Culvert Design

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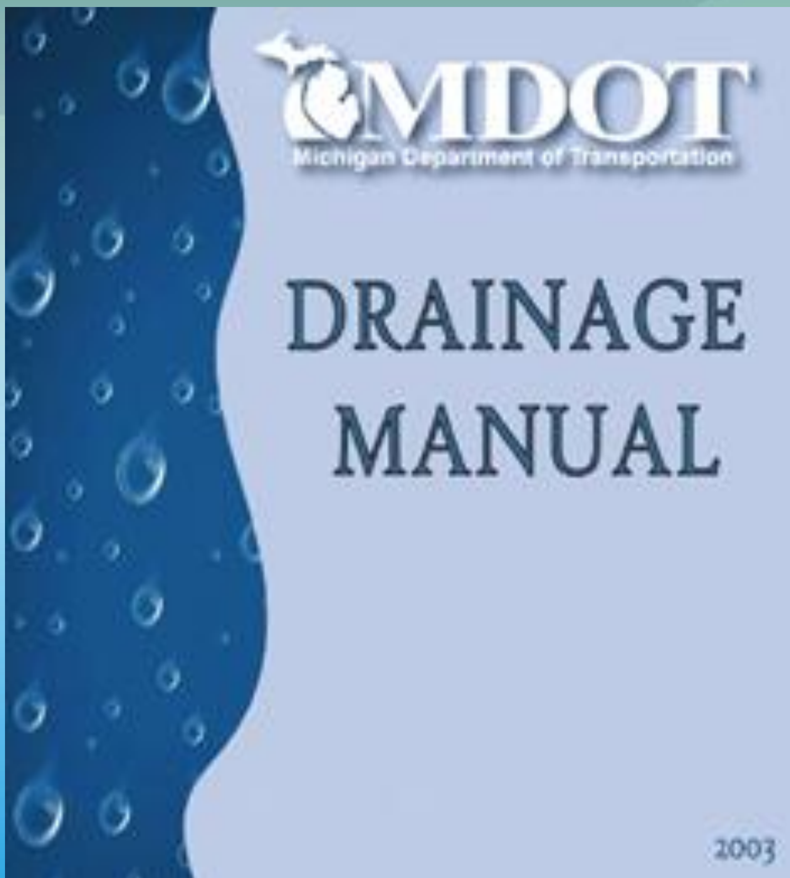
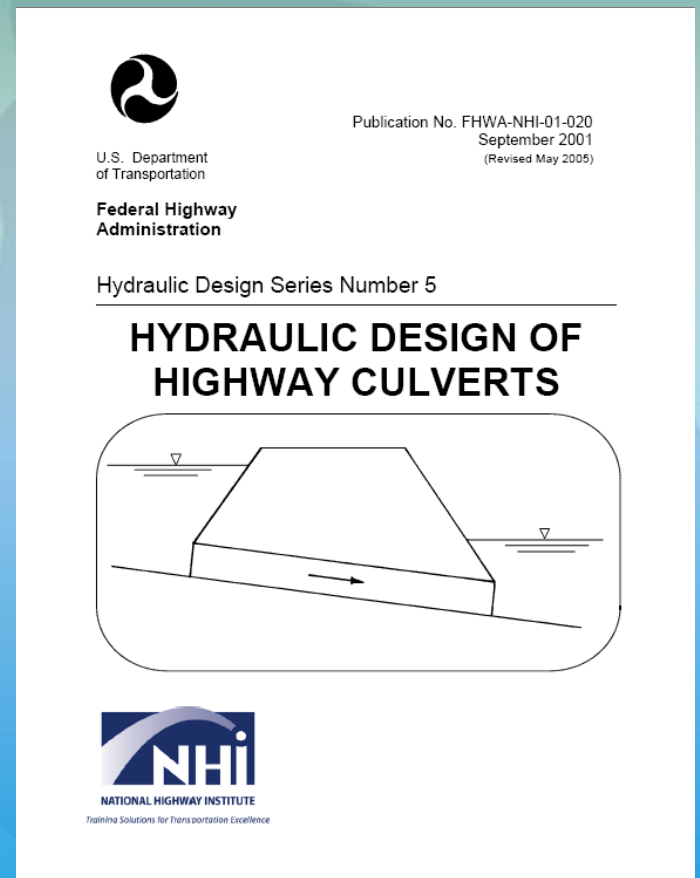
References


MDOT
Michigan Department of Transportation
DRAINAGE MANUAL
2003


U.S. Department of Transportation
Federal Highway Administration
Publication No. FHWA-NHI-01-020
September 2001
(Revised May 2005)
Hydraulic Design Series Number 5
HYDRAULIC DESIGN OF HIGHWAY CULVERTS
NHI
NATIONAL HIGHWAY INSTITUTE
Training Solutions for Transportation Excellence

Objectives

- Design Requirements
- Culvert Definitions
- Discuss required input data
- Site Visit
- Culvert Hydraulics (TW, HW, velocity)
- Example
- Class Exercise
- HY-8 for class exercise
- Questions

Topics Not Covered

- Fluid Mechanics
- Theory behind equations
- Weir flow with culverts

<u>For in depth coverage:</u>

<u>NHI's Culvert Design Workshop</u>

Design Requirements

HYDROLOGY

- MDOT culverts are sized for a 50 year (2% chance) event.

- Check for harmful interference in a 100 year (1% chance) event.

Design Requirements

DESIGN HEADWATER

Target standard used to achieve

Maximum Hydraulic Efficiency

- 0.9D (circular and elliptical culverts)
- Nearly full (box culverts)

Design Requirements

DESIGN HEADWATER

Maximum allowable per

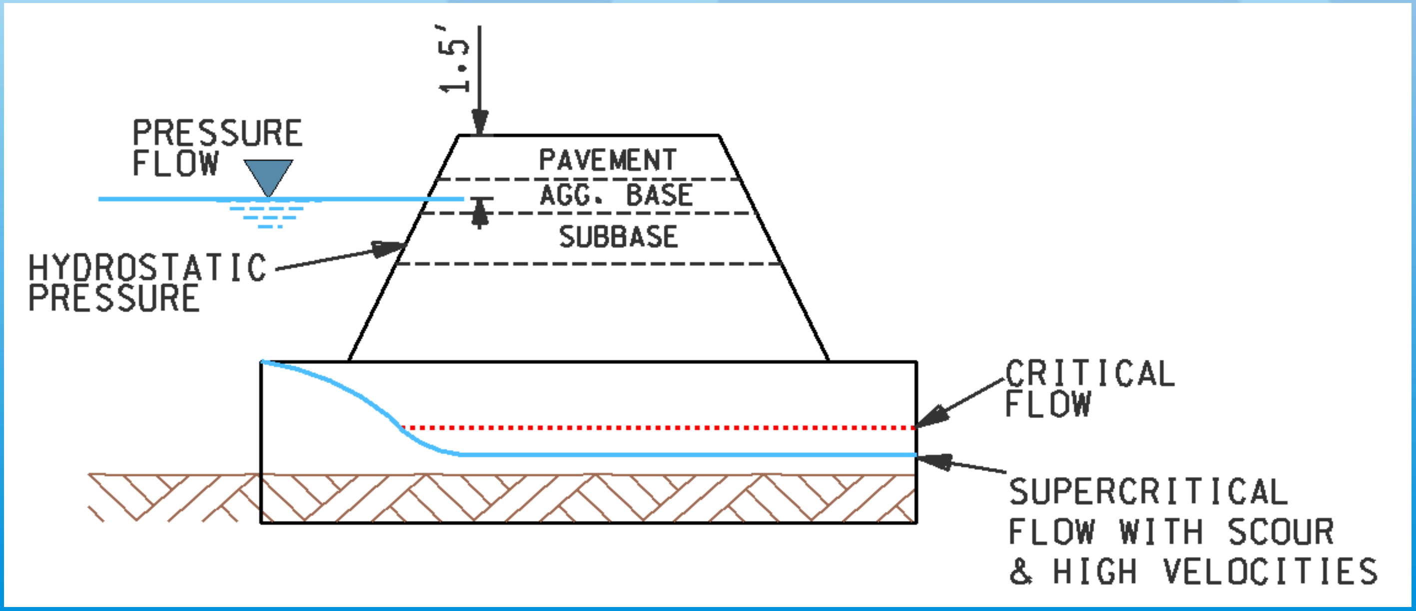
MDOT Drainage Manual

- 1.5 feet below the shoulder hinge for the 50 year storm.

This will likely place the culvert in **PRESSURE FLOW**

Pressure Flow Defined

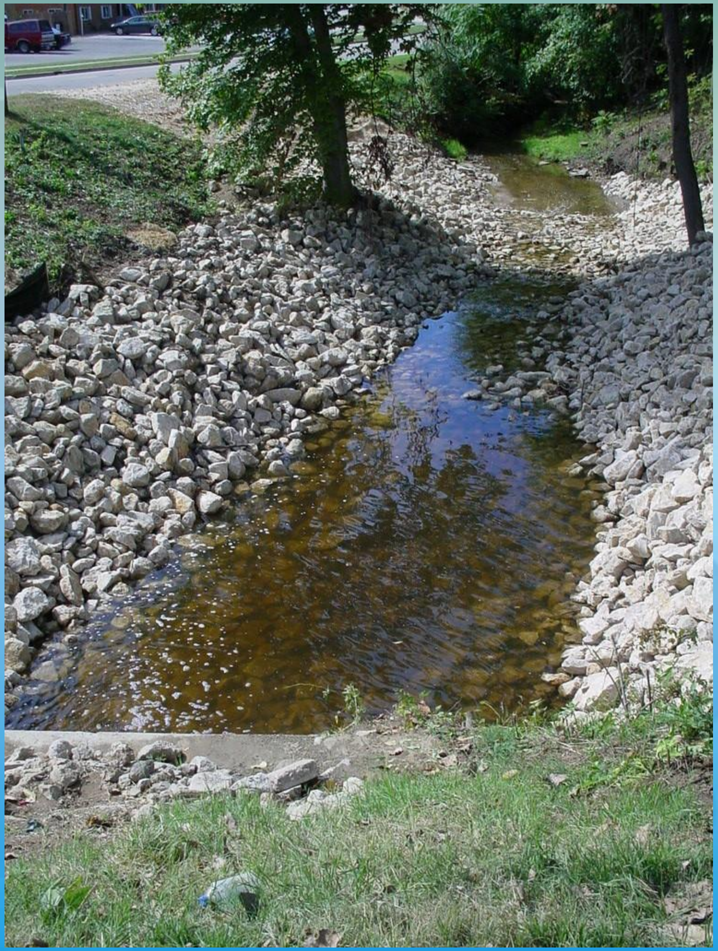
Headwater at 1.5 feet below the shoulder hinge can submerge the culvert creating a PRESSURE FLOW condition. Pressure flow should be avoided if possible as it causes high velocities and erosion (scour) at both ends of the culvert. Pressure flow places downward forces on the end section potentially leading to joint separation. Pressure flow also causes hydrostatic pressure on the embankment which can lead to saturation of the road subbase.



Design Requirements

OUTLET VELOCITY

- Maximum of 6 ft/s
- Energy dissipation required for exit v > 6 ft/s unless consistent with the downstream channel.



Design Requirements

FLOWLINE

Bury the inverts below the flowline as described on page 5-16 in the MDOT Drainage Manual

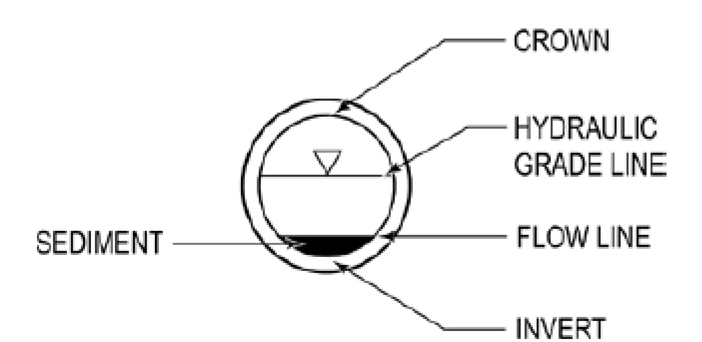


Figure 5-1 Culvert Terms

Design Requirements

EXISTING vs. PROPOSED

1. ALWAYS compare existing to proposed for HWE and velocity
2. Proposed conditions may not exceed existing conditions; *Harmful Interference*

PROCEED WITH CAUTION IF DOWNSIZING, LENGTHENING, OR LINING A CULVERT

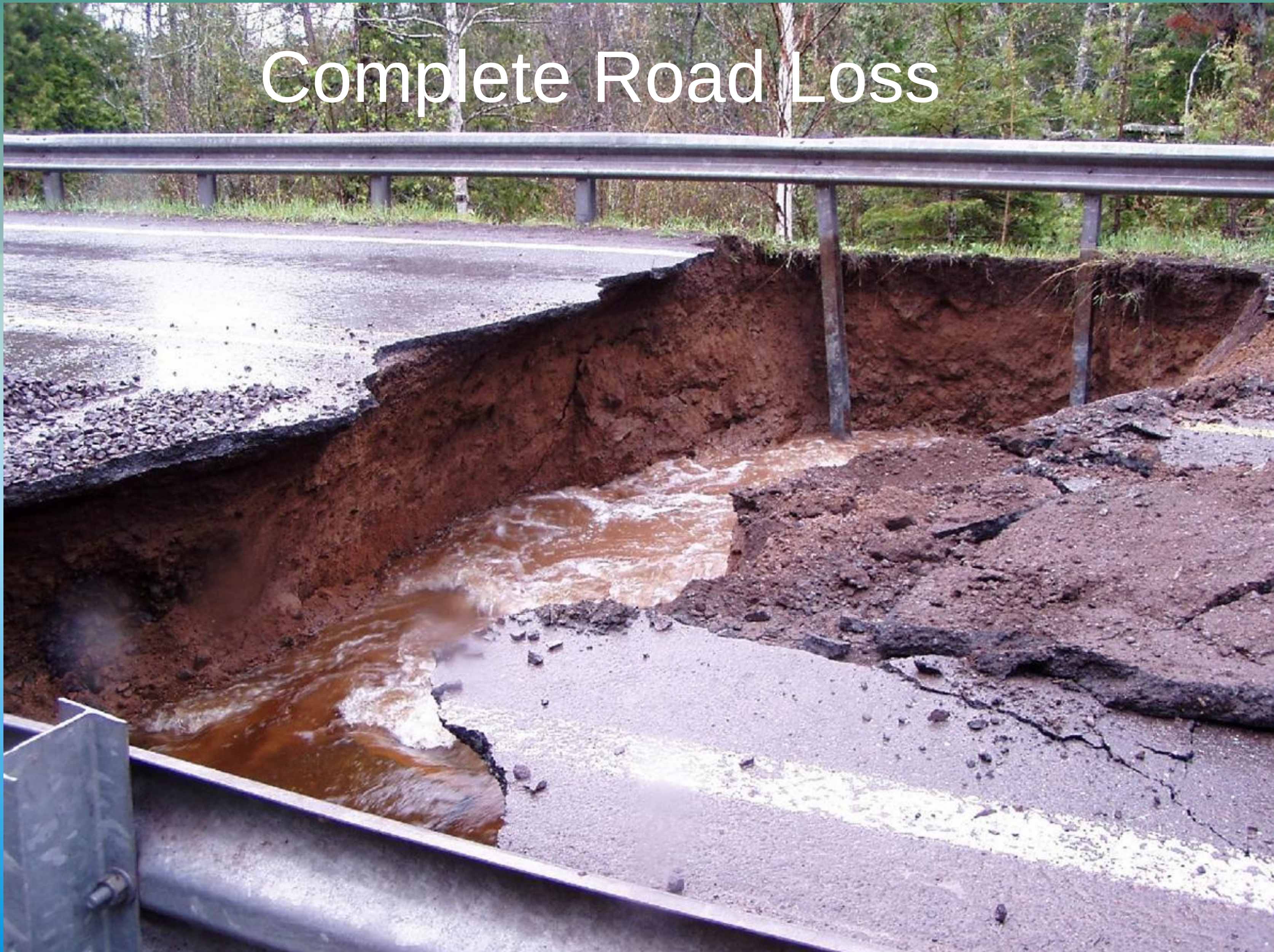
Culvert Failures

The next few slides show the importance of inspecting and replacing culverts as necessary.

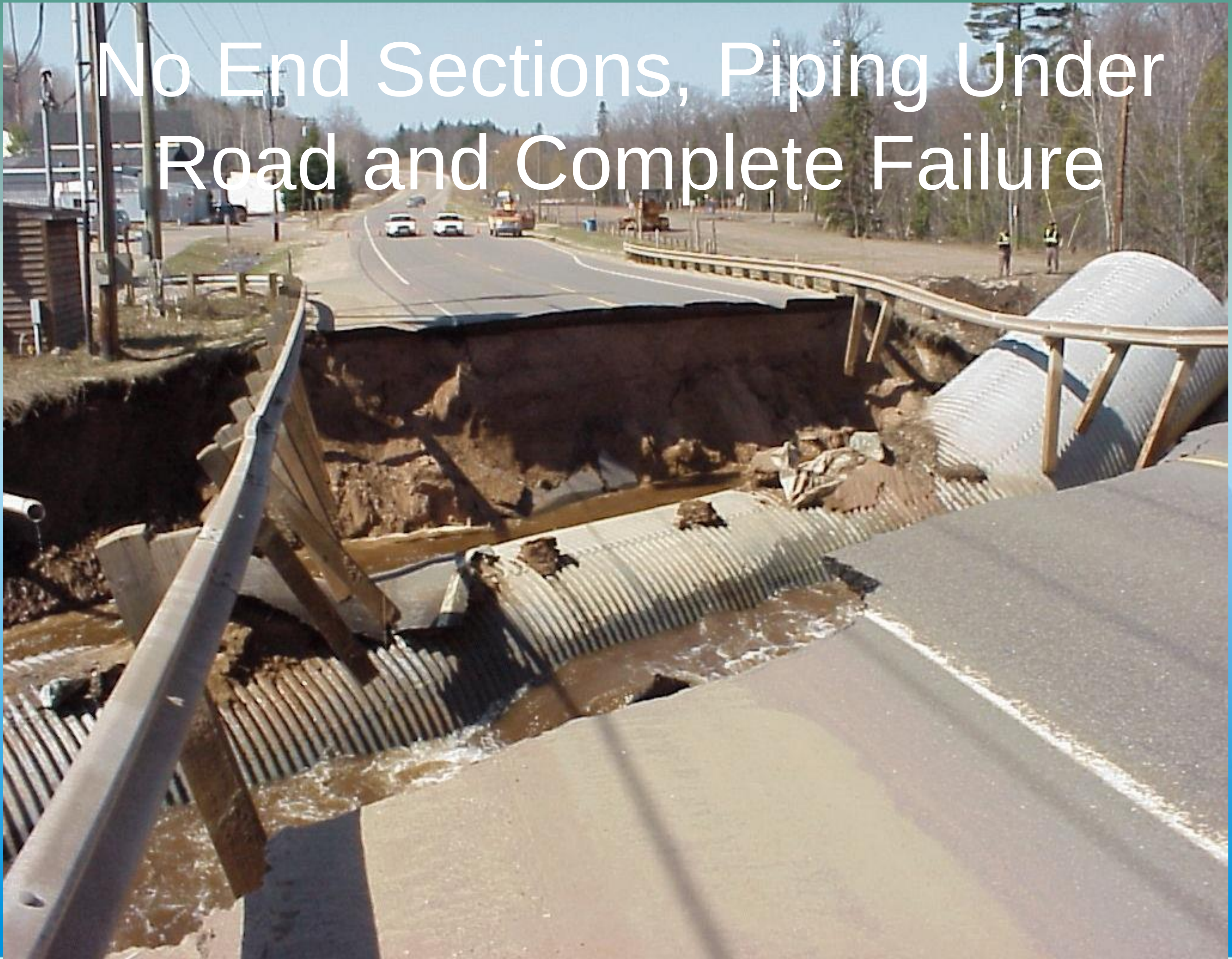
Culvert failures can lead to complete loss of the roadway resulting in injuries and even fatalities.

A common type of failure is joint separation for concrete structures, or excessive rusting for metal structures. These conditions can cause fill loss in the soil envelope surrounding the structure as it is drawn inside of the culvert. This removal of soil surrounding the culvert will lead to voids within the embankment and/or under the road itself.

Culvert Failures


Complete Road Loss

No End Sections, Piping Under Road and Complete Failure



Total loss followed by buoyancy

Culvert Failure & Road Washout

Poor designs may become disastrous

Misc. Considerations

Safety End Sections & Grates

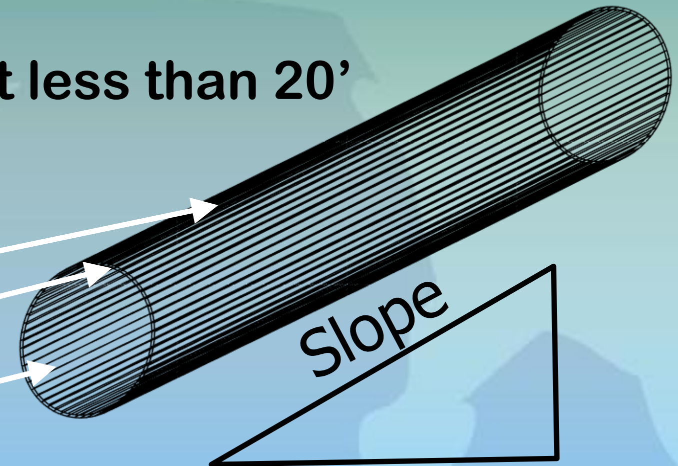
DEBRIS RESTRICTING FLOW

Culvert Definitions

Small culverts are less than 10’ wide

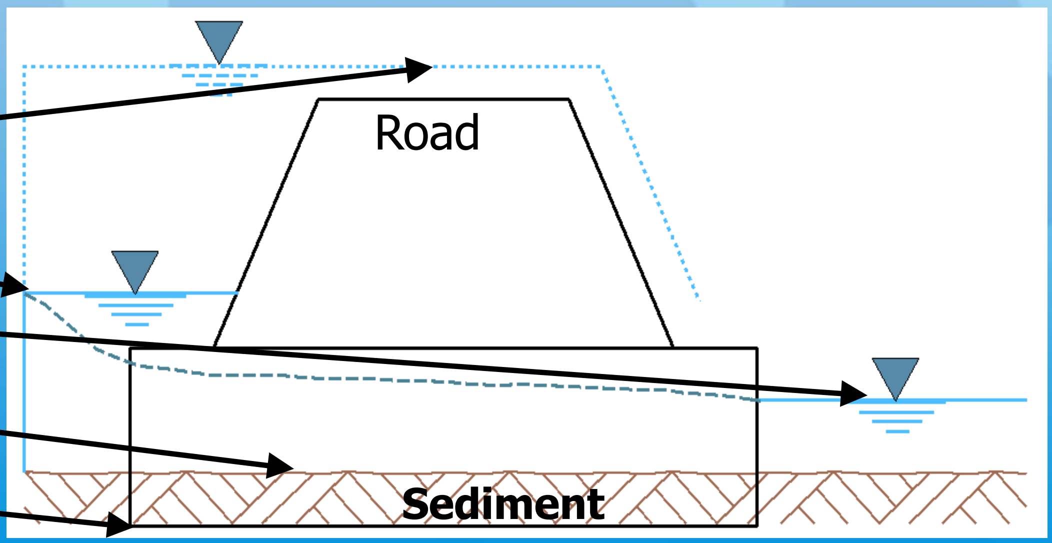
Numbered culverts are 10’ or greater but less than 20’

Bridges are 20’ and greater.



Culvert Terms

- Barrel -
- Crown -
- Inlet -
- Weir flow -
- Headwater -
- Tailwater -
- Flow Line -
- Invert -



Required Input Data

Flood Discharge Information

- 50 year (2% chance)
- 100 year (1% chance)

Existing and Proposed Culvert data

- U/S and D/S inverts and flowlines
- Culvert size, shape, and material
- Culvert length

Site Constraints

- Headwater
- Tailwater

Site Visit Process

<2 square mile culverts

Culvert data:

- Size, (measure – don't guess or assume the size)
- Shape: circular, box, ellipse, small plate arch
- Material: metal or concrete

Photos & Notes

Culvert:

- Look for erosion (scour) at culvert's end sections.
- Look for a loss of structural integrity, rust or separated joints.
- Determine if the culvert had been previously extended; if so, check extension material, size, shape.
- Check for debris at the culvert inlet and/or excessive debris in channel impeding flow.
- Check to see if riprap is in place.
- Other structures upstream or downstream and within influence of the design culvert.

Site Visit Process (cont.)

Upstream & Downstream channel:

- Signs of erosion and/or scour

Road & Foreslope:

- Check road foreslope for holes indicating culvert is removing soil surrounding culvert which may show on top of culvert.
- Check road over top of culvert for signs of sagging (asphalt) or potholes, possible subbase losses.

Studies by other agencies:

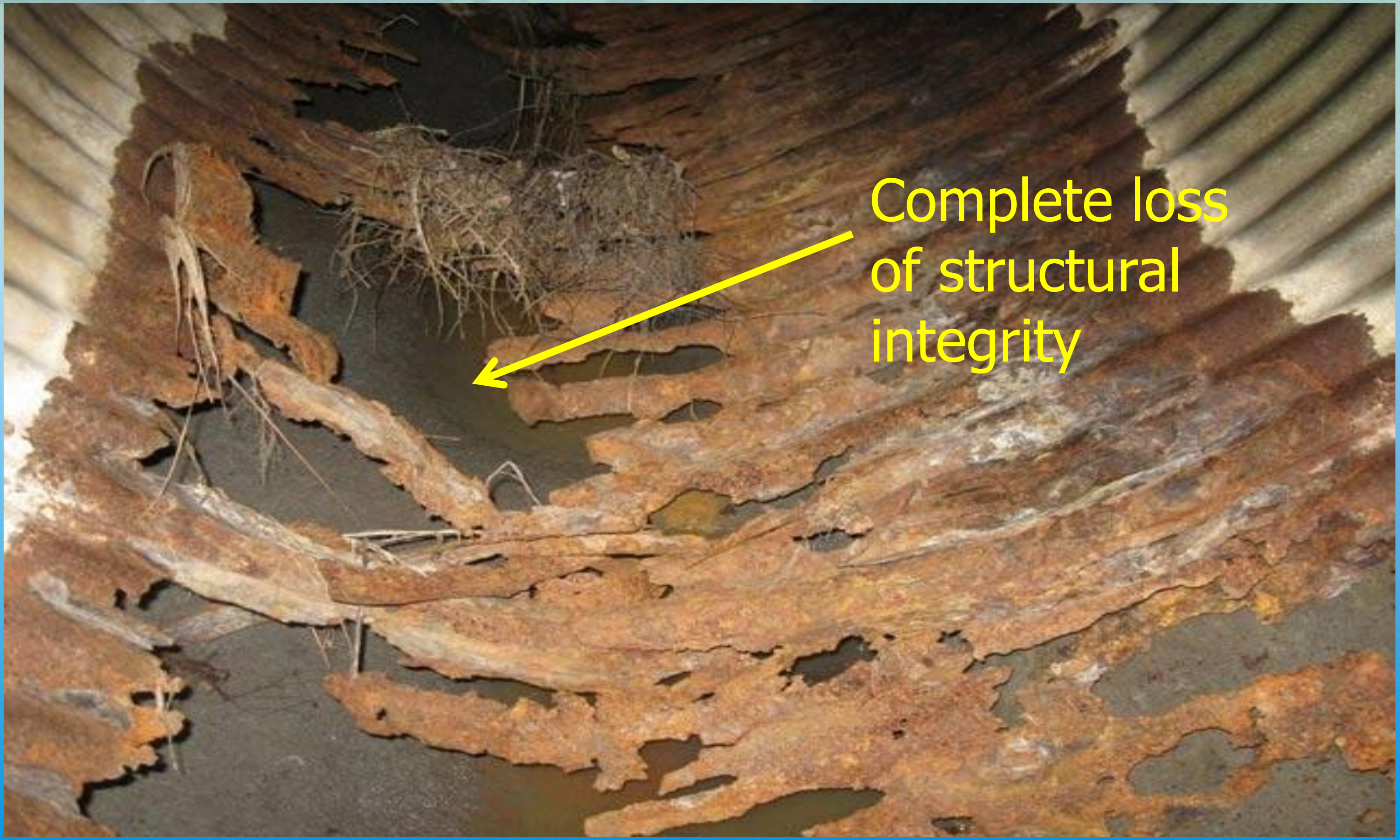
- This is unlikely with small culverts unless included in a past drainage study.

Environmental risk assessment:

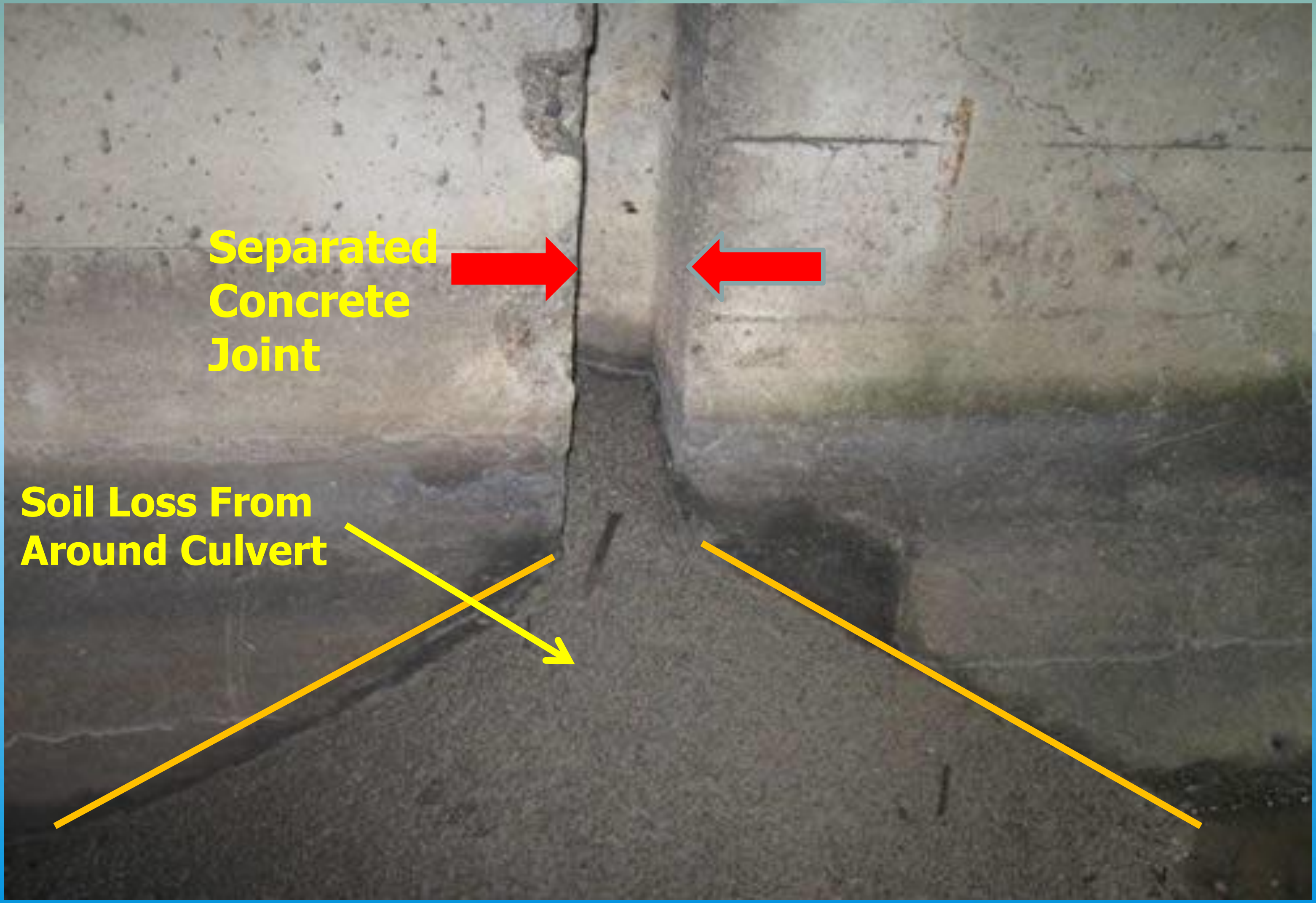
- Look for buildings near or within the floodplain
- Sensitive flood receptor

Site Visit Process (cont.)

Severe structural failure resulting in large voids around culvert and under road.



Site Visit Process (cont.)



Site Visit Process (cont.)

Perched Outlet

Determine Inlet or Outlet Control

To determine if a culvert is in Inlet or Outlet Control, first determine the Headwater (HW) for both conditions. The condition with the highest HW elevation determines which condition controls. To determine the HW we will first need to find the Tailwater (TW).

Design Procedures

Definitions

- Inlet Control – the condition when the culvert barrel is capable of conveying more flow than the inlet will accept

- Outlet Control – the condition when the culvert barrel is not capable of conveying as much flow as the opening will accept.

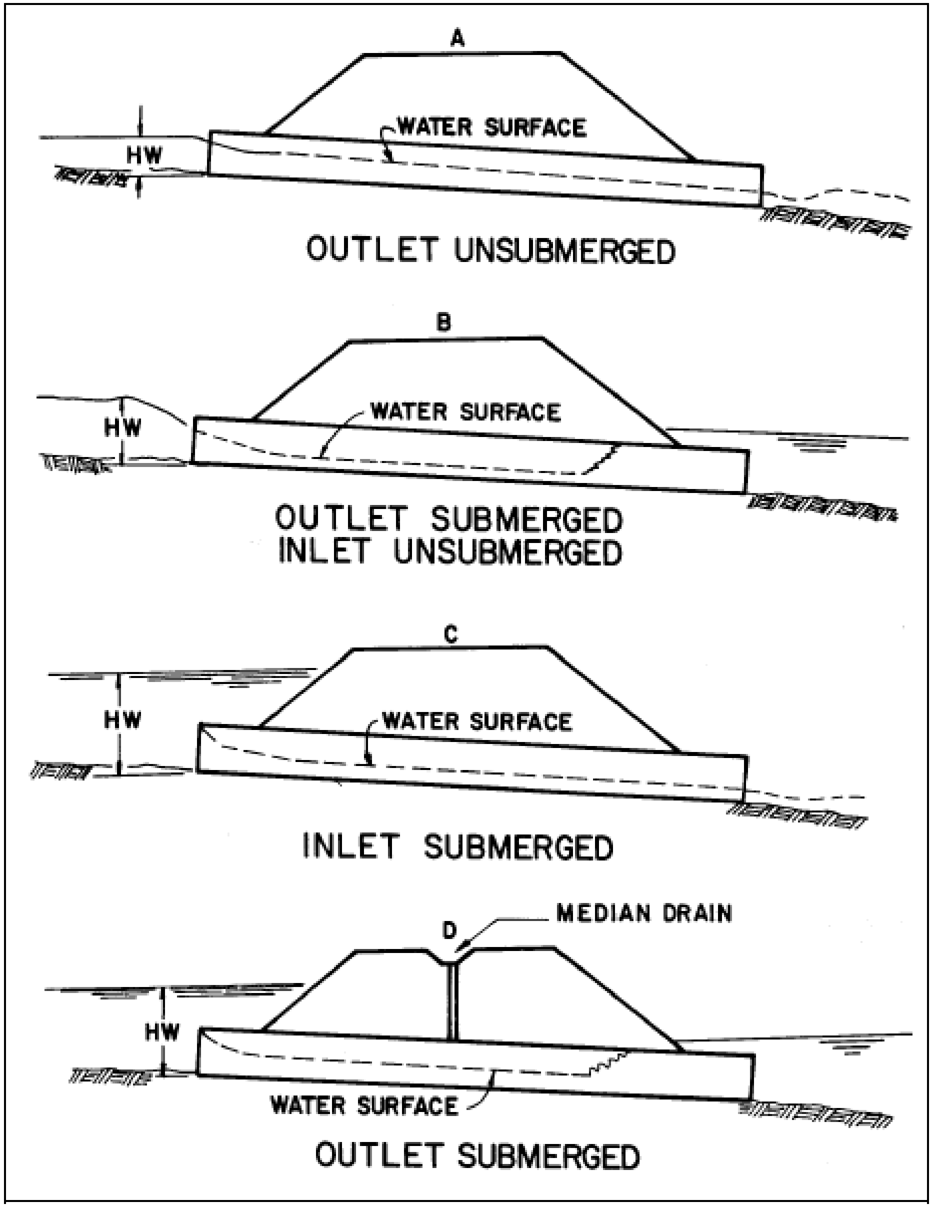


Figure III-1--Types of inlet control

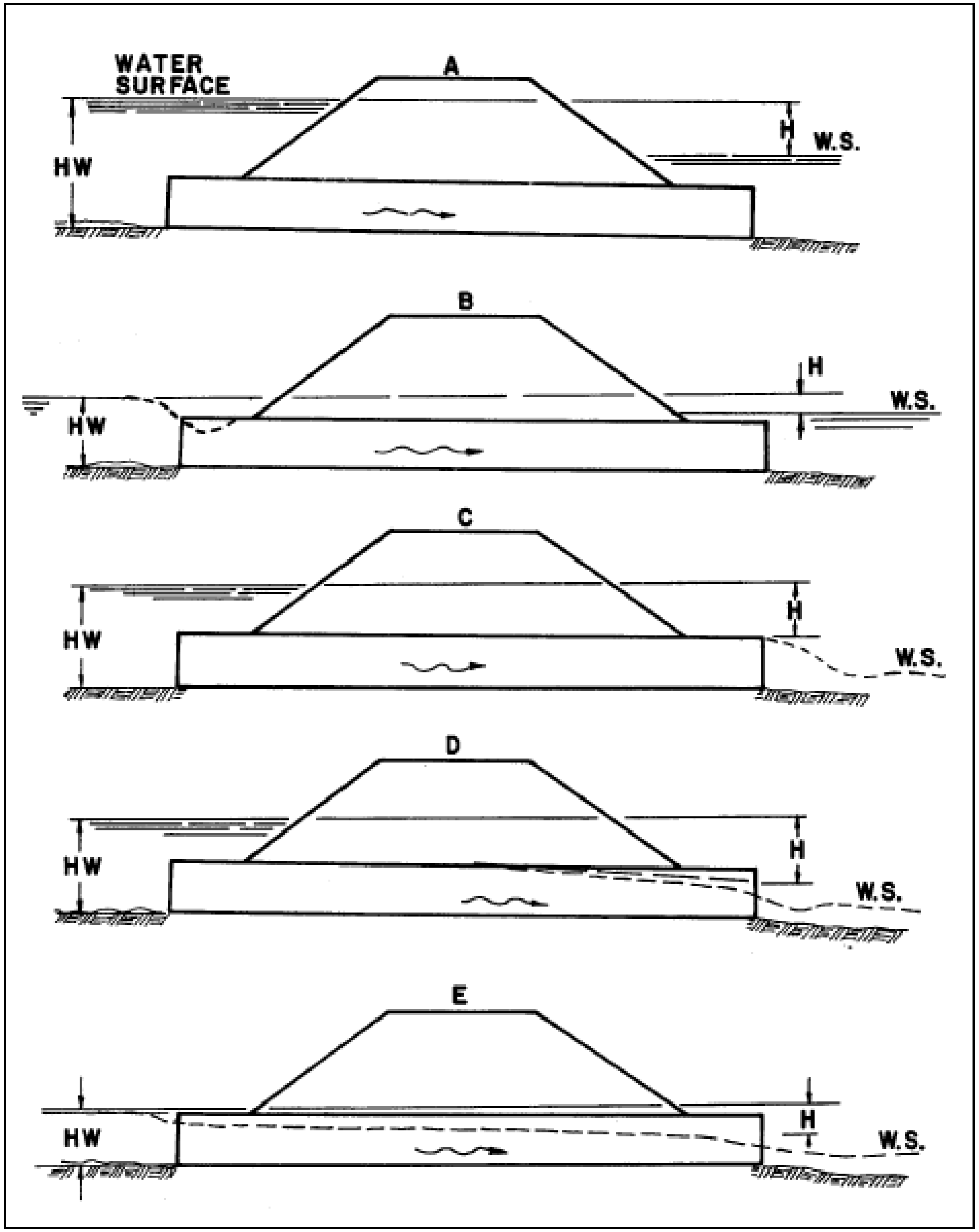
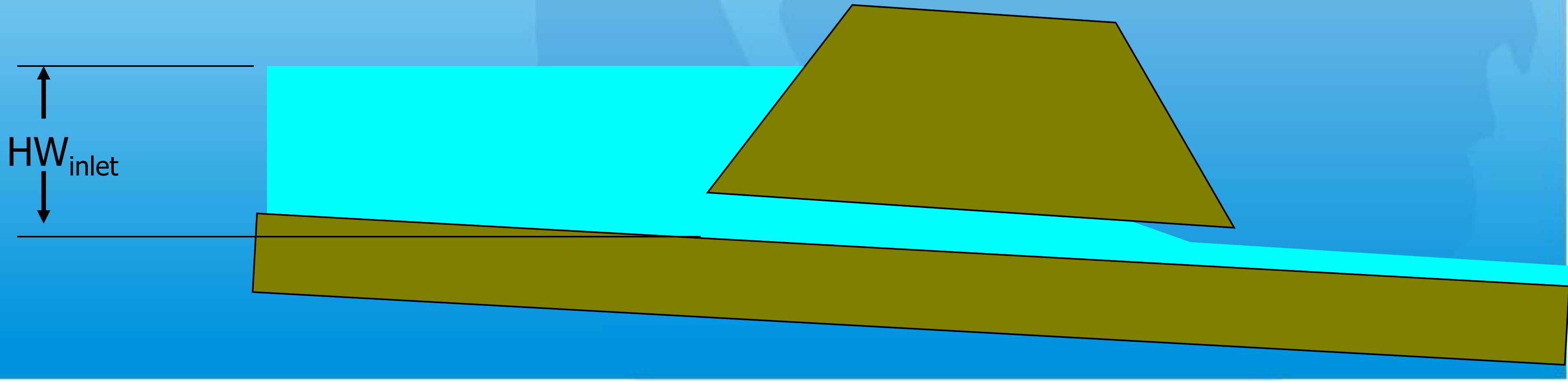


Figure III-7--Types of Outlet Control

Design Procedures

Inlet Control

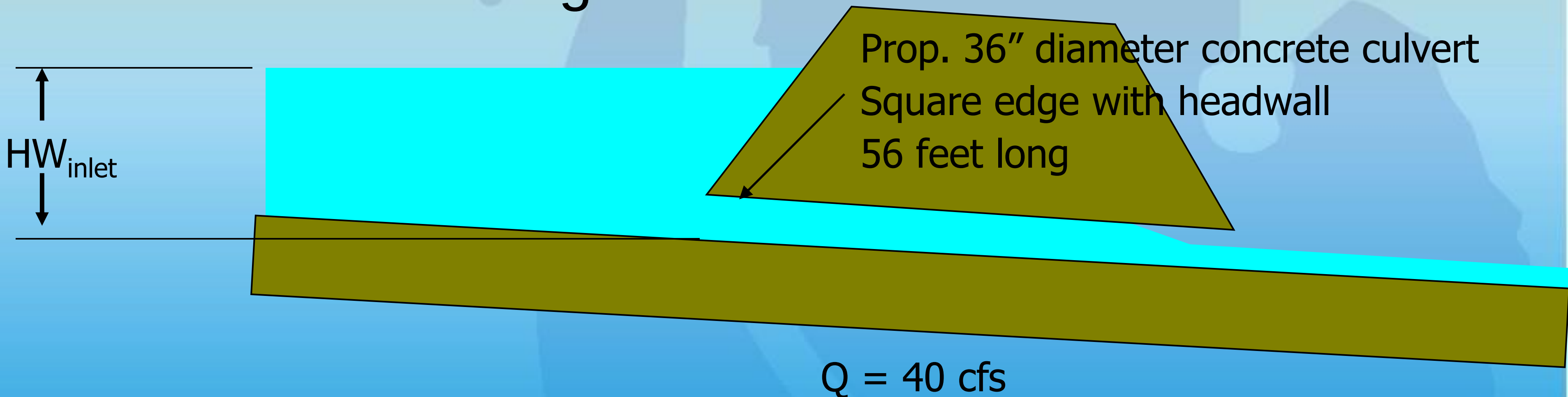
- HW/D values found in Nomographs in HDS-5 or MDOT Drainage Manual
- HW added to upstream invert
- <u>Beware of correct inlet configuration</u>



Design Procedures

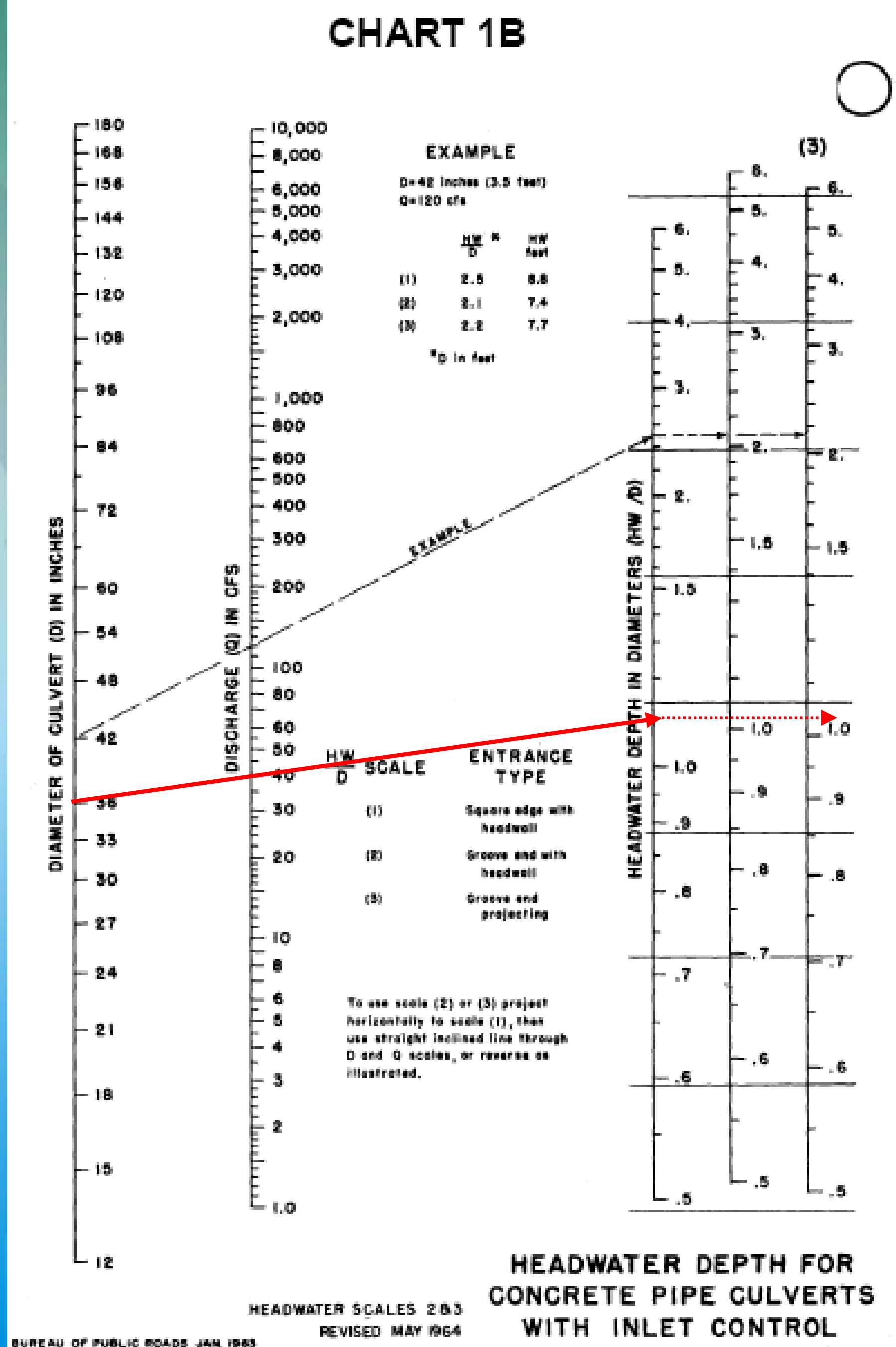
Inlet Control

- Find the inlet control HW value for the following:



- Answer: 3.3 feet   (Chart 1B)

Inlet Control



HW/D = 1.1

HW = 1.1 (3′)

HW = 3.3′

Design Procedure

Outlet Control

Based on the Energy Equation

$$HW_o + \frac{V_u^2}{2g} = TW + \frac{V_d^2}{2g} + H_L \qquad (HDS-5, Eq.6)$$

$$H_L = H_e + H_f + H_o + H_b + H_j + H_g \qquad (HDS-5, Eq.1)$$

$$V = \frac{Q}{A} \qquad (HDS-5, Eq.2)$$

Design Procedure

Outlet Control

Headwater and Headloss:

$$HW_o = TW + H_L \qquad (HDS-5, Eq.7)$$

$$H_L = \left[1 + k_e + \frac{29n^2L}{R^{1.33}}\right]\frac{V^2}{2g} \qquad (HDS-5, Eq.5)$$

Bend and grate losses neglected

Table C.2. Entrance Loss Coefficients.

Outlet Control, Full or Partly Full Entrance Head Loss

$$H_e = K_e\left[\frac{V^2}{2g}\right]$$

Type of Structure and Design of Entrance	Coefficient K_e	
• Pipe, Concrete		
Projecting from fill, socket end (groove-end)	0.2	
Projecting from fill, sq. cut end	0.5	
Headwall or headwall and wingwalls		
Socket end of pipe (groove-end	0.2	Cast In Place
Square-edge	0.5	R-86
Rounded (radius = D/12	0.2	
Mitered to conform to fill slope	0.7	R-95
*End-Section conforming to fill slope	0.5	
Beveled edges, 33.7^0 or 45^0 bevels	0.2	
Side- or slope-tapered inlet	0.2	
• Pipe. or Pipe-Arch. Corrugated Metal		
Projecting from fill (no headwall)	0.9	
Headwall or headwall and wingwalls square-edge	0.5	R-88
Mitered to conform to fill slope, paved or unpaved slope	0.7	R-95
*End-Section conforming to fill slope	0.5	
Beveled edges, 33.7^0 or 45^0 bevels	0.2	
Side- or slope-tapered inlet	0.2	
• Box, Reinforced Concrete		
Headwall parallel to embankment (no wingwalls)		
Square-edged on 3 edges	0.5	
Rounded on 3 edges to radius of D/12 or B/12 or beveled edges on 3 sides	0.2	
Wingwalls at 30^0 to 75^0 to barrel		
Square-edged at crown	0.4	
Crown edge rounded to radius of D/12 or beveled top edge	0.2	
Wingwall at 10^0 to 25^0 to barrel		
Square-edged at crown	0.5	
Wingwalls parallel (extension of sides)		
Square-edged at crown	0.7	
Side- or slope-tapered inlet	0.2	

*Note: "End Sections conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the beveled inlet.

Design Procedure

Outlet Control

- Hydraulic radius and velocity must be adjusted for partial depth
- Use outlet depth (TW) for partial elements

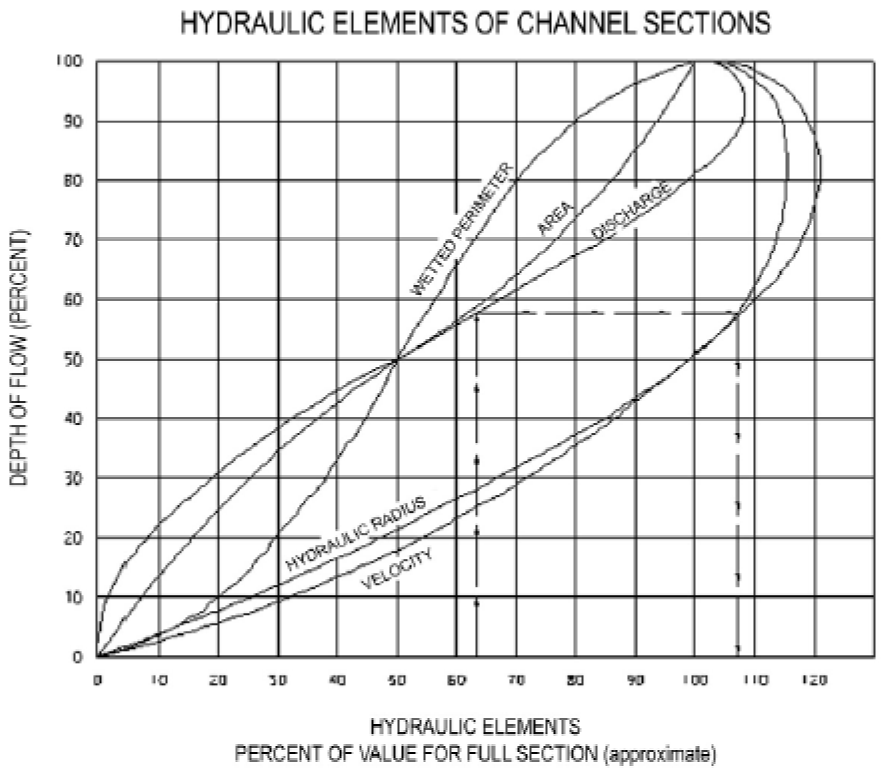
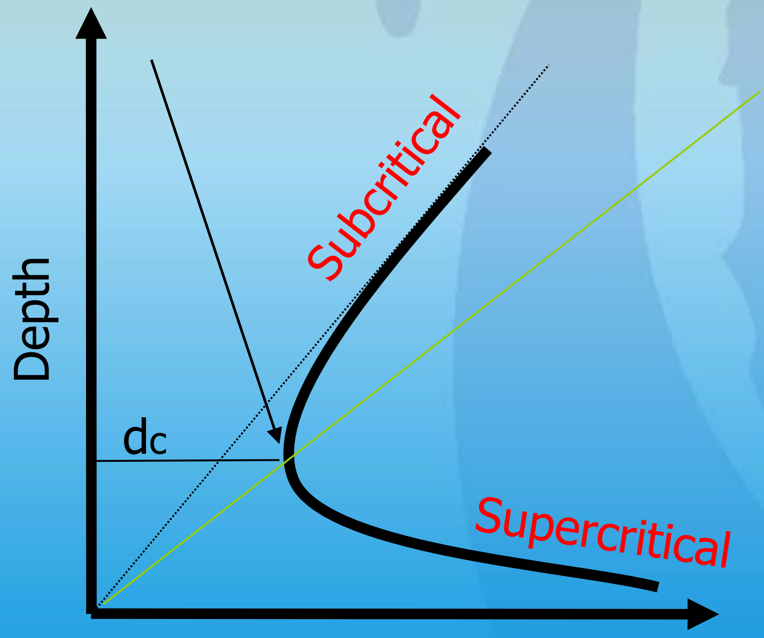


Figure 7-19 Values of Hydraulic Elements of Circular Section for Various Depths of Flow

Critical Depth (dc) defined

To determine the TW we will need the Critical Depth which is the elevation of least energy.

Any depth greater than or less than dc will be of greater energy as shown in the graph below.



Specific Energy = $y+V^2/2g$

Determine Tailwater

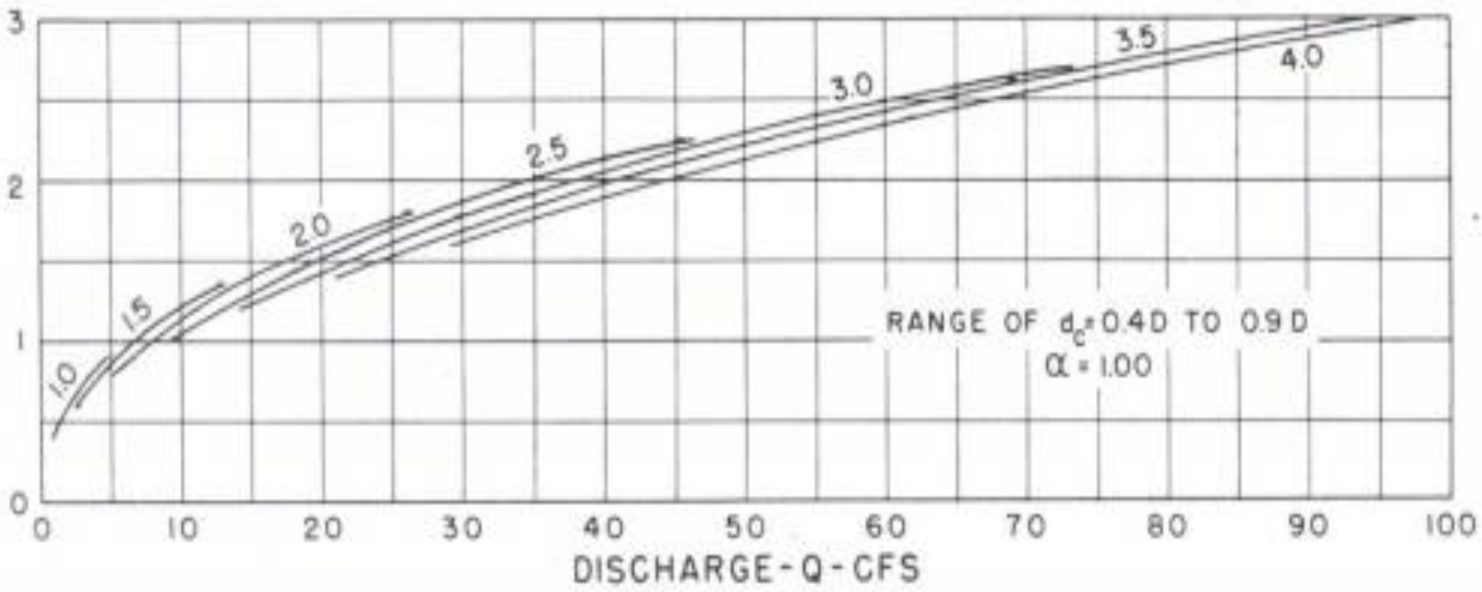
Simplest Method (The one we will use for hand calculations)

- Determine the average of critical depth plus diameter of pipe divided by 2: **TW= $(d_c + D)/2$**

- Using Chart 4B from HDS-5 Highway Design of Highway Culverts, determine dc for our subject culvert.

HDS-5 Critical Depth

Figure 2E-2.03A: Critical Depth Circular Pipe, Discharge = 0 to 100 cfs



Culvert Example

Assume the average of critical depth and barrel diameter for the tailwater conditions.

Find the outlet velocity (V)

- D = 36″ (3′)
- Q = 40 cfs

Culvert Example

Solution:

Step 1

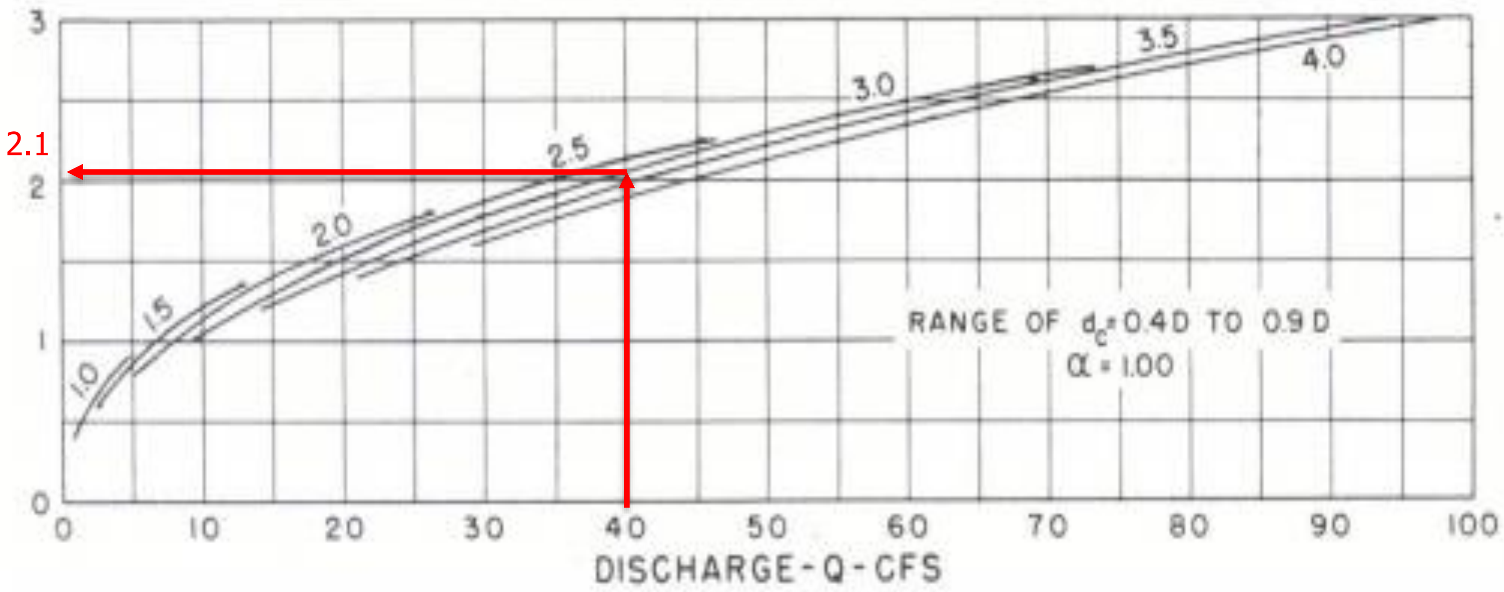
Find critical depth dc using the HDS charts

1. Using Figure 2E-2.03A, find Q = 40 cfs on the X axis
2. Find the curve for 3′ diameter circular culverts
3. From the X axis (at 40cfs), draw a vertical line to intersect the 3′ curve; from that point draw a horizontal line to intersect the Y axis.
4. Read the corresponding critical depth dc along the Y axis

d_c = 2.1′

HDS-5 Critical Depth

Figure 2E-2.03A: Critical Depth Circular Pipe, Discharge = 0 to 100 cfs



Culvert Example

Step 2

Determine Tailwater (TW)

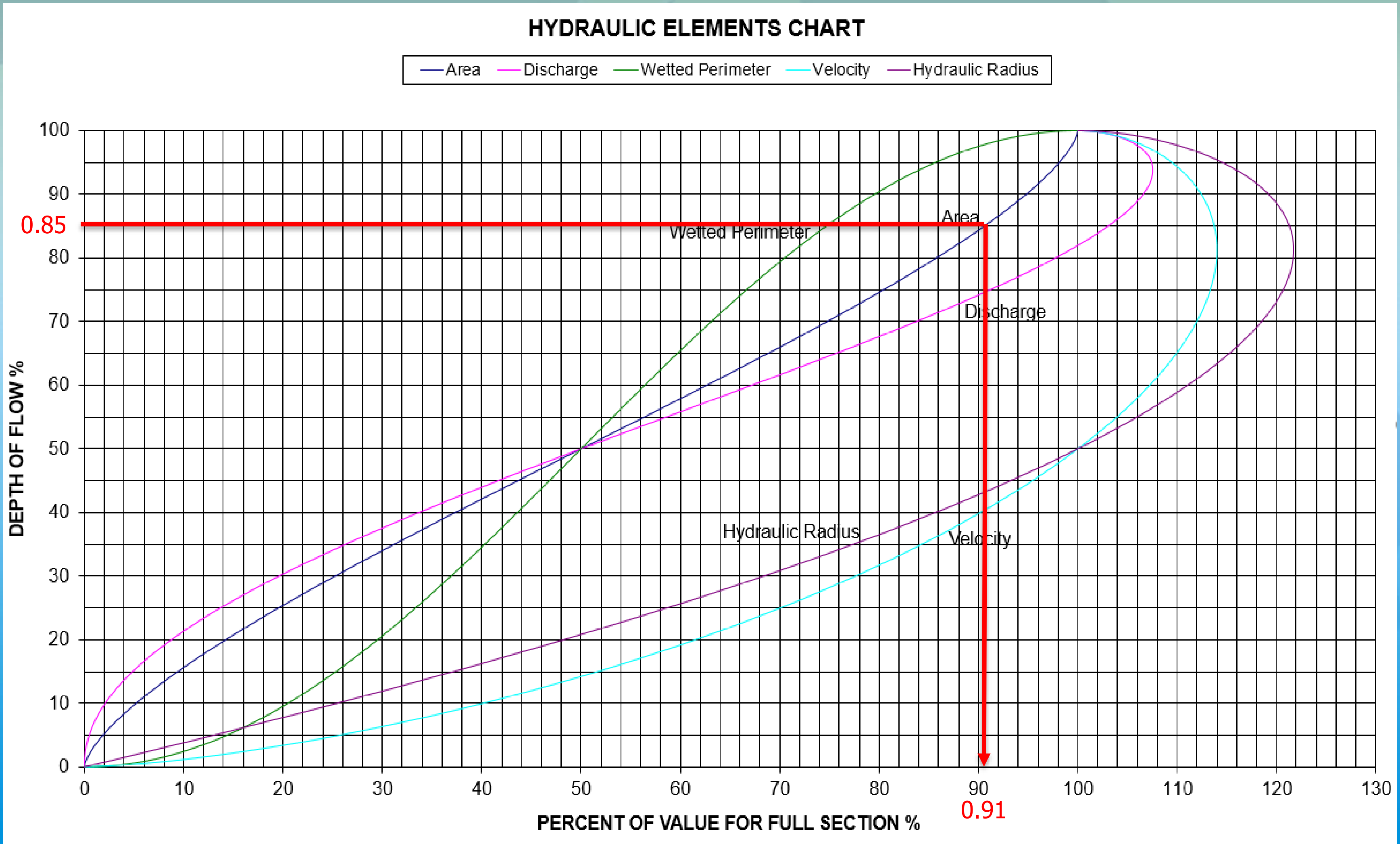
$$\textbf{TW} = \frac{dc+D}{2}$$

$$= \frac{2.1+3}{2} = 2.55; \ \frac{2.55}{3} = 0.85 \text{ (\% of Full Flow)}$$

Using the Hydraulic Elements Chart find 85% ratio along the Y axis

Culvert Example

- From the Y axis move along the horizontal line until you hit the Area curve.
- From that point, drop straight down and find the % Full Section.



Culvert Example

Step 3

We need $V_{partial}$, but don't know V_{full}. **We do know A_{full}**

$A_f = \pi 1.5^2$
$= 7.07$ sf

$A_p/A_f = 0.91$ (from partial elements chart)

$A_p = (0.91 \times Af)$
$= (0.91 \times 7.07)$
$= 6.43$ sf

To find V_p we will use the equation Q = VA, ➡ $V = \frac{Q}{A}$

$V_p = \frac{40}{6.43} = 6.22$ ft/s

Culvert Example

Now solve for the HW_o as **an elevation** (Outlet Control)

Upon inspection of the culvert we know the additional following information:

- U/S invert = 840.4
- D/S invert = 840.3
- Length of culvert = 40'
- k_e = 0.7 (Mitered to conform to slope - see handout)
- V_f = 6.22 ft/s (solved previously)
- n = 0.012 (Mannings roughness for concrete)
- Partial depth TW/D = 0.85 (solved previously)

Culvert Example

Recall:

$$HW_o = TW + H_L$$

$$H_L = \left[1 + k_e + \frac{29n^2L}{R^{1.33}}\right]\frac{V^2}{2g}$$

Step 1

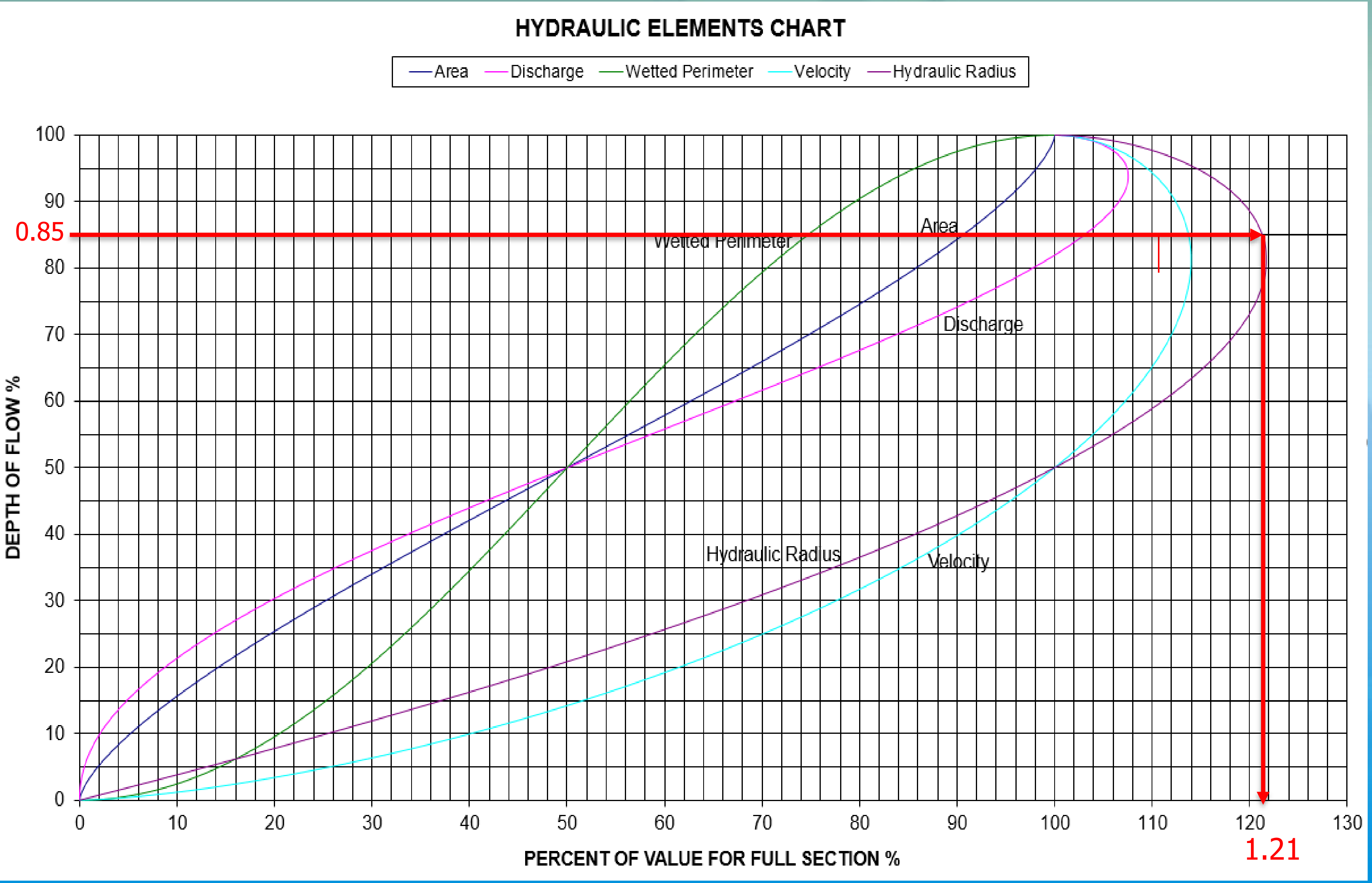
Determine R_p (Hydraulic Radius - partially full)

First calculate R_{full}

$$R_f = \frac{A}{P} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{1.5}{2} = \mathbf{0.75}$$

Determine the ratio of $\frac{Rp}{Rf}$ to find R_p using partial elements chart

Use .85 for flow depth (solved previously)



Culvert Example

Ratio of $\frac{Rp}{Rf}$ = **1.21**

Calculate R_p

R_f = 0.75 (solved previously)

$R_p = R_f$ (1.21)
= 0.75 (1.21)
= 0.91

Culvert Example

Step 2

Calculate Headloss

$$H_L = \left[1 + k_e + \frac{29n^2L}{R^{1.33}}\right]\frac{V^2}{2g}$$

$$H_L = [\ 1 + 0.7 + \frac{29(0.012^2)40}{0.91\text{^}1.33}\ ]\ \frac{6.22^2}{2(32.2)} = 1.14 \text{ ft}$$

Known Values

- TW = 2.55 ft
- H_L = 1.14
- D/S invert elevation = 840.3

HW_o = 2.55 + 1.14 + 840.3 = **843.99**

CLASS EXERCISE

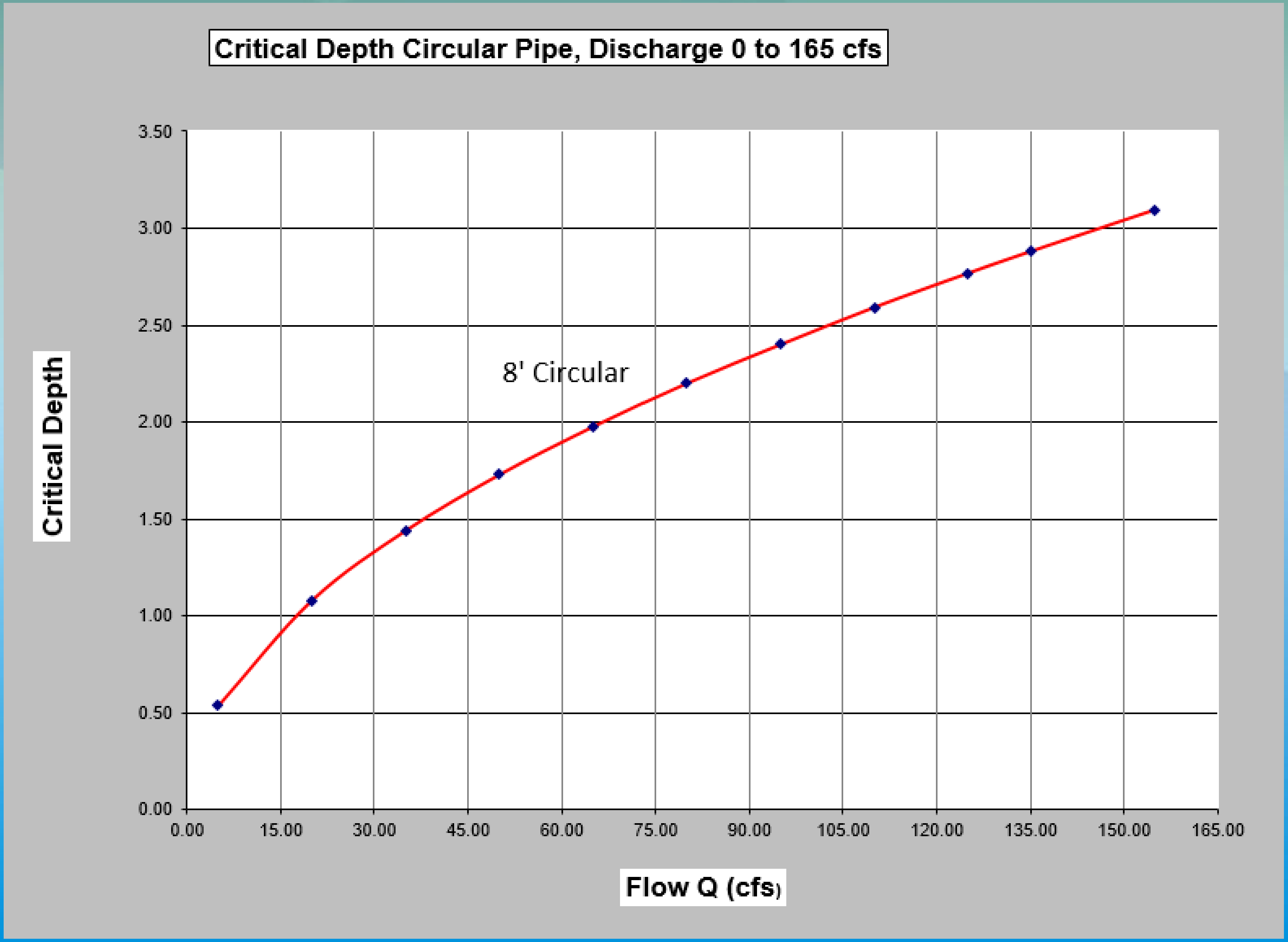
Class Exercise

Find the <u>Velocity</u> and the <u>HW</u> for both inlet and outlet control

The following are known:

- Culvert Material: Circular Concrete
- D = 96” (8’)
- Q = 135 cfs (50yr design) See next slide for critical depth chart
- U/S invert = 878.0
- D/S invert = 877.0
- Length of culvert = 84’
- k_e = Square edge headwall with wingwalls - see handout
- n = 0.012 Manning’s Roughness Coefficient

Custom Critical Depth Chart



HY-8 Example for Class Exercise

- For the purpose of this class we will explain how HY-8 is used to properly size a culvert.

  ⇨ Note: **When using HY-8 or any culvert sizing software you must always run both an existing and proposed model for comparison**.

  ⇨ **The intent of culvert modeling is to show an improvement in the proposed condition compared to the existing.**

- Once an existing culvert is modeled simply right click "Project" and select "Add Culvert Crossing" to add the Proposed culvert model.

- For the sake of class time we will only demonstrate entering the data for the proposed culvert and not the existing culvert to be replaced.

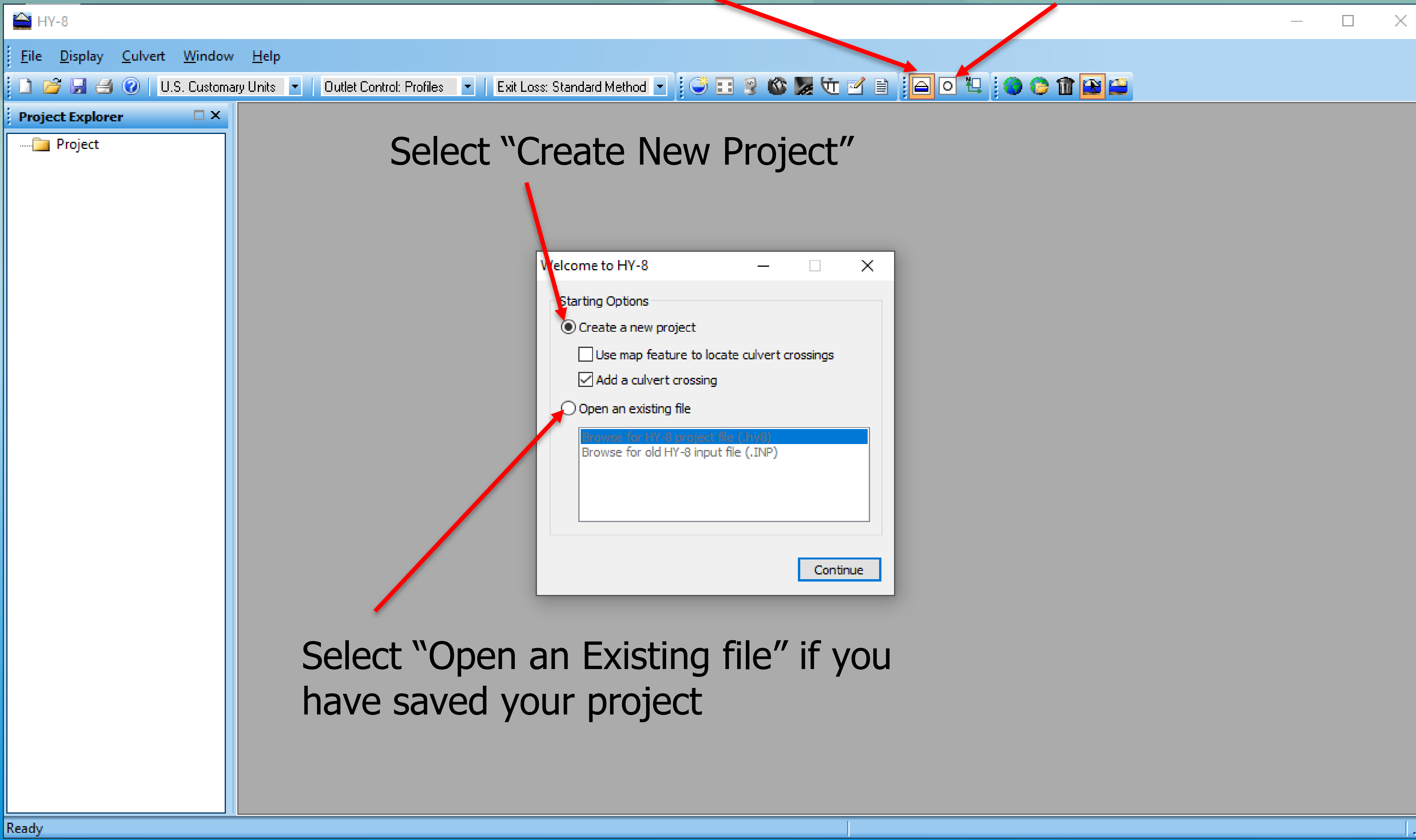
- The process of entering the data for the existing culvert model is the same as the proposed model.

HY-8 Example for Class Exercise

Select create a new project

Profile View

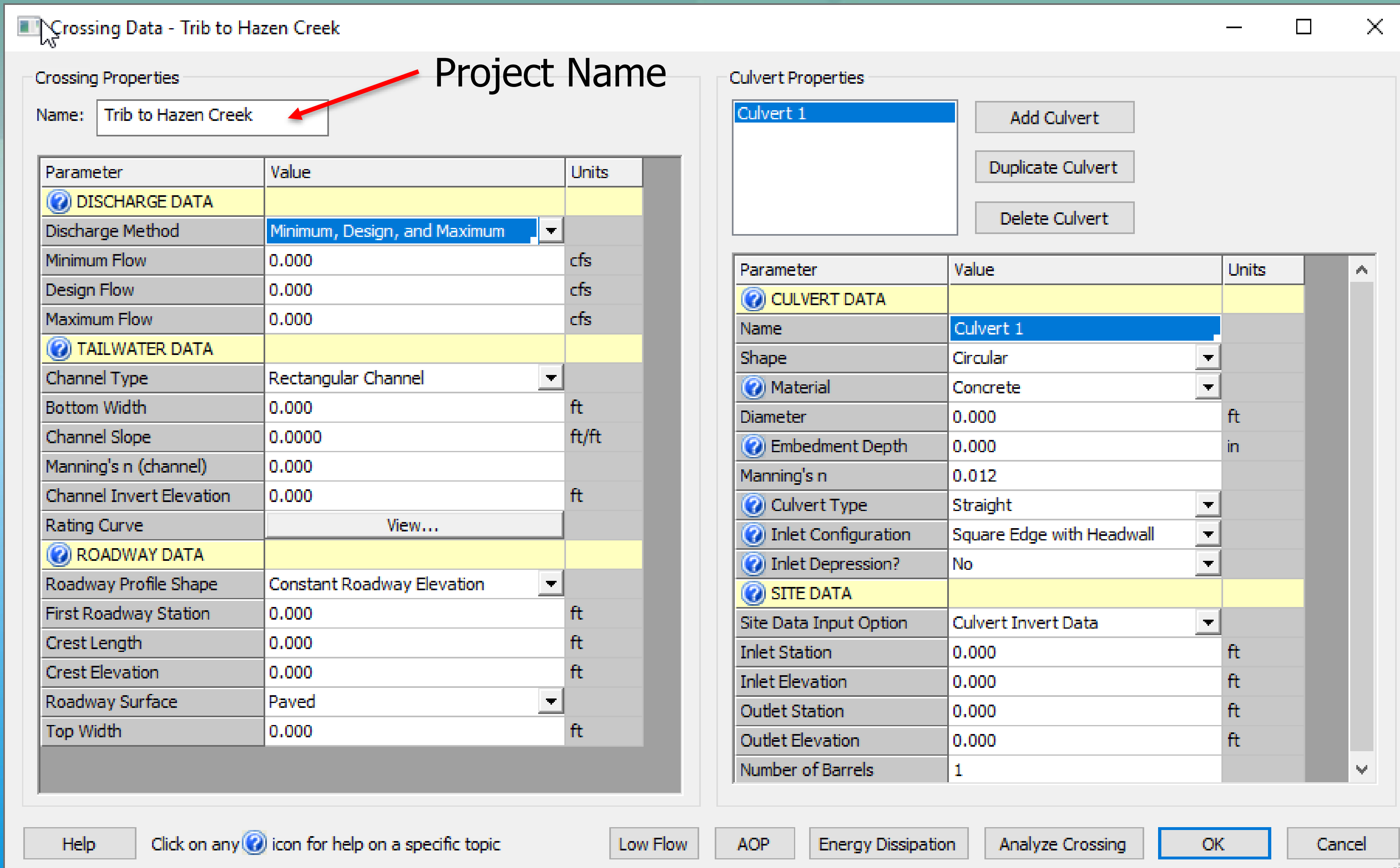
Front View



Select "Create New Project"

Select "Open an Existing file" if you have saved your project

HY-8 Example for Class Exercise



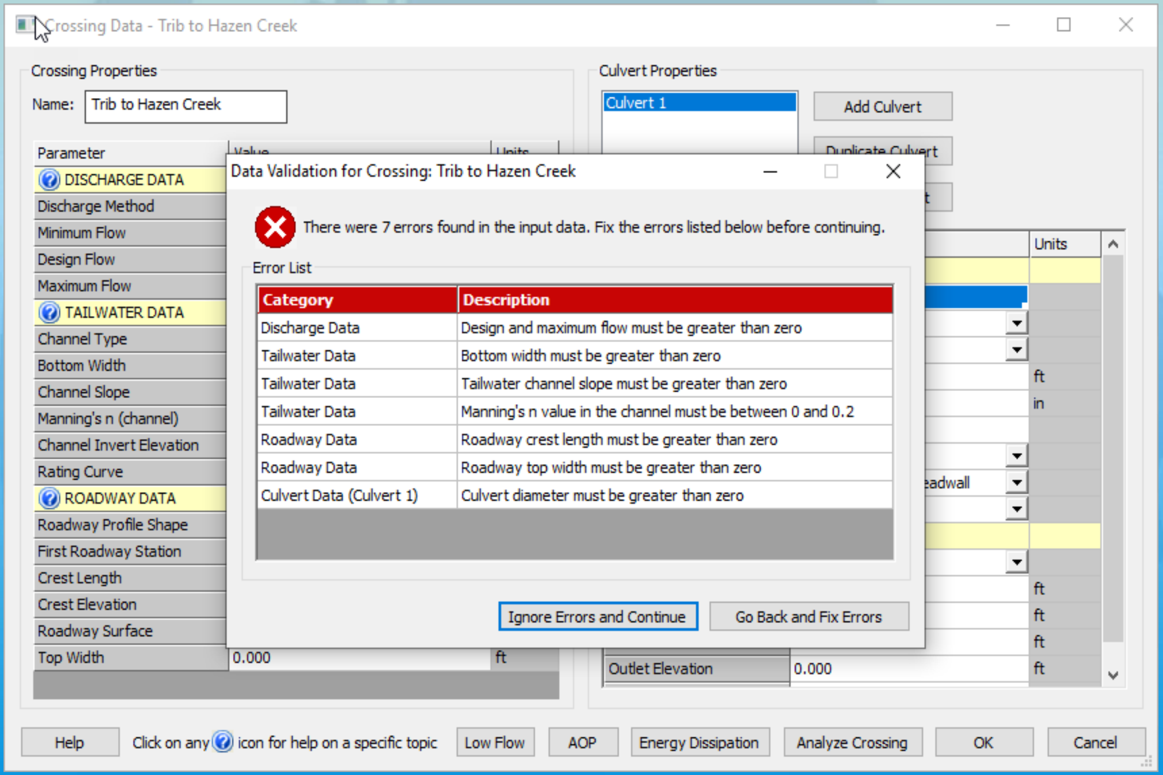
HY-8 Example for Class Exercise

This is a list of data not yet entered in the form of "Error List" provided in a manner which may cause a **sense of panic when first encountered**.

Not to worry the program is simply letting you know all of the data needed before an analysis can be computed.

You may "Ignore Errors and Continue" which closes the table.

You can then simply save the project and return to it later.



HY-8 Discharge Data Entry

- Minimum (suggest no less than 5 cfs)
- 50 year (2%)
- 100 year (1%) storm
- There are 2 other choices, Recurrence and User-Defined.
- Recurrence: use when more than 3 discharges are known

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	5.000	cfs
Design Flow	135.000	cfs
Maximum Flow	155.000	cfs

Number	Names	Flow (cfs)
1	1 year	
2	2 year	
3	5 year	
4	10 year	
5	25 year	
6	50 year	
7	100 year	
8	200 year	
9	500 year	

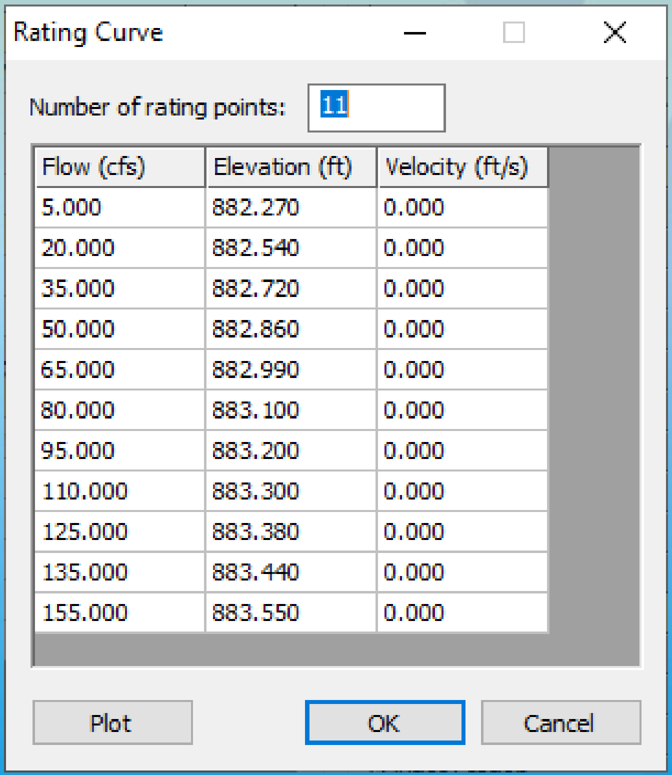
HY-8 Tailwater Options

HY-8 offers numerous options 6 options for entering Tailwater. Below are the 4 most commonly used.

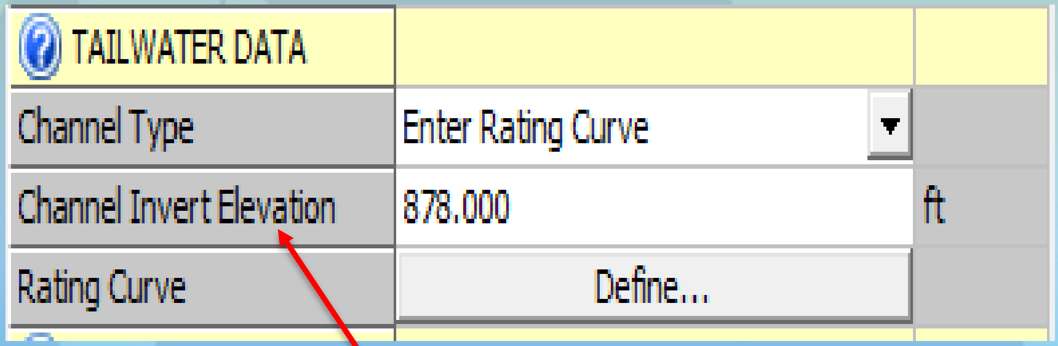
1. Rating Curve: Can be easily generated with the use of a spreadsheet designed for either **Circular** or **Box** culverts providing 11 Tw depths
2. Constant Tailwater-Calculated: This can also be used for Tw = dc+D/2 but will create a flat rating curve since the Tailwater never changes.
3. Constant Tailwater-Known: This is typically used when the downstream Tw is influenced by a downstream body of water with a known elevation.
4. Irregular Channel: This is a single survey cross-section, but not commonly used

HY-8 Example Tailwater

- Recommended method is a TW Rating Curve provides Tw depths for every discharge (more accurate)

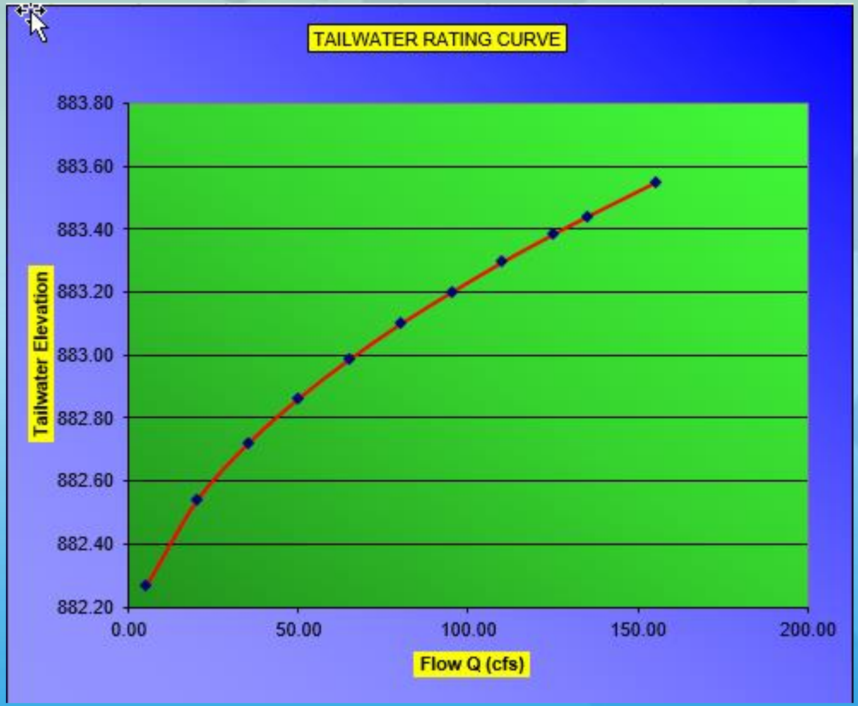


Flow (cfs)	Elevation (ft)	Velocity (ft/s)
5.000	882.270	0.000
20.000	882.540	0.000
35.000	882.720	0.000
50.000	882.860	0.000
65.000	882.990	0.000
80.000	883.100	0.000
95.000	883.200	0.000
110.000	883.300	0.000
125.000	883.380	0.000
135.000	883.440	0.000
155.000	883.550	0.000



Downstream Invert Elevation!

HY-8 Rating Curve



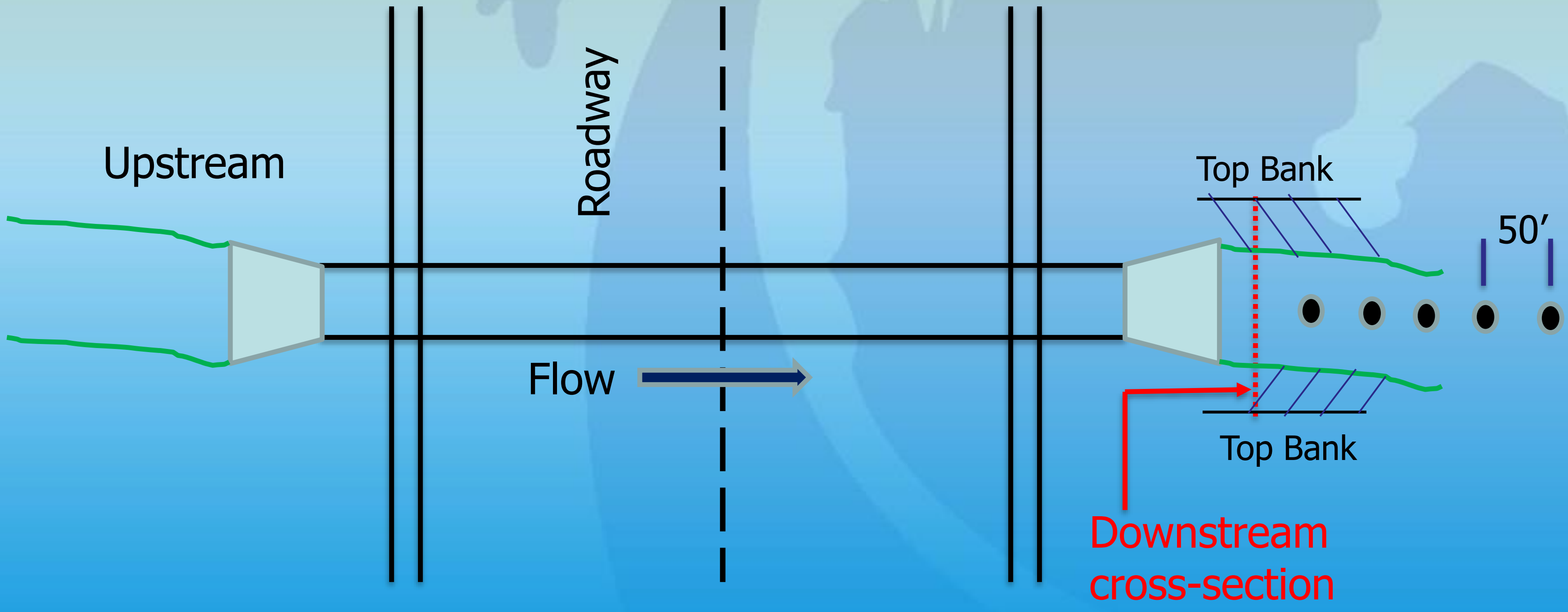
Rating curve:

- With the use of a spreadsheet critical depth (dc) is calculated over a range of discharges (Q).
- Using dc the corresponding Tailwater (TW) elevations for the range of discharges are calculated to provide a rating curve to be used in the HY-8 software.

Survey for Tailwater (HY-8)

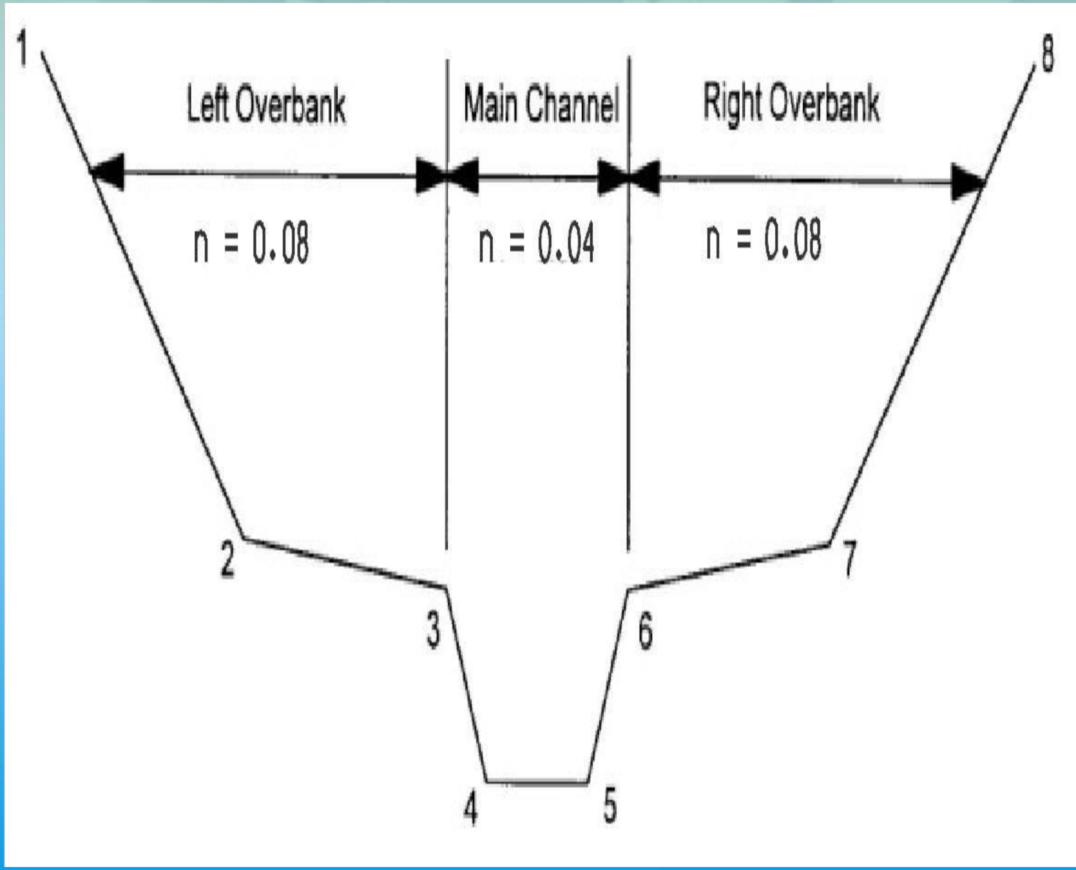
Irregular Channel: <u>Under 2 square mile survey (used in HY-8)</u>

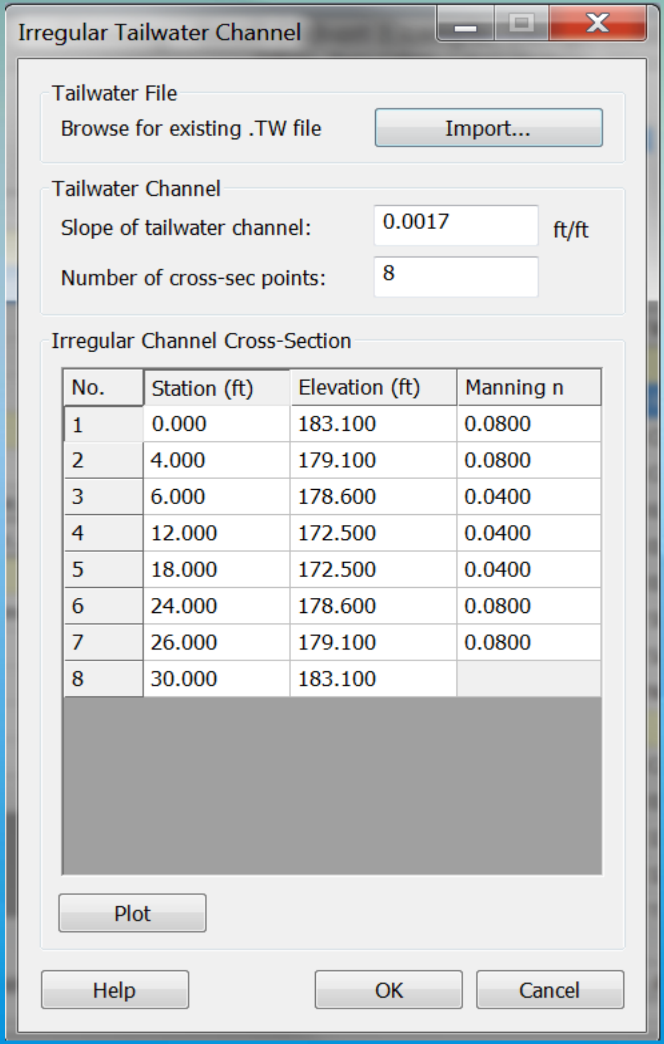
- 1 downstream cross section.
- 5 downstream water surface elevations at 50' spacing.



HY-8 Channel Configuration

Step 2A:





Irregular Tailwater Channel

Tailwater File

Browse for existing .TW file [Import...]

Tailwater Channel

Slope of tailwater channel: 0.0017 ft/ft

Number of cross-sec points: 8

Irregular Channel Cross-Section

No.	Station (ft)	Elevation (ft)	Manning n
1	0.000	183.100	0.0800
2	4.000	179.100	0.0800
3	6.000	178.600	0.0400
4	12.000	172.500	0.0400
5	18.000	172.500	0.0400
6	24.000	178.600	0.0800
7	26.000	179.100	0.0800
8	30.000	183.100	

Plot

Help OK Cancel

HY-8 Roadway Data

Constant Roadway Elevation

- **Roadway Profile Shape** is required – will be used in the event of overtopping
- **First Roadway Station** not required – cross-section front view of culvert.
- **Crest Length** is required, but if not known use 100 feet
- **Crest elevation** is required. HY-8 provides the Q at which overtopping occurs.
- **Roadway surface** is required – paved is assumed for MDOT
- **Top width** is required in the event of overtopping

ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	ft
Crest Length	100.000	ft
Crest Elevation	894.520	ft
Roadway Surface	Paved	
Top Width	48.000	ft

HY-8 optional Roadway Data

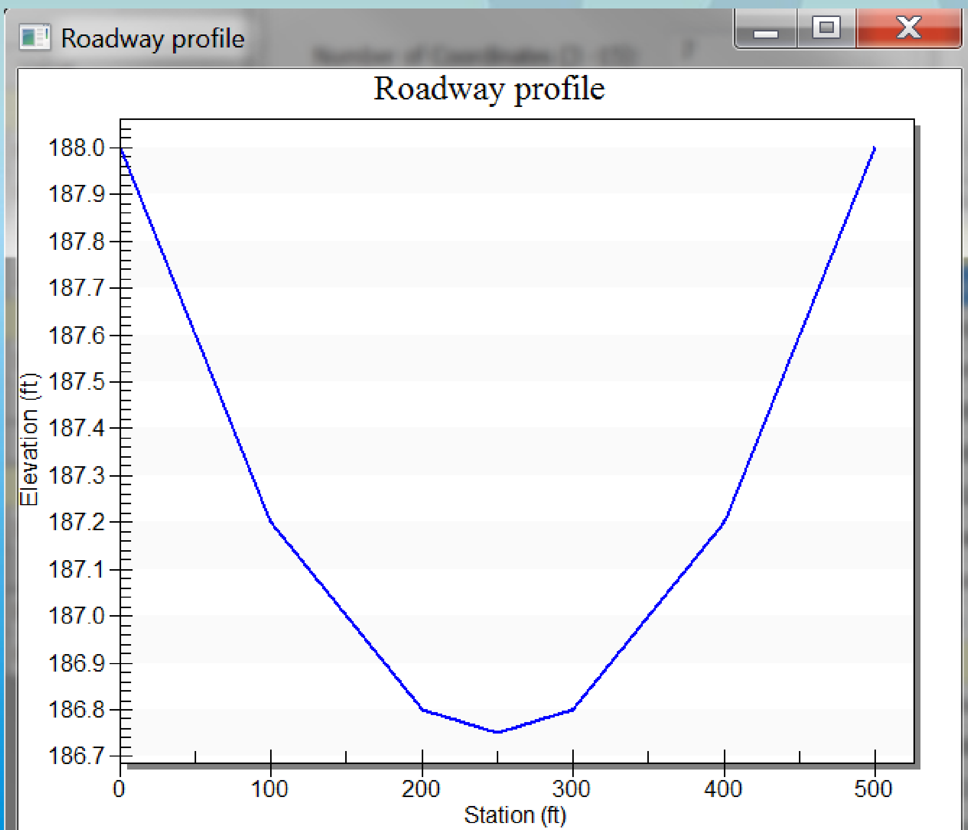
Irregular Roadway Elevation

A. Irregular is needed if weir flow may occur. **In this example we not be using *Irregular.***

B. Roadway Profile Shape: Use drop down menu and choose ***Irregular.***
C. Irregular Shape: Click Define to open the ***Irregular Roadway Shape*** form.
D. Irregular Roadway Shape form:
   - Enter number of coordinates.
   - Enter each Station and associated Elevation.
   - Click *"Plot"* and review your cross-section for any mistakes.
   - Once done click *"OK".*
E. Roadway Surface: Select *"Paved".*
F. Top Width: Enter road width = 48′.

HY-8 Irregular Roadway

ROADWAY DATA		
Roadway Profile Shape	Irregular	
Irregular Shape	Define...	
Roadway Surface	Paved	
Top Width	60.00	ft



Irregular Roadway Shape

Number of Coordinates (3 -15): 7

Number	Station (ft)	Elevation (ft)
1	0.00	188.00
2	100.00	187.20
3	200.00	186.80
4	250.00	186.75
5	300.00	186.80
6	400.00	187.20
7	500.00	188.00

Plot | OK | Cancel

Proposed Culvert Data

- Name: **Use logical name in the event of running several models.**
- Shape: **Circular**
- Material: **Concrete**.
- Diameter: **8 feet**
- Embedment Depth: **12** – note: **inches.**
- Culvert Manning's n: **0.012** (Automatically populated based on culvert material).
- Culvert bottom Manning's n: **0.035** (Assumes this value for sediment).
- Culvert Type: **Straight** (Others are for improved inlets).
- Inlet Configuration: **Square Edge with Headwall**.
- Inlet Depression: **No** (MDOT only uses conventional inlets in culvert designs, so by default the inlet depression will always be zero).

Culvert Data Input

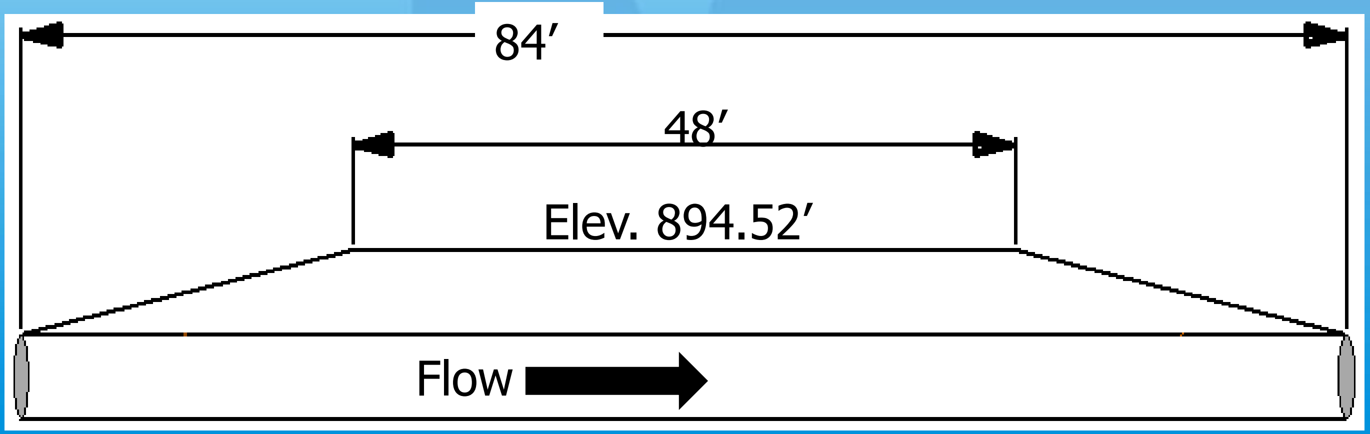
Parameter	Value	Units
CULVERT DATA		
Name	Proposed	
Shape	Circular	
Material	Concrete	
Diameter	8.000	ft
Embedment Depth	12.000	in
Manning's n (Top/Sides)	0.012	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Square Edge with Headwall	
Inlet Depression?	No	

Culvert Site Data

- Site Data Input Option: **Culvert Invert Data**
- Inlet Station: **0**
- Inlet Elevation: **878.0 feet**
- Outlet Station: **84 feet**
- Outlet Elevation: **877.0 feet**
- Number of Barrels: **1**

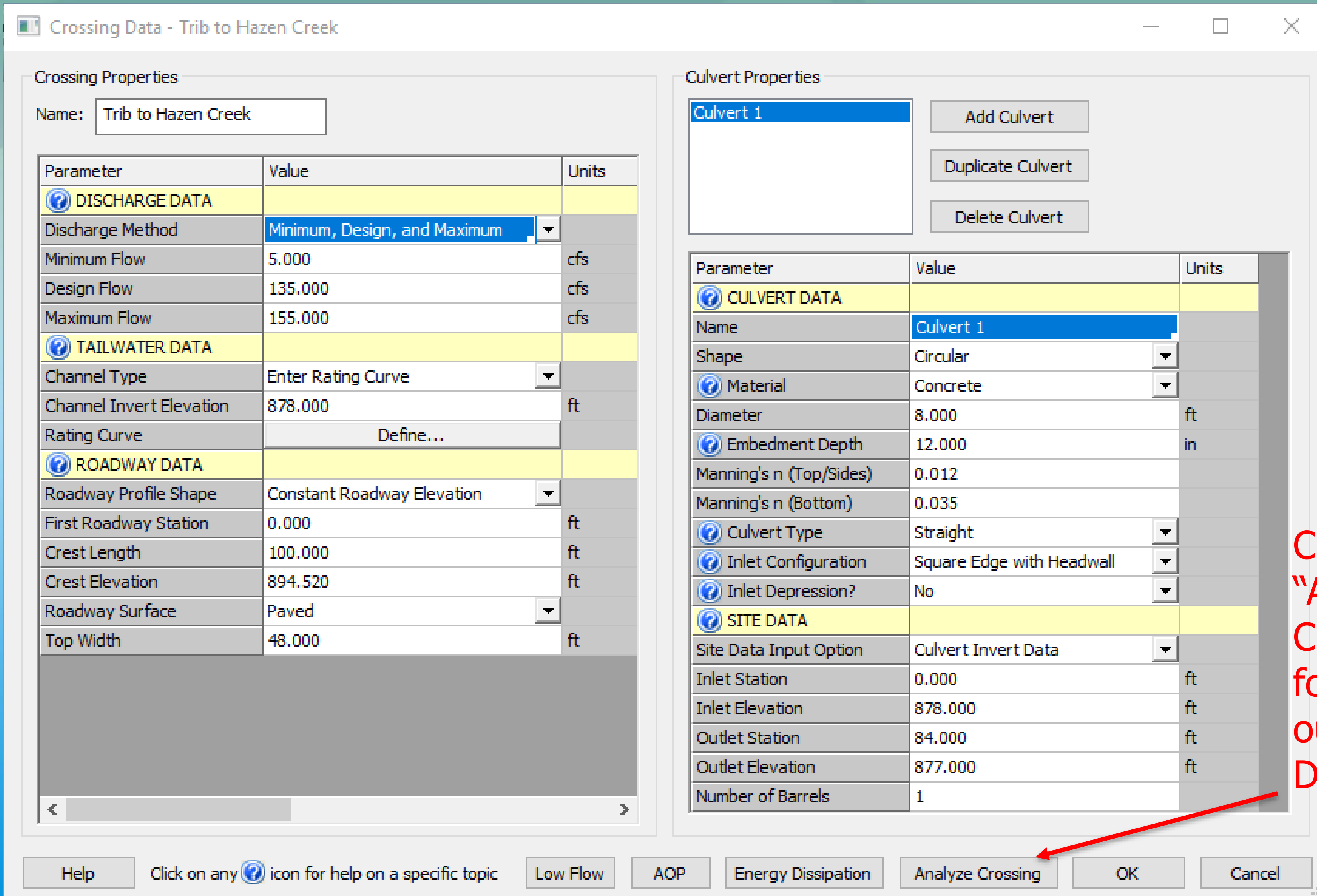
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	878.000	ft
Outlet Station	84.000	ft
Outlet Elevation	877.000	ft
Number of Barrels	1	

Sta. 0
878.0



Sta.120
877.0

Completed Crossing Data



Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Minimum, Design, and Maximum	
Minimum Flow	5.000	cfs
Design Flow	135.000	cfs
Maximum Flow	155.000	cfs
TAILWATER DATA		
Channel Type	Enter Rating Curve	
Channel Invert Elevation	878.000	ft
Rating Curve	Define...	
ROADWAY DATA		
Roadway Profile Shape	Constant Roadway Elevation	
First Roadway Station	0.000	ft
Crest Length	100.000	ft
Crest Elevation	894.520	ft
Roadway Surface	Paved	
Top Width	48.000	ft

Parameter	Value	Units
CULVERT DATA		
Name	Culvert 1	
Shape	Circular	
Material	Concrete	
Diameter	8.000	ft
Embedment Depth	12.000	in
Manning's n (Top/Sides)	0.012	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Square Edge with Headwall	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	878.000	ft
Outlet Station	84.000	ft
Outlet Elevation	877.000	ft
Number of Barrels	1	

Click "Analyze Crossing" for output Data

HY-8 Proposed Output

Summary of Flows at Crossing - Trib to Hazen Creek

Headwater Elevation (ft)	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
882.27	5.00	5.00	0.00	1
882.56	20.00	20.00	0.00	1
882.77	35.00	35.00	0.00	1
882.95	50.00	50.00	0.00	1
883.13	65.00	65.00	0.00	1
883.30	80.00	80.00	0.00	1
883.49	95.00	95.00	0.00	1
883.64	110.00	110.00	0.00	1
883.81	125.00	125.00	0.00	1
883.92	135.00	135.00	0.00	1
884.15	155.00	155.00	0.00	1
894.52	787.90	787.90	0.00	Overtopping

Display
- Crossing Summary Table (selected)
- Culvert Summary Table — Proposed
- Water Surface Profiles
- Tapered Inlet Table
- Customized Table — Options...

Geometry

Inlet Elevation:	879.00 ft
Outlet Elevation:	878.00 ft
Culvert Length:	84.01 ft
Culvert Slope:	0.0119
Inlet Crest:	0.00 ft
Inlet Throat:	0.00 ft

Outlet Control: Profiles

Plot
- Crossing Rating Curve
- Culvert Performance Curve
- Selected Water Profile
- Water Surface Profile Data

Help | Flow Types... | Edit Input Data... | Energy Dissipation... | AOP... | Low Flow... | Export Report | Adobe PDF (*.pdf) | Close

HY-8 Proposed Output

- Crossing Summary Table indicates at what Discharge the road will be overtopped (weir flow).
- For this model the road would overtop at 787.90 cfs, 5 times the 100 year flood.
- The 100 year headwater elevation is more than10’ below the highpoint of the road.
- In cases of low cover (amount of road over the culvert, overtopping may be a concern making this information of importance.

Crossing Summary Table

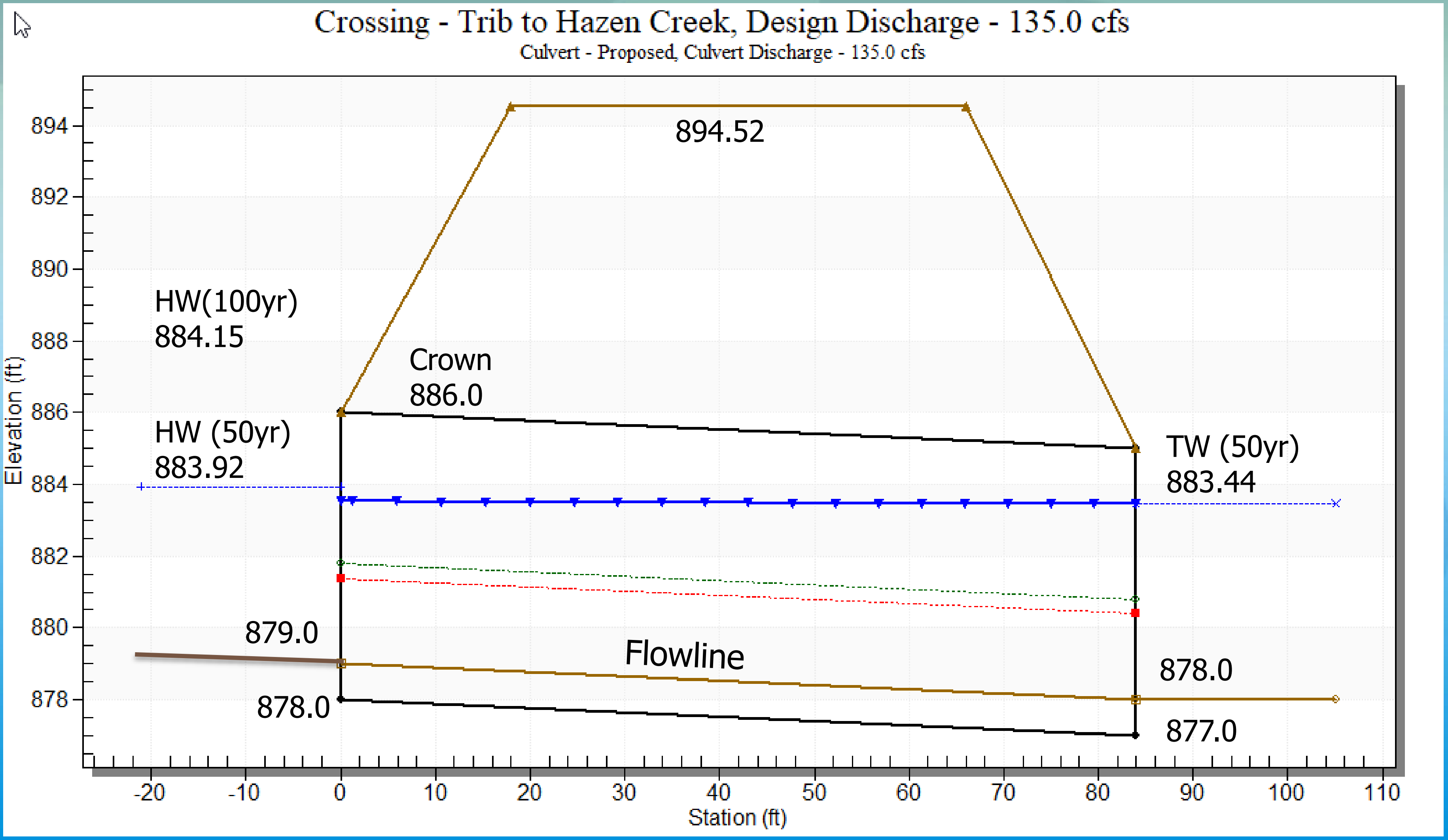
Headwater Elevation (ft)	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
882.27	5.00	5.00	0.00	1
882.56	20.00	20.00	0.00	1
882.77	35.00	35.00	0.00	1
882.95	50.00	50.00	0.00	1
883.13	65.00	65.00	0.00	1
883.30	80.00	80.00	0.00	1
883.49	95.00	95.00	0.00	1
883.64	110.00	110.00	0.00	1
883.81	125.00	125.00	0.00	1
883.92	135.00	135.00	0.00	1
884.15	155.00	155.00	0.00	1
894.52	787.90	787.90	0.00	Overtopping

HY-8 Proposed Output

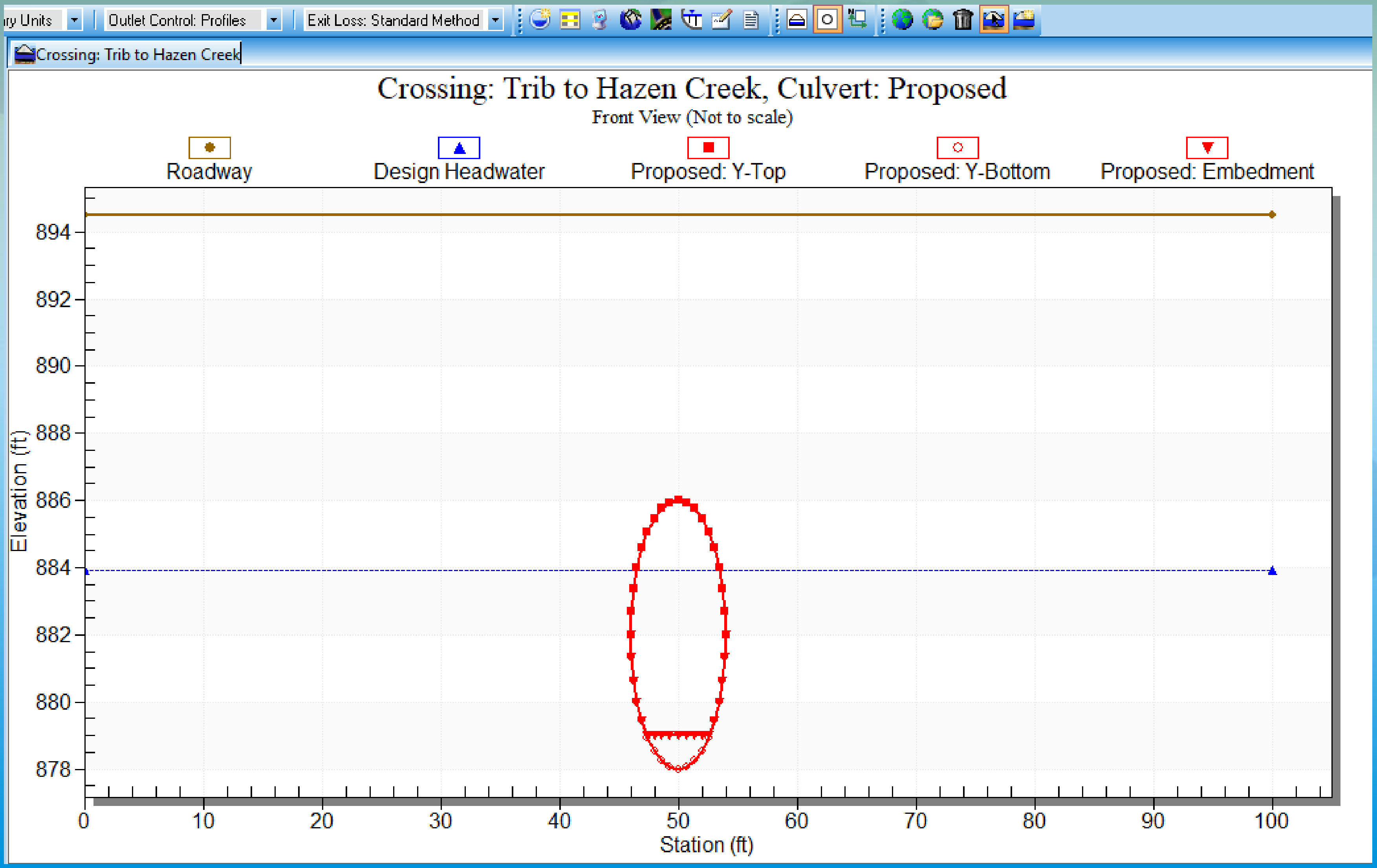
Culvert Summary Table

	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
	5.00	5.00	882.27	0.67	**3.27**	3-M1t	0.38	0.29	4.27	4.27	0.16	0.00
	20.00	20.00	882.56	0.92	**3.56**	3-M1t	0.87	0.73	4.54	4.54	0.60	0.00
	35.00	35.00	882.77	1.16	**3.77**	3-M1t	1.21	1.03	4.72	4.72	1.01	0.00
	50.00	50.00	882.95	1.39	**3.95**	3-M1t	1.50	1.29	4.86	4.86	1.40	0.00
	65.00	65.00	883.13	1.62	**4.13**	3-M1t	1.76	1.52	4.99	4.99	1.78	0.00
	80.00	80.00	883.30	1.83	**4.30**	3-M1t	2.00	1.72	5.10	5.10	2.14	0.00
	95.00	95.00	883.49	2.04	**4.49**	3-M1t	2.22	1.91	5.23	5.23	2.49	0.00
	110.00	110.00	883.64	2.24	**4.64**	3-M1t	2.44	2.10	5.30	5.30	2.84	0.00
	125.00	125.00	883.81	2.43	**4.81**	3-M1t	2.64	2.28	5.38	5.38	3.19	0.00
50yr	135.00	135.00	883.92	2.56	**4.92**	3-M1t	2.78	2.38	5.44	5.44	3.41	0.00
100yr	155.00	155.00	884.15	2.80	**5.15**	3-M1t	3.02	2.59	5.55	5.55	3.85	0.00

Proposed Culvert Profile



Proposed Culvert Front View



Software and References

- ✓HY-8 version 7.5
  - ✓https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/
- ✓Rating Curve Spreadsheets
  - ✓Circular culverts.
  - ✓Box culverts.

MDOT Design Manual 2006

Chapter 5, pg. 48.

Questions?