H&H Methods

- What is the difference between Hydraulics and Hydrology?
- What are the different methods used by WSDOT to calculate flow?
- What tools and software models does WSDOT require for Hydraulic and Stormwater design on WSDOT projects?
- How do I design:
  - a roadway culvert?
  - a roadway ditch?
  - a pipe network including inlet/Catch Basin/Manhole spacing?
H&H Methods

What’s the difference between Hydraulics and Hydrology anyways?

**Hydrology** - The study or science of transforming rainfall amount into quantity of runoff.

**Hydraulics** – The study or science of the motion of liquids in relation to disciplines such as fluid mechanics and fluid dynamics.

It rains and roadway surface runoff flows into the roadway ditch = hydrology

Determining the water level in the ditch and how fast the water is moving = hydraulics
Hydrology Methods:

Flow rates can be determined using:

- Santa Barbara Urban Hydrograph Method (SBUH)
- Continuous Simulation Method (western WA for stormwater design)
- United States Geological Survey (USGS) Regression Equations (StreamStats)
- USGS Streamflow Gages - Published Flow Records
- Rational Formula
- FEMA Flood Studies
- Documented Testimony – used to back up assumptions
Hydraulic Software/Tools

We take flow rates from the *hydrology methods* and use the following tools for *hydraulic calculations*:

- **StormShed3G** – conveyance (storm sewer, culvert, pipe, and ditch) design statewide and stormwater BMP design in eastern WA
- **MGSFlood** - stormwater Best Management Practice (BMP) design and temporary construction stream bypass design in western WA
- **FHWA HY-8** – culvert design
- **HEC-RAS** (one dimensional) and **SRH2D** (two dimensional) flow modeling to determine water surface profiles, scour design, fish passage design
- **WSDOT inlet spacing and sag inlet spreadsheets**
- **WSDOT pipe sizing spreadsheet** using Manning’s equation
We want to design a culvert.

We use this software for design and sizing the culvert.

We use this to develop the flow rate to the culvert.

### Design Frequency for Hydraulic Structures

**Figure 1-4**
One Stop Shopping!

MGSFlood (western WA only) and StormShed3G (statewide) are hydraulic models that also develop hydrology for the basin of interest.

MGSFlood is used for stormwater BMP sizing in western WA only.

StormShed3G is used for conveyance design statewide.

StormShed3G is used for stormwater BMP sizing in eastern WA only.
MGSFlood

Here’s what you will need to run the model for stormwater BMP design:

- Precipitation for your project area using mean annual precipitation maps or latitude and longitude coordinates
- Drainage basin sizes and land covers for predeveloped and post developed condition
  - Forest, Pasture, Grass, Saturated Soils, Impervious
  - Use MGSFlood Inputs Spreadsheet on HRM Revisions webpage
- Set up Basin to BMP links
- Use MGSFlood to size your BMP
- Use MGSFlood to design a temporary construction stream bypass when doing a fish passage or culvert replacement project.
MGSFlood

Predeveloped and Postdeveloped Scenarios = input basin and structure data and link data together

Simulate Tab is where MGSFlood runs the simulation for developing hydrology and sizing

Project Location and Scenario Tabs require different data
Here’s what you will need to run the model for conveyance design:

- Precipitation for your project area using isopluvial maps
- Drainage basin sizes and land covers
  - Curve Numbers (CN) represent forest (CN= 70) to impervious land covers (CN = 98)
  - Time of concentration needs to be developed using sheet, shallow, and channelized flow inputs
- Pipe and/or ditch locations, elevations, and geometry to lay out conveyance network
- Define any downstream tail water conditions

There are StormShed3G classes that walk though detailed analysis method and examples
**StormShed3G**

**Layout = where we link data together**

**DATA TREE = where we input information – CB/MH/PIPE/Ditch/Basin Information**

**Nodes = CB/MH/GI**

**Reach = Pipe/Ditch**
H&H Methods

Rain on Snow Design

Snow Water Equivalent = \frac{\text{Average Snow Depth (max. month (in/day))}}{5}

- Snow Depth Chart ([WRCC Data](#))
- Average Snow Depth > 2 inches/day
- Equation
- Max of 1.5 inches
- Additional considerations (Roadside drainage, retention ponds, frozen ground)
Hydrology: Rational Method

RATIONAL METHOD FUN FACTS FOR WSDOT DESIGNS

• Generally overestimates flow rates but requires minimal input
• Is suitable for new facility designs since it incorporates a level of safety into the design
• May not be suitable for determining the existing condition or existing capacity of hydraulic structure
Hydrology: Rational Method

\[ Q = \frac{CIA}{K_c} \]

Where:
- \( Q \) = runoff in cubic feet per second (cubic meters per second)
- \( C \) = runoff coefficient in dimensionless units
- \( I \) = rainfall intensity in inches per hour (millimeters per hour)
- \( A \) = drainage area in acres (hectares)
- \( K_c \) = conversion factor of 1 for English (360 for Metric units)

- **Limitations**
- \( C \) for different return intervals (Figure 2-5.2 applicable for 10-year frequency)
  - Increase \( C \) by 10% for 25-year frequency
  - Increase \( C \) by 20% for 50-year frequency
  - Increase \( C \) by 25% for 100-year frequency
Hydrology: Rational Method

Rainfall Intensity

\[ I = \frac{m}{(T_c)^n} \]

Where:
- \( I \) = rainfall intensity in inches per hour (millimeters per hour)
- \( T_c \) = time of concentration in minutes
- \( m \) & \( n \) = coefficients in dimensionless units (Figures 2-5.4A and 2-5.4B)

- \( m \) and \( n \) (HM Figure 2-5.4A)
- Coefficient assumptions
Hydrology: Rational Method

Time of Concentration - $T_c$

$$T_t = \frac{L}{K\sqrt{S}} = \frac{L^{1.5}}{K\sqrt{\Delta H}}$$

$$T_c = T_{t1} + T_{t2} + ... + T_{tnz}$$

Where:
- $T_t$ = travel time of flow segment in minutes
- $T_c$ = time of concentration in minutes
- $L$ = length of segment in feet (meters)
- $\Delta H$ = elevation change across segment in feet (meters)
- $K$ = ground cover coefficient in feet (meters)
- $S$ = slope of segment $\frac{\Delta H}{L}$ in feet per feet (meter per meter)

- $K$ (Figure 2-5.3)
- $T_c = 5$ minute minimum
Hydrology: Rational Method

Rational Method Spreadsheet

http://www.wsdot.wa.gov/Design/Hydraulics/ProgramDownloads.htm

<table>
<thead>
<tr>
<th>Description of Area</th>
<th>MRI</th>
<th>L</th>
<th>S</th>
<th>K</th>
<th>T&lt;sub&gt;r&lt;/sub&gt;</th>
<th>Rainfall Coefficients</th>
<th>K&lt;sub&gt;e&lt;/sub&gt;</th>
<th>C</th>
<th>I</th>
<th>A</th>
<th>Q</th>
</tr>
</thead>
</table>
USGS Regression Equations (StreamStats)

- Used for large rural or non-urban basins to develop flows for fish passage design and culvert design
- StreamStats Web Application - Uses USGS Regression Equations to develop flow rates at a certain point
  - Point and click and StreamStats gives basin information, flow rates, drainage area, etc.
- New regression equations and new 2 versions of StreamStats available
**Low-Flow Statistics Parameters**

<table>
<thead>
<tr>
<th>Parameter Code</th>
<th>Parameter Name</th>
<th>Value</th>
<th>Units</th>
<th>Min Limit</th>
<th>Max Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRRNARE</td>
<td>Drainage Area</td>
<td>2.32</td>
<td>square miles</td>
<td>0.1</td>
<td>46.9</td>
</tr>
<tr>
<td>PRECIP</td>
<td>Mean Annual Precipitation</td>
<td>79.9</td>
<td>inches</td>
<td>25.1</td>
<td>143</td>
</tr>
</tbody>
</table>

**Low-Flow Statistics Flow Report**


<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Unit</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Day 10 Year Low Flow</td>
<td>0.497</td>
<td>ft³/s</td>
<td>114</td>
</tr>
</tbody>
</table>

**Low-Flow Statistics Citations**

HY-8

• Developed by FHWA
• Based on FHWA’s Hydraulic Design Series (HDS) 5 and Hydraulic Engineering Circular (HEC) 14
• Preferred method for culvert design
• Multiple culverts
HY-8

Crossing - Resort Creek Bypass, Design Discharge - 270.0 cfs

Culvert - Culvert 2, Culvert Discharge - 270.0 cfs

Crossing Properties

Name: Resort Creek Bypass

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Method</td>
<td>Minimum, Design, and Maximum</td>
<td></td>
</tr>
<tr>
<td>Minimum Flow</td>
<td>0.00</td>
<td>cfs</td>
</tr>
<tr>
<td>Design Flow</td>
<td>270.0</td>
<td>cfs</td>
</tr>
<tr>
<td>Maximum Flow</td>
<td>500.0</td>
<td>cfs</td>
</tr>
</tbody>
</table>

Tailwater Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel Type</td>
<td>Enter Constant Tailwater Elevation</td>
</tr>
<tr>
<td>Channel Invert Elevation</td>
<td>2490.84</td>
</tr>
<tr>
<td>Constant Tailwater Elevation</td>
<td>0.00</td>
</tr>
<tr>
<td>Rating Curve</td>
<td>View....</td>
</tr>
</tbody>
</table>

Roadway Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Profile Shape</td>
<td>Constant Roadway Elevation</td>
</tr>
<tr>
<td>First Roadway Station</td>
<td>0.00</td>
</tr>
<tr>
<td>Crest Length</td>
<td>300.0</td>
</tr>
<tr>
<td>Crest Elevation</td>
<td>2530.0</td>
</tr>
<tr>
<td>Roadway Surface</td>
<td>Paved</td>
</tr>
<tr>
<td>Top Width</td>
<td>125.0</td>
</tr>
</tbody>
</table>

Culvert Properties

Name: Culvert 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Circular</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Smooth HDPE</td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>4.00</td>
<td>ft</td>
</tr>
<tr>
<td>Embedment Depth</td>
<td>0.00</td>
<td>in</td>
</tr>
<tr>
<td>Manning's n</td>
<td>0.0090</td>
<td></td>
</tr>
<tr>
<td>Culvert Type</td>
<td>Straight</td>
<td></td>
</tr>
<tr>
<td>Inlet Configuration</td>
<td>Beveled Edge (1.5:1)</td>
<td></td>
</tr>
<tr>
<td>Inlet Depression?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>SITE DATA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site Data Input Option</td>
<td>Culvert Invert Data</td>
<td></td>
</tr>
<tr>
<td>Inlet Station</td>
<td>0.00</td>
<td>ft</td>
</tr>
<tr>
<td>Inlet Elevation</td>
<td>2502.73</td>
<td>ft</td>
</tr>
<tr>
<td>Outlet Station</td>
<td>308.00</td>
<td>ft</td>
</tr>
<tr>
<td>Outlet Elevation</td>
<td>2490.84</td>
<td>ft</td>
</tr>
</tbody>
</table>

Help: Click on any checkmark icon for help on a specific topic.
WSDOT Hydraulic Spreadsheets

- Most use Rational Method and Manning’s Equation for sizing
  - Culvert Corrosion/Pipe Angle Calculation Worksheet
  - Storm Drain Design
  - Inlet Spacing and Sag Design
  - Short Duration Rainfall Depth Converter
  - Pond Hydraulics (orifice, wet pond, volume)
  - Biofiltration Swale (basic, wet, continuous)
  - CAVFS LID Calculator
  - MFD Underdrain
  - Slotted Pipe Flow Spreader

http://www.wsdot.wa.gov/Design/Hydraulics/ProgramDownloads.htm
Inlet Spacing (Curb and Gutter)

- Rational Method flows
  - Design Frequency (10 year vs 50 year)
  - Coefficient (m, n, and C values)
- Inlet sizes
- Allowable spread width $Z_d$
- Inlet Spacing Spreadsheet
- Sag Inlet Worksheet
# Inlet Spacing (Curb and Gutter)

## Inlet Spacing Spreadsheet

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W |
|   |   |   |   |   |   | INLET SPACING - CURB AND GUTTER SPREADSHEET (ENGLISH UNITS) |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Qc | Qs | m | n | Allowable |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 5.60 | 0.40 | 2.34 | 5.62 | 0.53 | 10.50 |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

<table>
<thead>
<tr>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>Distance</td>
<td>Widths</td>
<td>S L</td>
<td>Z G</td>
<td>Step-L</td>
<td>Super</td>
<td>G.M.</td>
<td>Q L</td>
<td>d</td>
<td>Z c</td>
<td>Q c</td>
<td>F c</td>
<td>F L</td>
<td>F c</td>
<td>Q c</td>
<td>Q c</td>
<td>Z c Check</td>
<td>V w Check</td>
<td>Q w Check</td>
<td>Comments (IAR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>50.00</td>
<td>0.25</td>
<td>0.25</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>6.60</td>
<td>0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>55.00</td>
<td>0.25</td>
<td>0.25</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.40</td>
<td>0.80</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Qc**: Curb Inlet Diameter
- **Qs**: Storm Sewer Diameter
- **m**: Curb Inlet Slope
- **n**: Storm Sewer Slope
- **Allowable**: Allowable Flow Rate

*WSDOT*
Sag Inlet Design Worksheet

Sag Inlet Design
Storm Drain Design Spreadsheet

- Rational method
- Design frequency
- Contributing inflow
- Pipe info
- Checks (velocity, flow, cover)
Manning’s Equation

\[ V = \frac{1.486}{n} R^{2/3} \sqrt{S} \]

\[ R = \frac{A}{P} \]

Where:
- \( V \) = Mean full velocity in the channel (ft/sec)
- \( n \) = Manning’s roughness coefficient (See Appendix 4-1)
- \( S \) = Channel slope (ft/ft)
- \( R \) = Hydraulic radius (ft)
- \( A \) = Area of the cross section of water (ft\(^2\))
- \( P \) = Wetted perimeter (ft)

Velocity in the pipe related to Manning’s roughness coefficient, the wetted area of the pipe, and the slope of the pipe
Storm Drain Design (Pipe Sizing)

### Storm Sewer Design (English Units)

This spreadsheet accomplishes a storm sewer design using the rational method. Enter the data in the spreadsheet columns. Please use one spreadsheet per subdrainage area.

<table>
<thead>
<tr>
<th>Location</th>
<th>Base Record No.</th>
<th>As Rx</th>
<th>Storm Curve</th>
<th>90th Percentile</th>
<th>Pipe Thinner [In]</th>
<th>Pipe Thinner [Inch]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>