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Outline

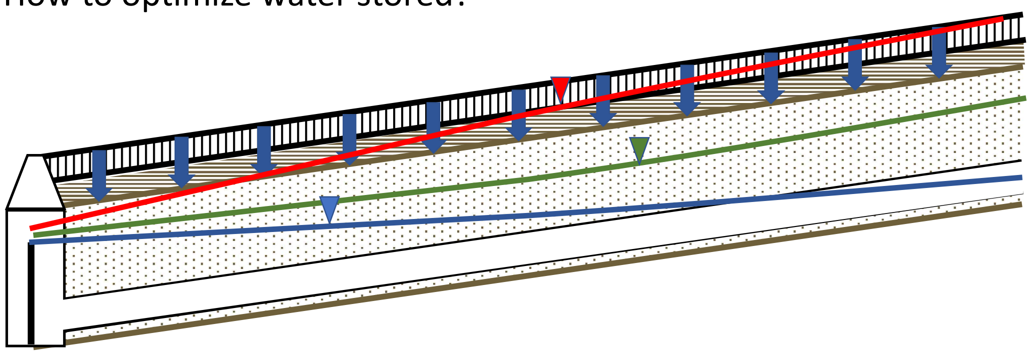
- Issues
- Materials investigation
- Design tool
- Findings
- Implemen-tation

Focus on the Subgrade

2

Questions with subgrade design

- Size and number of layers of stone?
- Drain tile or not?
- How to optimize water stored?



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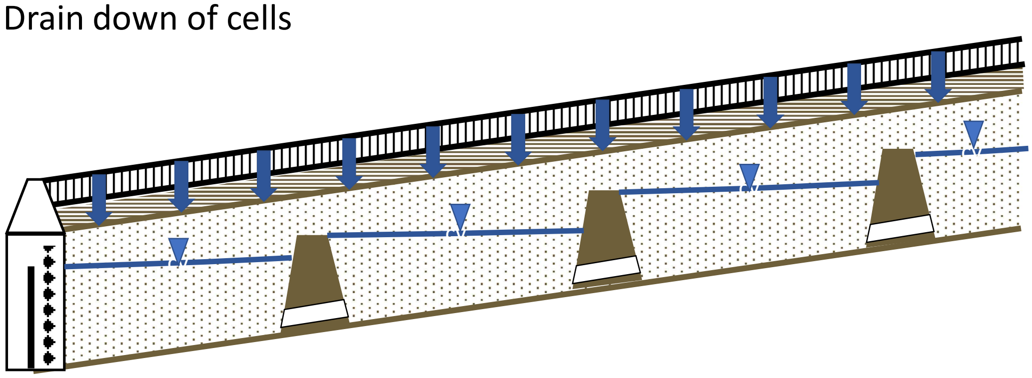
Issues with Design Guidance

- Construction difficulty
- Spacing and height of impermeable cores
- Drain down of cells



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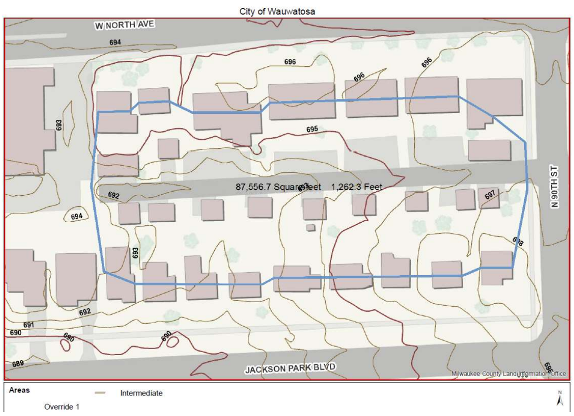
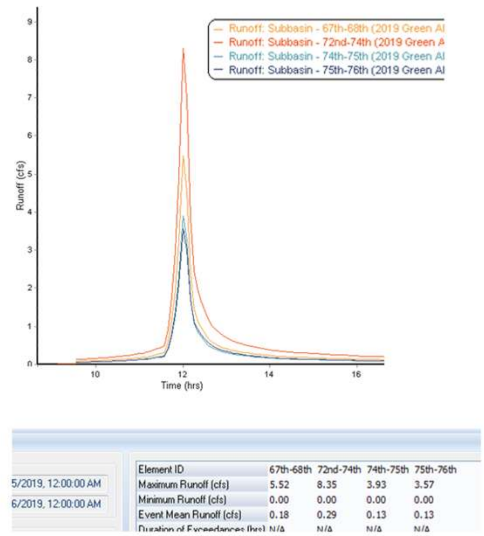
Wauwatosa previous design process

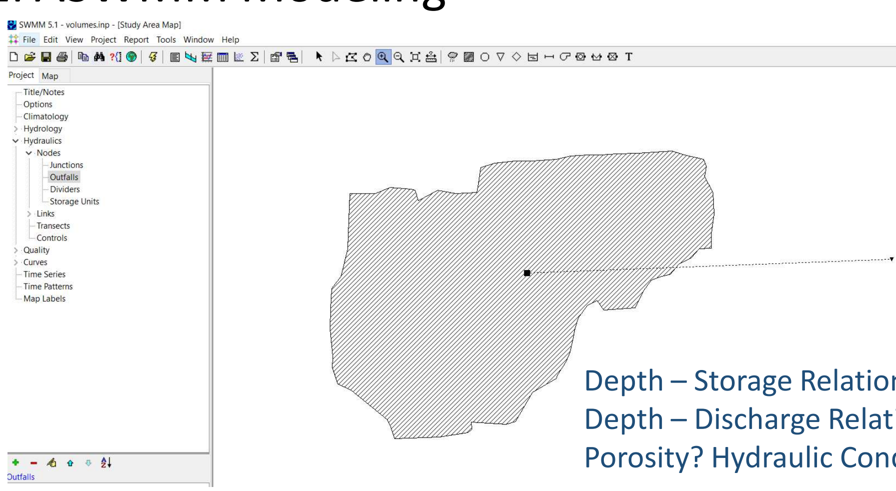
AutoDesk Storm & Sanitary Modeling





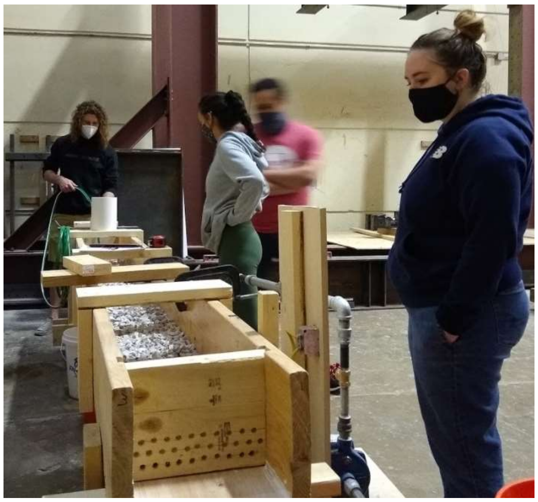
Wauwatosa previous design process

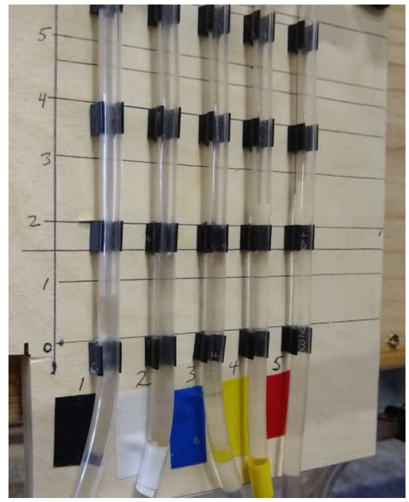
EPASWMM Modeling



Depth – Storage Relationship?
Depth – Discharge Relationship?
Porosity? Hydraulic Conductivity?

Materials Investigation:
Hydraulic Conductivity





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Materials Investigation:
Porosity, Gradation

ASTM C-29 1-cubic foot bucket

https://www.certifiedmtp.com/unit-weight-bucket-aluminum-1-cubic-feet/

https://www.humboldtmfg.com/shakers-sieve.html

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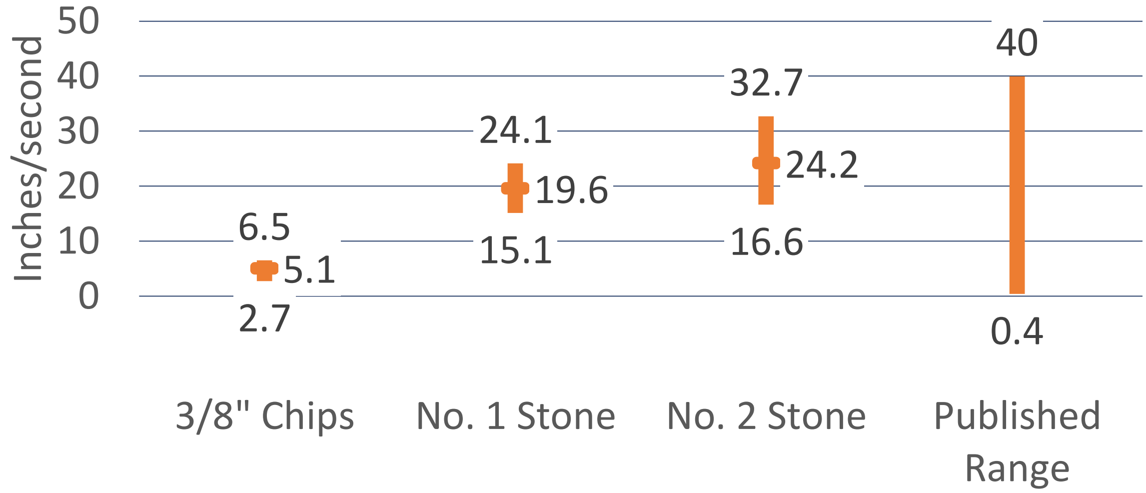
Findings: Hydraulic Conductivity



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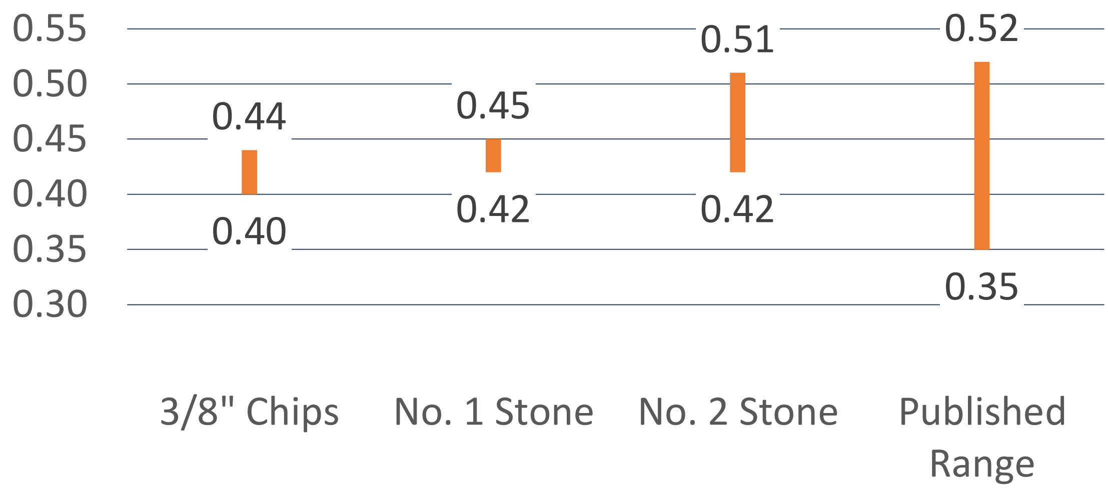
Findings: Porosity



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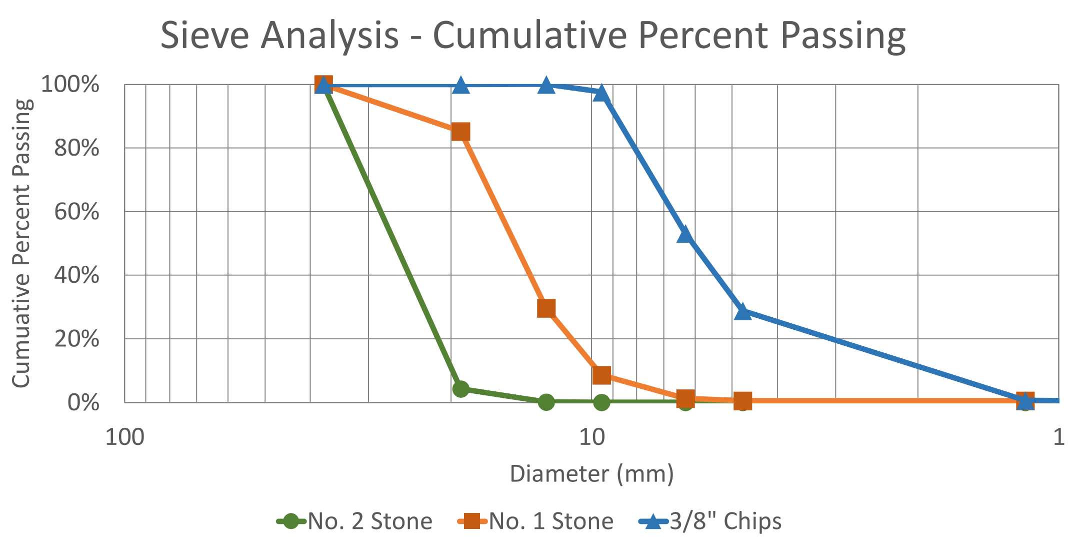
Findings: Gradation



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Design Tool Approach

Hydraulic Model

Determine subsurface storage and water table profile at different discharge flow rates

Hydrologic Model

Use storage routing to route storm through subsurface storage

Profile at Peak Discharge Rate

Analogous to **HEC-RAS** to determine flood storage in a channel segment

Analogous to **HEC-HMS** to determine flood flow at the outlet of a channel segment

Accomplish all this this in an Excel Spreadsheet

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Design Tool Assumptions

- 1 Hour 1st Quartile Huff distribution storm
- 1 Hour rainfall depth from NOAA Atlas 14
- Inflow to subgrade from adjacent properties and surface itself distributed uniformly along length of alley
- Permeable alley surface and choker course do not limit infiltration
- Subgrade has one or two layers of drainage stone with uniform thickness
- Infiltration rate to native soil either zero or specified
- Weir in manhole controls water level at downhill end

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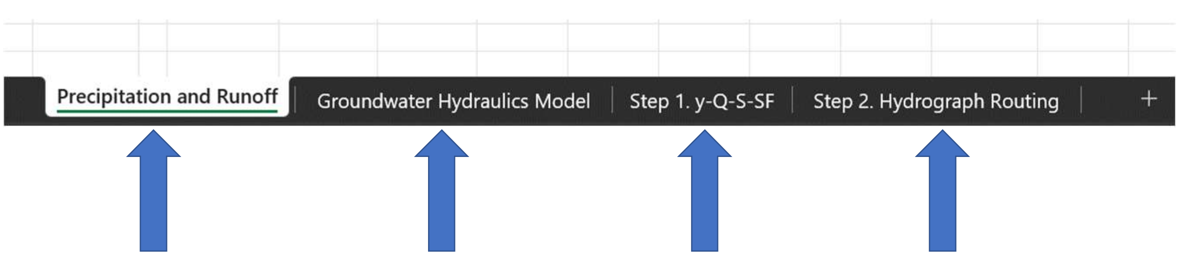
Design Tool Excel Spreadsheet

- One Single Spreadsheet
- Four Simple Tabs



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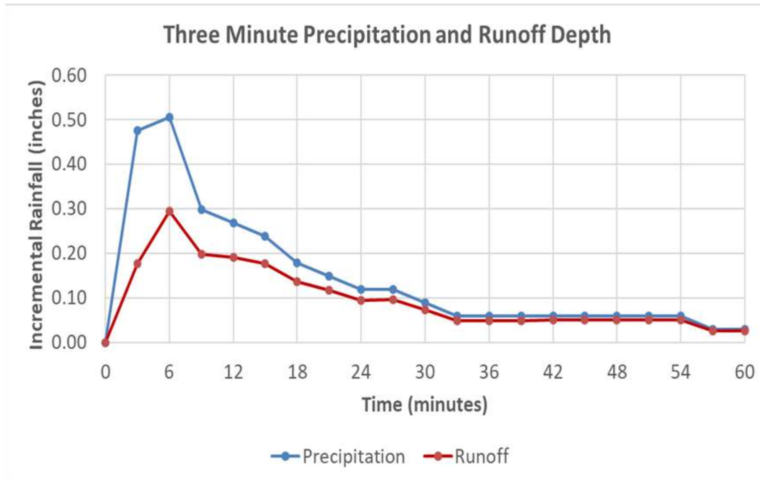
Design Tool Surface Hydrology Tab

		Imperv.	Perv.
CN		98	74
S (in)		0.20	3.51
Ia (in)		0.04	0.70
Area (ac)	1.00	60%	40%
Total P (in)	2.97		
Δt (hr)	0.05		



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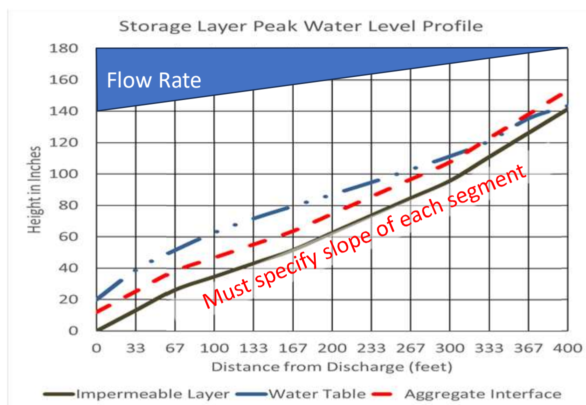
Design Tool

Groundwater Hydraulics Tab



Yields storage volume and maximum depth at specified outflow rate

Hydraulics Model										Hydr. Cond.	Porosity
										K (in/s)	η
Average Slope	S_0	0.03	in/in	Outflow rate	621	gpm			3/8" Chips	5.1	0.420
	d_L	12	in	Outflow rate	1.383	cfs			No. 1 Stone	19.3	0.435
	q_L	1.836	in^2/s	Outflow rate, Q	2391	in^3/s			No. 2 Stone	24.2	0.465
	ΔL	400	in	W	168	in					
"Normal" Depth	H_0	93.015	in	Unit outflow rate, q	14.231	in^2/s					
	$h_{initial}$	20	in	K_L	5.1	in/s	η_L	0.420			
				K_U	24.2	in/s	η_U	0.465			
				Infiltration rate	0	iph					
				Unit infiltration rate	0.000	in^2/s					

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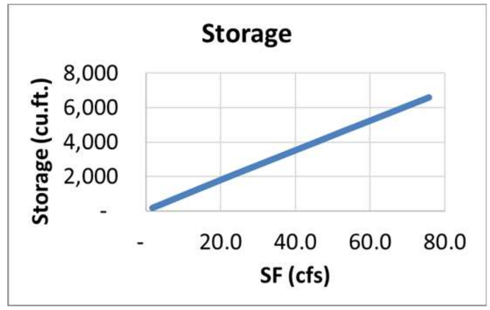
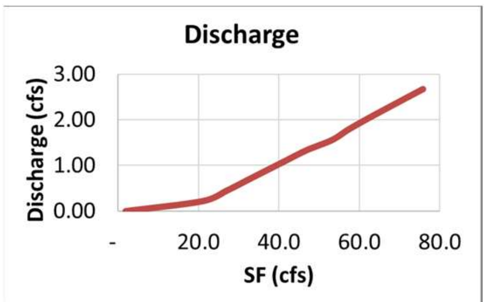
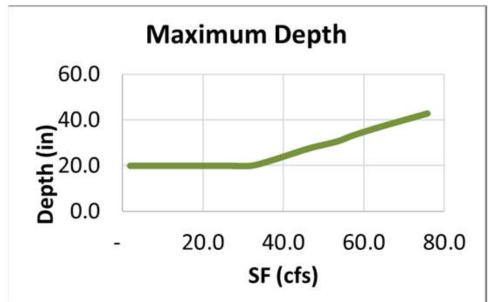
Design Tool Y-Q-S-SF Relationship Tab







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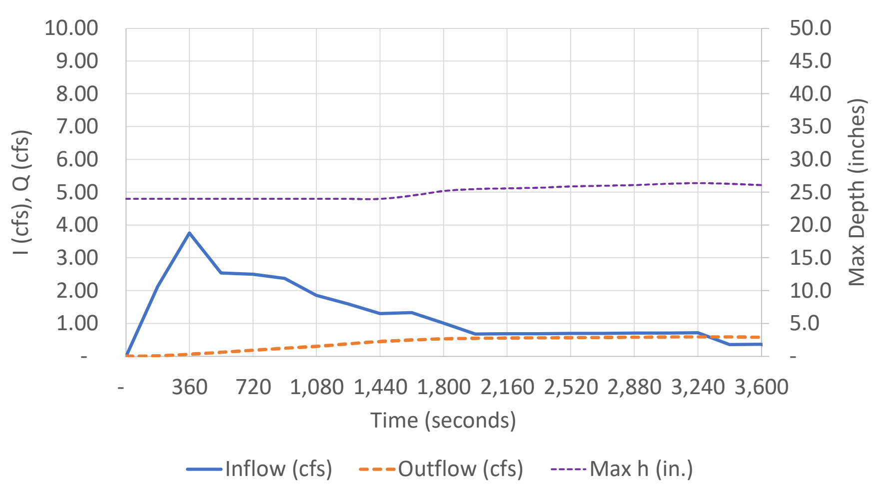
Design Tool Hydrograph Routing Tab



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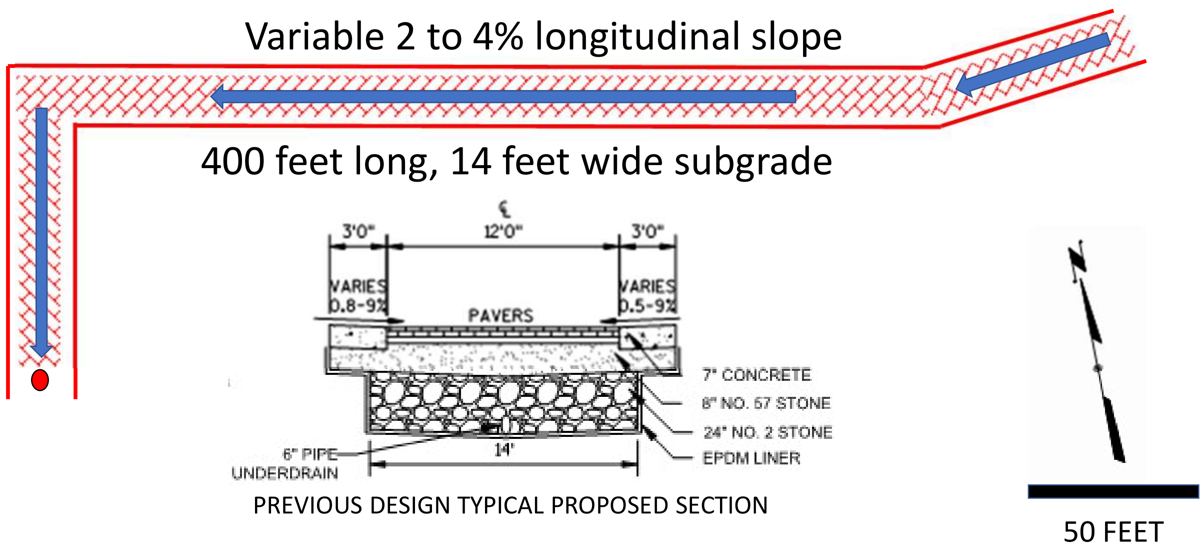
Design Tool - Testing



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Design Tool - Testing

- NRCS hydrology runoff from separate (60%) impervious and (40%) pervious (grass) areas
- Drainage area 1 acre

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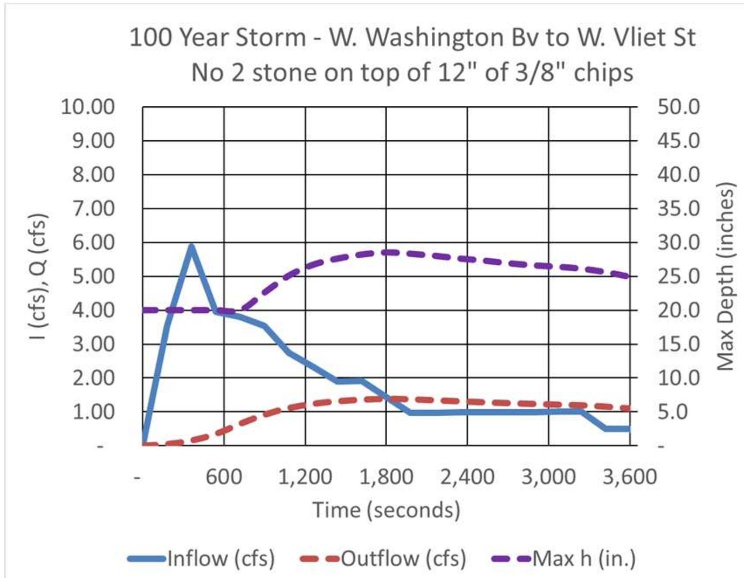
Findings

100 Year Storm Simulation



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Findings

1-Hour Design Storm Recurrence Interval	Peak Attenuation Ratio	Peak Delay (minutes)
100-Year	4.25	24
10-Year	5.55	30
2-Year	8.49	54
1-Year	9.02	54

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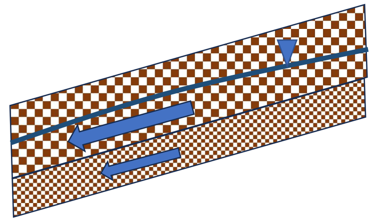
Findings

- No need for an underdrain (9 hour drain down)
- Two-layer design with 12” of 3/8” stone covered by 12” or more of No. 2 stone for storage course

This turns design guidance upside down!



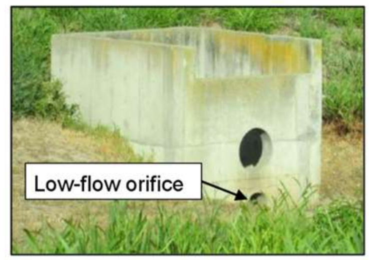


Photo M. Myburgh

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Findings

One-Layer Design (No. 1 Stone)	Two-Layer Design (No. 2 Stone on 12” 3/8” chips)
3 to 4 fold reduction in peak flow	4 to 9 fold reduction in peak flow
Peak delay 24 minutes	Peak delay 24 to 54 minutes
Little storage capacity used in 1- and 2-year storm	Substantial storage capacity used in 1- and 2-year storm
Little storage in uphill 25% of alley	More storage used in uphill 25% of alley

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Implementation: Design and Construction

Maggie Anderson, P.E.
City of Wauwatosa

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Implementation: Construction

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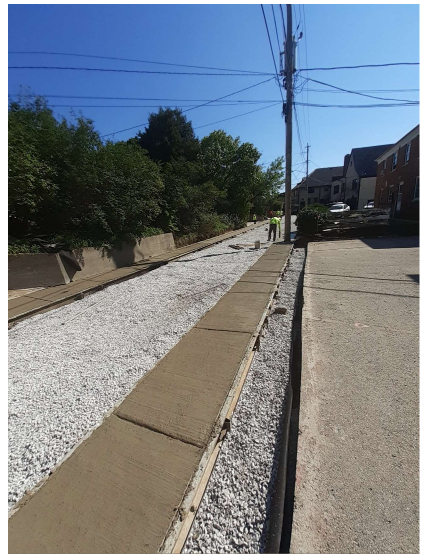
Implementation: Construction



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Implementation: Construction

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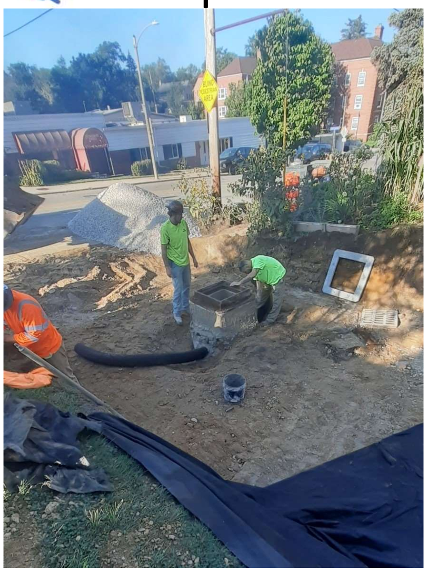
Implementation: Construction



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Implementation: Construction

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Implementation: Construction

- 25 green alleys installed
- 80,000 sq. ft. pavement removed
- 950,000 gallons stored

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