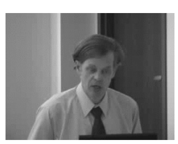
- Orifice flow when fully submerged H>M
- Weir flow when partially submerged H<M
- If tailwater is present
  - Weir flow occurs for area above TW
  - Constant-head orifice flow occurs for area below TW



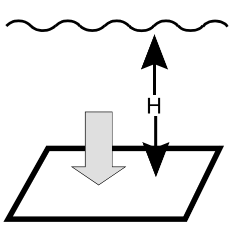
5-130

Rectangular Orifice - Horiz. Plane

For the top of a riser or openings in the bottom of a vessel



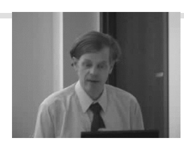
- Orifice flow is evaluated at all heads
- Head is reduced for any tailwater
- May also consider weir flow at low-heads
  - Details to follow



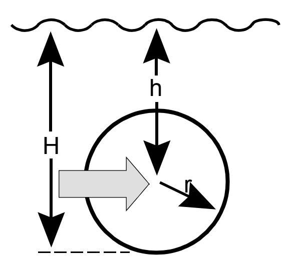
5-140

Circular Orifice - Vertical Plane

For openings in the sides of a vertical riser or dam wall



- Regular orifice flow occurs when h>r
- Head is adjusted when partially submerged or for tailwater

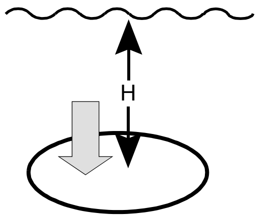


5-150

Circular Orifice - Horizontal Plane

For the top of a riser or openings in the bottom of a vessel

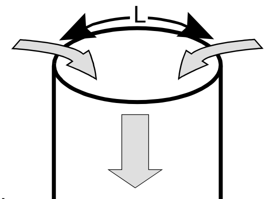
- Orifice flow is evaluated at all heads
- Head is reduced for any tailwater
- May also consider weir flow at low-heads
  - Details to follow



Orifices under Low-Head

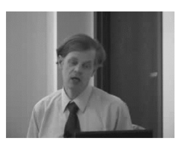
Automatically adjust for weir flow at low head

- Vertical orifice equations always reduce to weir flow when partially submerged
- Horizontal orifice (shown here) requires separate evaluation of weir flow
  - Done automatically when “Weir Flow” option is selected
  - Commonly used for an “orifice” at the top of a riser

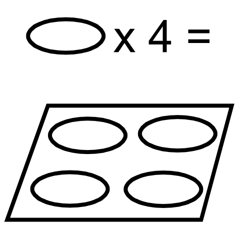


Modeling a Horizontal Grate

A typical use for the “discharge multiplier”

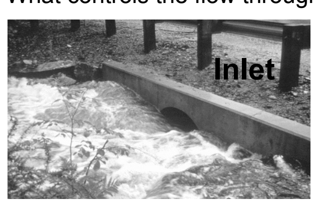


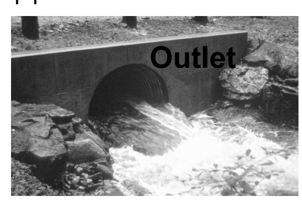
- To model several *identical* devices:
  - Describe one device
  - Set the discharge multiplier for the number of devices!
- Remember, all must be identical:
  - The openings in a *vertical* grate are at different elevations!



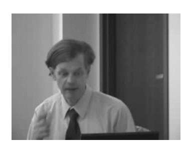
Modeling Pipe & Culvert Flow

What controls the flow through a pipe?



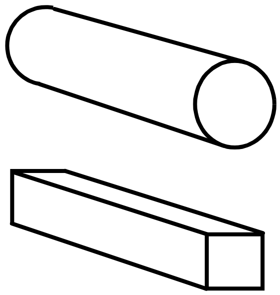


- Depending on the inlet geometry, Manning’s equation may not be the controlling factor.
- A square-edged inlet (show above) has an entrance energy loss Ke = 0.5 which often causes inlet control.



Culvert Outlet

Automatic evaluation of all flow controls

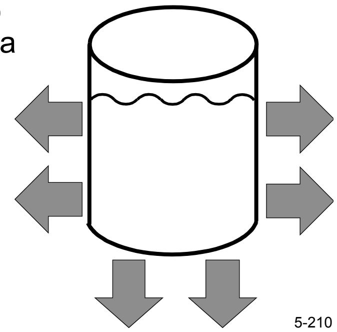


- Complete culvert evaluation for each headwater/tailwater combination
  - Details in Owner's Manual
- Automatic inlet/outlet control
  - More complete than a pipe reach, which considers only Manning's flow in barrel

5-200

Modeling Exfiltration

Allowing for water lost into the ground

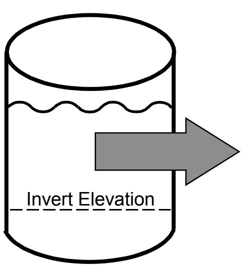


- Exfiltration (infiltration) is usually modeled as a pond outlet device
- The "pond" may be a drywell or other exfiltration area
- Exfiltration flows are "discarded" to prevent further routing

5-210

Constant-Flow Exfiltration

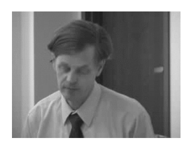
When you have a pre-determined flow



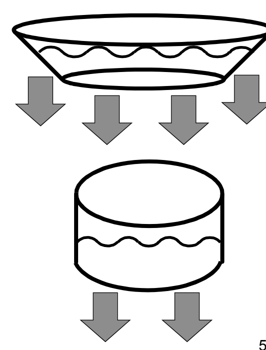
- Constant exfiltration flow (CFS) occurs at all elevations
  - Flow is entered directly
- Can set "invert" to prevent exfiltration through lower impervious area
  - No exfiltration occurs until water exceeds this level

5-220

Constant-Velocity Exfiltration #1



Exfiltration varies based on surface area



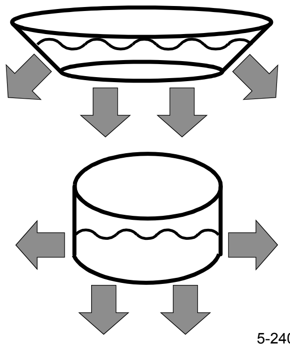
- Exfiltration velocity (FPM) applied to surface area
- Assumes all flow is vertical (downward)
  - If sides are vertical, flow occurs only through bottom
- Can use invert to stop bottom exfiltration
  - For impervious bottom

5-230

Constant-Velocity Exfiltration #2

Exfiltration varies based on wetted area

- Exfiltration velocity (FPM) applied to <u>wetted area</u>
- Flow occurs through all surfaces
  - Allows flow through vertical sides
- Use invert to prevent bottom exfiltration



Constant-Velocity Exfiltration #3

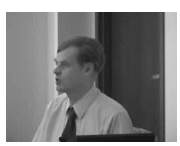
Why not enter the perc rate?

- HydroCAD exfiltration velocity is specified in feet-per-minute or inches-per-hour
- Can convert perc-rate to velocity
  - But, can a large pond sustain the same exfiltration rate as a small test pit?

$$V_{Feet/Minute} = \frac{1}{12\ Perc_{\ Minutes/Inch}}$$ (HydroCAD 6.0-7.0)

$$V_{Inches/Hour} = \frac{60}{Perc_{\ Minutes/Inch}}$$ (HydroCAD 7.1 and up)

Exfiltration Comments



Always use exfiltration with care!

- There are few standards for calculating exfiltration.
- Exfiltration capability is likely to degrade over time.
- Even the best exfiltration rates may not be a significant factor in peak-flow management.
  - Exfiltration must generally be used in conjunction with suitable detention storage.

Modeling Compound Outlets

Modeling these compound outlet devices is easy!

- HydroCAD can model most any combination of outlet devices.
- The key is in the “device routing”

Using the outlet "Device Routing"

- By default, each outlet device is routed directly to the **primary** discharge
- This causes all flows to be added together

Total Primary Outflow = $\sum$ Device #1: Weir ➜ Primary; Device #2: Culvert ➜ Primary; Device #3: Orifice ➜ Primary

- There is no interaction between devices!
- They are "Independent Parallel Outlets"

5-270

What about a Compound Outlet?

A compound outlet involves device interaction

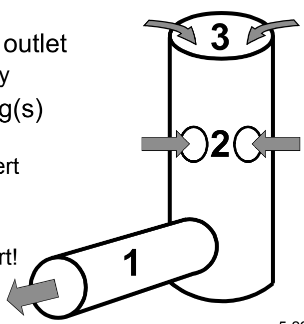
- Simple rules for creating compound outlets:
  - Always start with the final device
  - Work upwards into the pond
  - Route each device as required
  - Check the stage-discharge curve

5-280

Riser Example #1a

Modeling a riser outlet with side openings

- Follow these steps:
  - 1 Create the final culvert outlet
    - Leave the routing to Primary
  - 2 Create the side opening(s)
    - Set the routing to device #1
    - This routes flow to the culvert
  - 3 Create the top orifice
    - Set the routing to device #1
    - Flow also goes to the culvert!



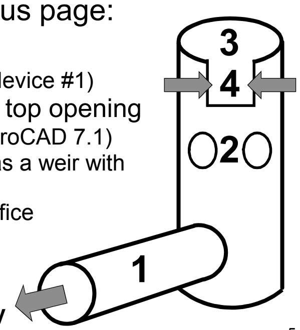
Primary

5-290

Riser Example #1b

Adding a weir notch to the top of the riser

- Continuing from previous page:
  - 4 Create a weir
    - Route flow to the culvert (device #1)
  - Beware of "overlap" with top opening
    - Set weir rise (requires HydroCAD 7.1)
    - Or model top opening #3 as a weir with reduced circumference
    - Or model weir #4 as an orifice



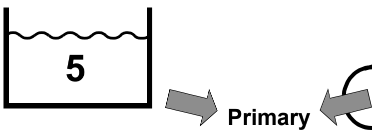
Primary

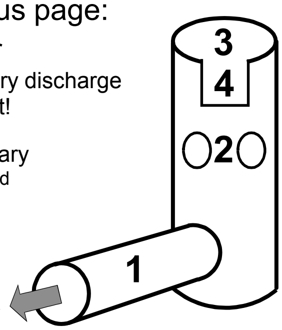
5-300

Riser Example #1c

What about an emergency spillway?

- Continuing from previous page:
  - 5 Create a separate weir
    - – Route the weir to the primary discharge
    - – Do NOT route to the culvert!
      - – (The flow doesn't go there)
    - – Could also route to secondary
      - – If the weir flow is being diverted



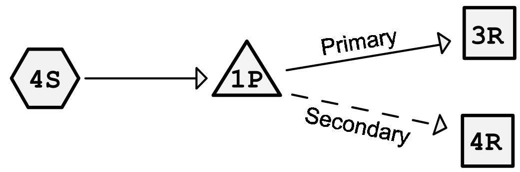


5-310

Automatic Flow Diversions

Routing outlfow in two different directions

- To divert an overflow weir:
  - Create a weir outlet
  - Set the weir routing to "secondary"
    - – A secondary outflow appears on the diagram!
  - Route the secondary outflow as required
    - – Just drag the outflow handle to the destination



5-320

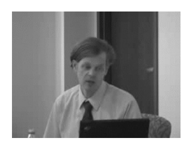
Outlet Calculations #1a

How is the discharge calculated?

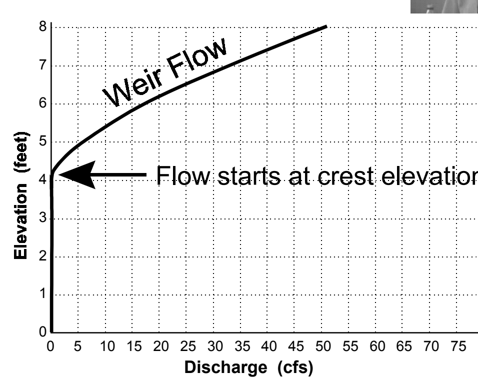
- First we'll examine some basic outlets
  - Weir flow
  - Orifice flow
- What happens when we combine them?
  - Weir + Orifice flow (independent devices)
  - Weir routed to Orifice (series devices)

5-330

Outlet Calculations #1b



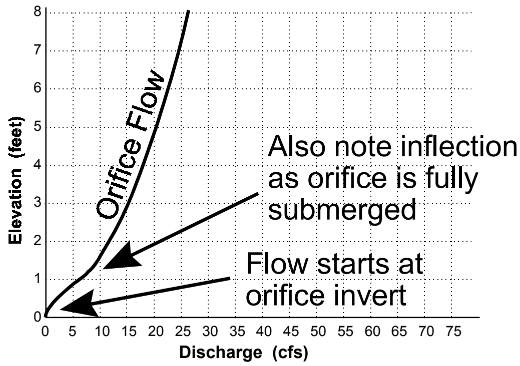
Typical stage-discharge curve for **weir flow**



5-340

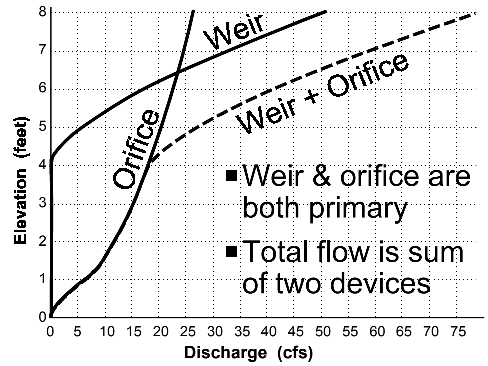
Outlet Calculations #1c

Typical discharge curve for **orifice flow**



Outlet Calculations #1d

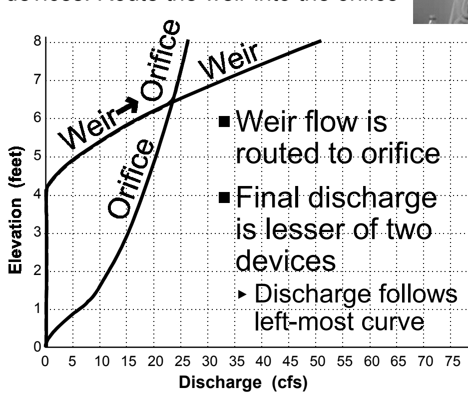
Now combine (add) the weir and orifice flows



- Weir & orifice are both primary
- Total flow is sum of two devices

Outlet Calculations #1e

Series devices: Route the weir into the orifice

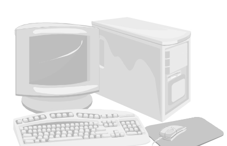


- Weir flow is routed to orifice
- Final discharge is lesser of two devices
  - Discharge follows left-most curve

Software Exercises

Exploring pond outlets in HydroCAD

- Before we begin the software demonstration, are there any other questions about **pond outlet calculations**?
- If you wish, you may perform the following exercises yourself, or just watch the demo.



Getting Started

Prepare a pond to receive
the outlet definitions

- Get ready:
  - Start HydroCAD
  - Open the project “Seminar1”
    - Or create a new project if it doesn’t exist
- Prepare a pond to receive the outlet data:
  - Drag a pond from the palette
  - Edit the pond
  - Set the “Catch Basin” option
  - Select the “Outlets” tab

5-390

Culvert Outlet #1

Let’s create a basic culvert outlet

- Define the culvert outlet:
  - On the outlet table, double-click the first blank line
  - Select “Culvert” and click OK
  - Set the culvert parameters:
    - Invert=100', length=20', S=0.01
    - n=0.013, diameter=24"
    - Select CMP, square edge headwall (Ke=0.5)
    - Leave Routing at “Primary”
    - Click OK to save the culvert data
- Continue to next page...

5-400

Culvert Outlet #2

Examining the outlet calculations

- To extend the discharge graph:
  - Select the Advanced tab
  - Set Flood Elevation = 108'
- Click “OK” to save pond data
- Open the pond report:
  - Double-click the pond
  - Explore the Summary report
  - Explore the Discharge plot
- (Leave the report open...)

5-410

Riser Example

Let’s add a riser to the culvert barrel

- Modify the same pond:
  - Click the “Edit” button on the report window
  - Select the Outlets tab
  - Create a circular orifice for the top of the riser:
    - Create an orifice (double-click the next blank line)
    - Set Invert=105', Diameter=48", Horizontal
    - Set Routing = Device 1 (Route to the culvert!)
  - Click OK (twice) to save the description
- Report is automatically updated!
  - Examine the Stage-Discharge plot
    - Note orifice flow starts at 105'
    - Culvert flow resumes at 106'

5-420

Low-Flow Orifice

Add a multiple orifice in the side of the riser

- Modify the same pond:
  - Click “Edit” button on the report window
  - Select the Outlets tab
    - Double-click a blank line
    - Define a 3" vertical orifice with Invert=102'
    - For a multiple opening, set Discharge Multiplier=4
    - Set Routing = Device 1 (the culvert)
  - Click OK (twice) to save the description
- Report is automatically updated!
  - Examine the Stage-Discharge plot
    - Note side orifice flow at 102'

5-430

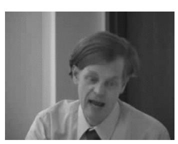
Emergency Spillway

Create a weir to be routed separately

- Modify the existing pond:
  - Click Edit button on the report window
  - Select the Outlets tab
  - Create a Broad-Crested Rectangular Weir
    - Invert=107', Length=10', Breadth=2'
    - Set Routing = Secondary
  - Click “OK” twice to save the pond

5-440

Spillway Results



Let’s examine the reports

- When we clicked “OK”, reports are automatically updated
- Examine the Stage-Discharge plot
    - Note secondary discharge curve (red)
    - Total discharge also shown (grey)
    - Right-click to select curves

5-445

Setting a Fixed Tailwater

HydroCAD provides several options for tailwater handling

- Modify the existing pond:
  - Click Edit button on the report window
  - Select the Tailwater tab
  - Select “Fixed Elevation” for the Primary Tailwater
  - Enter an elevation of 103'
  - Click OK to save the description
- Report is automatically updated
  - Examine the Stage-Discharge plot
    - Note no discharge below 103'

5-450

Vee/Trapezoidal Weir

Lets explore the other outlet devices

- Vee/trapezoidal weir
  - Invert Elevation - used for all devices
  - Notch Angle (total included angle)
  - Weir Coefficient (set automatically)
  - Crest Length (zero for V-notch)
  - Weir Rise (added in HydroCAD 7.1)
- Remember to use HELP button

Rectangular Weir

Lets explore the other outlet devices

- Sharp-crested rectangular weir
  - Invert Elevation
  - Crest Length
  - End Contractions (0-2)
  - Crest Height (above approach channel)
  - Weir Rise (added in HydroCAD 7.1)
- Can also use broad-crested weir
  - But SC is usually sufficient

Special Outlet

Lets explore the other outlet devices

- Special outlet
  - Accepts user-defined rating table
  - Discharge vs Elevation -or- Discharge vs Head
  - Can extrapolate when table is exceeded
- Reminder:
  - Right-click any table for special options

Exfiltration Outlet

Lets explore the other outlet devices

- Exfiltration
  - Can set exfiltration **Flow** -or- **Velocity**
  - Velocity can be applied to:
    - Surface Area (flow horizontal surfaces only)
    - Wetted Area (flow through all areas, vert & horiz)
    - Horizontal Area
  - Invert can be used to exclude impervious areas
  - Can use Special outlet for custom curves

*** End of Section ***

- Are there any other questions about **pond outlet devices**?
- For detailed outlet equations, please see the HydroCAD Owner’s manual.
- If you performed these exercises, you may close HydroCAD at this time.
  - SAVE YOUR CHANGES when asked