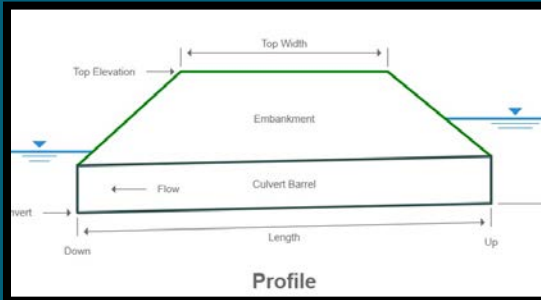


Hydraulic Modeling with HY-8



Linda Hansen PE, PWS

*MI Dept. of Environmental
Quality
Water Resources Division*

UP District Floodplain Engineer

Today's Outline

- What is HY-8?
- Best Applications & Limitations
- Input Data and Resources
- Example Project - Culvert Replacement
- Calculations & Output Considerations
- Advanced Modeling Options
- Web Resources & DEQ Contact Info



What is HY-8?

- Hydraulic computation model for roadway stream crossings (culverts)
- It is FREE
- Created & Provided Online by FHWA:
<https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/>
- Current Version is HY-8 7.50 (Build Date 7/28/16)
- It enables users to:
 - ✓ Analyze the performance of culverts (velocities, water depths, flow profiles)
 - ✓ Allows for multi-barrel crossings and multiple crossings in 1 project*
 - ✓ Analyze roadway overtopping (weir flow over road)
 - ✓ Develop report tables and graphs

Best Applications & Limitations

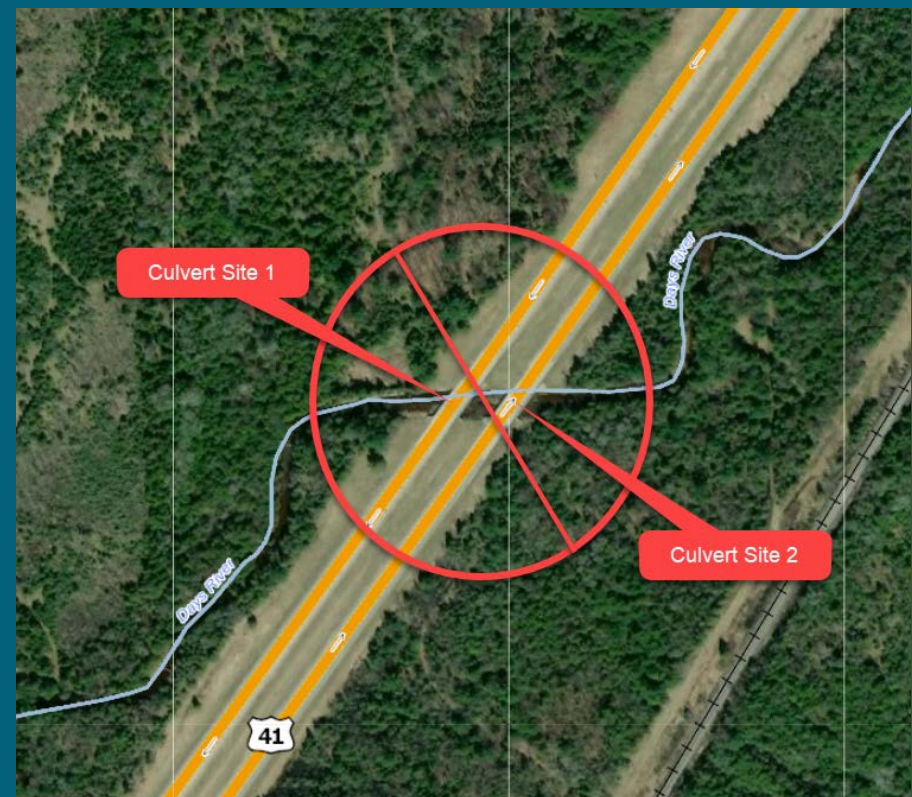
- SIMPLE & BASIC PROJECTS
 - ✓ **Single stream crossings with one or more pipes**
 - ✓ **Simple bridges (modeled as 3-sided box culvert)**
 - ✓ Not appropriate for bridges with piers
 - ✓ Where NO OTHER pipes, structures or floodplain/stream encroachments exist within the area of influence of the crossing being analyzed
 - ✓ ***CANNOT compute multiple “In-Line” pipes (Ex: N-Bound and S-Bound HWY crossings)**

Can include multiple culverts in 1 Project (i.e. 1 file) – but will not process culverts “In Line”

Yes



No



Can use HY-8 to Compare Various Culvert Designs for 1 Replacement Site

- Modify pipe cross-section designs (circular, box, ellipse, arch)
- Modify pipe elevations and inlet conditions
- Modify pipe lengths and roadway elevations
- Modify pipe materials

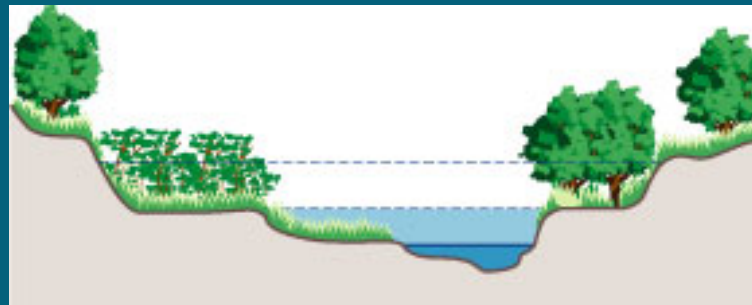


Best Applications (cont'd)

- DEQ Permit Applications
 - ✓ DEQ WRD can require hydraulic models under certain permit application situations, for Part 31 (Floodplain) review
 - ✓ HY-8 is accepted in lieu of HEC-RAS as long as culvert site is appropriate per the criteria discussed above
 - ✓ HY-8 Provides Existing and Proposed Headwater Elevations → For 100 year flow yeilds “Existing” and “Proposed” 100 yr Flood Elevations → **Are Flood Stages Increasing or Decreasing going from “Existing” to “Proposed?”**

Input Data & Resources

- Basic Data Required for Input:
 1. Flows (cfs) – 50% (2-year), 10% (10-year), 2% (50-year) 1% (100-year) and 0.2% (500-year) flows are common
 2. Tailwater Cross-section - Stations, Elevations and Mannings 'n' of Channel & Overbank/Floodplain
 3. Slope - Slope of tailwater channel (d/s of x-ing)
 4. Roadway - Shape, Surface Elevations and Surface Type
 5. Culvert Data - Type, Number, Inlet/Outlet Elevations, Length, Inlet Configuration



Input Data & Resources

➤ DEQ Flood or Low-Flow Discharge Request Site

The screenshot shows the Michigan Department of Environmental Quality (DEQ) website. The top navigation bar includes links for DEQ, Contacts, Permits, Online Services, Programs, Locations, and MI.gov. The DEQ logo and name are prominently displayed. A search bar is located in the top right. Below the navigation bar, there are tabs for ABOUT THE DEQ, AIR, LAND, WASTE, WATER, and SUSTAINABILITY. The 'WATER' tab is selected, and a sidebar on the left lists various water-related topics, with 'Water Management' highlighted. The main content area is titled 'Request a Flood or Low-Flow Discharge Form' and includes the following text:

DEQ / WATER / WATER MANAGEMENT / HYDROLOGIC DATA COLLECTION & ANALYSIS

Request a Flood or Low-Flow Discharge Form

Authorized by PA 451 of 1994. Completion of this form is voluntary.

Important:

- Please email any additional information to deq-wrd-qreq@michigan.gov with "Discharge Request" in the subject line. Our email attachment size limit is 25 MB.
- A confirmation e-mail will be sent to you. If you do not receive it, please e-mail your form information directly to deq-wrd-qreq@michigan.gov?subject=Discharge Request. You must click the Submit button at the end of the form to send the request to us and get a confirmation e-mail.

Please fill-in this form to request a flood or low flow discharge. Note that a site location map is required. You may send it by [email](#), fax it to 517-241-9003 (please note Discharge Request on the cover sheet), or mail it to:

Water Resources Division
PO Box 30458
Lansing, MI 48909-7958

If you have questions about requesting a flood discharge, please call Susi Greiner at 517-284-5579. If you have questions about requesting a low flow discharge, please call Marlio Lesmez at 517-284-5580.

Note

- Use the Tab key or the mouse to move between fields. Hitting the Enter key will immediately send the form.
- You should see a Confirmation page after you submit the form confirming your request.
- Low flow discharges are typically only needed if you are applying for an NPDES permit, a mixing zone determination, or a dam impoundment drawdown. If this is the case, please indicate your DEQ program contact person.

*** Required Fields**

Contact Information:

*E-mail Address Example: email@domain.com

Form Continues Below

Input Data & Resources

- Previously Calculated Flows: DEQ Flood Flow Database
- <http://www.deq.state.mi.us/flow/hflowqry.asp>

Not secure | www.deq.state.mi.us/flow/hflowqry.asp

DEQ Department of Environmental Quality

Joint Permit Application | DEQ Home | MiWaters | Online Services | Permits | Programs | Contact DEQ

Flood Discharge Database 11/26/2018

Home | Water Management | Lowflows | Discharge Requests | Watersheds Map

Select By: Search Results For County: Marquette

County: MARQUETTE

Watershed: Watershed

Requestor Name:

Watercourse:

Submit

Reset

Access to the Flood Flow Database is provided as a service to allow you to check the status of your flood flow requests or discharges from previous requests for preliminary design purposes. The information is provided for informational purposes only and does not constitute a permit. You must accompany your permit application.

File No.	Watercourse:	Location:	Area (mi ²)	Watershed
20100037	Alder Creek	County Road 550	4.47	Falls (Lake)
20120020	Alder Creek	County Road 550	4.47	Falls (Lake)
20130423	Barnhardt Creek	County Road CCO	14.92	Dead
20090277	Bear Creek	County Road 565	12.06	Escanaba
20000590	Beaver Farm Creek	Mouth	2.3	Dead
20010008	Beaver Farm Creek	Dirt road	2.3	Dead
20050527-2	Big Brook	County Road EAA	32.44	Escanaba
20050213	Big Creek	Karen Road	15.74	Chocolay
H-94135	Big Creek	center of section	14	Chocolay
20060335	Big Garlic River	Saux Head Lake outlet	29.63	Falls (Lake)
	Big Garlic River	KE Road	14.9	Falls (Lake)
	Big Garlic River	County Road 550	12.08	Falls (Lake)
	Big Garlic River	County Road 550	12.08	Falls (Lake)
	Big Garlic River	Driveway crossing 1720 feet upstream of south section line	0.72	Falls (Lake)
	Big Garlic River	County Road 510	0.33	Falls (Lake)
20100300	Big Pup Creek	County Road 510	5.1	Falls (Lake)
20030529	Bismark Creek	500 feet east of west section line (downstream of tribs)	1.55	Falls (Lake)
20030551	Bismark Creek	upstream of confluence in southwest 1/4 of section	1.1	Falls (Lake)
20090505-3	Black River	County Road 478	23.28	Escanaba
20170272	Black River	County Road 478	23.28	Escanaba
H-97065	Bobs Creek	Bobs Creek Truck Trail	8.9	Escanaba
20070291	Boise Creek	County Road GGA	7.79	Dead
20140417	Bruce Creek	County Road 601	3.87	Escanaba

Just enter county and listing of all previously calc'd flows comes up

Input Data & Resources

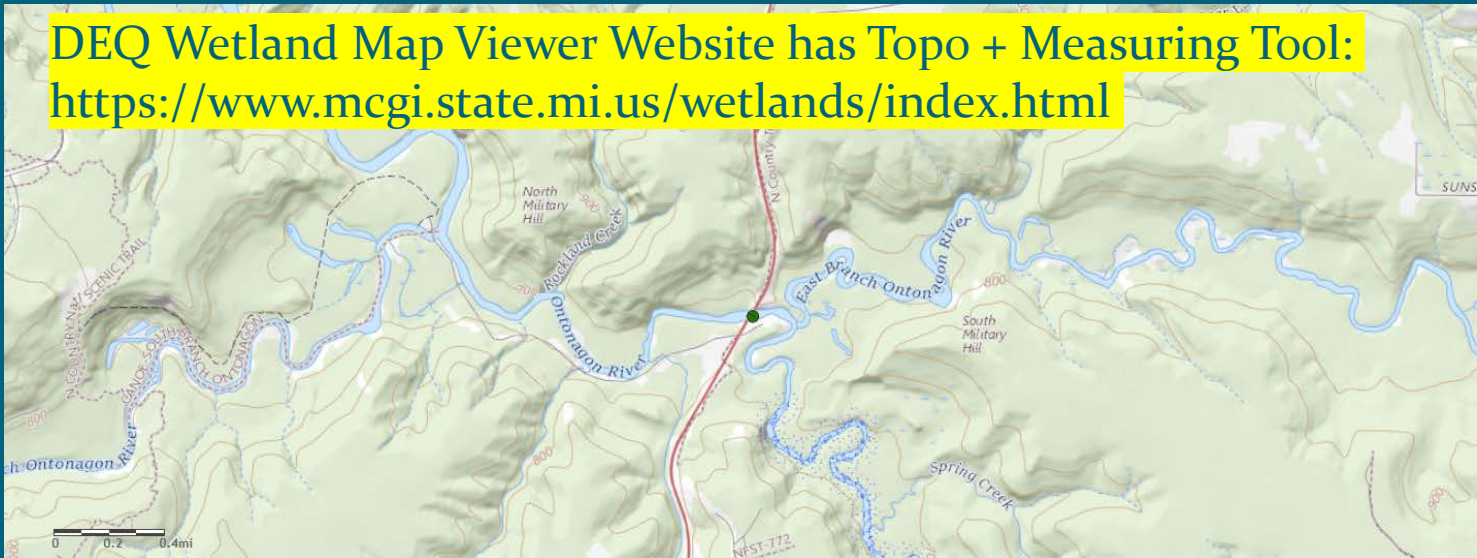
- Manning's "n" (Roughness Coefficient) for Stream Channels and Overbank Areas:
 - Several references exist for Manning's n for various stream conditions
 - "Open Channel Hydraulics", Chow 1959 is commonly used:
http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm



Input Data & Resources

- Slope of Tailwater Channel
 - Channel downstream of road crossing
 - Obtain from Survey Data (stream bottom elevations measured at riffles – not in pools)
 - Obtain from Topo Maps (measure stream channel length between known elevation contours)
 - Rise over Run

DEQ Wetland Map Viewer Website has Topo + Measuring Tool:
<https://www.mcgi.state.mi.us/wetlands/index.html>



Input Data & Resources

- Project Survey and Design Data
 - Tailwater Cross-section and Roadway Survey Data:
 - ✓ Both need to span ENTIRE floodplain of interest*
**If unsure contact local floodplain engineer for elevation estimate*
 - ✓ Stationing is Left to Right, looking downstream
 - ✓ Stationing should be consistent (referenced to same base line), Elevations referenced to local datum or BM
 - ✓ Road cover material and width
 - Existing Culvert Data
 - ✓ Material, shape & dimensions, invert and crown elevations (inlet & outlet), inlet condition, length
 - Proposed Design Data
 - ✓ Proposed Road Grade sta. + elevs., cover material and width

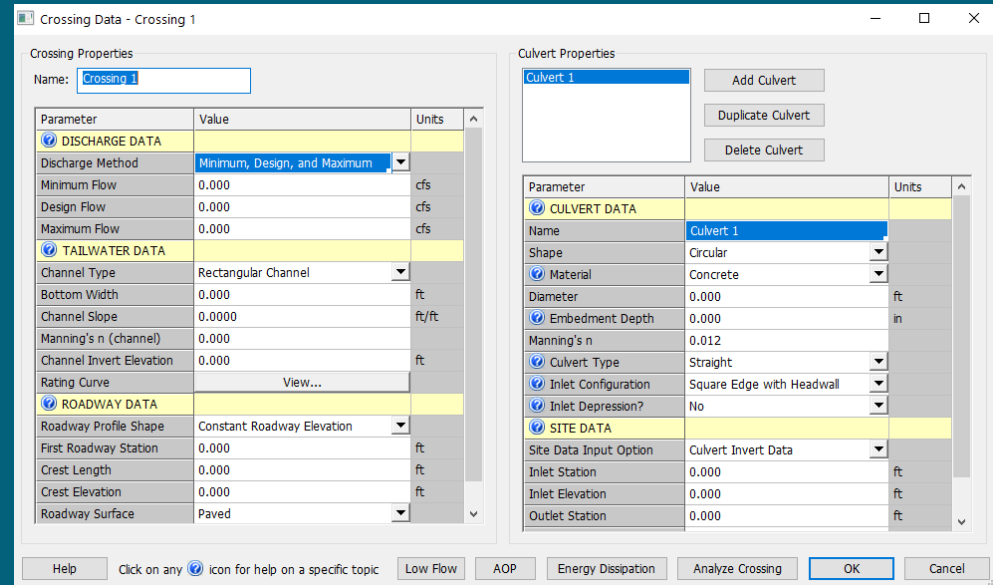
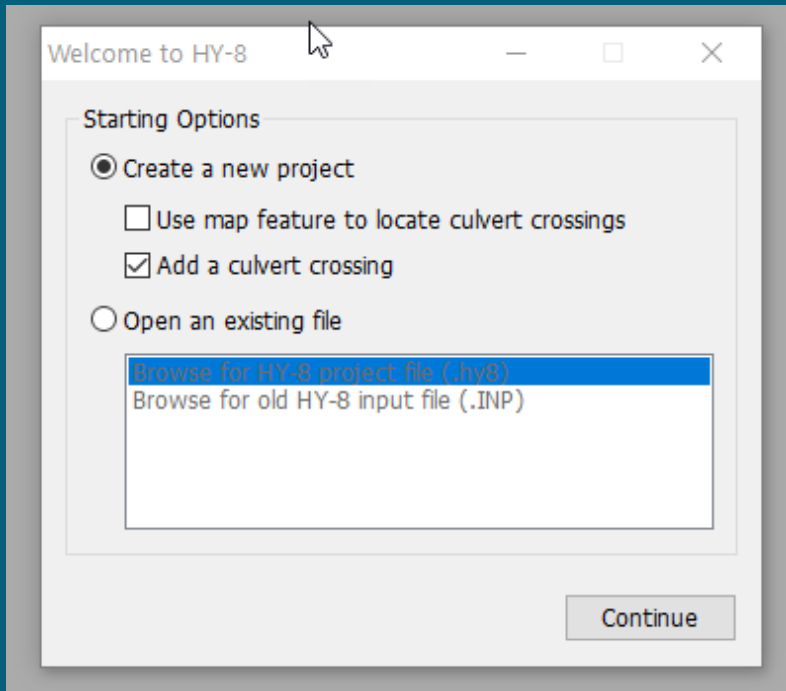
Example Project

- Remove two 4' high x 6' wide x 40' long corrugated metal ellipse culverts (projecting inlets)
 - Install one 5' high x 10' wide x 48' long reinforced concrete box culvert (headwall inlet)
 - Road is gravel and has a 30' width for both Existing and Proposed
- Run the model to ensure this design will result in the same or lower 100-year flood stage to meet Part 31 (Floodplain) requirements.

Example Project

Open new Project File:

Input Screen pops up when box is checked:




Example Project

Name Crossing & Enter Crossing Properties: Flow, Tailwater & Road Data

Crossing Properties

Name: CR 601 over Bruce Creek (dup)

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Recurrence	
Discharge List	Define...	
TAILWATER DATA		
Channel Type	Irregular Channel	
Irregular Channel	Define...	
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Irregular	
Irregular Shape	Define...	
Roadway Surface	Gravel	
Top Width	30.000	ft

Help Click on any  icon for help on a specific topic Low Flow A

Example Project

Enter Culvert Properties: Name, Shape, Material, Dimensions, Embedment Depth, Inlet Configuration, Inlet & Outlet Sta + Elevs., # of Barrels

Culvert Properties

Existing

Add Culvert

Duplicate Culvert

Delete Culvert

Parameter	Value	Units
CULVERT DATA		
Name	Existing	
Shape	User Defined	
Material	Corrugated Metal Riveted or Welded	
Coordinates	Define...	
Span	5.890	ft
Rise	4.000	ft
Embedment Depth	0.000	in
Manning's n (Top/Sides)	0.035	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Thin Edge Projecting	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	992.270	ft
Outlet Station	40.000	ft
Outlet Elevation	991.710	ft
Number of Barrels	2	

Note "User Defined" vs. Template

Stationing ALONG culvert defines length

Example Project

Create Proposed Box Culvert & Repeat

Crossing Properties

Name:

Parameter	Value	Units
DISCHARGE DATA		
Discharge Method	Recurrence	
Discharge List	Define...	
TAILWATER DATA		
Channel Type	Irregular Channel	
Irregular Channel	Define...	
Rating Curve	View...	
ROADWAY DATA		
Roadway Profile Shape	Irregular	
Irregular Shape	Define...	
Roadway Surface	Gravel	
Top Width	30.000	ft

Culvert Properties

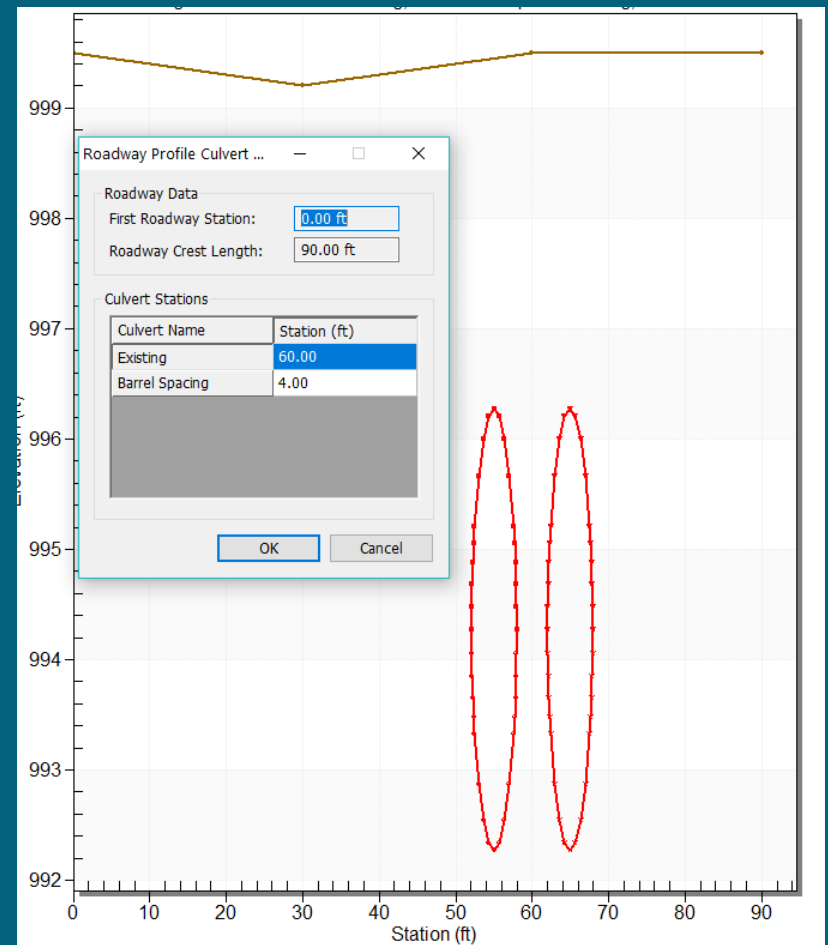
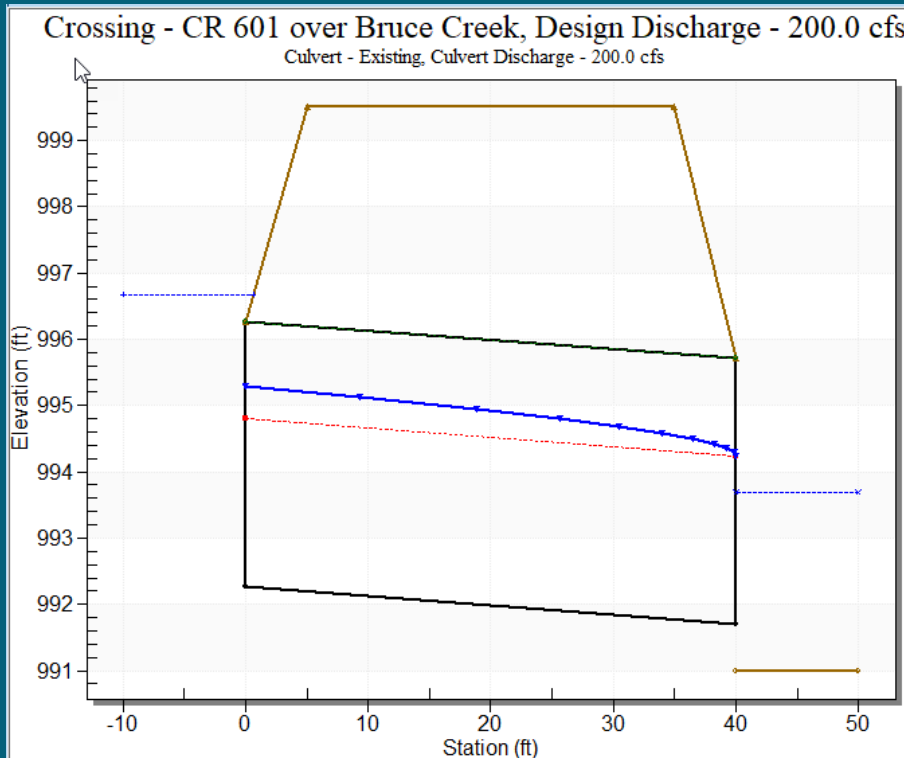
Parameter	Value	Units
CULVERT DATA		
Name	Proposed	
Shape	Concrete Box	
Material	Concrete	
Span	10.000	ft
Rise	5.000	ft
Embedment Depth	1.000	in
Manning's n (Top/Sides)	0.012	
Manning's n (Bottom)	0.035	
Culvert Type	Straight	
Inlet Configuration	Square Edge with Headwall	
Inlet Depression?	No	
SITE DATA		
Site Data Input Option	Culvert Invert Data	
Inlet Station	0.000	ft
Inlet Elevation	991.190	ft
Outlet Station	48.000	ft
Outlet Elevation	990.830	ft
Number of Barrels	1	

Template Culvert Used

Help Click on any icon for help on a specific topic Low Flow AOP Energy Dissipation Analyze Crossing

Example Project

Hit “Analyze Crossing”, View Culvert Profiles, Enter Road Station Location of Culvert(s) + View X-Section



Example Project

Review Results:

Existing 100 yr Elev. = 996.7 ft.

Summary of Flows at Crossing - CR 601 over Bruce Creek

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Existing Discharge (cfs)	Roadway Discharge (cfs)	Iterations
993.69	2 year	25.00	25.00	0.00	1
994.69	10 year	70.00	70.00	0.00	1
995.96	50 year	150.00	150.00	0.00	1
996.67	100 year	200.00	200.00	0.00	1
999.20	Overtopping	324.75	0.00	1.00	

→ **RESULT:** The project as proposed is a **hydraulic improvement** (does not increase flood stages) and can be permitted under **Part 31 (Floodplains)**

Proposed 100 yr Elev. = 995.4 ft.

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
992.72	2 year	25.00	25.00	0.00	1
993.62	10 year	70.00	70.00	0.00	1
994.75	50 year	150.00	150.00	0.00	1
995.40	100 year	200.00	200.00	0.00	1
999.20	Overtopping	516.54	0.00	1.00	

Example Project

Various Ways to View Results

Crossing Summary Table

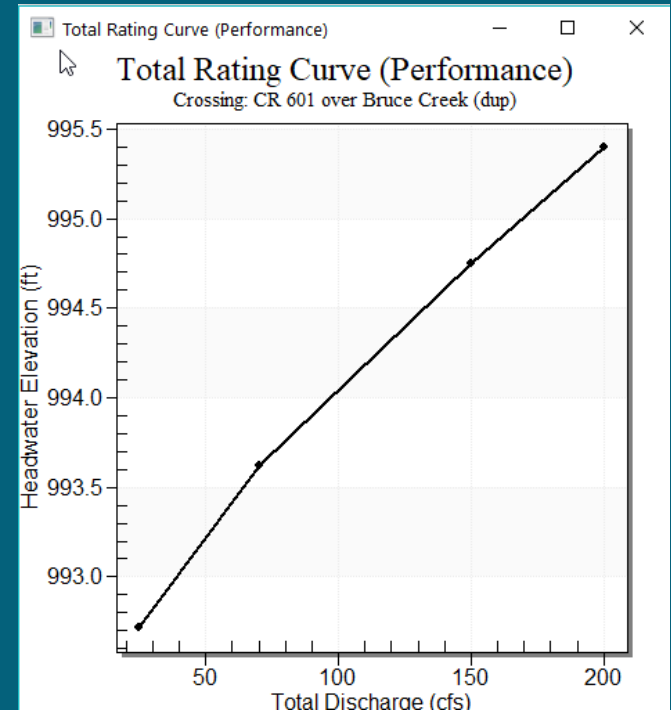
Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Proposed Discharge (cfs)	Roadway Discharge (cfs)	Iterations
992.72	2 year	25.00	25.00	0.00	1
993.62	10 year	70.00	70.00	0.00	1
994.75	50 year	150.00	150.00	0.00	1
995.40	100 year	200.00	200.00	0.00	1
999.20	Overtopping	516.54	0.00	1.00	

Water Surface Profiles

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth(ft)	Outlet Control Depth(ft)	Flow Type	Length Full (ft)	Length Free (ft)
2 year	25.00	25.00	992.72	0.83	1.36	3-M1t	0.00	48.00
10 year	70.00	70.00	993.62	1.66	2.27	3-M1t	0.00	48.00
50 year	150.00	150.00	994.75	2.74	3.39	3-M2t	0.00	48.00
100 year	200.00	200.00	995.40	3.36	4.04	3-M2t	0.00	48.00

Culvert Summary Table

Discharge Names	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)
2 year	25.00	25.00	992.72	0.83	1.36	3-M1t	0.82	0.57	1.58	1.57	1.59	4.04
10 year	70.00	70.00	993.62	1.66	2.27	3-M1t	1.60	1.16	2.19	2.19	3.20	3.65
50 year	150.00	150.00	994.75	2.74	3.39	3-M2t	2.64	1.92	2.54	2.54	5.90	3.26
100 year	200.00	200.00	995.40	3.36	4.04	3-M2t	3.13	2.32	2.69	2.68	7.44	3.28



Calculations & Output Considerations

- Water Surface Profiles are calculated using the Direct Step Method
 - Uses Manning's, Continuity Equations
 - Guesses and iterates until an answer is converged upon
 - The entered flow data, tailwater cross-section and tailwater slope (which equates to the assumed tailwater depth) are required to begin the iterations
- Weir flow (over road) is calculated using a broad-crested weir equation
 - Roadway width & surface type inputs
 - Weir and Pressure flow equations are balanced until they result in the same headwater elevation.

Calculations & Output Considerations

- HY-8 Computes Inlet Control Headwater Elevation:
 - Headwater elevation is entirely a function of inlet size, geometry and entrance condition
 - Flow passes through critical depth at the culvert entrance and is supercritical in the barrel
- HY-8 Computes Outlet Control Headwater Elevation:
 - Headwater elevation is a function of barrel size, material, geometry and tailwater condition
 - Flow in barrel is subcritical and the energy equation is used to calculate the headwater elevation
- HY-8 uses the **higher of the two answers** for the water profile solution

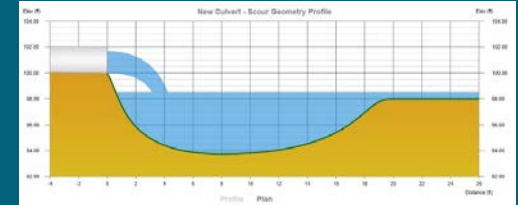
Calculations & Output Considerations

- Make sure Output Data makes sense:
 - Does it make logical sense based on your inputs?
 - How does it compare to existing data or previous on site observations?
 - Comparing between existing and proposed – do drastic changes in design result in drastic hydraulic changes? (and vice versa)
 - Multiple culverts (multi-barrel or floodplain overflow pipes) do flows compared between them make sense?
 - Weir flow over road - would it really rise that high?
 - If something looks logically wrong – **check your input data!**



Advanced Modeling Options of V. 7.50

- Energy Dissipation Evaluation
 - Estimate Scour Hole Geometry
 - Design Internal and External Energy Dissipators
- Aquatic Organism Passage (AOP) Design Calculator (FHWA HEC-26)
 - Enter hydraulic and stream morphology data and determine if the stream is stable (not aggrading or degrading) → Design culvert based on stability
 - Analysis of flows based on culvert size, alignment, material selection → Compare in-pipe Velocity with u/s and d/s Velocities
- Evaluation of Fish Passage in Large Culverts for Low Flows (FHWA-HRT-14-064)
 - Evaluates velocities across pipe x-sec



Web Resources & DEQ Contact

- HY-8 Download Page
<https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/>
- DEQ Flood Flow Database (and link to Discharge Requests)
<http://www.deq.state.mi.us/flow/hflowqry.asp>
- DEQ Wetland Map Viewer (topo, aerials with measuring tools) <https://www.mcgi.state.mi.us/wetlands/index.html>
- Manning's 'n' values
[http://www.fsl.orst.edu/geowater/FX3/help/8 Hydraulic Reference/Mannings n Tables.htm](http://www.fsl.orst.edu/geowater/FX3/help/8%20Hydraulic%20Reference/Mannings%20n%20Tables.htm)
- DEQ WRD Transportation Staff Map (Contacts Listed by County) https://www.michigan.gov/documents/deq/wrd-trans-hydraulics-staff_402907_7.pdf

Questions?

