Designing for Multiple Municipal Storm Water Criteria

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Old Municipal Standards

Drainage Area (cf)	1.37	Maximum Allowable Discharge (cfs)	1.32
Impervious Area (ac)	0.82	Existing “C”	0.4
Pervious Area (ac)	0.55	Detention Size Required (cf)	**3541**

Duration	t (hr)	I (in/hr)	R (in)	Average C	30-year Runoff (cf)	Permitted Outflow (cf)	Required Storage (cf)
10 min	0.17	7.15	1.19	0.60	3551	789	2762
20 min	0.33	5.05	1.68	0.60	5013	1578	3435
30 min	0.50	3.96	1.98	0.60	5908	2367	3541
40 min	0.67	3.28	2.19	0.60	6535	3156	3378
50 min	0.83	2.82	2.35	0.60	7012	3946	3066
60 min	1.00	2.48	2.48	0.60	7400	4735	2665
70 min	1.17	2.22	2.59	0.60	7728	5524	2204
80 min	1.33	2.02	2.69	0.60	8027	6313	1714
90 min	1.50	1.85	2.77	0.60	8265	7102	1163
100 min	1.67	1.71	2.85	0.60	8504	7891	613
110 min	1.83	1.59	2.92	0.60	8713	8680	33
120 min	2.00	1.49	2.98	0.60	8892	9469	-578
24 hrs	24.00	0.21	5.02	0.60	14979	113633	-98654

New Municipal Standards

Category	Design Event	Description
Water Quality Treatment Volume	90% non-exceedance	Retain (preferred) or treat runoff from the entire site. Treatment is 80% TSS removal or a maximum discharge of 80 mg/L.
Channel Protection	Up to and including the 2-year 24-hour	Retain to meet volume and peak flow of condition prior to development
Collection System	10-year 24-hour (non-sag points) 50-year 24-hour (sag points)	Peak flow limited to rates prior to development. HGL at least 1-ft below ground surface.
Flood Control	Up to and including the 100-year 24-hour	Peak flow limited to rates prior to development.

How do you calculate and design everything?

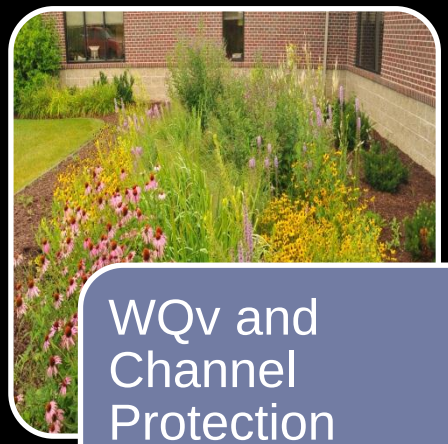
- Where do you start?
- What methods and models are appropriate?
- What's the impact on the design when practices are placed in series?
  - If I remove volume for the 2-year event, what's the impact on the detention storage volume for the 10-year?
- How do I size the outlet controls (underdrains, weirs and orifices) for each of the practices?
  - What's needed? Geometry? Elevation?
- How do you check that systems are drained and ready for the next storm event?

Design Criteria

		Water Quality Treatment	Channel Protection	Municipal Collection	Local Flood Control
Level of Service	Recurrence	90%	1.5-2 year	5-10 year	25-100 year
	Rainfall (in)	0.75 – 1.0	1.5 – 2.5	2.5 – 4.0	3.5 – 7.0
Criteria Target(s)	Sediment	●			
	Volume	○	●		
	Peak Flow		●	●	●
Methods	Settling, Filtration	●			
	ET, Infiltration, Water Reuse	●	●	○	○
	Detention, Routing			●	●

ET = Evapotranspiration
Rainfall Values are based on 24-hour duration

Calculation Order



WQv and Channel Protection

- Green Roof
- Bioretention
- Porous Pavement
- 90% to 2-year

Municipal Collection System

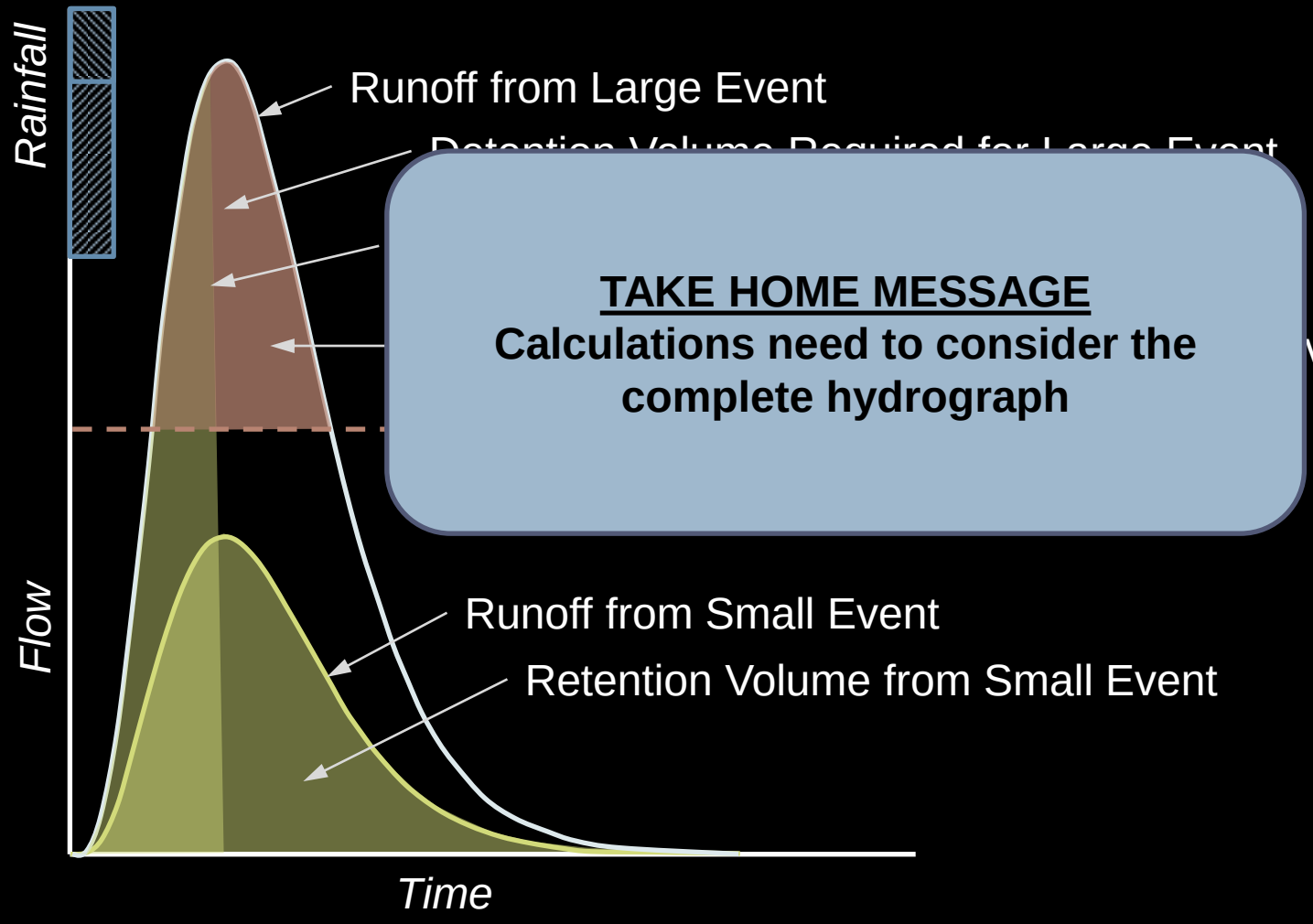
- Detention
- Retention
- 5 to 10-year

Local Flood Control

- More detention
- Route flow away from buildings
- 25 to 100-year

WQv = Water Quality Volume

Fitting Criteria Together

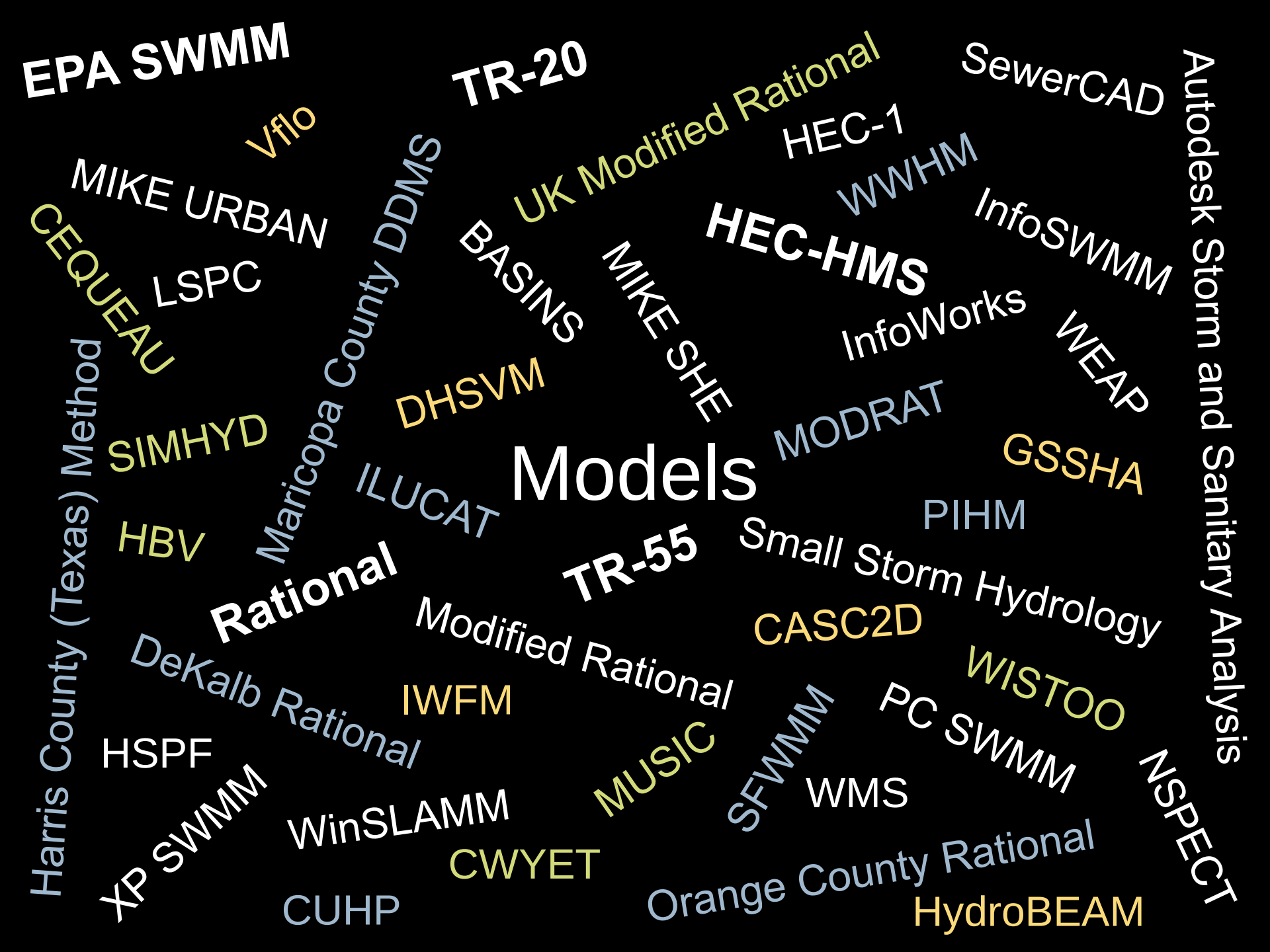


TAKE HOME MESSAGE
Calculations need to consider the complete hydrograph

Project Site

Bioretention Small Storms

Detention Large Storms


Models
EPA SWMM
TR-20
SewerCAD
Autodesk Storm and Sanitary Analysis
Vflo
UK Modified Rational
HEC-1
WWHM
InfoSWMM
MIKE URBAN
HEC-HMS
CEQUEAU
LSPC
BASINS
MIKE SHE
InfoWorks
WEAP
Maricopa County DDMS
DHSVM
MODRAT
GSSHA
SIMHYD
ILUCAT
PIHM
Harris County (Texas) Method
HBV
Rational
TR-55
Small Storm Hydrology
Modified Rational
CASC2D
DeKalb Rational
IWFM
WISTOO
PC SWMM
HSPF
MUSIC
SFWMM
NSPECT
XP SWMM
WinSLAMM
WMS
CWYET
Orange County Rational
CUHP
HydroBEAM

Common Computational Hydrology Methods

Method	Peak Flow	Runoff Volume	Hydrograph Shape	Other
Rational	●	○		
Modified Rational		○		Detention storage sizing
Small Storm Hydrology		●		
Curve Number		●		
Unit Hydrograph			●	Combine with runoff volume method
Regression Equations	●			Common for stream response but not urban hydrology
SWMM Runoff	●	●	●	

So if SWMM is so great, why not use it?

- You can!
- Complex
- Steep learning curve
- Hydrology needs to be calibrated
- Not friendly for iterative design

Subcatchment Variables

- Area
- Width ***
- % Slope
- % Impervious ***
- Roughness (n) Impervious
- Roughness (n) Pervious
- Depression Storage Impervious
- Depression Storage Pervious
- % of area no depression storage
- Routing between pervious and impervious

Infiltration

- Horton Infiltration
  - Max and Min Infiltration Rate
  - Decay Constant
  - Drying Time
  - Max Infitrationl Volume
- Green Ampt Infiltration
  - Suction Head
  - Conductivity
  - Initial Deficit

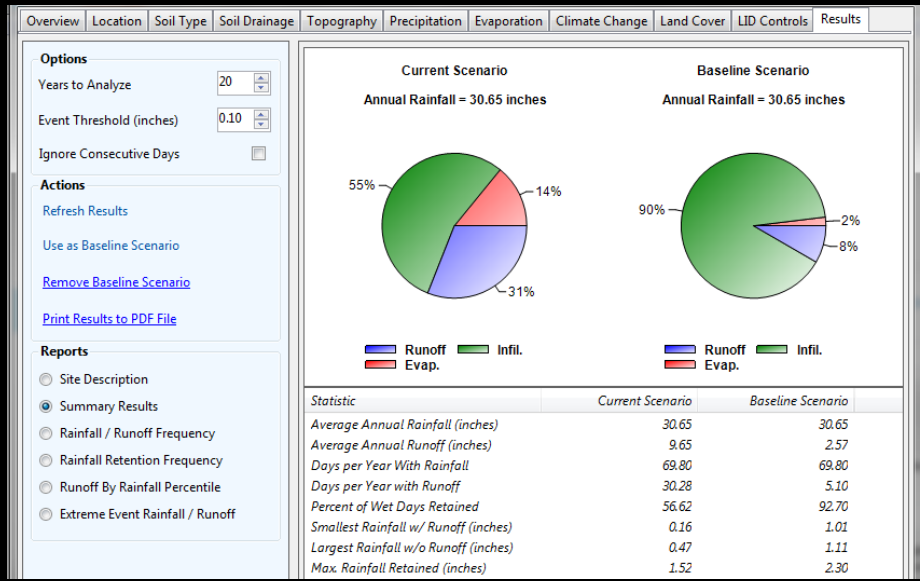
Optional Routines for

- Groundwater
- Snow Packs
- LID Controls
- Water Quality

Just to name a few . . .

National Stormwater Calculator?

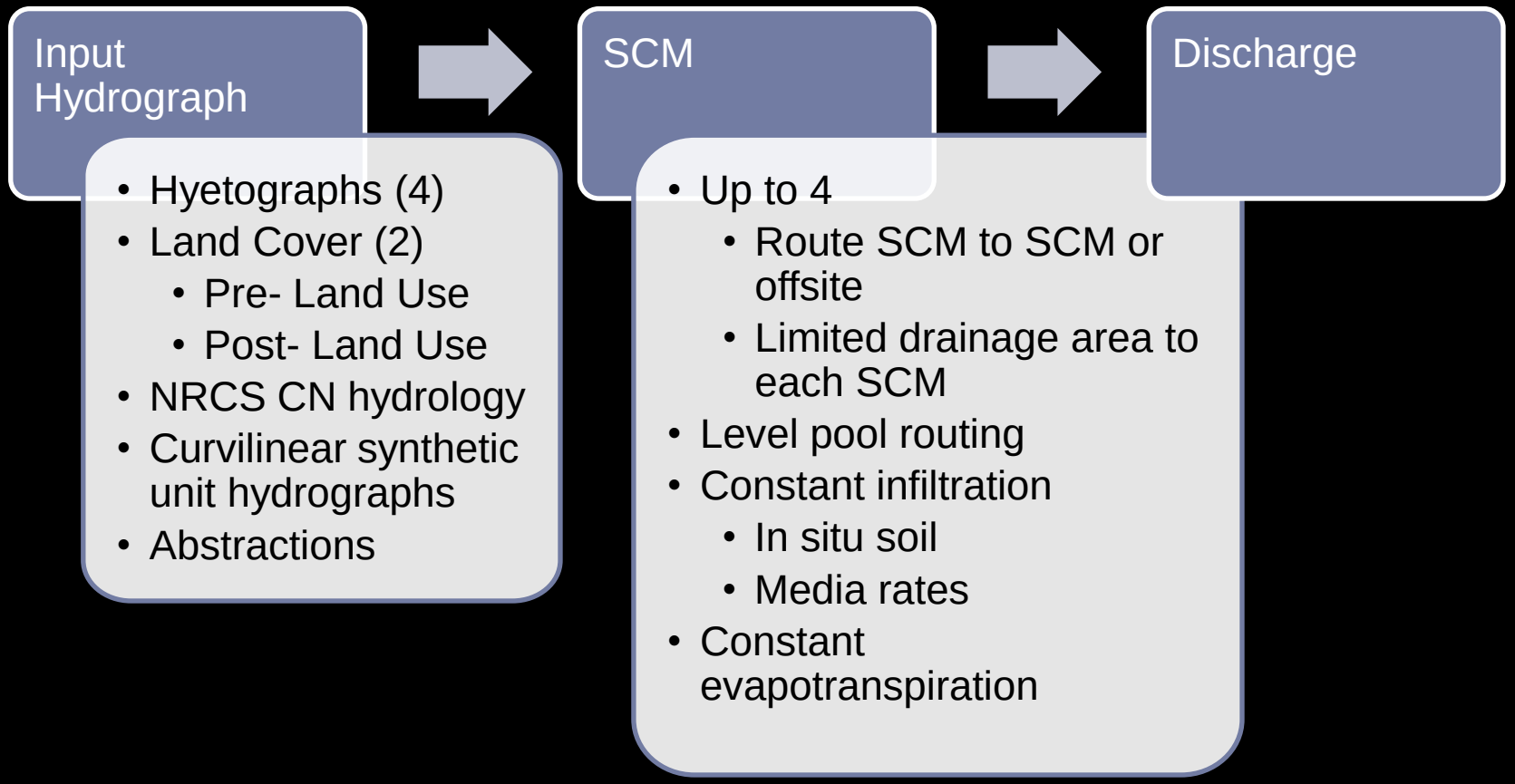
- Continuous simulation
- Good at average annual
- Good for big picture concept planning
- Doesn’t work for discrete design storms
- No control over water release
- Not a design tool



Spreadsheet Approach

- Site development scale
- Stormwater design criteria
  - Flexible
  - Multiple requirements (frequency, peak flow, volume, dewater)
- Adaptable to different conditions (soils, climate)
- Calculations
  - Industry standards
  - No black boxes
  - Reproducible
  - Documented
- Useful to design engineer
- Quick

Methodology



SCM = Stormwater Control Measure (e.g. bioretention, pervious pavement, green roof, water harvesting, detention, retention)

Input – Project Information

1	**SITE DEVELOPMENT STORMWATER TOOL (SDST)**	
2		
3	**SITE**	
4	Name	EXAMPLE
5	Parcel Identification	00-00-000-000-0000
6	Location Address	999 Here
7		
8	Nearest Major Intersection	Main St at First Ave
9		
10	**OWNER**	
11	Contact	Superman, PE
12	Organization	DC Comics
13	Address	1 Clark Kent Lane
14		Planet Krypton
15	Phone	(123) 456-7890
16	Email	Superman@DCComics.com
17		
18	**CALCULATIONS PERFORMED BY**	
19	Contact	Bugs Bunny
20	Organization	Warner Bros.
21	Address	123 Main St.
22		Albuquerque, NM 12345
23	Phone	(123) 456-7890
24	Email	Bugs.Bunny@warner.com
25	Date	May 20, 2013
26		
27	**PROJECT DESCRIPTION**	
28	This is a test project	

Input – Job Control

STEP 4

CLIMATOLOGY DATA

	Water Quality Treatment Volume	Channel Protection	Collection (Pipe) System	Roadway Flood System
Recurrence Interval	0.9	2-year	10-year	100-year
Duration (hr)	24-hr	24-hr	24-hr	24-hr
Precipitation (in)	0.90	2.42	3.43	5.20

Evapotranspiration (in/day)	0.1
Hyetograph Distribution	Type II

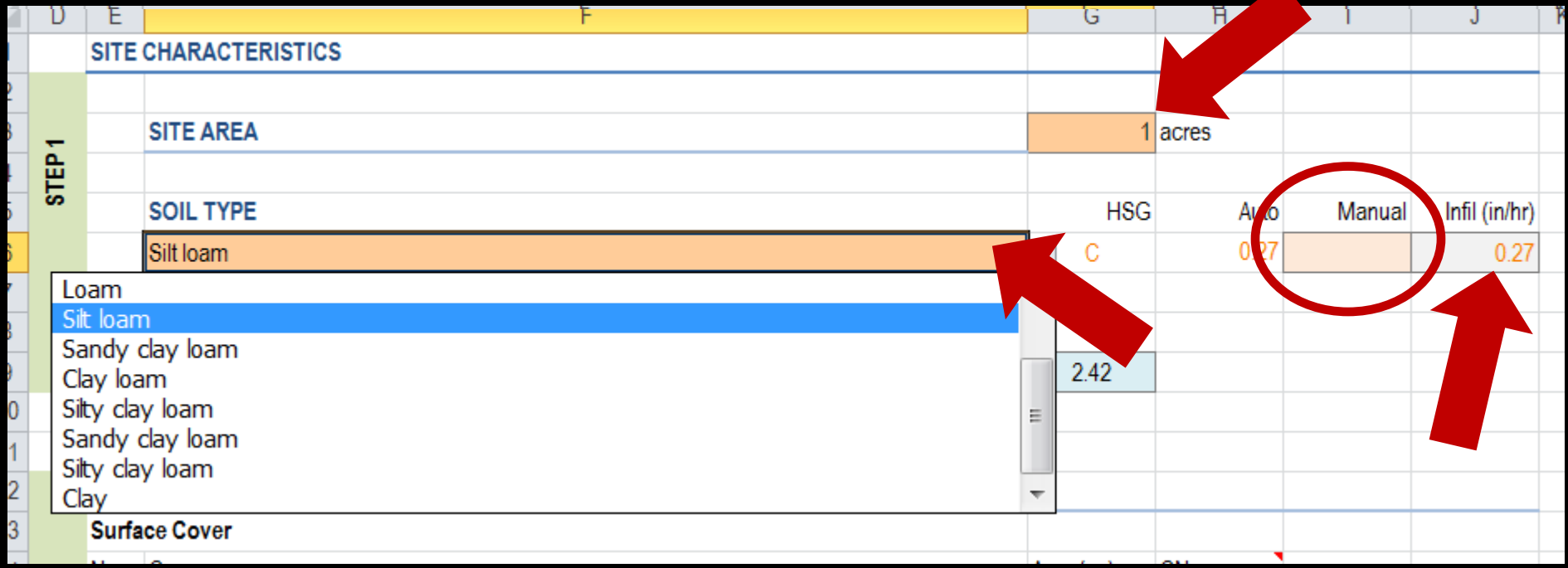
DESIGN CRITERIA

Recurrence Interval	90%	2-year	10-year	100-year
Treatment of Runoff for Sediment Load	Yes	NA	NA	NA
Peak flow (% of CPD)	NA	100%	100%	100%
Volume (% of CPD)	NA	100%	NA	NA
Dewater Time (hr), surface water [time from end of rainfall]	NA	48	48	48
Dewater Time (hr), complete drainage [time from end of rainfall]	NA	48	72	72

CONDITION PRIOR TO DEVELOPMENT

Peak Rate Factor (PRF)	484
Ratio of Initial Abstraction to Potential Maximum Retention [λ=Ia/S]	0.05

Input – Site Characteristics



Input – Site Characteristics

STEP 2

CONDITION PRIOR TO DEVELOPMENT

Surface Cover

No.	Cover	Area (ac)	CN
1	Natural | Brush, Forb, Grass Mix | Good	0.5	52
2	Urban | Open Space (lawns, parks, golf, cemeteries) | Fair (grass cover 50% to 75%)	0.5	71
3	Not Used		NA
4	Not Used		NA
5	Not Used		NA
6	Manual Entry		
	Total	1	

Composite CN calculations
Not weighted average

Time of Concentration

No.	Surface Feature	Slope (ft/ft)	Manning n	Length (ft)	Tt (hr)
1	Sheet Flow - Woods light underbrush	0.01	0.4	100	0.54
2	Shallow Conc. - Woodlands	0.01	0.101	100	0.06
3	Sheet Flow - Short-grass prairie	0.02	0.15	100	0.19
4	Not Used		NA		0.00
5	Not Used		NA		0.00
6	Manual Entry				
				CPD Tc (hr)	0.79

POST DEVELOPMENT CONDITIONS

Surface Cover

No.	Cover	Area (ac)	CN
1	Urban | Paved Parking, Roofs, Driveways (excl. ROW) | 100% impervious	0.8	98

Input – Control Measures

STORMWATER CONTROL MEASURES — **STEP 5**

SCM 1

Practice

Drainage Are

Dischar

otes and Comments

Sediment St

X-sec

nd Side Slopes

Stormwater Control Measures
- Define up to 4
- Each with
  - unique characteristics,
  - drainage areas, and
  - discharge paths

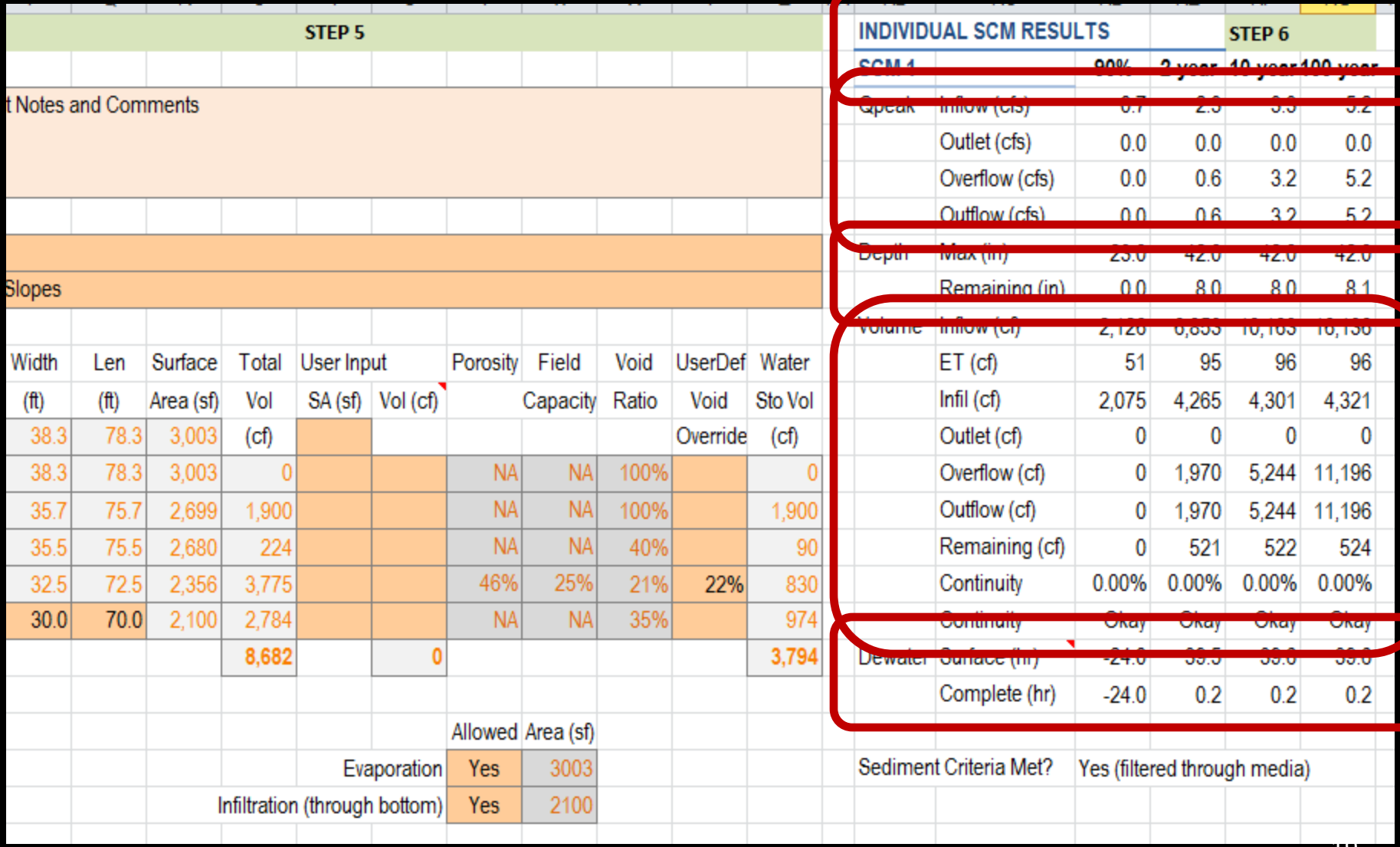
Cross S	Media	(in)	Side Slope	Width (ft)	Len (ft)	Surface Area (sf)	Total Vol (cf)	User Input SA (sf)	User Input Vol (cf)	Porosity	Field Capacity	Void Ratio	UserDef Void Override	Water Vol (cf)
Top			xH:1V	38.3	78.3	3003								
	NA	0	0	38.3	78.3	3003	0				NA	NA	100%		0
	Surface Storage	8	2	35.7	75.7	2699	1900				NA	NA	100%		1,900
	Mulch	1	1	35.5	75.5	2680	224				NA	NA	40%		90
	Loam	18	1	32.5	72.5	2356	3775			6%	25%	21%	22%		830
Bottom	Aggregate Reservoir (35%)	15	1	30.0	70.0	2100	2784				NA	NA	35%		974
	Total	42					8682								3,794

Surface Storage Depth (in)	8
Media Storage Depth (in)	34
Media (limiting) Infiltration Rate (in/hr)	6

	Allowed	Area (sf)
Evaporation	Yes	3003
Infiltration (through bottom)	Yes	2100

Outlet Type	Orifice	Weir	None	None	None
Offset from bottom (in)	8	36			
coefficient c	0.5	3			
Area (sf) or Length (ft)	0.02	5			
Volume below the offset (cf)	519.61	2369.3	NA	NA	NA

Results – Individual SCM Results



STEP 5

t Notes and Comments

Slopes

Width (ft)	Len (ft)	Surface Area (sf)	Total Vol (cf)	User Input SA (sf)	User Input Vol (cf)	Porosity	Field Capacity	Void Ratio	UserDef Void Override	Water Sto Vol (cf)
38.3	78.3	3,003	0			NA	NA	100%		0
38.3	78.3	3,003	1,900			NA	NA	100%		1,900
35.7	75.7	2,699	224			NA	NA	40%		90
35.5	75.5	2,680	3,775			46%	25%	21%	22%	830
32.5	72.5	2,356	2,784			NA	NA	35%		974
30.0	70.0	2,100	8,682		0					3,794

	Allowed	Area (sf)
Evaporation	Yes	3003
Infiltration (through bottom)	Yes	2100

STEP 6

INDIVIDUAL SCM RESULTS		90%	2 year	10 year	100 year
SCM 1					
Qpeak	Inflow (cfs)	0.7	2.0	3.0	5.2
	Outlet (cfs)	0.0	0.0	0.0	0.0
	Overflow (cfs)	0.0	0.6	3.2	5.2
	Outflow (cfs)	0.0	0.6	3.2	5.2
Depth	Max (in)	23.0	42.0	42.0	42.0
	Remaining (in)	0.0	8.0	8.0	8.1
Volume	Inflow (cf)	2,126	6,855	10,165	16,156
	ET (cf)	51	95	96	96
	Infil (cf)	2,075	4,265	4,301	4,321
	Outlet (cf)	0	0	0	0
	Overflow (cf)	0	1,970	5,244	11,196
	Outflow (cf)	0	1,970	5,244	11,196
	Remaining (cf)	0	521	522	524
	Continuity	0.00%	0.00%	0.00%	0.00%
	Continuity	Okay	Okay	Okay	Okay
Dewater	Surface (hr)	-24.0	39.5	39.6	39.6
	Complete (hr)	-24.0	0.2	0.2	0.2

Sediment Criteria Met? Yes (filtered through media)

Results – Total System

STEP 7

DRAINAGE AREA SUMMARY

Practice	Type	Drainage Area (ac)	% of Drainage	Discharge To	Sediment Criteria
SCM 1	Bioretention	0.5	50.0%	SCM 2	NA
SCM 2	Porous Pvmt	0.4	40.0%	Offsite	NA
SCM 3	None	0	0.0%	NA	NA
SCM 4	None	0	0.0%	NA	NA
Uncontrolled		0.1	10.0%	Offsite	No
Total		1	100.0%		

SEDIMENT CONTROL STRATEGY FOR UNCONTROLLED PORTIONS OF THE SITE

Required	Yes	Strategy	Select Strategy
		Notes:	

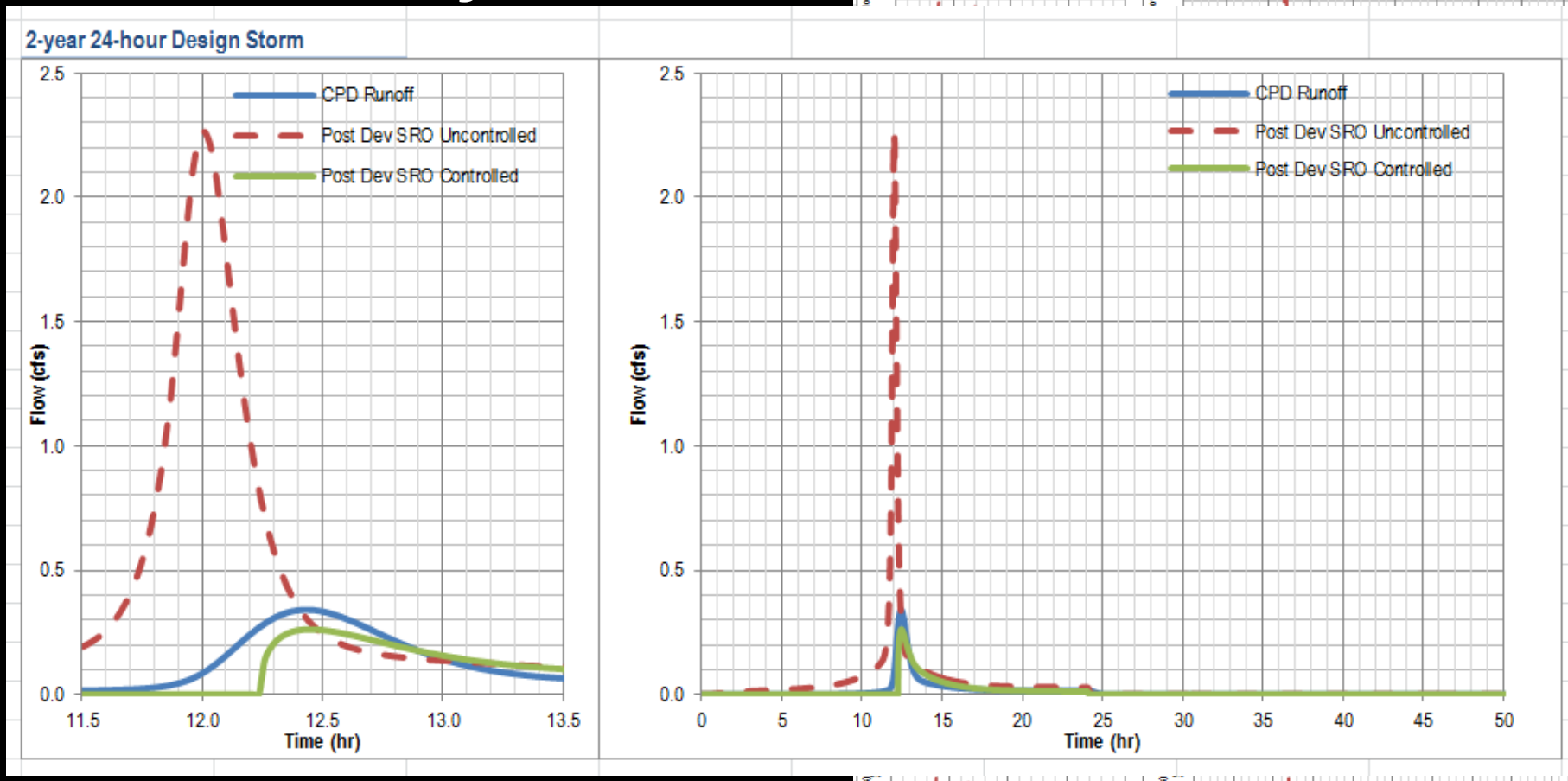
TOTAL SYSTEM RESULTS

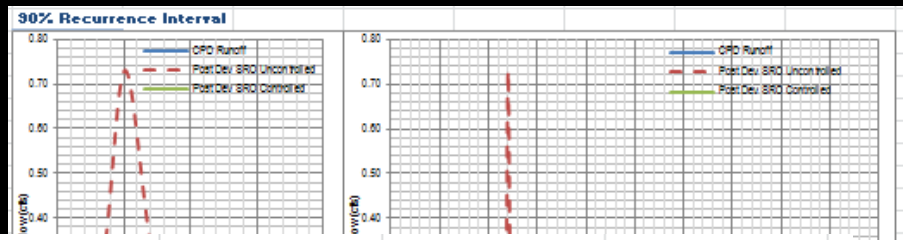
	Recurrence Interval	90%	2-year	10-year	100-year
PEAK FLOW	CPD Runoff (cfs)	0.03	0.34	0.67	1.38
	Post Dev SRO Uncontrolled (cfs)	0.73	2.27	3.32	5.23
	Post Dev SRO Controlled (cfs)	0.34	1.11	1.66	3.65
	Difference CPD - Post Dev (cfs)	(0.3)	(0.8)	(1.0)	(2.3)
	Criteria	NA	Qpost<= 0.3 cfs	Qpost<= 0.7 cfs	Qpost<= 1.4 cfs
	Criteria Met (Y/N)	NA	No	No	No
VOLUME	CPD Runoff (cf)	219	2,035	3,892	7,902

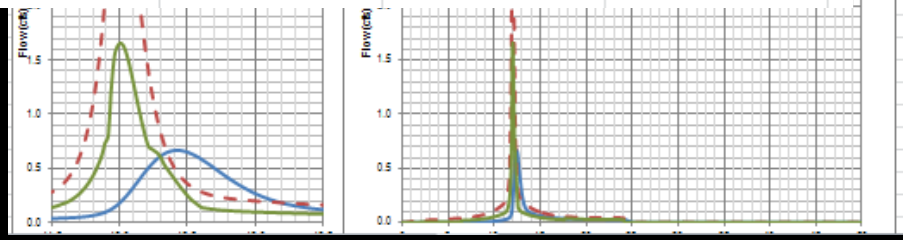
Results – Total System

TOTAL SYSTEM RESULTS						
		Recurrence Interval	90%	2-year	10-year	100-year
PEAK FLOW		CPD Runoff (cfs)	0.03	0.34	0.67	1.38
		Post Dev SRO Uncontrolled (cfs)	0.73	2.27	3.32	5.23
		Post Dev SRO Controlled (cfs)	0.00	0.26	0.60	5.21
		Difference CPD - Post Dev (cfs)	0.0	0.1	0.1	(3.8)
		Criteria	NA	Qpost<= 0.3 cfs	Qpost<= 0.7 cfs	Qpost<= 1.4 cfs
		Criteria Met (Y/N)	NA	Yes	Yes	No
VOLUME		CPD Runoff (cf)	219	2,035	3,892	7,902
		Post Dev Runoff (cf)	2,126	6,853	10,163	16,136
		ET (cf)	51	105	105	106
		Infiltration (cf)	2,075	4,373	4,411	4,433
		Outflow (cf)	0	1,854	5,124	11,073
		Remaining Storage (cf)	0	521	522	524
		Continuity Error (%)	0.00%	0.00%	0.00%	0.00%
		Continuity Check	Okay	Okay	Okay	Okay
		Criteria	NA	Qpost<= 2035 cf	NA	NA
		Criteria Met (Y/N)	NA	Yes	NA	NA
SEDIMENT		Criteria Met (Y/N)	Yes	NA	NA	NA
DEWATER TIME		Surface Water Dewater Time (hr)	-24.0	39.5	39.6	39.6
		Criteria	NA	<= 48 hrs	<= 48 hrs	<= 48 hrs
		Criteria Met (Y/N)	Yes	Yes	Yes	Yes
		Complete Drainage Dewater Time (hr)	-24.0	0.2	0.2	0.2
		Criteria	NA	<= 48 hrs	<= 72 hrs	<= 72 hrs
		Criteria Met (Y/N)	Yes	Yes	Yes	Yes

Results
Total System

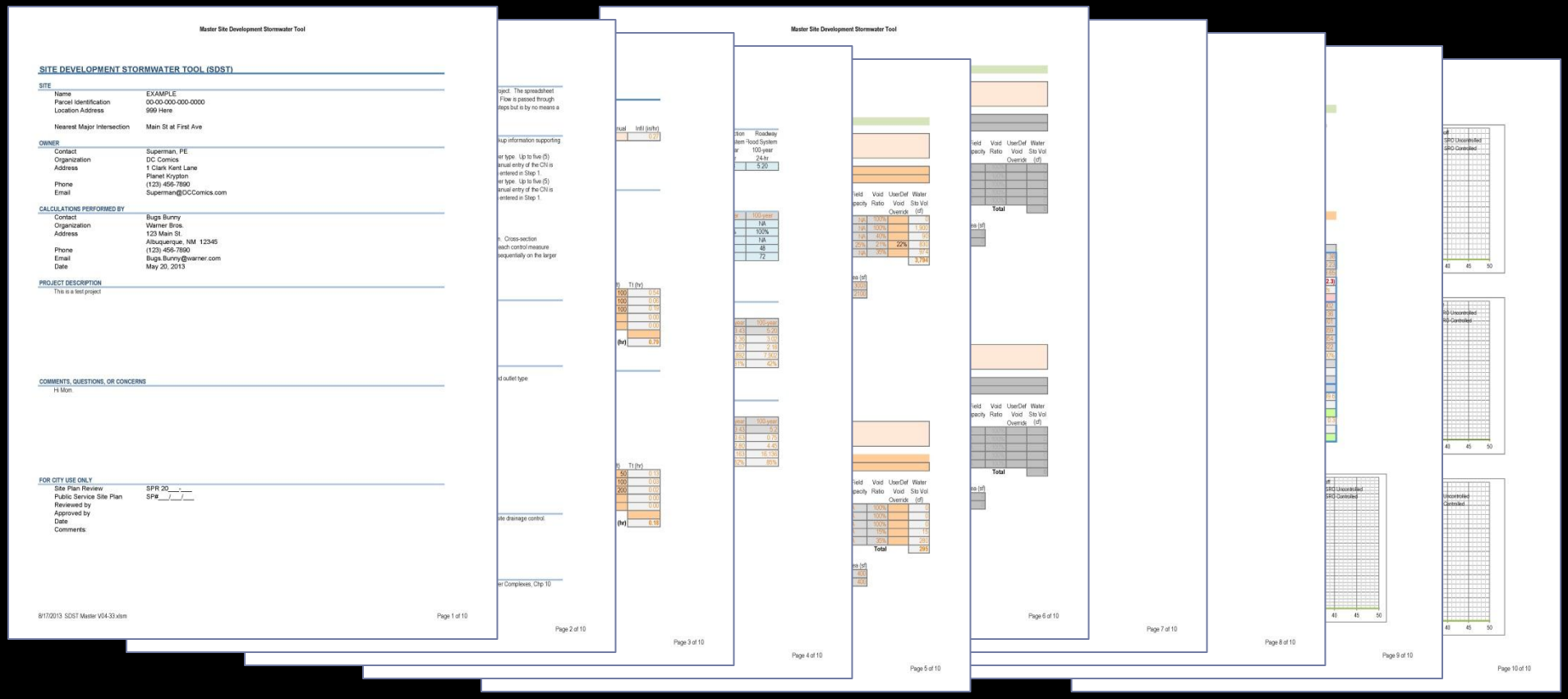






Results – Total System

- 10 page printable report
- Complete engineering notes
- Input and results



It’s not Perfect

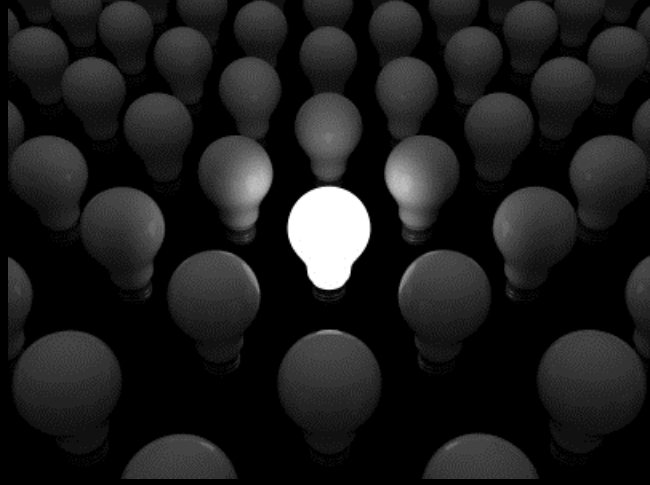
- Runoff from land area lumped together, not specific to stormwater control practice
- Limited to 24-hour rainfall duration
- Ignores pipe and channel routing
- Simplifies infiltration, ET, etc.
- File size is really big

Conclusion

- Purpose
  - Design tool for stormwater control measures
  - Site development scale
  - Municipal staff and development engineers
- Complete hydrograph routing allows for
  - Comprehensive sizing for multiple criteria
  - Avoid excessive over sizing
- Spreadsheet
  - No black boxes
  - Customizable
  - Familiar interface

Wish List

- Hydrology
  - Additional time of concentration options
  - Add Small Storm Hydrology Method
  - Add Rational Method
  - Additional unit hydrographs
  - Add Huff rainfall distribution
- Hydraulics
  - Inlet sizing
  - Gutter spread calculations
- Cost-Benefit calculator
- Output file for direct input into SWMM
- Shrink file size



- Got any better ideas?
- Questions?
- If you would like a copy of the spreadsheet, let me know

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