MILE HIGH FLOOD DISTRICT

DETENTION BASIN DESIGN WORKBOOK

MHFD-Detention, Version 4.06 (July 2022)
Mile High Flood District
Denver, Colorado
www.mhfd.org

Purpose:

This workbook aids in the estimation of stormwater detention basin sizing and outlet routing based on the modified puls routing method for urban watersheds. Several different BMP types and various outlet configurations can be sized.

Function:

1. Approximates the stage-area-volume relationship for a detention basin based on watershed parameters and basin geometry parameters. Also evaluates existing user-defined basin stage-area relationships.

2. Sizes filtration media orifice, outlet orifices, elliptical slots, weirs, trash racks, and develops stage-discharge relationships. Uses the Modified Puls method to route a series of hydrographs (i.e., 2-, 5-, 10-, 25-, 50-, 100- and 500-year) and calibrates the peak discharge out of the basin to match the pre-development peak discharges for the watershed.

Content: **This workbook consists of the following sheets:**

Basin	Tabulates stage-area-volume relationship estimates based on watershed parameters
Outlet Structure	Tabulates a stage-discharge relationship for the user-defined outlet structure (inlet control).
Reference	Provides reference equations and figures.
User Tips and Tools	Provides instructions and video links to assist in using this workbook. Includes a stage-area calculator.
BMP Zone Images	Provides images of typical BMP zone confirgurations corresponding with Zone pulldown selections.

Acknowledgements: ***Spreadsheet Development Team:***
Ken MacKenzie, P.E., Holly Piza, P.E.
Mile High Flood District

Derek N. Rapp, P.E.
Peak Stormwater Engineering, LLC

Dr. James C.Y. Guo, Ph.D., P.E.
Professor, Department of Civil Engineering, University of Colorado at Denver

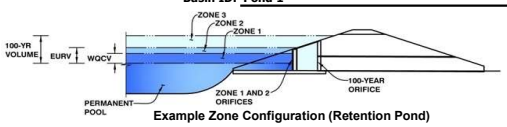
Comments? Direct all comments regarding this spreadsheet workbook to: **MHFD E-Mail**
Revisions? Check for revised versions of this or any other workbook at: **Downloads**

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.06 (July 2022)

Project: Haven Valley

Basin ID: Pond 1



Example Zone Configuration (Retention Pond)

Watershed Information

Selected BMP Type =	**EDB**	
Watershed Area =	41.99	acres
Watershed Length =	2,000	ft
Watershed Length to Centroid =	500	ft
Watershed Slope =	0.023	ft/ft
Watershed Imperviousness =	57.80%	percent
Percentage Hydrologic Soil Group A =	100.0%	percent
Percentage Hydrologic Soil Group B =	0.0%	percent
Percentage Hydrologic Soil Groups C/D =	0.0%	percent
Target WQCV Drain Time =	40.0	hours
Location for 1-hr Rainfall Depths =	User Input	

After providing required inputs above including 1-hour rainfall depths, click 'Run CUHP' to generate runoff hydrographs using the embedded Colorado Urban Hydrograph Procedure.

			Optional User Overrides	
Water Quality Capture Volume (WQCV) =	0.801	acre-feet		acre-feet
Excess Urban Runoff Volume (EURV) =	2.914	acre-feet		acre-feet
2-yr Runoff Volume (P1 = 1.19 in.) =	2.123	acre-feet	1.19	inches
5-yr Runoff Volume (P1 = 1.5 in.) =	2.801	acre-feet	1.50	inches
10-yr Runoff Volume (P1 = 1.75 in.) =	3.345	acre-feet	1.75	inches
25-yr Runoff Volume (P1 = 2 in.) =	4.111	acre-feet	2.00	inches
50-yr Runoff Volume (P1 = 2.25 in.) =	4.864	acre-feet	2.25	inches
100-yr Runoff Volume (P1 = 2.52 in.) =	5.798	acre-feet	2.52	inches
500-yr Runoff Volume (P1 = 3.49 in.) =	9.040	acre-feet	3.49	inches
Approximate 2-yr Detention Volume =	1.886	acre-feet		
Approximate 5-yr Detention Volume =	2.473	acre-feet		
Approximate 10-yr Detention Volume =	2.998	acre-feet		
Approximate 25-yr Detention Volume =	3.634	acre-feet		
Approximate 50-yr Detention Volume =	4.026	acre-feet		
Approximate 100-yr Detention Volume =	4.464	acre-feet		

Define Zones and Basin Geometry

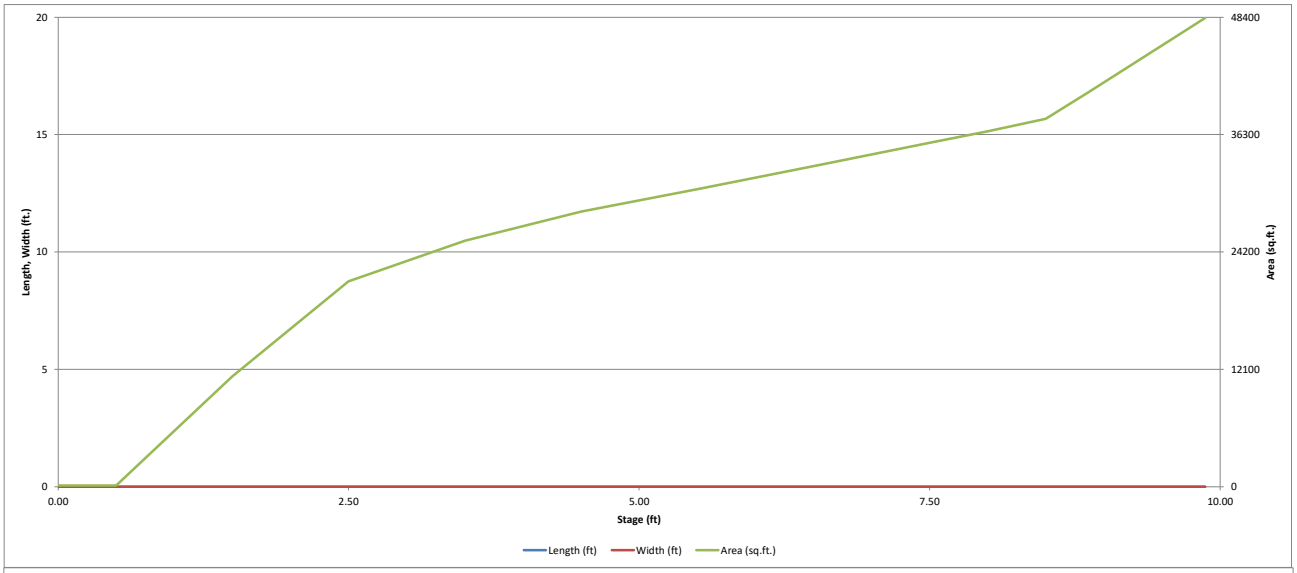
Zone 1 Volume (WQCV) =	0.801	acre-feet
Zone 2 Volume (EURV - Zone 1) =	2.113	acre-feet
Zone 3 Volume (100-year - Zones 1 & 2) =	1.550	acre-feet
Total Detention Basin Volume =	4.464	acre-feet
Initial Surcharge Volume (ISV) =	user	ft^3
Initial Surcharge Depth (ISD) =	user	ft
Total Available Detention Depth (H_{total}) =	user	ft
Depth of Trickle Channel (H_{TC}) =	user	ft
Slope of Trickle Channel (S_{TC}) =	user	ft/ft
Slopes of Main Basin Sides (S_{main}) =	user	H:V
Basin Length-to-Width Ratio ($R_{L/W}$) =	user	
Initial Surcharge Area (A_{ISV}) =	user	ft^2
Surcharge Volume Length (L_{ISV}) =	user	ft
Surcharge Volume Width (W_{ISV}) =	user	ft
Depth of Basin Floor (H_{FLOOR}) =	user	ft
Length of Basin Floor (L_{FLOOR}) =	user	ft
Width of Basin Floor (W_{FLOOR}) =	user	ft
Area of Basin Floor (A_{FLOOR}) =	user	ft^2
Volume of Basin Floor (V_{FLOOR}) =	user	ft^3
Depth of Main Basin (H_{MAIN}) =	user	ft
Length of Main Basin (L_{MAIN}) =	user	ft
Width of Main Basin (W_{MAIN}) =	user	ft
Area of Main Basin (A_{MAIN}) =	user	ft^2
Volume of Main Basin (V_{MAIN}) =	user	ft^3
Calculated Total Basin Volume (V_{total}) =	**user**	acre-feet

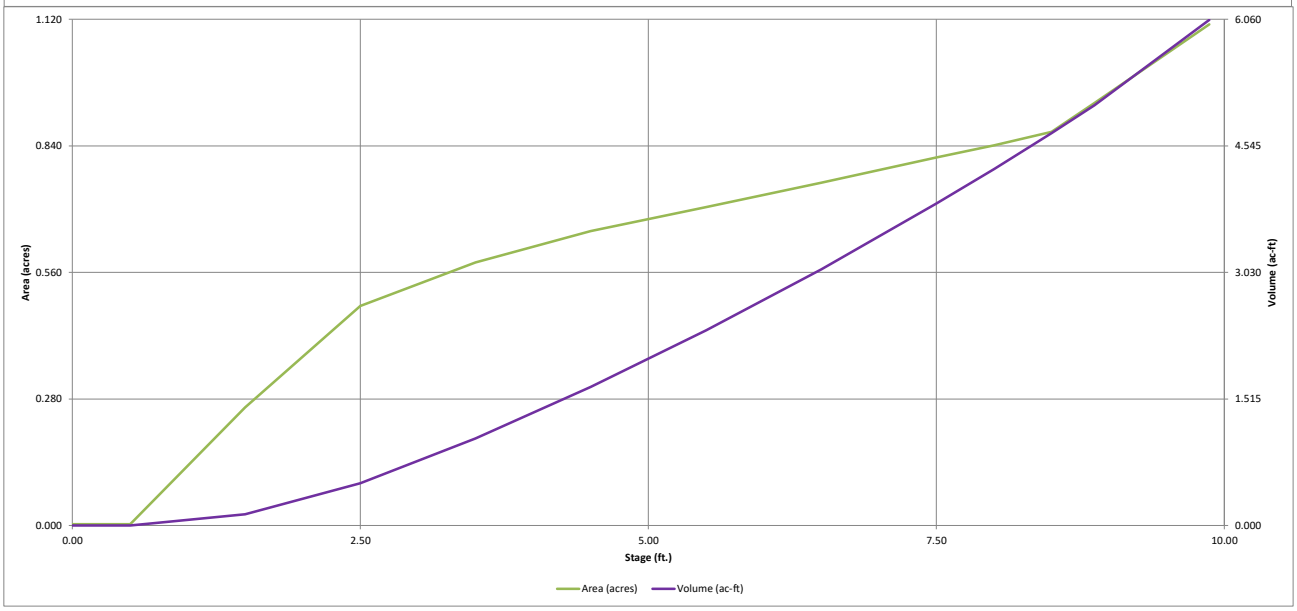
Depth Increment = ft

Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft^2)	Optional Override Area (ft^2)	Area (acre)	Volume (ft^3)	Volume (ac-ft)
Top of Micropool	--	0.00	--	--	--	120	0.003		
5808.63	--	0.50	--	--	--	120	0.003	60	0.001
5809.63	--	1.50	--	--	--	11,398	0.262	5,819	0.134
5810.63	--	2.50	--	--	--	21,163	0.486	22,099	0.507
5811.63	--	3.50	--	--	--	25,363	0.582	45,362	1.041
5812.63	--	4.50	--	--	--	28,381	0.652	72,234	1.658
5813.63	--	5.50	--	--	--	30,687	0.704	101,768	2.336
5814.63	--	6.50	--	--	--	33,049	0.759	133,636	3.068
5815.63	--	7.50	--	--	--	35,467	0.814	167,894	3.854
Spillway-5816.13	--	8.00	--	--	--	36,640	0.841	185,921	4.268
5816.63	--	8.50	--	--	--	37,941	0.871	204,566	4.696
5817	--	8.87	--	--	--	40,720	0.935	219,119	5.030
5818	--	9.87	--	--	--	48,320	1.109	263,639	6.052

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

MHFD-Detention, Version 4.06 (July 2022)





Please upload the latest MHFD-Detention workbook with the next submittal. The version in the FDR is more up to date than this one.

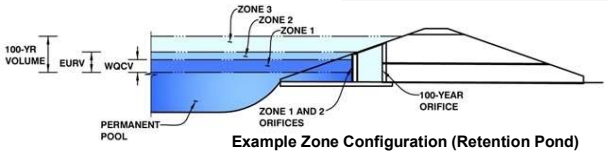
For example, this is now 7.5 in the FDR version.

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.06 (July 2022)

Project: Haven Valley

Basin ID: Pond 1



Example Zone Configuration (Retention Pond)

	Estimated Stage (ft)	Estimated Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	3.08	0.801	Orifice Plate
Zone 2 (EURV)	6.30	2.113	Orifice Plate
Zone 3 (100-year)	8.24	1.550	Weir&Pipe (Restrict)
Total (all zones)		4.464	

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration BMP)

			Calculated Parameters for Underdrain		
Underdrain Orifice Invert Depth =		ft (distance below the filtration media surface)	Underdrain Orifice Area =		ft^2
Underdrain Orifice Diameter =		inches	Underdrain Orifice Centroid =		feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation BMP)

			Calculated Parameters for Plate		
Centroid of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)	WQ Orifice Area per Row =	N/A	ft^2
Depth at top of Zone using Orifice Plate =	5.89	ft (relative to basin bottom at Stage = 0 ft)	Elliptical Half-Width =	N/A	feet
Orifice Plate: Orifice Vertical Spacing =	N/A	inches	Elliptical Slot Centroid =	N/A	feet
Orifice Plate: Orifice Area per Row =	N/A	sq. inches	Elliptical Slot Area =	N/A	ft^2

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (required)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)	0.00	2.00	4.00					
Orifice Area (sq. inches)	4.17	4.17	5.00					

	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								

User Input: Vertical Orifice (Circular or Rectangular)

	Not Selected	Not Selected		Calculated Parameters for Vertical Orifice	Not Selected	Not Selected	
Invert of Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)	Vertical Orifice Area =	N/A	N/A	ft^2
Depth at top of Zone using Vertical Orifice =	N/A	N/A	ft (relative to basin bottom at Stage = 0 ft)	Vertical Orifice Centroid =	N/A	N/A	feet
Vertical Orifice Diameter =	N/A	N/A	inches				

User Input: Overflow Weir (Dropbox with Flat or Sloped Grate and Outlet Pipe OR Rectangular/Trapezoidal Weir and No Outlet Pipe)

	Zone 3 Weir	Not Selected		Calculated Parameters for Overflow Weir	Zone 3 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	6.50	N/A	ft (relative to basin bottom at Stage = 0 ft)	Height of Grate Upper Edge, H_t =	6.50	N/A	feet
Overflow Weir Front Edge Length =	4.00	N/A	feet	Overflow Weir Slope Length =	4.00	N/A	feet
Overflow Weir Grate Slope =	0.00	N/A	H:V	Grate Open Area / 100-yr Orifice Area =	6.41	N/A	
Horiz. Length of Weir Sides =	4.00	N/A	feet	Overflow Grate Open Area w/o Debris =	11.14	N/A	ft^2
Overflow Grate Type =	Type C Grate	N/A		Overflow Grate Open Area w/ Debris =	5.57	N/A	ft^2
Debris Clogging % =	50%	N/A	%				

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Zone 3 Restrictor	Not Selected		Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate	Zone 3 Restrictor	Not Selected	
Depth to Invert of Outlet Pipe =	0.00	N/A	ft (distance below basin bottom at Stage = 0 ft)	Outlet Orifice Area =	1.74	N/A	ft^2
Outlet Pipe Diameter =	24.00	N/A	inches	Outlet Orifice Centroid =	0.62	N/A	feet
Restrictor Plate Height Above Pipe Invert =	13.00		inches	Half-Central Angle of Restrictor Plate on Pipe =	1.65	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

			Calculated Parameters for Spillway		
Spillway Invert Stage=	8.00	ft (relative to basin bottom at Stage = 0 ft)	Spillway Design Flow Depth=	0.87	feet
Spillway Crest Length =	46.00	feet	Stage at Top of Freeboard =	9.87	feet
Spillway End Slopes =	4.00	H:V	Basin Area at Top of Freeboard =	1.11	acres
Freeboard above Max Water Surface =	1.00	feet	Basin Volume at Top of Freeboard =	6.05	acre-ft

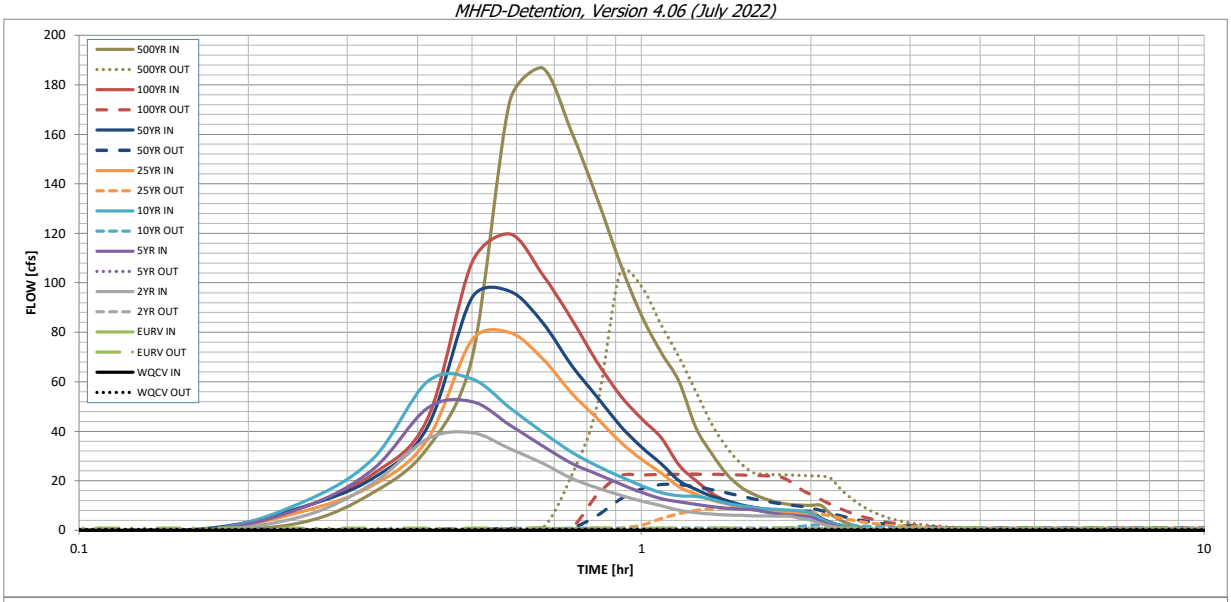
Routed Hydrograph Results

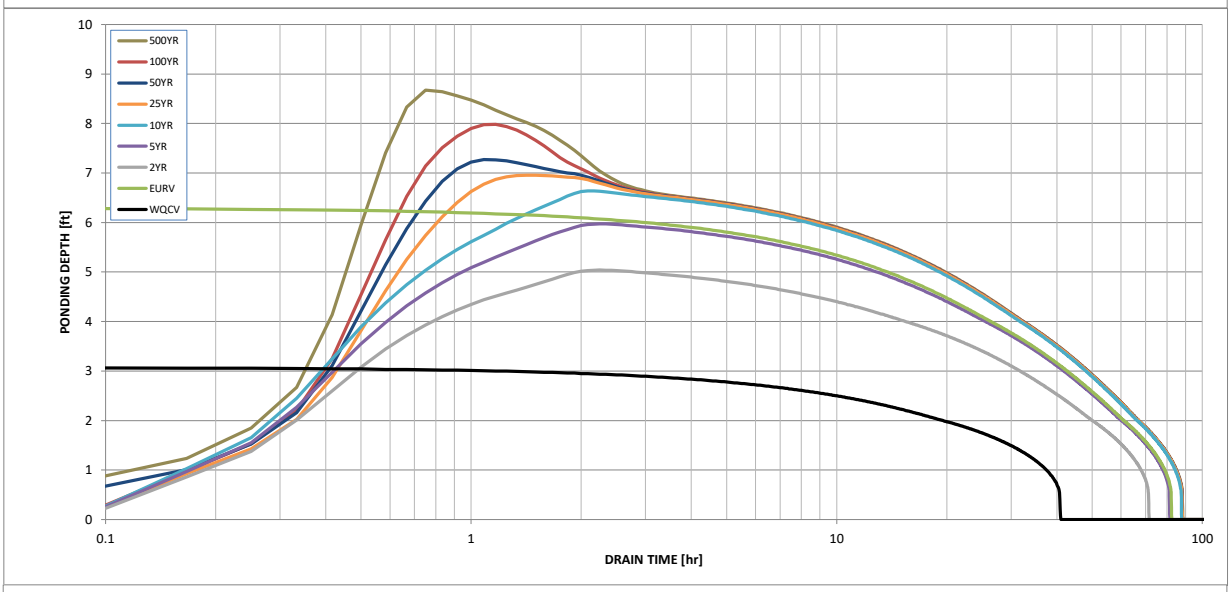
The user can override the default CUHP hydrographs and runoff volumes by entering new values in the Inflow Hydrographs table (Columns W through AF).

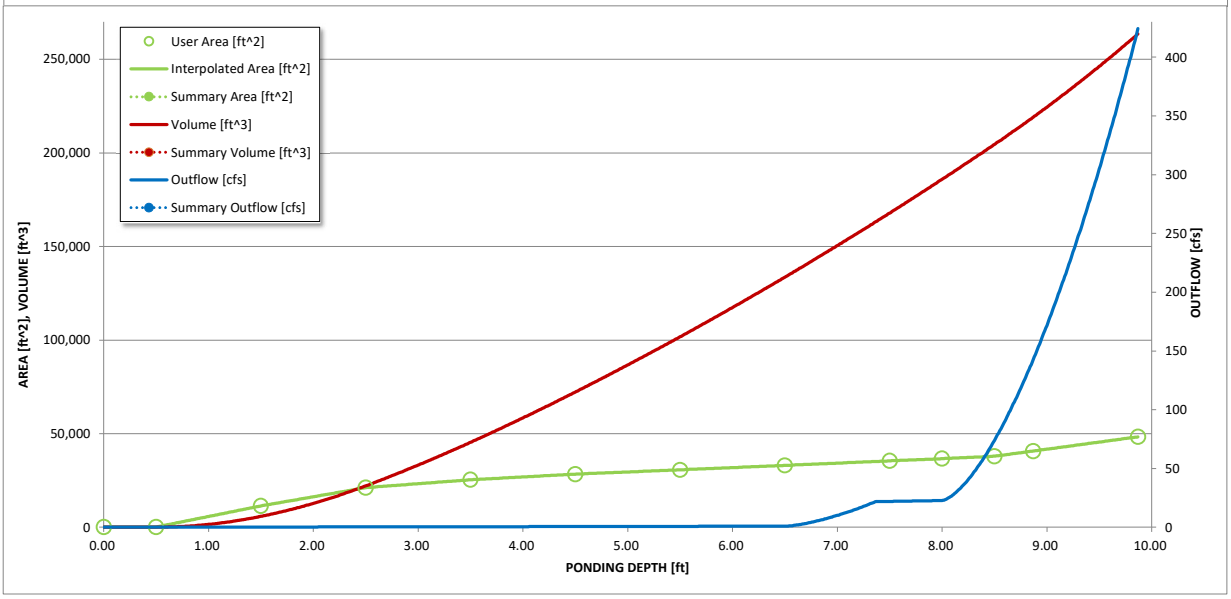
Design Storm Return Period =	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
One-Hour Rainfall Depth (in) =	N/A	N/A	1.19	1.50	1.75	2.00	2.25	2.52	3.49
CUHP Runoff Volume (acre-ft) =	0.801	2.914	2.123	2.801	3.345	4.111	4.864	5.798	9.040
Inflow Hydrograph Volume (acre-ft) =	N/A	N/A	2.123	2.801	3.345	4.111	4.864	5.798	9.040
CUHP Predevelopment Peak Q (cfs) =	N/A	N/A	0.4	0.8	1.1	10.1	19.9	32.7	74.0
OPTIONAL Override Predevelopment Peak Q (cfs) =	N/A	N/A							
Predevelopment Unit Peak Flow, q (cfs/acre) =	N/A	N/A	0.01	0.02	0.03	0.24	0.47	0.78	1.76
Peak Inflow Q (cfs) =	N/A	N/A	39.4	52.0	61.2	79.9	96.6	119.8	186.8
Peak Outflow Q (cfs) =	0.4	0.9	0.7	0.9	2.3	9.0	18.5	22.7	104.2
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	1.1	2.1	0.9	0.9	0.7	1.4
Structure Controlling Flow =	Plate	Plate	Plate	Plate	Overflow Weir 1	Overflow Weir 1	Overflow Weir 1	Outlet Plate 1	Spillway
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	N/A	0.1	0.7	1.6	1.9	2.0
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time to Drain 97% of Inflow Volume (hours) =	39	75	66	74	79	78	76	75	68
Time to Drain 99% of Inflow Volume (hours) =	**40**	80	69	79	85	84	84	83	81
Maximum Ponding Depth (ft) =	3.08	6.30	5.04	5.97	6.64	6.96	7.27	7.98	8.68
Area at Maximum Ponding Depth (acres) =	0.54	0.75	0.68	0.73	0.77	0.78	0.80	0.84	0.90
Maximum Volume Stored (acre-ft) =	0.805	2.917	2.018	2.673	3.167	3.415	3.669	4.251	4.847

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.06 (July 2022)







S-A-V-D Chart Axis Override	X-axis	Left Y-Axis	Right Y-Axis
minimum bound			
maximum bound			

DETENTION BASIN OUTLET STRUCTURE DESIGN

Outflow Hydrograph Workbook Filename:

Inflow Hydrographs

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

	SOURCE	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP	CUHP
Time Interval	TIME	WQCV [cfs]	EURV [cfs]	2 Year [cfs]	5 Year [cfs]	10 Year [cfs]	25 Year [cfs]	50 Year [cfs]	100 Year [cfs]	500 Year [cfs]
5.00 min	0:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.06	3.20
	0:15:00	0.00	0.00	5.66	9.19	11.41	7.68	9.48	9.37	15.23
	0:20:00	0.00	0.00	19.11	24.72	29.00	18.23	21.11	22.81	33.20
	0:25:00	0.00	0.00	37.00	49.38	60.10	36.67	41.73	45.18	69.52
	0:30:00	0.00	0.00	39.40	52.03	61.16	76.89	94.01	108.19	173.19
	0:35:00	0.00	0.00	32.97	42.49	49.49	79.88	96.63	119.78	186.79
	0:40:00	0.00	0.00	27.10	34.15	39.65	69.44	84.01	103.39	161.36
	0:45:00	0.00	0.00	21.04	27.13	31.70	55.59	66.87	85.63	134.48
	0:50:00	0.00	0.00	17.15	22.76	26.07	45.35	54.02	68.14	107.93
	0:55:00	0.00	0.00	14.28	18.76	21.73	35.78	42.31	54.61	86.75
	1:00:00	0.00	0.00	11.78	15.36	18.03	28.72	33.64	45.15	71.94
	1:05:00	0.00	0.00	9.95	12.80	15.20	23.18	26.91	37.49	60.07
	1:10:00	0.00	0.00	8.10	11.54	14.02	17.52	19.99	26.37	41.37
	1:15:00	0.00	0.00	7.10	10.53	13.66	14.62	16.58	20.06	31.05
	1:20:00	0.00	0.00	6.54	9.58	12.55	12.19	13.76	15.05	22.85
	1:25:00	0.00	0.00	6.21	8.96	10.97	10.74	12.09	11.87	17.59
	1:30:00	0.00	0.00	6.02	8.55	9.91	9.22	10.37	10.04	14.57
	1:35:00	0.00	0.00	5.88	8.31	9.19	8.25	9.28	8.80	12.53
	1:40:00	0.00	0.00	5.78	7.32	8.72	7.63	8.58	8.01	11.21
	1:45:00	0.00	0.00	5.73	6.61	8.41	7.21	8.11	7.53	10.42
	1:50:00	0.00	0.00	5.72	6.15	8.19	6.98	7.85	7.36	10.19
	1:55:00	0.00	0.00	4.78	5.84	7.78	6.84	7.69	7.28	10.08
	2:00:00	0.00	0.00	4.11	5.44	6.97	6.77	7.62	7.28	10.08
	2:05:00	0.00	0.00	2.72	3.60	4.63	4.50	5.05	4.84	6.69
	2:10:00	0.00	0.00	1.73	2.30	2.98	2.91	3.27	3.13	4.31
	2:15:00	0.00	0.00	1.10	1.44	1.89	1.85	2.08	1.98	2.72
	2:20:00	0.00	0.00	0.64	0.87	1.13	1.12	1.25	1.19	1.63
	2:25:00	0.00	0.00	0.36	0.53	0.67	0.68	0.76	0.72	0.98
	2:30:00	0.00	0.00	0.16	0.27	0.33	0.35	0.39	0.36	0.49
	2:35:00	0.00	0.00	0.06	0.10	0.11	0.13	0.14	0.13	0.16
	2:40:00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00
	2:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:05:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:10:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:15:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:20:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:25:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:30:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:35:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:40:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:45:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:50:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5:55:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DETENTION BASIN OUTLET STRUCTURE DESIGN

MHFD-Detention, Version 4.06 (July 2022)

Summary Stage-Area-Volume-Discharge Relationships

The user can create a summary S-A-V-D by entering the desired stage increments and the remainder of the table will populate automatically.

The user should graphically compare the summary S-A-V-D table to the full S-A-V-D table in the chart to confirm it captures all key transition points.

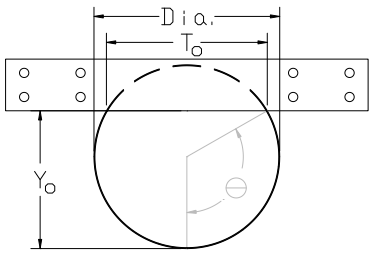
Stage - Storage Description	Stage [ft]	Area [ft ^{2}]	Area [acres]	Volume [ft ^{3}]	Volume [ac-ft]	Total Outflow [cfs]

For best results, include the stages of all grade slope changes (e.g. ISV and Floor) from the S-A-V table on Sheet 'Basin'.

Also include the inverts of all outlets (e.g. vertical orifice, overflow grate, and spillway, where applicable).

REFERENCE FIGURES AND EQUATIONS

Circular Pipe with Restrictor Plate



WQ Elliptical Slot Weir (Alternative to WQ Orifice Plate for Large Watersheds)

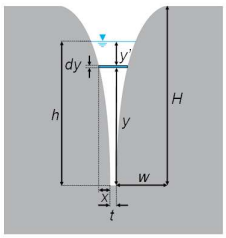
$$f(y)=\sqrt{2g(h-y)}\left[2\frac{H}{R}\left(1-1\sqrt{1-\frac{y^2}{H^2}}\right)+t\right]$$

$$Q_{app}=0.3015h\left[f(0)+f(0.603h)\right]+0.1415h\left[f(0.603h)+f(0.886h)\right]+0.0570h\left[f(0.886h)\right]$$

Orifice Equations

$$Q=C_d A_t\sqrt{2g(h-C_y)}$$

$$A_t=H(2W+t)-\frac{\pi HW}{2} \qquad C_y=\frac{\frac{H}{2}(2W+t)-\frac{2HW}{3}}{2W+t-\frac{\pi W}{2}}$$



- dy = elementary flow vertical distance [L];
- h = total flow depth [L];
- H = total weir height and semi-major ellipse axis [L];
- t = weir gap thickness [L];
- W = semi-minor ellipse axis [L];
- x = horizontal distance along the ellipse shape [L];
- y = vertical depth measured from the weir crest to the elementary flow strip [L]; and
- y' = vertical distance measured from the water surface to the elementary flow strip [L].

WQCV and EURV Equations

$$WQCV=\frac{A}{12}*a[0.91I^3-1.19I^2+0.78I]$$

$$EURV=Area*[0.140(IMP)^{1.28}*A\%+0.113(IMP)^{1.08}*B\%+0.100(IMP)^{1.08}*C/D\%]$$

Where *WQCV* is the water quality capture volume (acre-ft), EURV is the excess urban runoff volume (acre-ft), *a* is a coefficient corresponding to WQCV drain time (1.0 for 40 hours, 0.9 for 24 hours, and 0.8 for 12 hours), *A* is the contributing watershed area (acres), *I* is the percentage imperviousness (expressed as a decimal), *A%*, *B%*, and *CD%* are the percent of each hydraulic soil group (expressed as a decimal).

Approximate Storage Volume Equations

$$V_{Storage\_2yr}(ac-ft)=P_1A[(0.078I^{1.324})A\%+(0.077I^{1.184})B\%+(0.077I^{1.134})CD\%]$$

$$V_{Storage\_5yr}(ac-ft)=P_1A[(0.080I^{1.298})A\%+(0.079I^{1.100})B\%+(0.077I^{1.001}+0.003I^{0.001})CD\%]$$

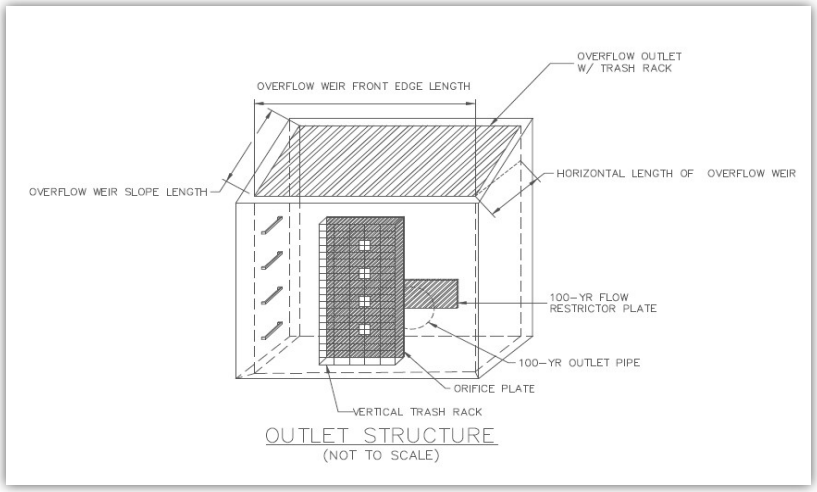
$$V_{Storage\_10yr}(acft)=P_1A[(0.081I^{1.251})A\%+(0.077I^{1.056}+0.005I^{0.056})B\%+(0.069I^{1.167}+0.011I^{0.167})CD\%]$$

$$V_{Storage\_25yr}(ac-ft)=P_1A[(0.083I^{1.188})A\%+(0.056I^{1.290}+0.021I^{0.290})B\%+(0.048I^{1.382}+0.026I^{0.382})CD\%]$$

$$V_{Storage\_50yr}(ac-ft)=P_1A[(0.078I^{1.182}+0.002I^{0.182})A\%+(0.045I^{1.381}+0.026I^{0.381})B\%+(0.037I^{1.457}+0.030I^{0.457})CD\%]$$

$$V_{Storage\_100yr}(ac-ft)=P_1A[(0.067I^{1.225}+0.009I^{0.225})A\%+(0.034I^{1.371}+0.031I^{0.371})B\%+(0.028I^{1.389}+0.033I^{0.389})CD\%]$$

Where $V_{STORAGE\_yr}$ is the estimated storage volume for the given return period (acre-ft), P_1 is the one-hour rainfall depth (in), *A* is the contributing watershed area (acres), *I* is the percentage imperviousness (expressed as a decimal), *A%*, *B%*, and *CD%* are the percent of each hydraulic soil group (expressed as a decimal).



Basin Volume Calculations

Initial Surcharge Volume:

$$ISV=0.003WQCV \qquad L_{ISV}=\sqrt{A_{ISV}}$$

$$A_{ISV}=\frac{ISV}{ISD} \qquad W_{ISV}=\sqrt{A_{ISV}}$$

Where *ISV* is the initial surcharge volume (ft^3), A_{ISV} is *ISV* surface area (ft^2), *ISD* is the initial surcharge depth (ft, typically 0.33 to 0.50), and L_{ISV} and W_{ISV} are the length and width of the *ISV* (ft).

Basin Floor Volume:

$$L_{floor}=L_{ISV}+\frac{H_{floor}}{S_{TC}}+H_{floor}(S_{main}) \qquad W_{floor}=W_{ISV}+\frac{H_{floor}}{R_{L:W}(S_{TC})}$$

$$A_{floor}=L_{floor}(W_{floor})$$

$$V_{floor}=\frac{H_{floor}}{3}\left(A_{ISV}+A_{floor}+\sqrt{A_{ISV}(A_{floor})}\right)$$

Where L_{floor} and W_{floor} (ft) are the length and width of the basin floor section at the point where the top of the basin floor section meets the toe of the basin main section, H_{floor} is the depth of the basin floor section (ft), S_{TC} is the trickle channel slope (ft/ft), S_{main} is the side slope of the basin main section (H:V; e.g., 4 if the horizontal:vertical ratio is 4:1), $R_{L:W}$ is the basin length:width ratio (e.g., 2 if the basin length is twice the basin width), A_{floor} is top area of the basin floor section (ft^2), and V_{floor} is volume of the basin floor section (ft^3).

Main Basin Volume:

$$L_{main}=L_{floor}+2H_{main}(S_{main}) \qquad A_{main}=L_{main}(W_{main})$$

$$W_{main}=W_{floor}+2H_{main}(S_{main})$$

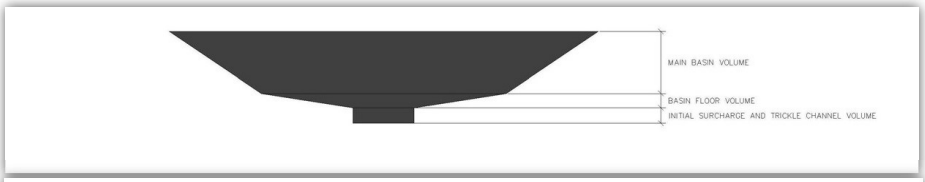
$$V_{main}=\frac{H_{main}}{3}\left(A_{main}+A_{floor}+\sqrt{A_{main}(A_{floor})}\right)$$

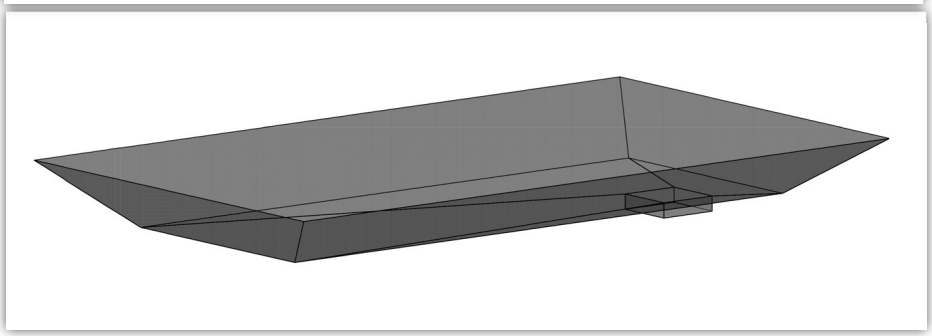
Where L_{main} and W_{main} (ft) are the length and width of the main basin section at the point at the top of the basin, H_{main} is the depth of the main basin section (ft), A_{main} is top area of the main basin section (ft^2), and V_{main} is volume of the main basin section (ft^3).

Total Basin Volume:

$$V_{total}=ISV+A_{ISV}\cdot D_{TC}+V_{floor}+V_{main}$$

Where V_{total} is the volume of the total basin (ft^3) and D_{TC} is the depth of the trickle channel (ft).





Default Horton's Equation Parameters			
NRCS Hydrologic Group	Infiltration (inches per hour)		Decay Coefficient (1/sec)
	Initial - f_i	Final - f_o	
A	5.0	1.0	0.0007
B	4.5	0.6	0.0018
C/D	3.0	0.5	0.0018

Default Depression Storage	
Impervious (in)	Pervious (in)
0.10	0.35

USER TIPS AND TOOLS

MHFD-Detention, Version 4.06 (July 2022)

Video Links: Click the link below to visit the MHFD YouTube Channel where you can access instructional videos for this and other workbooks.
MHFD Workbook Instructional Videos

Manual: **Click here** to download the **Technical Reference Manual** for the MHFD-Detention workbook. The manual provides background information on methods and equations used in this workbook.

User Tips:

Basin Sheet

- To evaluate a Detention Basin without a water quality component, select "**Flood Control Only**" from the BMP Type selection box.

- **Rainfall depths** can be overridden by entering user-defined values in cells D28:D34. Not all values have to be overriden, some can remain consistent with the pulldown selection.

- **Required Storage Volumes** can be overriden for each zone by selecting "**User Defined**" from the pulldown lists for each zone. This allows the user to adjust the required storage volume to better match local requirements. The user-defined storage values can be input as an equations which references other cells on the worksheet. For example, if the user wants to set the Zone 2 storage equal to the 100-year storage volume plus half of the WQCV minus Zone 1, an equation such as "=B40 + 0.5*(B26) - B43" can be entered in the cell. This will allow the volume to update automatically if other inputs change.

- **User Defined Stage-Area inputs** can be entered one row at a time or by entering all stages and then going back and entering all the areas. It is recommended that the latter approach be used in order to speed up the input process. This is because every time there are an equal number of stage and area values, the code will update calculations.

Outlet Structure Sheet

- If an outlet is not being used for one of the zone pulldowns, selecting "**Not Utilized**" from the pulldown list will assist in populating the unused inputs with "N/A".

- There is only one outlet type pulldown per zone. However, **additional outlets** can be added by providing the additional inputs and the effects will be accounted for in the stage-discharge table and routing results. However, some of the automatic sizing routines will no longer be available if additional outlets are utilized.

- When sizing an **orifice plate for WQCV and EURV**, the uppermost orifice can be manually changed to better satisfy 72 hour drain time requirements.

- The **Stage-Area-Volume-Discharge chart** can be manipulated automatically by changing the min/max scale values below the chart. This allows the user to zoom in on areas of interest and helps to ensure that summary tables include all critical stages.

- **Inflow hydrographs** can be overridden by simplying copying over the default values with values from another model or with exported outflow hydrographs from an upstream MHFD-Detention workbook. Please note that when using exported hydrographs from another MHFD-Detention workbook, there is no accounting for travel time or attenuation between detention basins. If there is additional runoff between the detention basins or complex routing, a more sophisticated program like EPA-SWMM is recommended.

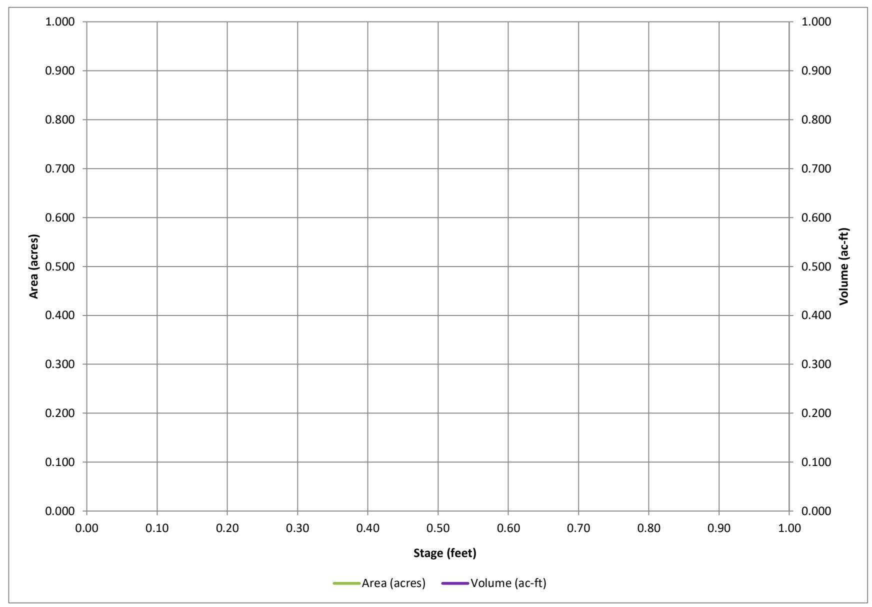
Calculate Stage-Area relationship from known Stage-Volume Relationship

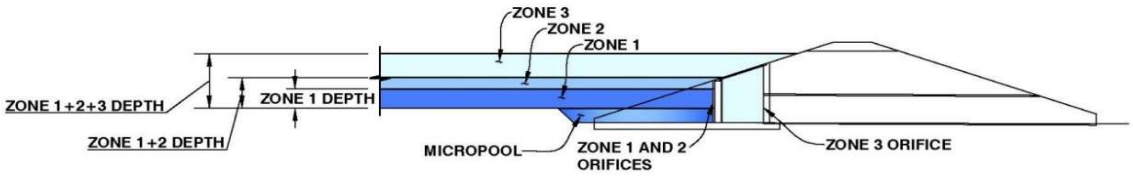
Stage - Storage Description	User Stage (ft)	User Volume (ac-ft)	User Volume (ft^3)	Calculated Volume (ft^3)	Calculated Area (ft^2)	Calculated Area (acre)	Volume % Diff (ft^3)	SSD 0.00E+00 Squared Difference in Area (ft^2)
Bottom of Basin	0.00	0.000	0	0			0%	

- The Stage-Area Tool is designed to help the user develop a Stage-Area relationship from a known Stage-volume relationship.
- The calculated volume is determined using the conic approximation method and is consistent with the method used on the Basin worksheet.

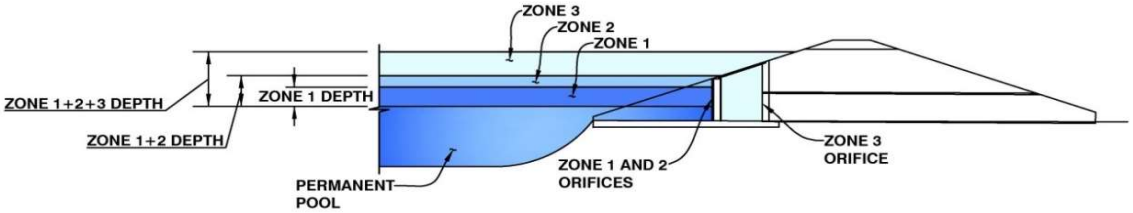
- The tool requires the user to provide a stage-volume relationship as the minimum input. The basin bottom area is an optional input.
  - If the user provides the bottom area, the program will automatically run the sizing routine to determine the area at each depth increment.
  - If the user clicks the "Minimize SSD" button, the program will iteratively solve for the bottom area that provides the best overall fit.

- If the program returns the message that the program could not find a solution, try the following:
  - Check the user inputs for stage and volume to determine if they are reasonable and try to identify any potential input mistakes.
  - Try manually changing the bottom area to see if you can get a closer fit.
  - Identify the row where the program failed and look closely at the volumes to determine what may be causing the routine to fail.

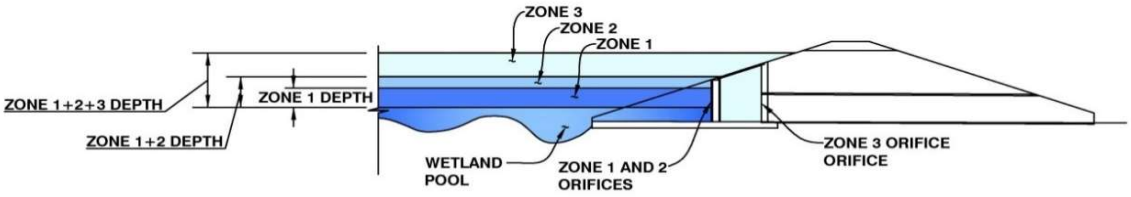




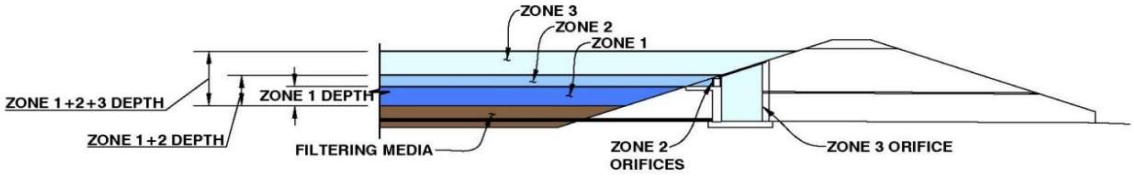
EXTENDED DETENTION BASIN WITH 3 ZONES



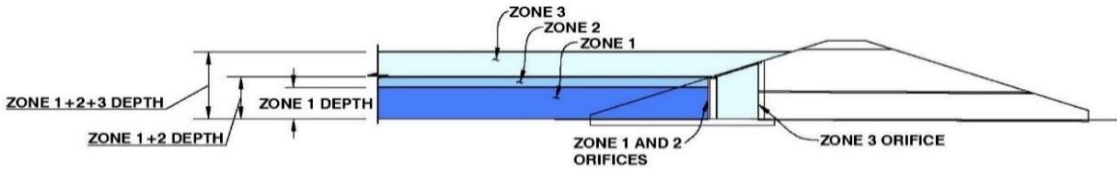
RETENTION POND WITH 3 ZONES



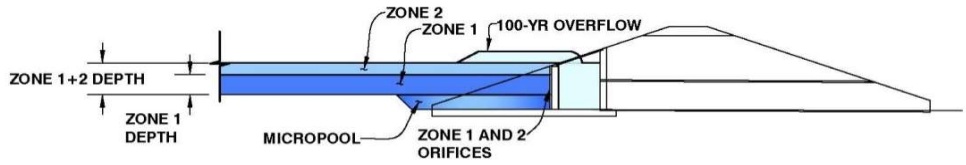
CONSTRUCTED WETLAND POND WITH 3 ZONES



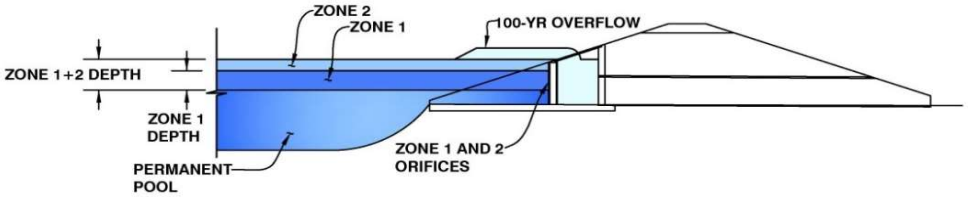
FILTERING BMP WITH 3 ZONES



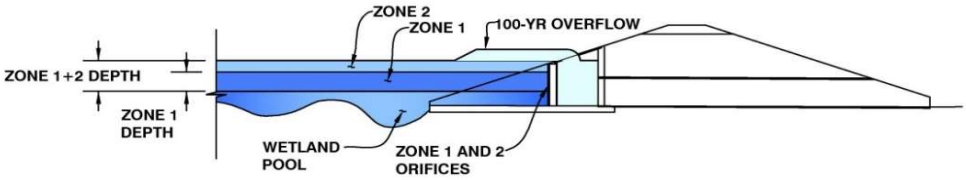
FLOOD CONTROL WITH THREE ZONES



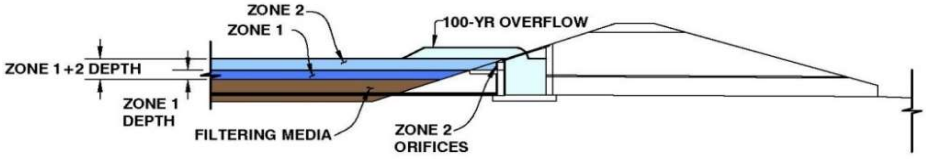
EXTENDED DETENTION BASIN WITH ZONE 1 AND ZONE 2



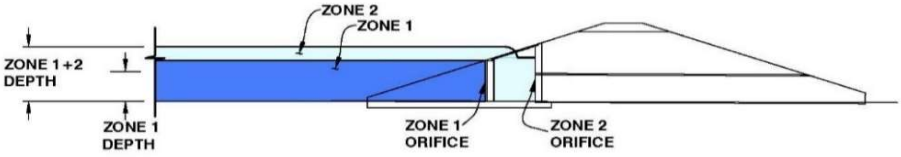
RETENTION POND WITH ZONE 1 AND ZONE 2



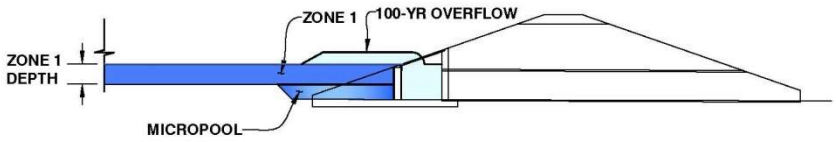
CONSTRUCTED WETLAND POND WITH ZONE 1 AND ZONE 2



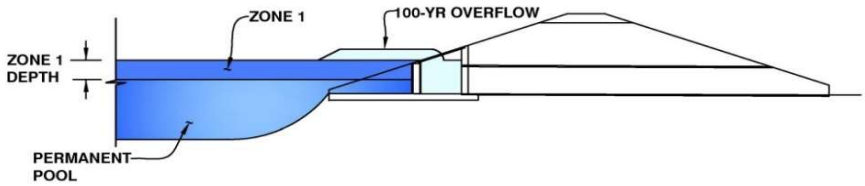
FILTERING BMP ZONE 1 AND ZONE 2



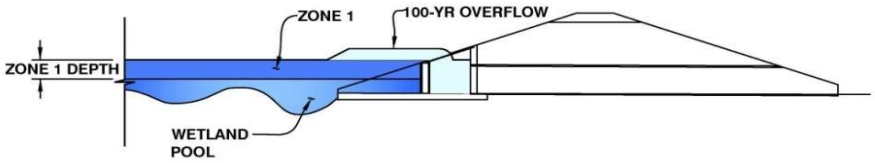
FLOOD CONTROL WITH TWO ZONES



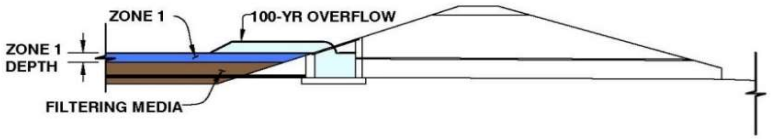
EXTENDED DETENTION BASIN WITH ZONE 1 ONLY



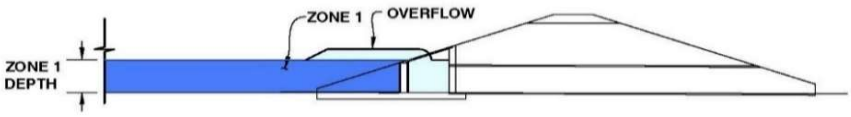
RETENTION POND WITH ZONE 1 ONLY



CONSTRUCTED WETLAND POND WITH ZONE 1 ONLY



FILTERING BMP WITH ZONE 1 ONLY



FLOOD CONTROL WITH ONE ZONE

Worksheet Protected