

**FHWA HYDRAULIC ANALYSIS TOOLS**

NASECA ANNUAL CONFERENCE  
February 10, 2021

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**Other Tools and Services**

- Inlet Spacing Spreadsheet
- WisDOT SharePoint site

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**CONTACT INFORMATION**

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**Hydraulic Toolbox**

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**FHWA Tools and Services**

- Hydraulic Toolbox
- Other FHWA H&H Analysis Software
- Training Opportunities
  - Introduction to Highway Hydraulics
  - Culvert Design
  - Urban Drainage Design

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**Toolbox**

**What is it?**


- Public Domain (Free!)
- Series of Calculators Including:
  - Channel Analysis
  - Inlet Design

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**Toolbox**

### Where Can I Find it?

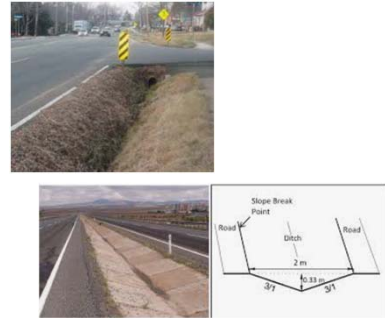
- <https://highways.dot.gov/federal-lands/hydraulics>



The screenshot shows the Federal Highway Administration website with a sidebar menu and a main content area titled 'Hydraulics'. The sidebar includes links for Home, Federal Lands & Technical Resources, Existing Federal Lands, and various technical services like Standard Specifications, Easements, Standard Drawings, CADD Support, Highway Design, Design Visualization, Construction, Materials, and Project Management. The main content area describes the role of the Federal Lands Hydraulics Team in providing technical expertise and support for hydraulic, water, and coastal highway projects.

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**Ditch and Pipe Capacity**



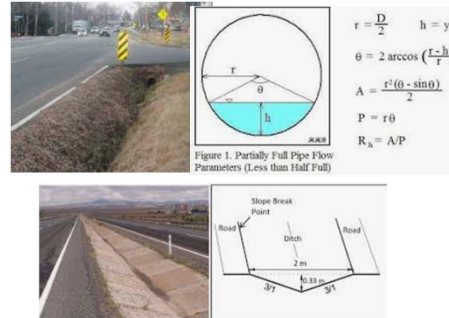
The top image is a photograph of a road ditch with yellow and black hazard markers. The bottom image is a cross-section diagram of a trapezoidal ditch. The diagram shows a ditch with a top width of 2 m, a bottom width of 0.33 m, and side slopes of 3/1. A 'Slope Break Point' is indicated at the top of the ditch.

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### Channel Analysis

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**Ditch and Pipe Capacity**



The top image is a photograph of a road ditch. The middle image is a circular pipe cross-section diagram showing a partially full pipe with radius  $r$ , water depth  $h$ , and angle  $\theta$ . The diagram includes the following equations:  

$$r = \frac{D}{2} \quad h = y$$

$$\theta = 2 \arccos \left( \frac{r-h}{r} \right)$$

$$A = \frac{r^2 (\theta - \sin \theta)}{2}$$


$$P = r \theta$$

$$R_h = A/P$$
 Figure 1. Partially Full Pipe Flow Parameters (Less than Half Full)

The bottom image is a cross-section diagram of a trapezoidal ditch, identical to the one in slide 10.

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**Ditch and Pipe Capacity**

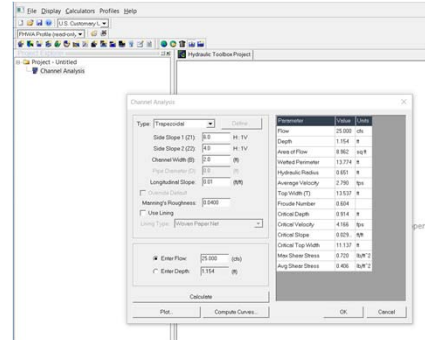


The image is a photograph of a road ditch with yellow and black hazard markers, similar to the one in slide 10.

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**Determine Capacity for:**

- Trapezoidal



The screenshot shows a software interface for channel analysis. The 'Channel analysis' window is open, displaying a table of parameters and their values. The 'Type' is set to 'Trapezoidal'. The 'Calculate' button is highlighted.

Parameter	Value	Units
Type	Trapezoidal	
Side Slope 1 (S1)	3.0	H: 1V
Side Slope 2 (S2)	3.0	H: 1V
Channel Width (B)	2.0	m
Flow Coefficient (C)	3.0	m
Longitudinal Slope	0.001	m/m
Manning's Roughness	0.040	
Use Long	Open Paper Roll	
Enter Flow	25.000	m <sup>3</sup> /s
Enter Depth	1.154	m
Flow	25.000	m <sup>3</sup> /s
Depth	1.154	m
Area	1.154	m <sup>2</sup>
Wetted Perimeter	3.272	m
Hydraulic Radius	0.353	m
Average Velocity	2.166	m/s
Top Width (T)	3.332	m
Flow Number	0.004	
Channel Depth	0.914	m
Channel Velocity	4.168	m/s
Critical Slope	0.023	m/m
Critical Top Width	11.227	m
Max Shear Stress	0.700	N/m <sup>2</sup>
Avg Shear Stress	0.400	N/m <sup>2</sup>

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Determine Capacity for:

- Trapezoidal

Easy Pull-Down Menu  
Range of geometry

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Determine Capacity for:

- Trapezoidal
- Triangular

No bottom width included

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Determine Capacity for:

- Trapezoidal

Solve for Depth with a known flow OR for flow with a known depth

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Determine Capacity for:

- Trapezoidal
- Triangular
- Rectangular

Bottom width with vertical sidewalls

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Determine Capacity for:

- Trapezoidal

Returns other hydraulic properties

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Determine Capacity for:

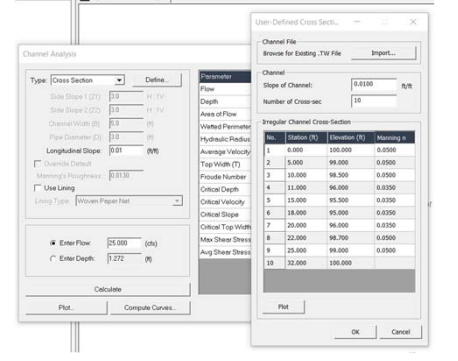
- Trapezoidal
- Triangular
- Rectangular
- Circular (pipes not flowing under pressure)

Good for sizing storm sewers for full-flow capacity and determining hydraulic properties for pipes not flowing full

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Determine Capacity for:

- Trapezoidal
- Triangular
- Rectangular
- Circular (pipes not flowing under pressure)
- Irregular Cross Sections



No.	Station (ft)	Channel (ft)	Manning
1	0.000	100.000	0.0500
2	5.000	99.000	0.0500
3	10.000	98.500	0.0500
4	11.000	96.000	0.0500
5	10.000	95.000	0.0500
6	18.000	95.000	0.0500
7	20.000	96.000	0.0500
8	22.000	98.700	0.0500
9	20.000	99.000	0.0500
10	30.000	100.000	0.0500

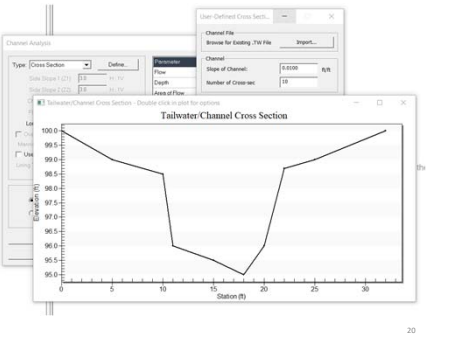
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# Channel Lining

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Determine Capacity for:

- Trapezoidal
- Triangular
- Rectangular
- Circular (pipes not flowing under pressure)
- Irregular Cross Sections



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## Channel Lining Analysis

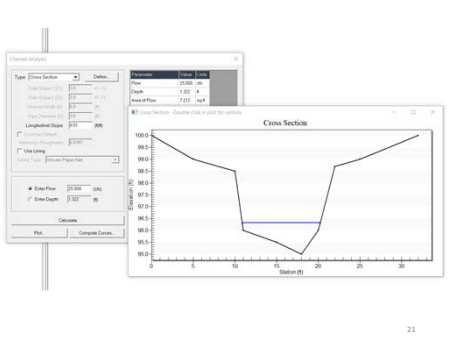
### Benefits

- Same procedure as FDM

23

Determine Capacity for:

- Trapezoidal
- Triangular
- Rectangular
- Circular (pipes not flowing under pressure)
- Irregular Cross Sections



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## Channel Lining Analysis

### Benefits

- Same procedure as FDM
- Easy to analyze different channel sections

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### Channel Lining Analysis

**Benefits**

- Same procedure as FDM
- Easy to analyze different channel sections
- All the math is done in the program

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**Lining Materials:**

- Riprap or stone
- Vegetation
- Rolled Erosion Control Products



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**Lining Materials:**

- Riprap or stone



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**Lining Materials:**

- Riprap or stone
- Vegetation
- Rolled Erosion Control Products
- Gabions



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**Lining Materials:**

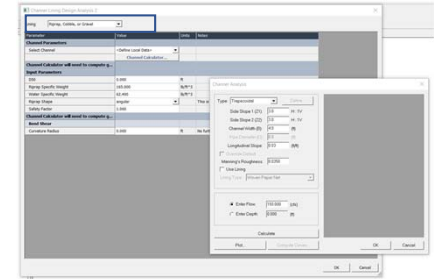
- Riprap or stone
- Vegetation



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**Process:**

- Select Lining Material



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Process:

- Select Lining Material
- Channel Analysis

Transfers results of Channel Analysis to Lining Calculator

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# Culvert Outlet Protection

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Process:

- Select Lining Material
- Channel Analysis
- Riprap Size

Estimate D50 of material. Can base on standard distributions in FDM/Standard Bid Items

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Is outlet protection required?

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Process:

- Select Lining Material
- Channel Analysis
- Riprap Example
- Compute

Channel is stable for this flow and geometry. May wish to iterate solution for smaller riprap

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Is outlet protection required?

What size of stone?

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Is outlet protection required?

What size of stone?

Dimension of pad?

PLAN VIEW  
CULVERT WITHOUT STANDARD END SECTION

SECTION B-B

Original ground  
Variable slope  
Geotextile

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Process:

- Define Channel Geometry
- Edit Culvert Data
- Review Results

Calculator returns the riprap classification required and the dimension of the apron at the culvert outfall

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Process:

- Define Channel Geometry

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## Gradation Analysis

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Process:

- Define Channel Geometry
- Edit Culvert Data

This data is obtained from HY-8 or other culvert analysis program

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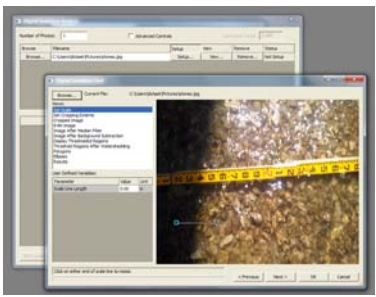
## Gradation Analysis

- Upload Photo(s)

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### Gradation Analysis

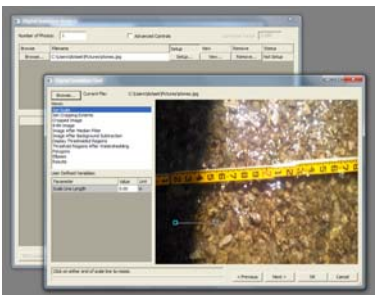
- Upload Photo(s)
- Requires scale or scalable object



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### Gradation Analysis


- Upload Photo(s)
- Requires scale or scalable object
- Channel substrate
- Material delivered to site
- Follow prompts to complete computations



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### Gradation Analysis

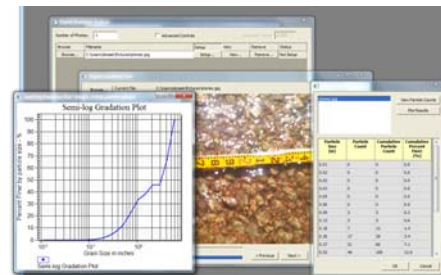
- Upload Photo(s)
- Requires scale or scalable object
- Channel substrate



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### Gradation Results

Results include particle size distribution



Grain Size (mm)	Percent Finer (%)
75	10
150	25
300	45
600	75
1200	95
2500	100

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### Gradation Analysis

- Upload Photo(s)
- Requires scale or scalable object
- Channel substrate
- Material delivered to site



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### Curb and Gutter Analysis

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Curb and Gutter Analysis

Inlet Sizing



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Curb and Gutter Analysis

Benefits

- Easy to calculate encroachment

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Curb and Gutter Analysis

Inlet Sizing




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Curb and Gutter Analysis

Benefits

- Easy to calculate encroachment
- Evaluates depth at curb

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Curb and Gutter Analysis

Inlet Sizing





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Curb and Gutter Analysis

Benefits

- Easy to calculate encroachment
- Evaluates depth at curb
- Allows for different transverse slopes between roadway and gutter

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Curb and Gutter Analysis

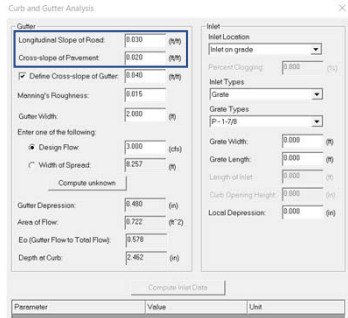
### Benefits

- Easy to calculate encroachment
- Evaluates depth at curb
- Allows for different transverse slopes between roadway and gutter
- Great for calculating inlet sizing at sags and curb opening inlets (rare in Wisconsin)

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Curb and Gutter Process:

- Roadway Geometry



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Curb and Gutter Analysis  
  
 Inlet Sizing

### Benefits

- Easy to calculate encroachment
- Evaluates depth at curb
- Allows for different transverse slopes between roadway and gutter
- Great for calculating inlet sizing at sags and curb opening inlets (rare in Wisconsin)

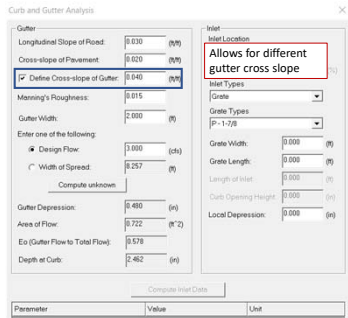
### Drawbacks

- Inlets on grade
  - Doesn't use Neenah inlets

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Curb and Gutter Process:

- Roadway Geometry



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Curb and Gutter Analysis  
  
 Inlet Sizing

### Benefits

- Easy to calculate encroachment
- Evaluates depth at curb
- Allows for different transverse slopes between roadway and gutter
- Great for calculating inlet sizing at sags and curb opening inlets (rare in Wisconsin)

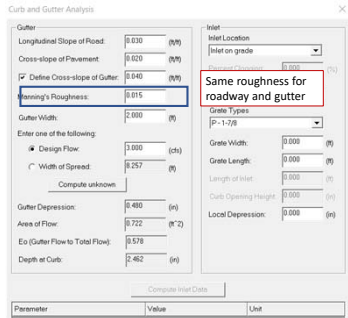
### Drawbacks

- Inlets on grade and in sag
  - Doesn't use Neenah inlets
  - Uses FHWA inlets and methodology

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Curb and Gutter Process:

- Roadway Geometry
- Gutter Geometry
- Roughness



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**Curb and Gutter Process:**

- Roadway Geometry
- Gutter Geometry
- Roughness
- Compute

Can compute for either flow or width of spread (encroachment)

61

**Inlets in Sag Process:**

- Roadway Geometry
- Gutter Geometry
- Roughness
- Compute
- Results

Returns depth at curb and width of spread for a known flow

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**Curb and Gutter Process:**

- Roadway Geometry
- Gutter Geometry
- Roughness
- Compute

Can compute for either flow or width of spread (encroachment)

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### Inlet Spacing

Why don't we use the Hydraulic Toolbox?

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**Curb and Gutter Process:**

- Roadway Geometry
- Gutter Geometry
- Roughness
- Compute
- Results

Returns depth at curb and width of spread for a known flow

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## WisDOT Inlet Spacing Spreadsheet

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### Wisconsin Doesn't Use "FHWA" Inlets

Figure 6-2. P-20 and P-20 x 100 grate (P-20 to this grate without Street (ST) transverse ribs)

Figure 6-3. P-20 grate

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### Neenah Foundry

13th EDITION  
CATALOG

NEENAH

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### Other Typical FHWA Inlet Types

Found in FHWA HEC-22

Figure 6-7. Standard grate

Figure 6-8. Rectangular grate

Figure 6-9. Rectangular grate

Figure 6-10. Rectangular grate

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### Neenah Foundry

13th EDITION  
CATALOG

NEENAH

INLET GRATE CAPACITIES  
FOR GUTTER FLOW  
and  
PONDED WATER

NEENAH

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### FHWA Methodology

- Capacity determined by:
  - Amount of flow intercepted
  - Amount of flow bypassing
- Interception depends on:
  - Flow in the gutter section
  - Size and configuration of the grate
  - Flow velocity

INTERCEPTION BY GRATE INLET

Side flow

Frontal flow

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### WisDOT SDDs Correspond to Neenah Catalog Items

SAC sheet - Inlet Covers Type A, H, A.S., H.S. & Z

GENERAL NOTES

TYPE 'A'

TYPE 'H'

TYPE 'A.S.'

TYPE 'H.S.'

TYPE 'Z'

LEAD DETAIL

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### Grate Testing

Empirical testing developed inlet capacity curves

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### Capacity Curves and Equations

- Developed for each inlet to be used on grade
- R<sup>2</sup> value of > 0.99 for each equation
- K values plotted as a function of cross slope for six longitudinal slopes
- Interpolated values for 3% and 5% slopes

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### Testing Developed Efficiency Curves

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### Spreadsheet Details

- Available on WisDOT SharePoint:
- <https://wigov.sharepoint.com/sites/dot-dtsd/bpd/drainage/SitePages/Home.aspx>

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### WisDOT Spreadsheet for Neenah Inlets

Station	Change Area	Slope	Inlet	Slope	T <sub>s</sub>	Q	Long Slope S <sub>L</sub>	Sloped Cross Slope S <sub>C</sub>	Gutter Width	Gutter Depth	Flow Area	Flow Velocity	Total Flow	Total Capacity	Type
10	1.0	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.40	0.01	18	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Performs calculations and documents design for project files

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### Spreadsheet Details

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- Moving to Box for easier access

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Inlet Spacing in a Sag

Use spreadsheet to calculate

- Weir Flow
- Orifice Flow
- Minimum Controls

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- Spreadsheet includes detailed instructions and inlet capacity curves

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Other Resources

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- Spreadsheet includes detailed instructions and inlet capacity curves
- Reviewed by Neenah product engineers

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NHI

FHWA NHI Training

- Online Courses  
<https://www.nhi.fhwa.dot.gov/home.aspx>

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NHI	FHWA NHI Training
	<ul style="list-style-type: none"> <li>• Online Courses  <a href="https://www.nhi.fhwa.dot.gov/home.aspx">https://www.nhi.fhwa.dot.gov/home.aspx</a></li> <li>• Culvert Design</li> </ul>

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HY-8	Other FHWA Tools
	<p>Culvert Design</p> <ul style="list-style-type: none"> <li>• Free!</li> </ul>

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NHI	FHWA NHI Training
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HY-8	Other FHWA Tools
	<p>Culvert Design</p> <ul style="list-style-type: none"> <li>• Free!</li> <li>• Standard software incorporated into other tools</li> </ul>

89

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HY-8	Other FHWA Tools
	<p>Culvert Design</p> <ul style="list-style-type: none"> <li>• Free!</li> <li>• Standard software incorporated into other tools</li> <li>• Energy dissipation design</li> </ul>

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**HY-8**

Other FHWA Tools

Culvert Design

- Free!
- Standard software incorporated into other tools
- Energy dissipation design
- Aquatic Organism Passage consideration

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**WisDOT**

Drainage Design SharePoint

- NOAA Atlas 14 IDF Curves
- Previous Presentations
- Neenah Inlet Capacity Publication

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**WisDOT**

Drainage Design SharePoint

- NOAA Atlas 14 IDF Curves

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**WisDOT**

Drainage Design SharePoint

- NOAA Atlas 14 IDF Curves
- Previous Presentations
- Neenah Inlet Capacity Publication
- Inlet Spreadsheet Tool

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