Geosyntec consultants

What the Flow?!? A Modeling Approach to Assess Flow-Through BMPs

By: Mike Hardin, PhD, PE, CFM
Mark Ellard, PE, CFM, DWRE, ENV. SP

Florida Stormwater Association
2019 Annual Conference
6-20-2019

FSA
Florida Stormwater Association

Outline

- Introduction
- Methodology
  - Rainfall data QA/QC
  - Continuous simulation modeling (EPA SWMM)
- Conclusions

Top Image: https://www.deeproot.com/blog/blog-entries/urban-runoff-negatively-impacts-stream-biodiversity
Bottom Image: https://forterrabp.com/stormwater-management-systems/

Introduction

Water Quality Standards

- Need to meet TMDLs/BMAP
- Tools exist to help us achieve water quality goals (BMPs)
- Each site has its own unique challenges

Less of this

More of this

Top Image: https://earthjustice.org/blog/2016-march/the-massive-fish-kill-florida-could-have-prevented
Bottom Image: https://www.skyscanner.com/tips-and-inspiration/best-florida-springs

Traditional BMPs

Advantages

- Attenuation/storage
- Water quality evaluation is well understood (BMPTRAINS)
- Aesthetically pleasing
- Wildlife habitat

Disadvantages

- Maintenance to remove sediments deposited on bottom
- Potential for mosquitoes
- Toxic algal blooms if not properly maintained

Source: https://www.tavares.org/1162/Ruby-Street-StormwaterBeautification-Pla

Source: Google Images

Traditional BMPs - Disadvantages

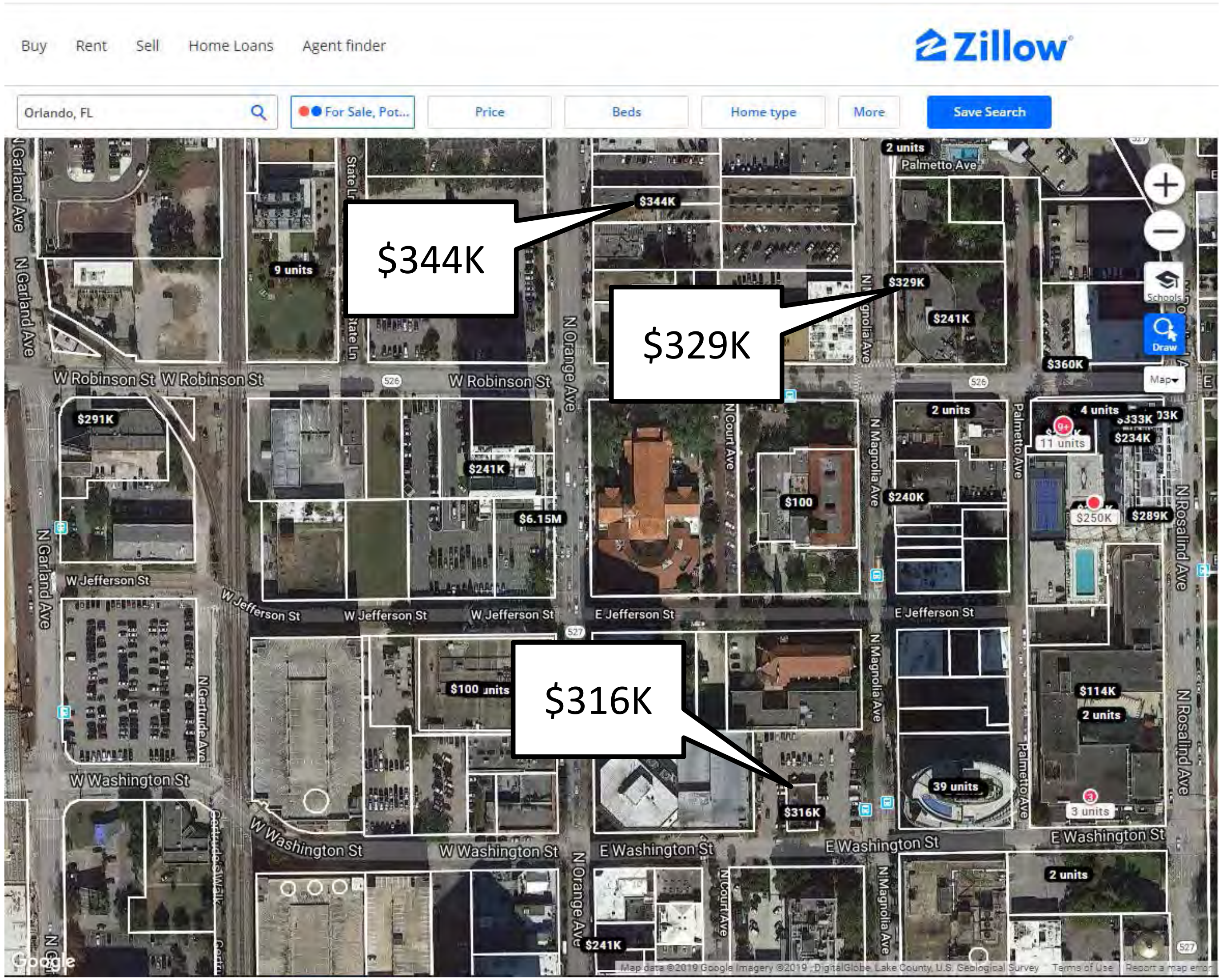
What if space is limited?

Source: https://www.tavares.org/1162/Ruby-Street-StormwaterBeautification-Pla

Source: https://www.dailymail.co.uk/news/article-2176224/A-13-year-old-girl-launches-grandmothers-car-vehicle-Michigan-mall-parking-lot.html

Traditional BMPs - Disadvantages

- High urban land costs
- Which buildings to acquire?
- Reduce developable land



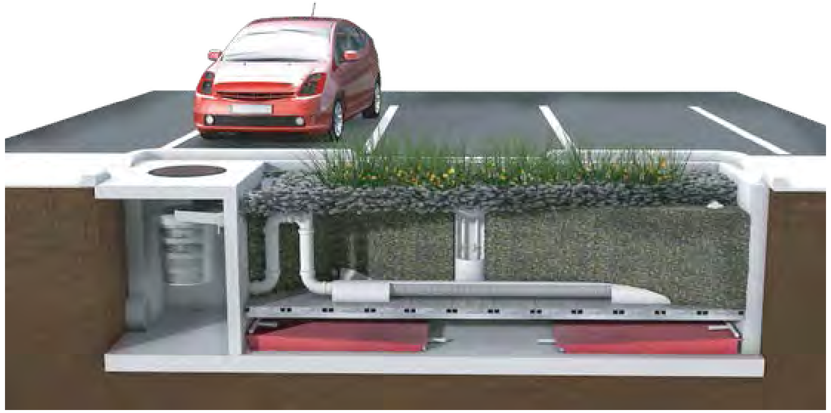
Flow-Through BMPs

Advantages

- Small footprint
- Treating water as it is generated, close to where it is generated (LID principals)
- Remove course particles/debris as well as nutrients (filter media)

Disadvantages

- Limited by the design flow rate that it can treat
- Does not provide attenuation or storage
- Need more units to provide equivalent treatment

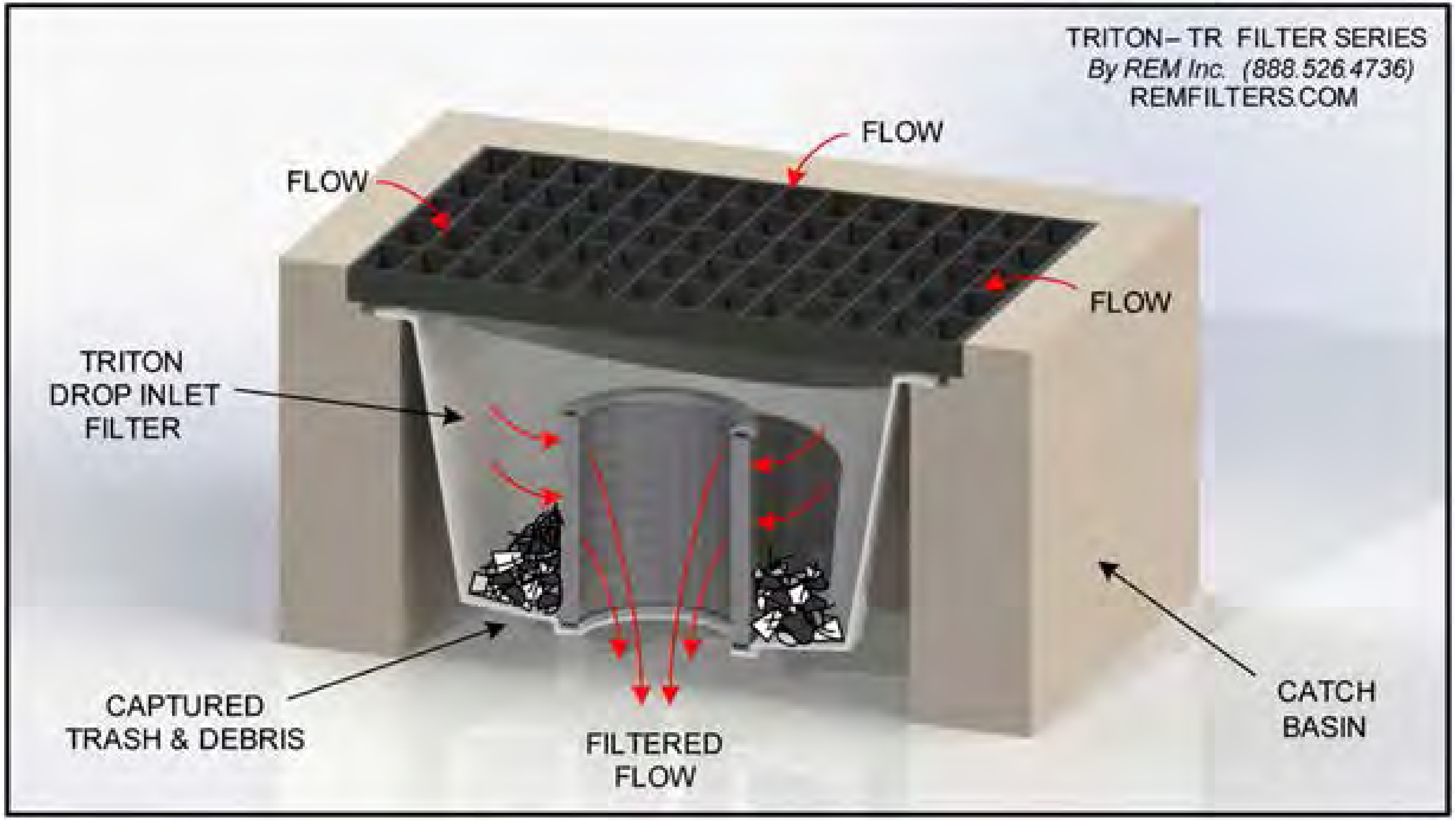


Source: https://www.suntreetech.com/nutrimax.html

Source: https://www.crwa.org/hs-fs/hub/311892/file-640261436-pdf/Our_Work_/Blue_Cities_Initiative/Resources/Stormwater_BMPs/CRWA_Tree_Pit.pdf

Flow-Through BMPs - Examples

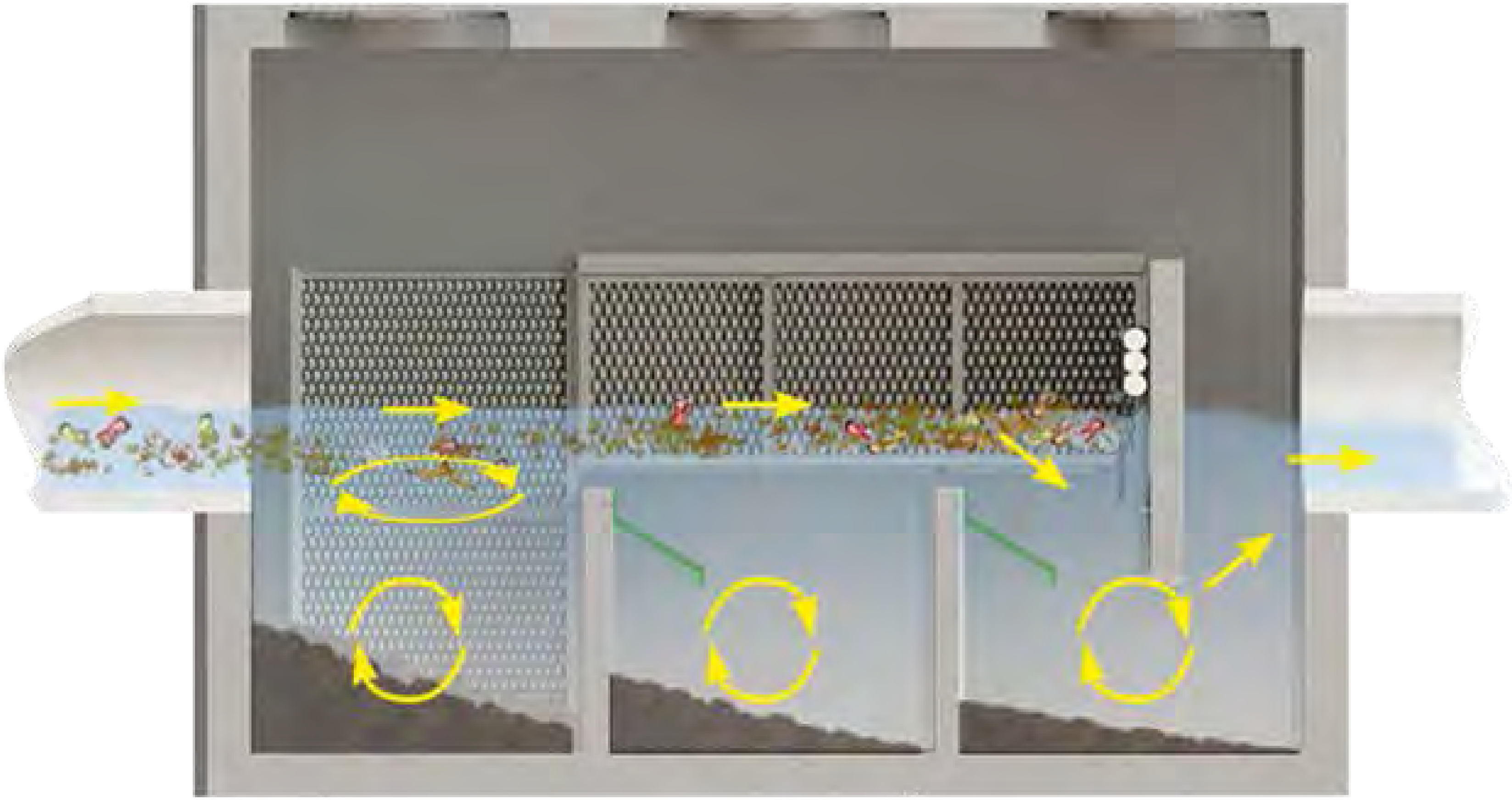
Inlet Insert



Source: https://remfilters.com/drop-inlet-filter-2/

Flow-Through BMPs - Examples

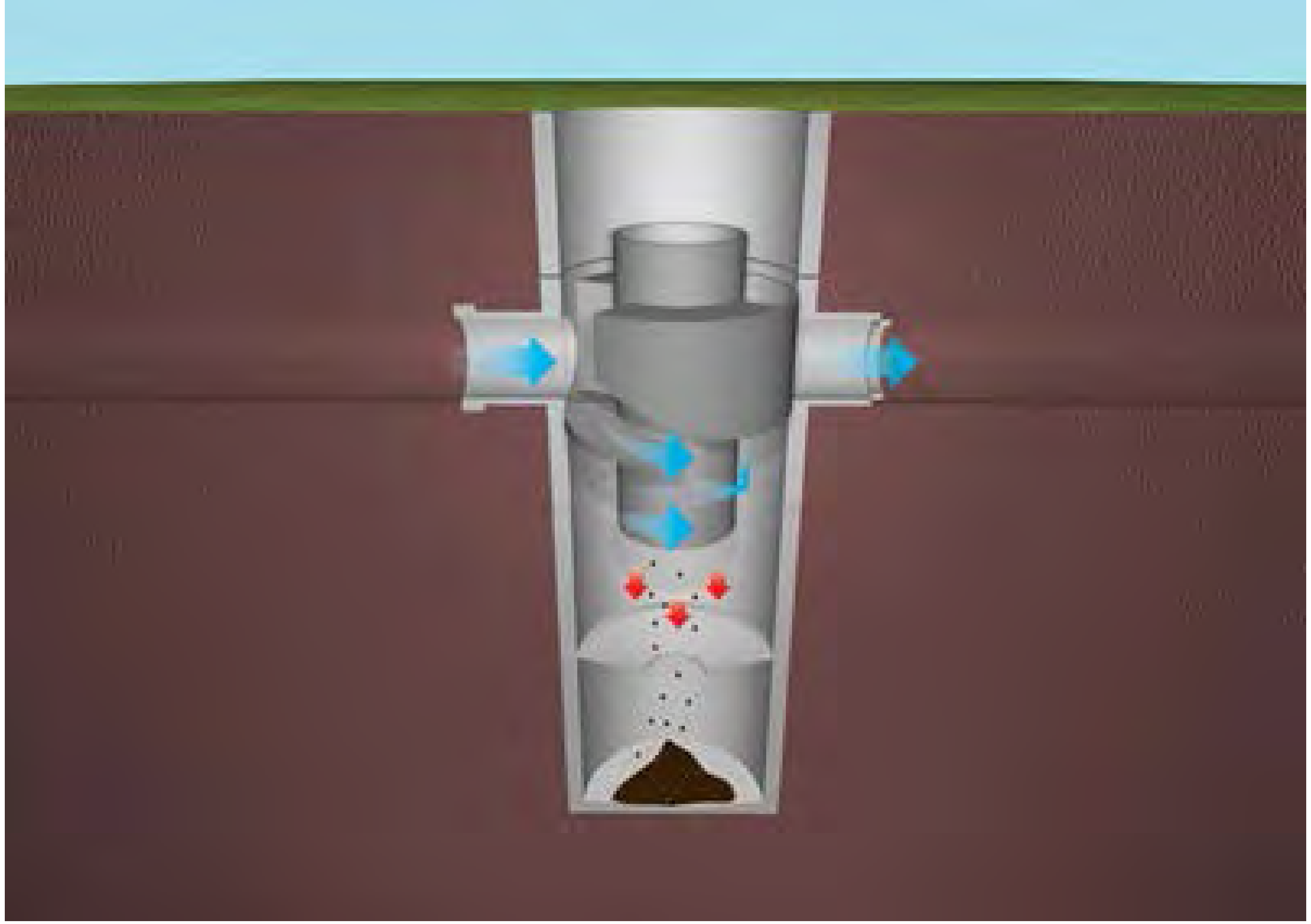
Baffle box



Source: https://biocleanenvironmental.com/debris-separating-baffle-box/

Flow-Through BMPs - Examples

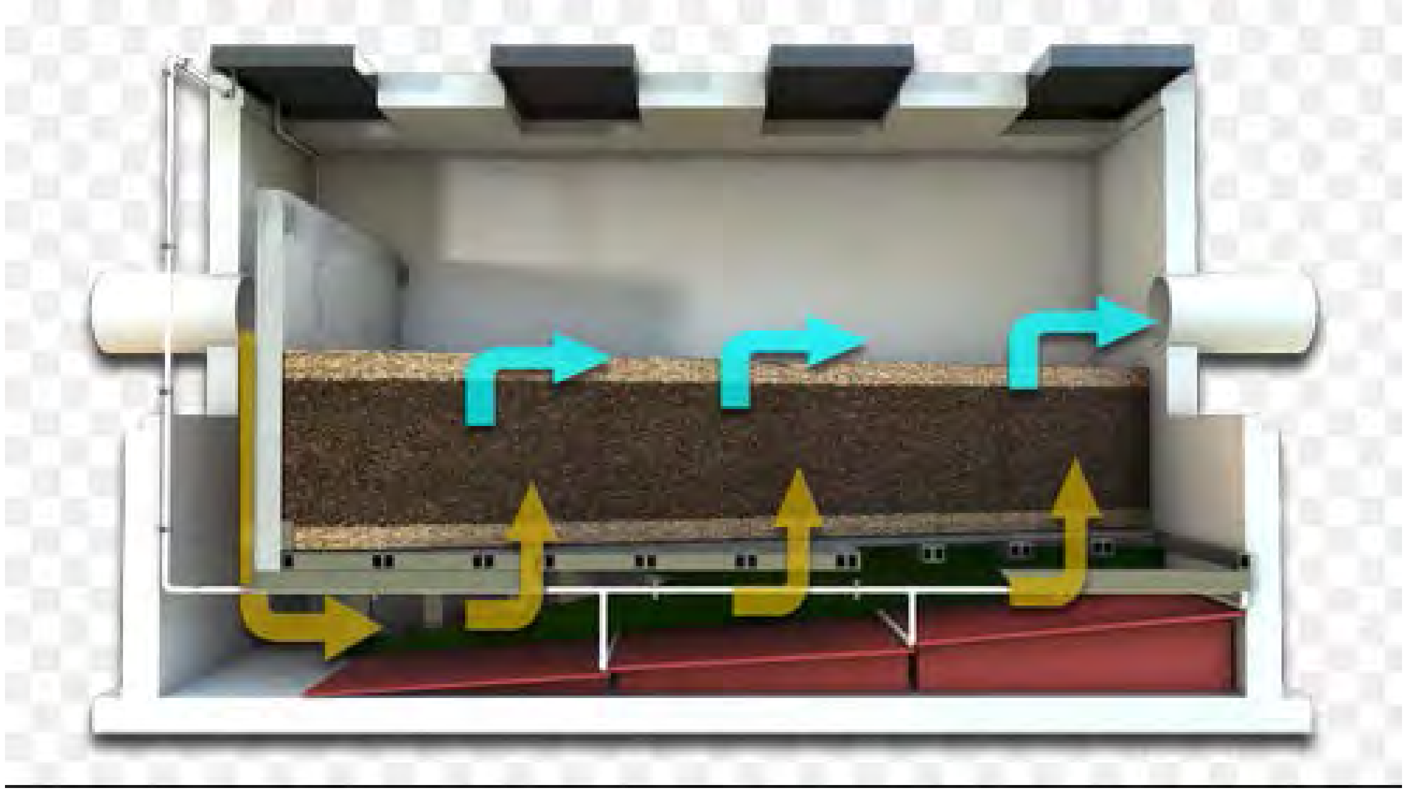
Hydrodynamic Separator



Source: https://fpmccann.co.uk/product/stormcleanser-hydrodynamic-separator/

Flow-Through BMPs - Examples

Upflow Filter



Source: https://www.suntreetech.com/nrfs.html

Flow-Through BMPs - Examples

Upflow Filter

Source: https://www.wateronline.com/doc/new-jersey-certification-hydro-flo-filter-0001

But how do you evaluate a flow-through BMP?

Methodology

Overview

- Flow-through BMP evaluation
  - Accepted methods already exist for traditional BMPs (e.g., BMPTRAINS Model)
    - How to leverage existing tools?
    - What is water quality benefit based on?
      - Typically volume capture
    - Using flow-through BMP volume for this can result in underestimation of actual performance

Overview

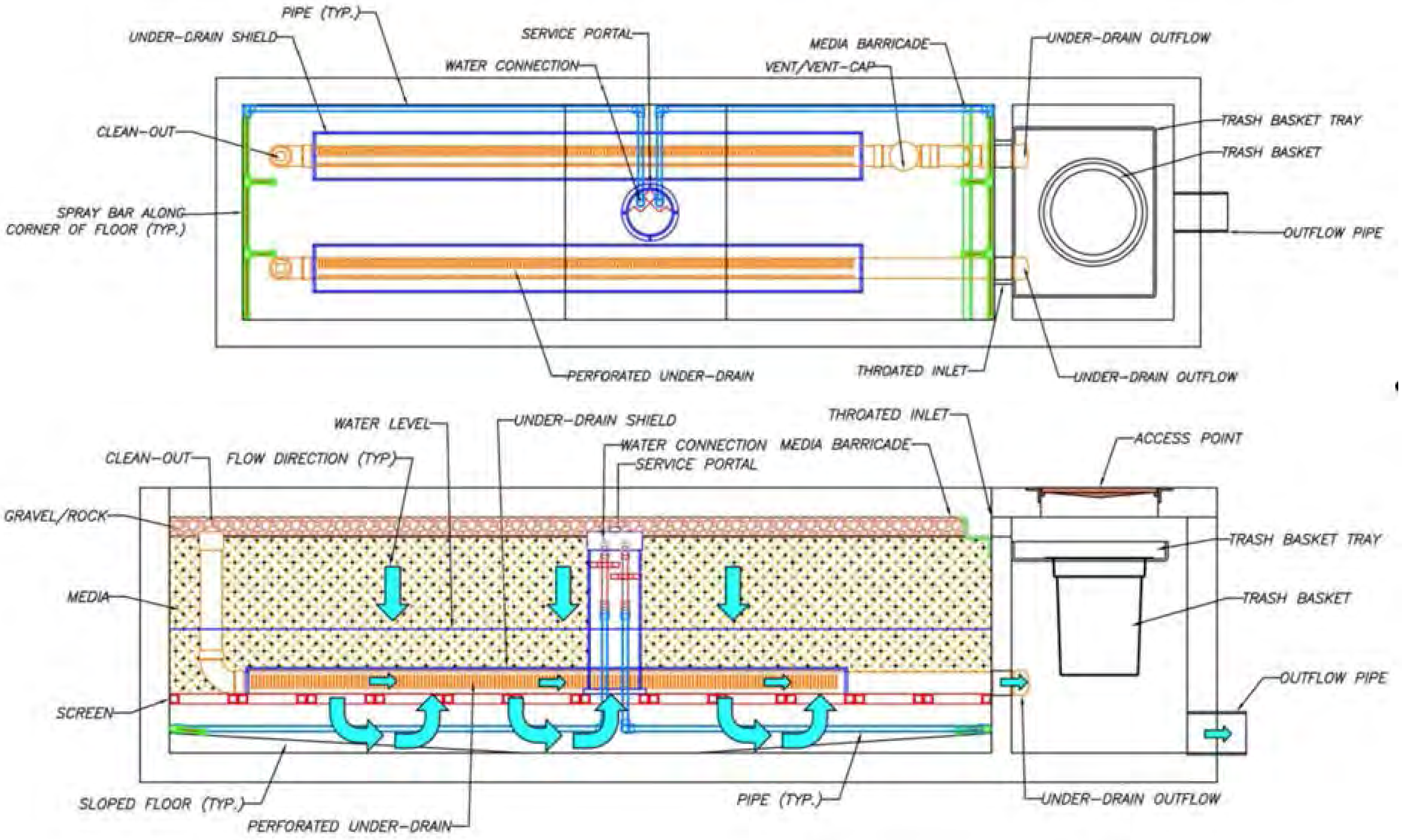
- Flow-through BMP evaluation
  - Methodology focuses on developing data that can be input into existing models and evaluate the water quality benefit
  - Perform Continuous simulation modeling
    - Determine the long-term capture efficiency
    - Convert to equivalent retention volume using the Harper curves
    - Input data into BMPTRAINS Model (filtration worksheet)

Overview

- Engineered wetland BMP, using as example to illustrate methodology
  - Flow through engineered wetland BMP
  - Precast concrete box
    - Replace traditional curb inlet
  - Uses filter media and vegetation
    - Bold & Gold ECT3 media
  - Three pathways for water to go
    - Primary treatment
    - High-flow treatment
    - Overflow

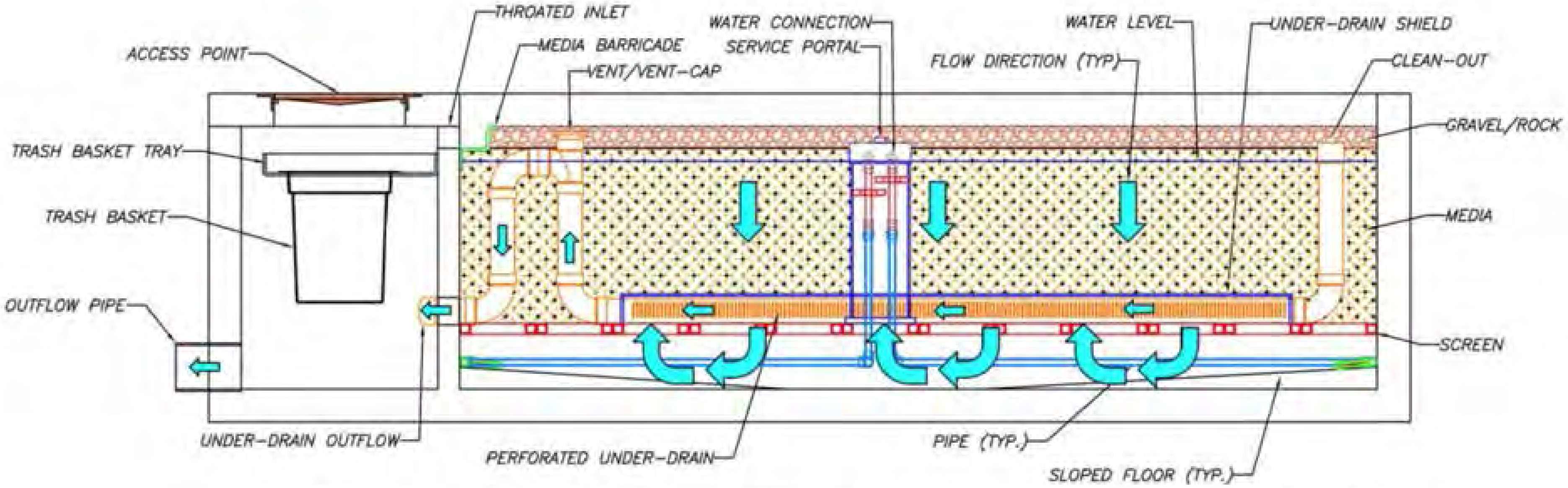
Source: https://www.suntreetech.com/nutrimax.html

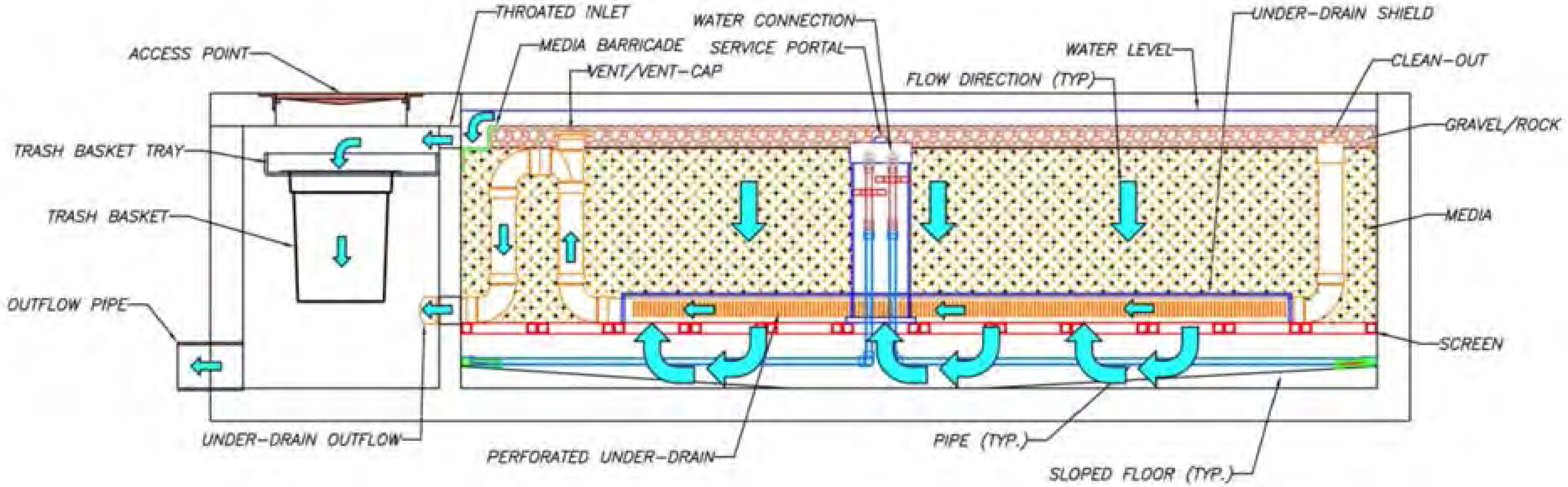
Overview – Flow pathways



Source: https://www.suntreetech.com/nutrimax.html

Overview – Flow pathways





Source: https://www.suntreetech.com/nutrimax.html

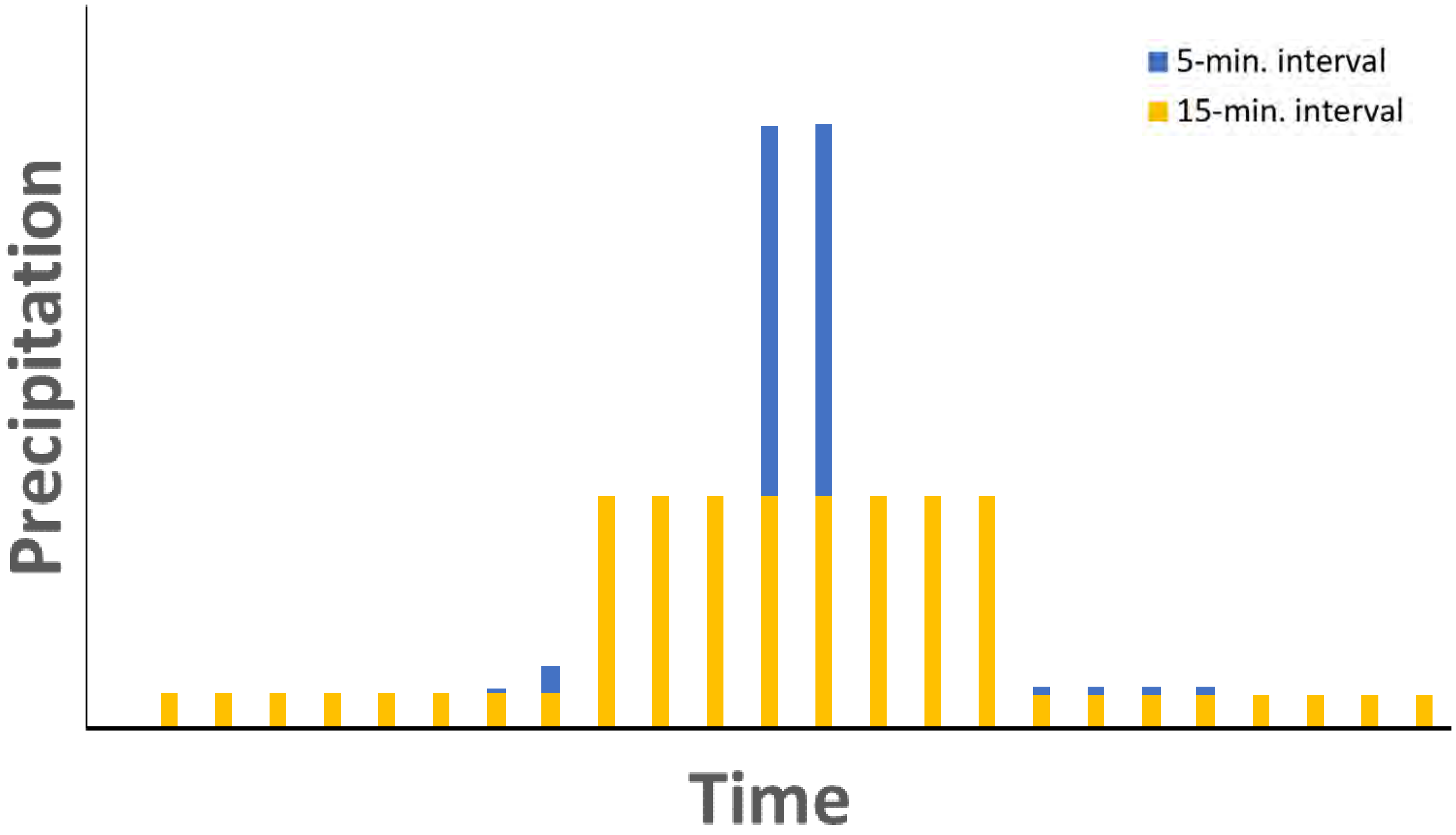
Methodology

- Determination of contact time
  - Used orifice equation to determine flow
  - Calculated contact time based on the following equation
    - $T_\theta = \frac{V * \varepsilon}{Q * 60}$
      - Where T_θ = Contact time (minutes)
      - V = Volume of media chamber minus pipes (cf)
      - ε = Media porosity
      - Q = Flow rate (cfs)
      - 60 = Unit conversion (sec → minutes)
  - This is an instantaneous contact time, i.e. when the peak flow happens

Methodology

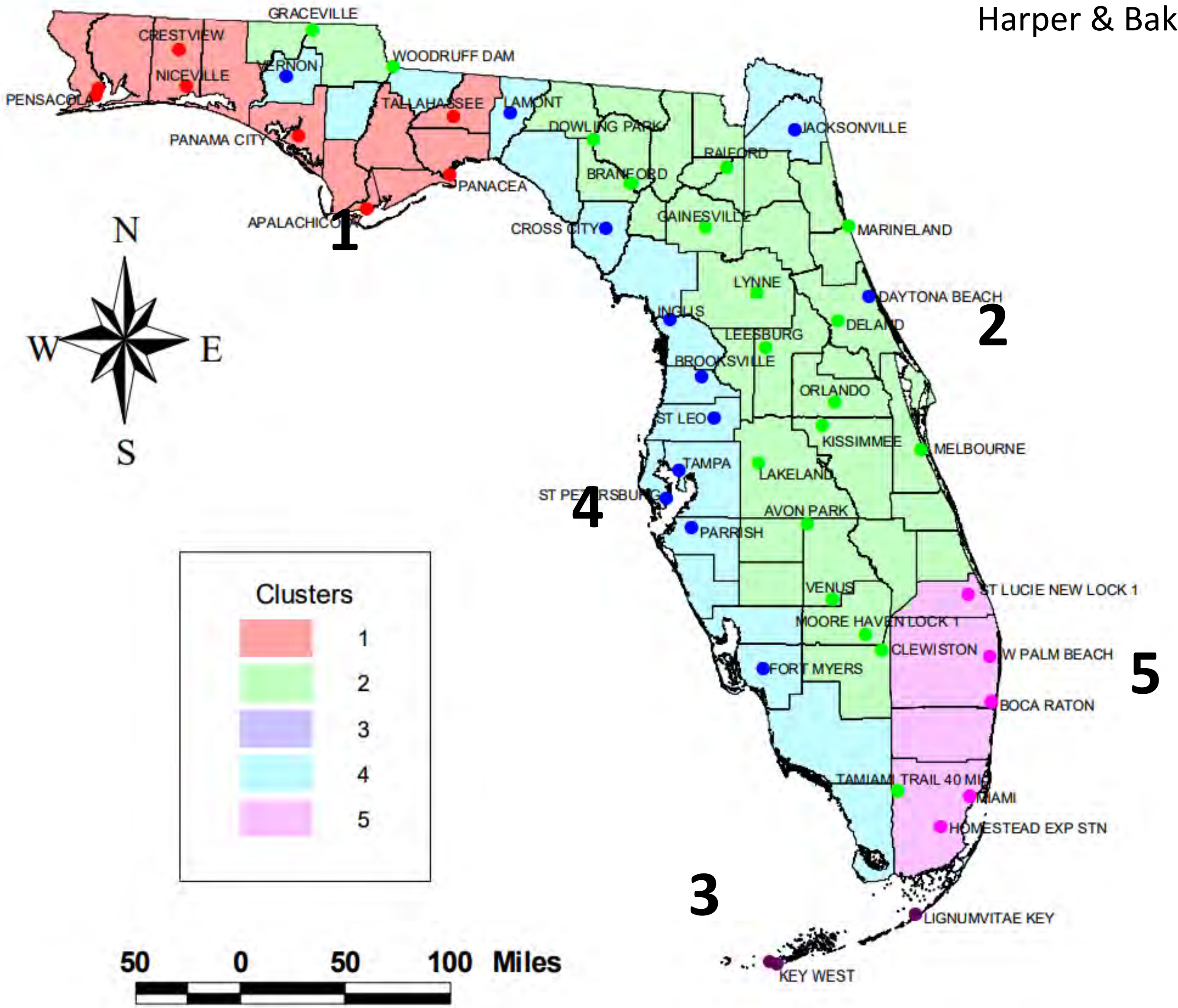
- Determination of average annual capture efficiency
  - Use continuous simulation model over 15 years
  - Since flow-through, need rainfall data with short collection time interval
    - Data collected with longer collection time intervals miss peaks that occur during storm events
    - Typically NCDC and other sources minimum time is 15 minutes
    - Automated Surface Observing System (ASOS) provides 5 minute and 1 minute interval data

Methodology – Rainfall Data

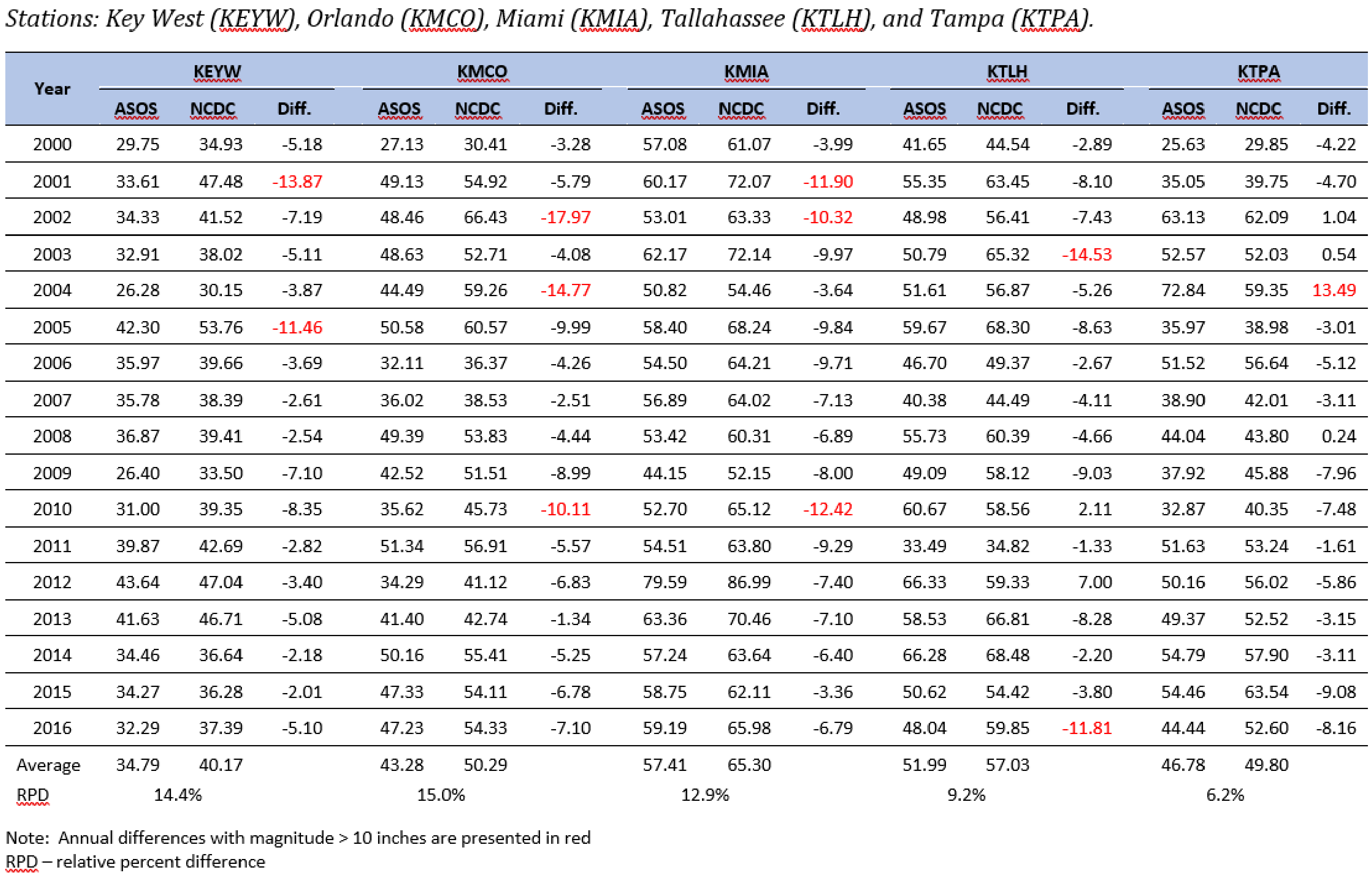


Methodology – Florida Rainfall Zones

Harper & Baker (2007)



Methodology – Rainfall Data QC



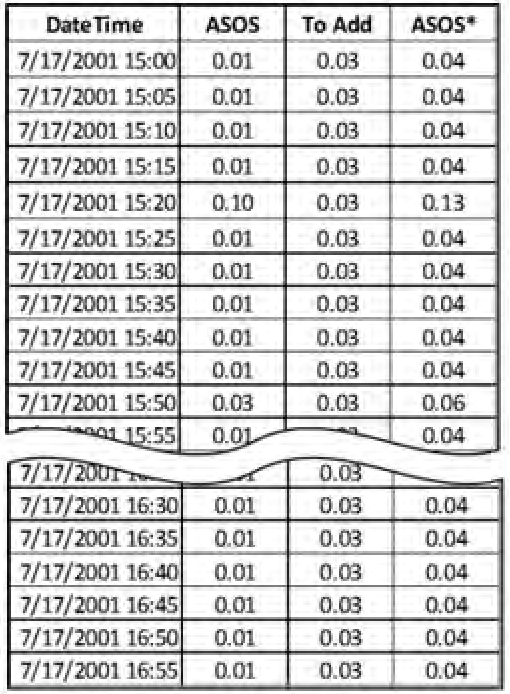
Stations: Key West (KEYW), Orlando (KMCO), Miami (KMIA), Tallahassee (KTLH), and Tampa (KTPA).

Year	KEYW			KMCO			KMIA			KTLH			KTPA		
	ASOS	NCDC	Diff.	ASOS	NCDC	Diff.	ASOS	NCDC	Diff.	ASOS	NCDC	Diff.	ASOS	NCDC	Diff.
2000	29.75	34.93	-5.18	27.13	30.41	-3.28	57.08	61.07	-3.99	41.65	44.54	-2.89	25.63	29.85	-4.22
2001	33.61	47.48	-13.87	49.13	54.92	-5.79	60.17	72.07	-11.90	55.35	63.45	-8.10	35.05	39.75	-4.70
2002	34.33	41.52	-7.19	48.46	66.43	-17.97	53.01	63.33	-10.32	48.98	56.41	-7.43	63.13	62.09	1.04
2003	32.91	38.02	-5.11	48.63	52.71	-4.08	62.17	72.14	-9.97	50.79	65.32	-14.53	52.57	52.03	0.54
2004	26.28	30.15	-3.87	44.49	59.26	-14.77	50.82	54.46	-3.64	51.61	56.87	-5.26	72.84	59.35	13.49
2005	42.30	53.76	-11.46	50.58	60.57	-9.99	58.40	68.24	-9.84	59.67	68.30	-8.63	35.97	38.98	-3.01
2006	35.97	39.66	-3.69	32.11	36.37	-4.26	54.50	64.21	-9.71	46.70	49.37	-2.67	51.52	56.64	-5.12
2007	35.78	38.39	-2.61	36.02	38.53	-2.51	56.89	64.02	-7.13	40.38	44.49	-4.11	38.90	42.01	-3.11
2008	36.87	39.41	-2.54	49.39	53.83	-4.44	53.42	60.31	-6.89	55.73	60.39	-4.66	44.04	43.80	0.24
2009	26.40	33.50	-7.10	42.52	51.51	-8.99	44.15	52.15	-8.00	49.09	58.12	-9.03	37.92	45.88	-7.96
2010	31.00	39.35	-8.35	35.62	45.73	-10.11	52.70	65.12	-12.42	60.67	58.56	2.11	32.87	40.35	-7.48
2011	39.87	42.69	-2.82	51.34	56.91	-5.57	54.51	63.80	-9.29	33.49	34.82	-1.33	51.63	53.24	-1.61
2012	43.64	47.04	-3.40	34.29	41.12	-6.83	79.59	86.99	-7.40	66.33	59.33	7.00	50.16	56.02	-5.86
2013	41.63	46.71	-5.08	41.40	42.74	-1.34	63.36	70.46	-7.10	58.53	66.81	-8.28	49.37	52.52	-3.15
2014	34.46	36.64	-2.18	50.16	55.41	-5.25	57.24	63.64	-6.40	66.28	68.48	-2.20	54.79	57.90	-3.11
2015	34.27	36.28	-2.01	47.33	54.11	-6.78	58.75	62.11	-3.36	50.62	54.42	-3.80	54.46	63.54	-9.08
2016	32.29	37.39	-5.10	47.23	54.33	-7.10	59.19	65.98	-6.79	48.04	59.85	-11.81	44.44	52.60	-8.16
Average	34.79	40.17		43.28	50.29		57.41	65.30		51.99	57.03		46.78	49.80	
RPD	14.4%			15.0%			12.9%			9.2%			6.2%		

Note: Annual differences with magnitude > 10 inches are presented in red
RPD – relative percent difference

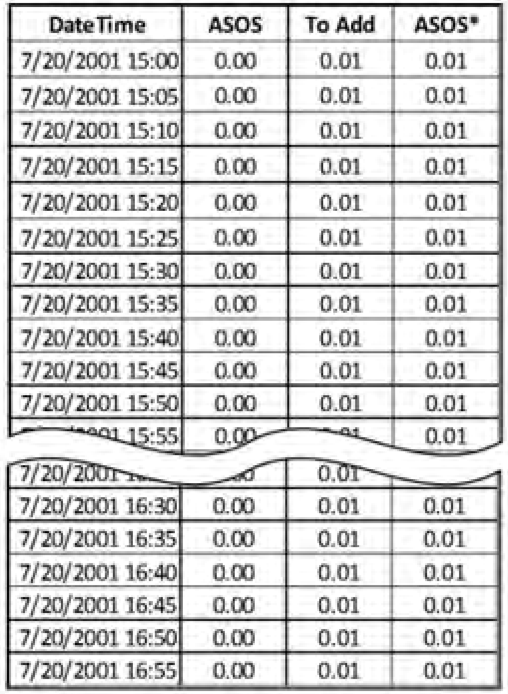
Methodology – Data Filling

Case A:
Add to existing storm



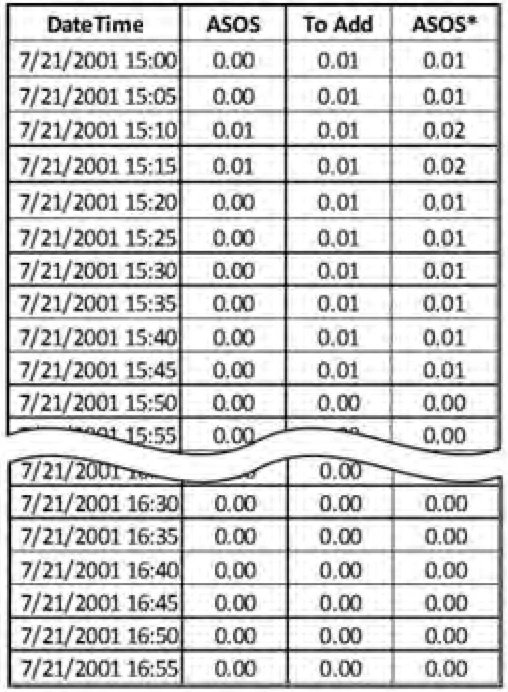
DateTime	ASOS	To Add	ASOS*
7/17/2001 15:00	0.01	0.03	0.04
7/17/2001 15:05	0.01	0.03	0.04
7/17/2001 15:10	0.01	0.03	0.04
7/17/2001 15:15	0.01	0.03	0.04
7/17/2001 15:20	0.10	0.03	0.13
7/17/2001 15:25	0.01	0.03	0.04
7/17/2001 15:30	0.01	0.03	0.04
7/17/2001 15:35	0.01	0.03	0.04
7/17/2001 15:40	0.01	0.03	0.04
7/17/2001 15:45	0.01	0.03	0.04
7/17/2001 15:50	0.03	0.03	0.06
001 15:55	0.01		0.04
7/17/2001		0.03	
7/17/2001 16:30	0.01	0.03	0.04
7/17/2001 16:35	0.01	0.03	0.04
7/17/2001 16:40	0.01	0.03	0.04
7/17/2001 16:45	0.01	0.03	0.04
7/17/2001 16:50	0.01	0.03	0.04
7/17/2001 16:55	0.01	0.03	0.04

Case B:
Add to no storm



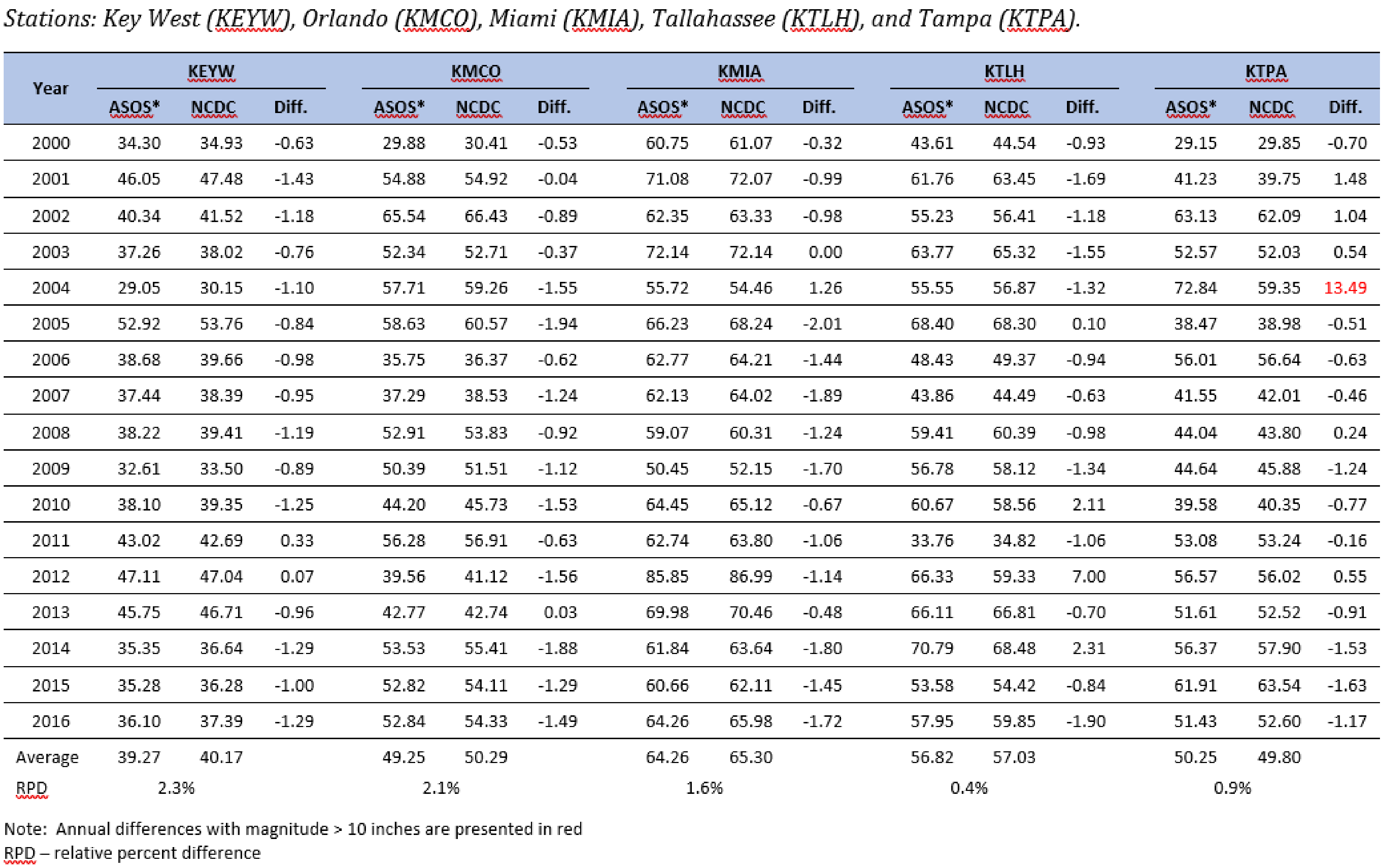
DateTime	ASOS	To Add	ASOS*
7/20/2001 15:00	0.00	0.01	0.01
7/20/2001 15:05	0.00	0.01	0.01
7/20/2001 15:10	0.00	0.01	0.01
7/20/2001 15:15	0.00	0.01	0.01
7/20/2001 15:20	0.00	0.01	0.01
7/20/2001 15:25	0.00	0.01	0.01
7/20/2001 15:30	0.00	0.01	0.01
7/20/2001 15:35	0.00	0.01	0.01
7/20/2001 15:40	0.00	0.01	0.01
7/20/2001 15:45	0.00	0.01	0.01
7/20/2001 15:50	0.00	0.01	0.01
001 15:55	0.00		0.01
7/20/2001		0.01	
7/20/2001 16:30	0.00	0.01	0.01
7/20/2001 16:35	0.00	0.01	0.01
7/20/2001 16:40	0.00	0.01	0.01
7/20/2001 16:45	0.00	0.01	0.01
7/20/2001 16:50	0.00	0.01	0.01
7/20/2001 16:55	0.00	0.01	0.01

Case C:
Add at default minimum intensity until volume achieved



DateTime	ASOS	To Add	ASOS*
7/21/2001 15:00	0.00	0.01	0.01
7/21/2001 15:05	0.00	0.01	0.01
7/21/2001 15:10	0.01	0.01	0.02
7/21/2001 15:15	0.01	0.01	0.02
7/21/2001 15:20	0.00	0.01	0.01
7/21/2001 15:25	0.00	0.01	0.01
7/21/2001 15:30	0.00	0.01	0.01
7/21/2001 15:35	0.00	0.01	0.01
7/21/2001 15:40	0.00	0.01	0.01
7/21/2001 15:45	0.00	0.01	0.01
7/21/2001 15:50	0.00	0.00	0.00
001 15:55	0.00		0.00
7/21/2001		0.00	
7/21/2001 16:30	0.00	0.00	0.00
7/21/2001 16:35	0.00	0.00	0.00
7/21/2001 16:40	0.00	0.00	0.00
7/21/2001 16:45	0.00	0.00	0.00
7/21/2001 16:50	0.00	0.00	0.00
7/21/2001 16:55	0.00	0.00	0.00

Methodology – Modified Rainfall Data QC



Stations: Key West (KEYW), Orlando (KMCO), Miami (KMIA), Tallahassee (KTLH), and Tampa (KTPA).

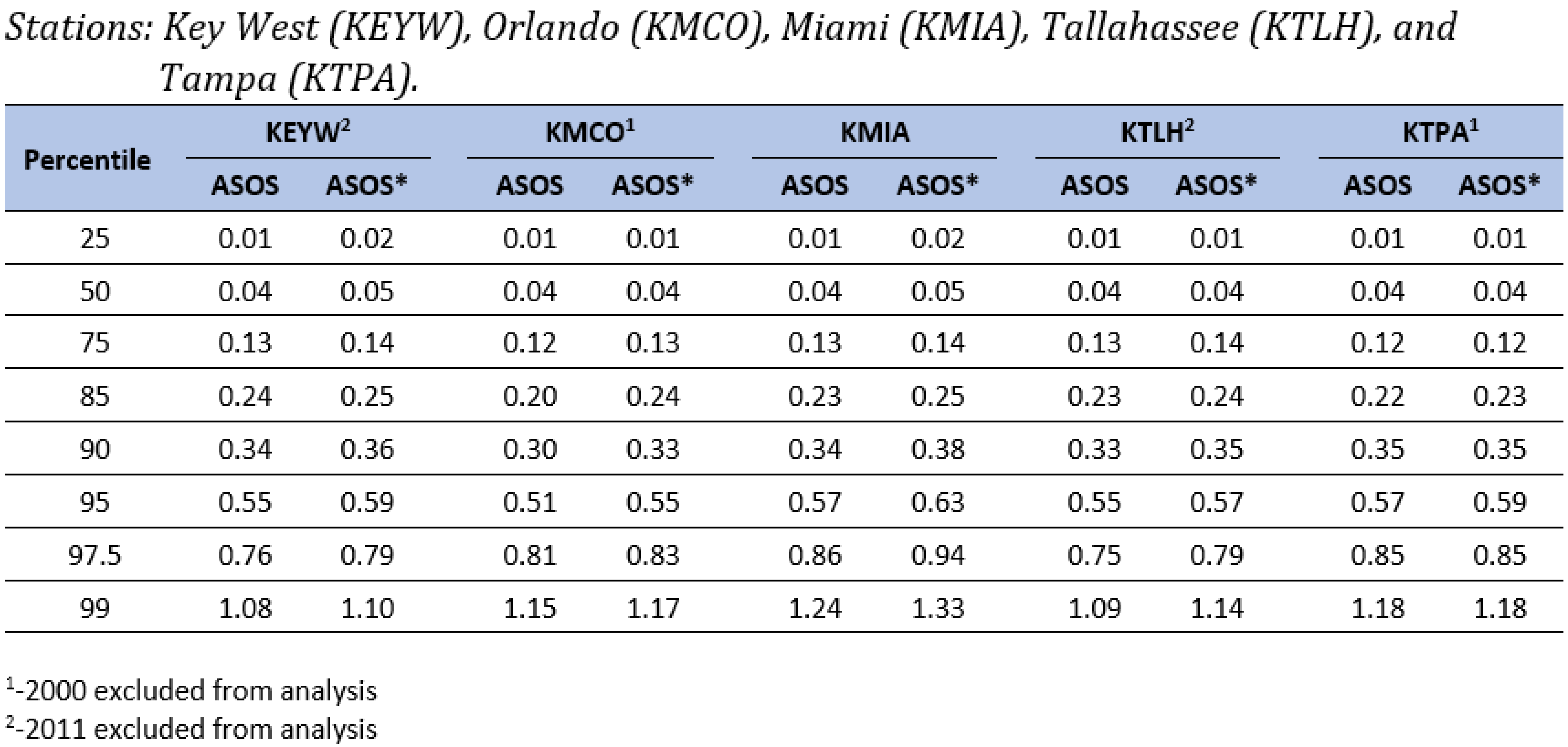
Year	KEYW			KMCO			KMIA			KTLH			KTPA		
	ASOS*	NCDC	Diff.	ASOS*	NCDC	Diff.	ASOS*	NCDC	Diff.	ASOS*	NCDC	Diff.	ASOS*	NCDC	Diff.
2000	34.30	34.93	-0.63	29.88	30.41	-0.53	60.75	61.07	-0.32	43.61	44.54	-0.93	29.15	29.85	-0.70
2001	46.05	47.48	-1.43	54.88	54.92	-0.04	71.08	72.07	-0.99	61.76	63.45	-1.69	41.23	39.75	1.48
2002	40.34	41.52	-1.18	65.54	66.43	-0.89	62.35	63.33	-0.98	55.23	56.41	-1.18	63.13	62.09	1.04
2003	37.26	38.02	-0.76	52.34	52.71	-0.37	72.14	72.14	0.00	63.77	65.32	-1.55	52.57	52.03	0.54
2004	29.05	30.15	-1.10	57.71	59.26	-1.55	55.72	54.46	1.26	55.55	56.87	-1.32	72.84	59.35	13.49
2005	52.92	53.76	-0.84	58.63	60.57	-1.94	66.23	68.24	-2.01	68.40	68.30	0.10	38.47	38.98	-0.51
2006	38.68	39.66	-0.98	35.75	36.37	-0.62	62.77	64.21	-1.44	48.43	49.37	-0.94	56.01	56.64	-0.63
2007	37.44	38.39	-0.95	37.29	38.53	-1.24	62.13	64.02	-1.89	43.86	44.49	-0.63	41.55	42.01	-0.46
2008	38.22	39.41	-1.19	52.91	53.83	-0.92	59.07	60.31	-1.24	59.41	60.39	-0.98	44.04	43.80	0.24
2009	32.61	33.50	-0.89	50.39	51.51	-1.12	50.45	52.15	-1.70	56.78	58.12	-1.34	44.64	45.88	-1.24
2010	38.10	39.35	-1.25	44.20	45.73	-1.53	64.45	65.12	-0.67	60.67	58.56	2.11	39.58	40.35	-0.77
2011	43.02	42.69	0.33	56.28	56.91	-0.63	62.74	63.80	-1.06	33.76	34.82	-1.06	53.08	53.24	-0.16
2012	47.11	47.04	0.07	39.56	41.12	-1.56	85.85	86.99	-1.14	66.33	59.33	7.00	56.57	56.02	0.55
2013	45.75	46.71	-0.96	42.77	42.74	0.03	69.98	70.46	-0.48	66.11	66.81	-0.70	51.61	52.52	-0.91
2014	35.35	36.64	-1.29	53.53	55.41	-1.88	61.84	63.64	-1.80	70.79	68.48	2.31	56.37	57.90	-1.53
2015	35.28	36.28	-1.00	52.82	54.11	-1.29	60.66	62.11	-1.45	53.58	54.42	-0.84	61.91	63.54	-1.63
2016	36.10	37.39	-1.29	52.84	54.33	-1.49	64.26	65.98	-1.72	57.95	59.85	-1.90	51.43	52.60	-1.17
Average	39.27	40.17		49.25	50.29		64.26	65.30		56.82	57.03		50.25	49.80	
RPD	2.3%			2.1%			1.6%			0.4%			0.9%		

Note: Annual differences with magnitude > 10 inches are presented in red

RPD – relative percent difference

Methodology

- Does filling method fundamentally change characteristics of storm events?
- Compared percentiles, results were satisfactory



Stations: Key West (KEYW), Orlando (KMCO), Miami (KMIA), Tallahassee (KTLH), and Tampa (KTPA).

Percentile	KEYW[2]		KMCO[1]		KMIA		KTLH[2]		KTPA[1]	
	ASOS	ASOS*	ASOS	ASOS*	ASOS	ASOS*	ASOS	ASOS*	ASOS	ASOS*
25	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
50	0.04	0.05	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04
75	0.13	0.14	0.12	0.13	0.13	0.14	0.13	0.14	0.12	0.12
85	0.24	0.25	0.20	0.24	0.23	0.25	0.23	0.24	0.22	0.23
90	0.34	0.36	0.30	0.33	0.34	0.38	0.33	0.35	0.35	0.35
95	0.55	0.59	0.51	0.55	0.57	0.63	0.55	0.57	0.57	0.59
97.5	0.76	0.79	0.81	0.83	0.86	0.94	0.75	0.79	0.85	0.85
99	1.08	1.10	1.15	1.17	1.24	1.33	1.09	1.14	1.18	1.18

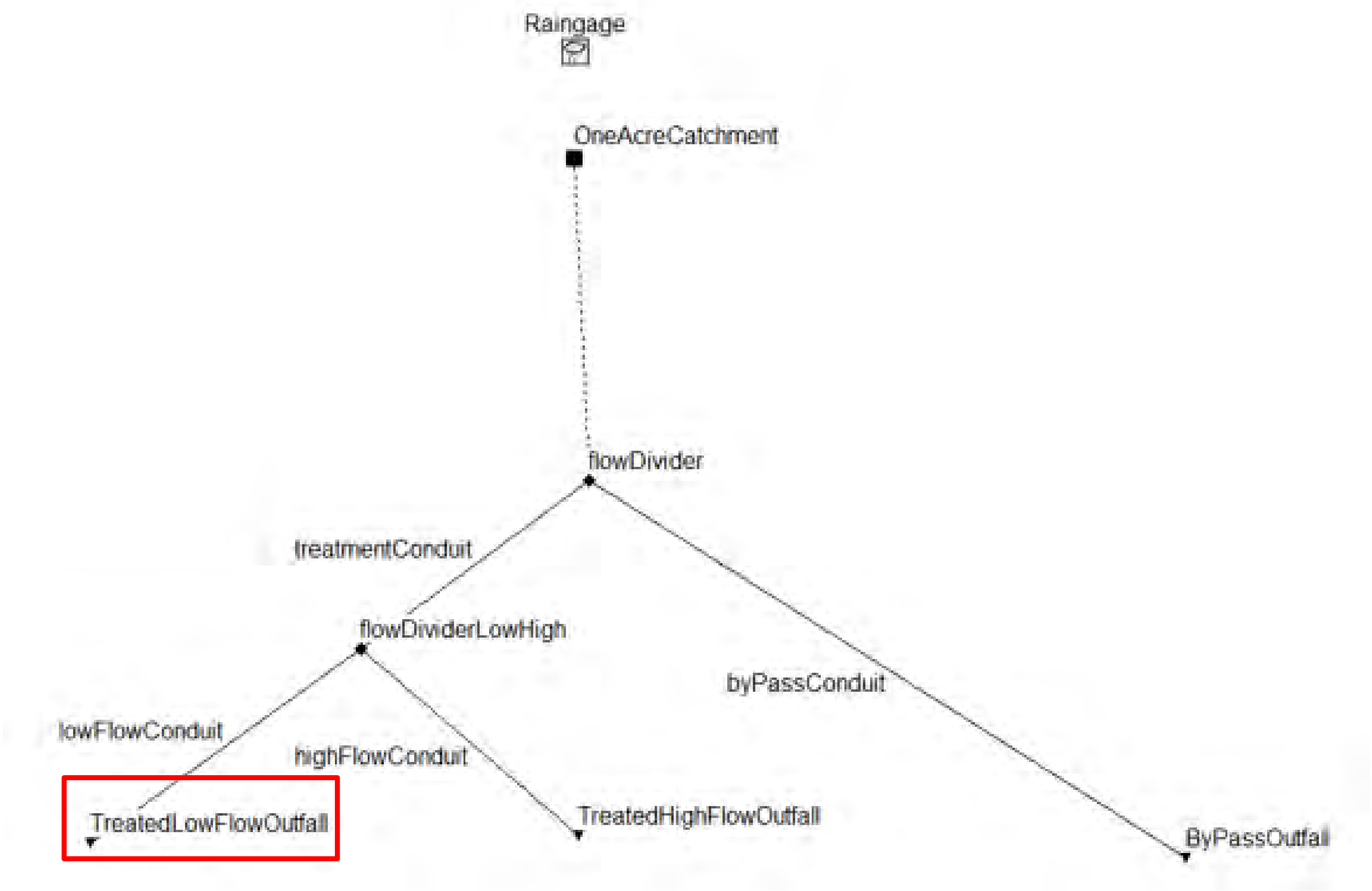
[1]-2000 excluded from analysis

[2]-2011 excluded from analysis

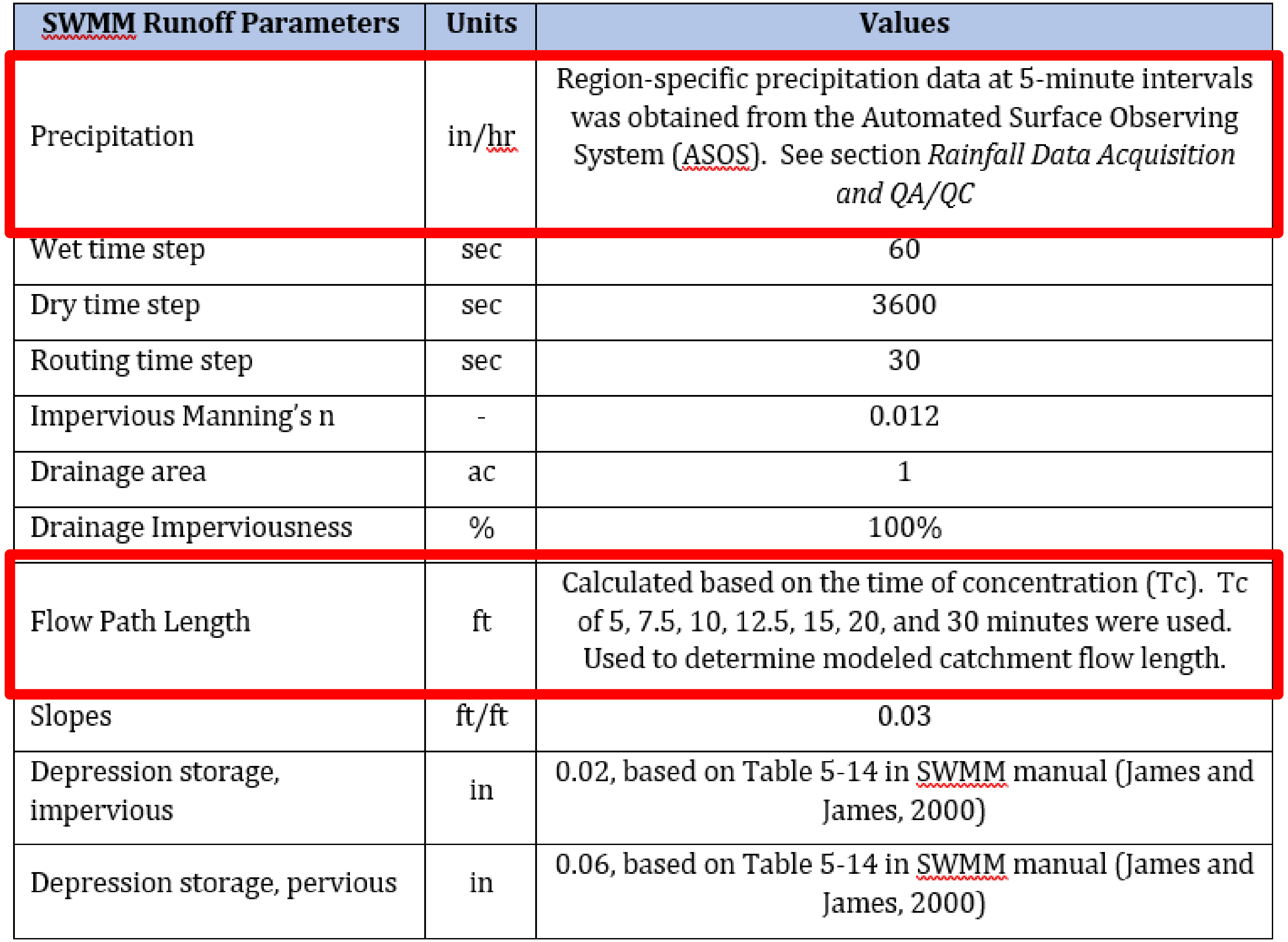
Methodology

- Performed modeling using EPA SWMM
  - Based on hypothetical catchment
    - 1 acre
    - 100% impervious
    - Representing typical urban catchment
  - Model template schema uses divider node (FlowDivider) to partition runoff received by engineered wetland BMP
    - Treated
    - Bypassed (nontreated)
  - Treated branch further divided
    - Design flow
    - High flow (not used for the calculator and treated as overflow)

Methodology – Model Schematic



Methodology – Model Input Parameters



SWMM Runoff Parameters	**Units**	**Values**
Precipitation	in/hr	Region-specific precipitation data at 5-minute intervals was obtained from the Automated Surface Observing System (ASOS). See section *Rainfall Data Acquisition and QA/QC*
Wet time step	sec	60
Dry time step	sec	3600
Routing time step	sec	30
Impervious Manning's n	-	0.012
Drainage area	ac	1
Drainage Imperviousness	%	100%
Flow Path Length	ft	Calculated based on the time of concentration (Tc). Tc of 5, 7.5, 10, 12.5, 15, 20, and 30 minutes were used. Used to determine modeled catchment flow length.
Slopes	ft/ft	0.03
Depression storage, impervious	in	0.02, based on Table 5-14 in SWMM manual (James and James, 2000)
Depression storage, pervious	in	0.06, based on Table 5-14 in SWMM manual (James and James, 2000)

Methodology

- Flow path was altered to get desired time of concentration (TOC)
  - Based on the kinematic wave routing form of TOC equation

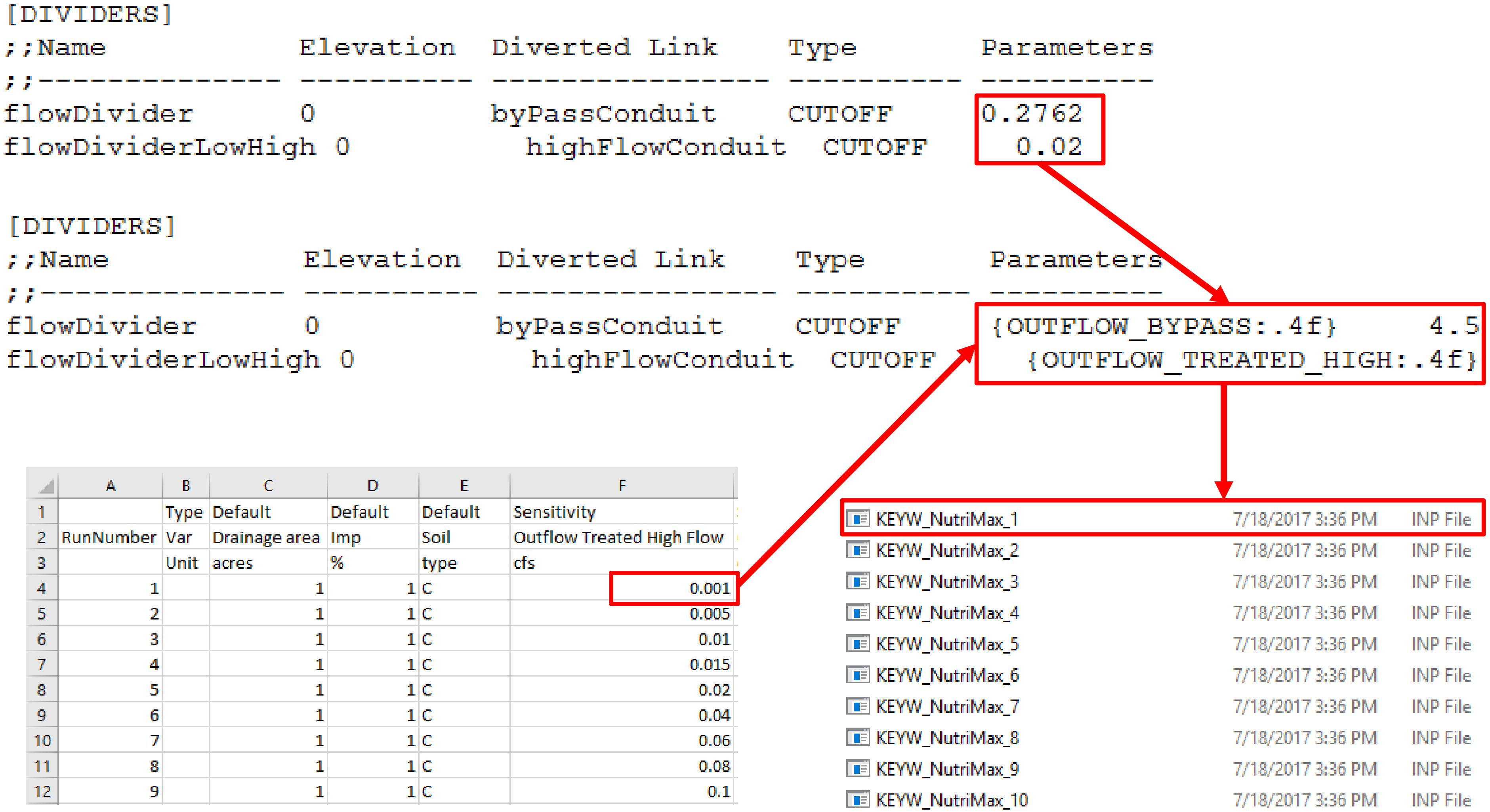
$$T_c = \frac{0.93 * L^{0.6} * n^{0.6}}{I^{0.4} * S^{0.3}}$$

    - Where Tc = Time of concentration (minutes)
    - L = Flow path length
    - n = Manning’s roughness coefficient (set at 0.012, paved surface)
    - S = Slope (ft/ft; set at 0.03)
    - I = Rainfall intensity (in/hr, set to the 90th percentile non-zero 1-hr intensity for a given site)

Methodology

- Modeled range of flow rates through low flow treatment branch
  - 0.001 to 13.25 cfs
    - 61 different flow rates
  - Done for each combination of rainfall zone and TOC
    - TOC ranged from 5 to 30 minutes
  - Resulted in 427 model runs for each rainfall zone
  - 2,135 total model runs

Methodology - Batch Model Runs



```
[DIVIDERS]
;;Name           Elevation  Diverted Link    Type       Parameters
;;-------------- ---------- ---------------- ---------- ----------
flowDivider      0          byPassConduit    CUTOFF     0.2762
flowDividerLowHigh 0          highFlowConduit  CUTOFF     0.02
```

```
[DIVIDERS]
;;Name           Elevation  Diverted Link    Type       Parameters
;;-------------- ---------- ---------------- ---------- ----------
flowDivider      0          byPassConduit    CUTOFF     {OUTFLOW_BYPASS:.4f}      4.5
flowDividerLowHigh 0          highFlowConduit  CUTOFF     {OUTFLOW_TREATED_HIGH:.4f}
```

	A	B	C	D	E	F
1		Type	Default	Default	Default	Sensitivity
2	RunNumber	Var	Drainage area	Imp	Soil	Outflow Treated High Flow
3		Unit	acres	%	type	cfs
4	1		1	1	C	0.001
5	2		1	1	C	0.005
6	3		1	1	C	0.01
7	4		1	1	C	0.015
8	5		1	1	C	0.02
9	6		1	1	C	0.04
10	7		1	1	C	0.06
11	8		1	1	C	0.08
12	9		1	1	C	0.1

KEYW_NutriMax_1	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_2	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_3	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_4	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_5	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_6	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_7	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_8	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_9	7/18/2017 3:36 PM	INP File
KEYW_NutriMax_10	7/18/2017 3:36 PM	INP File

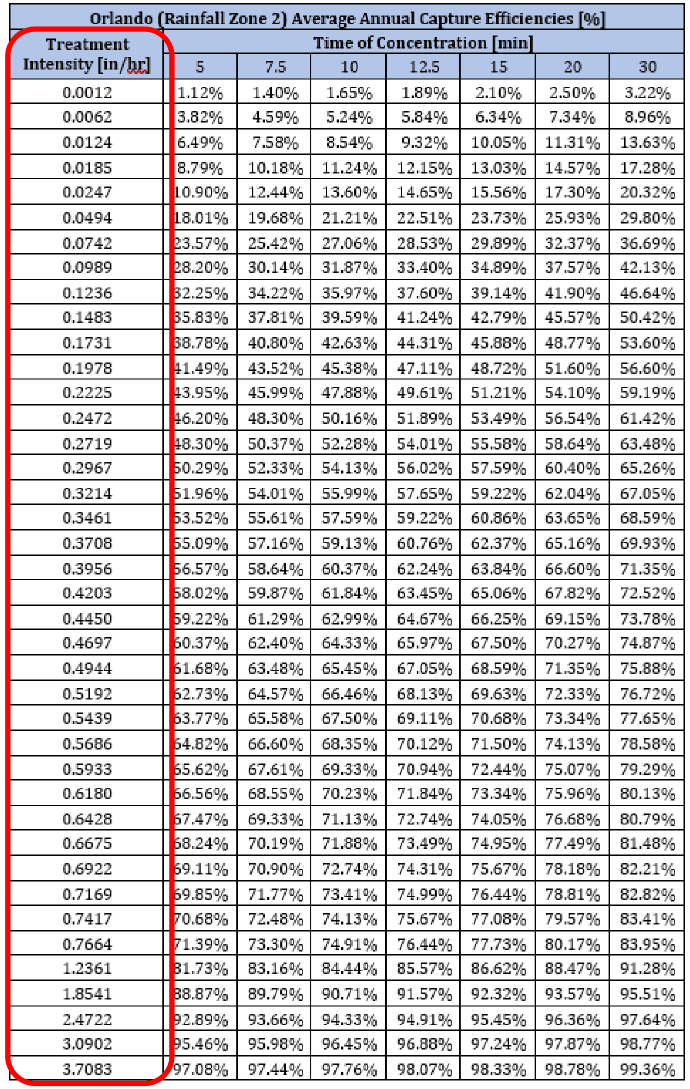
Methodology

- Needed way to relate model results to different sites
- Used inverse form of Rational Method

$$I_{treatment} = \frac{Q}{A * R_v}$$

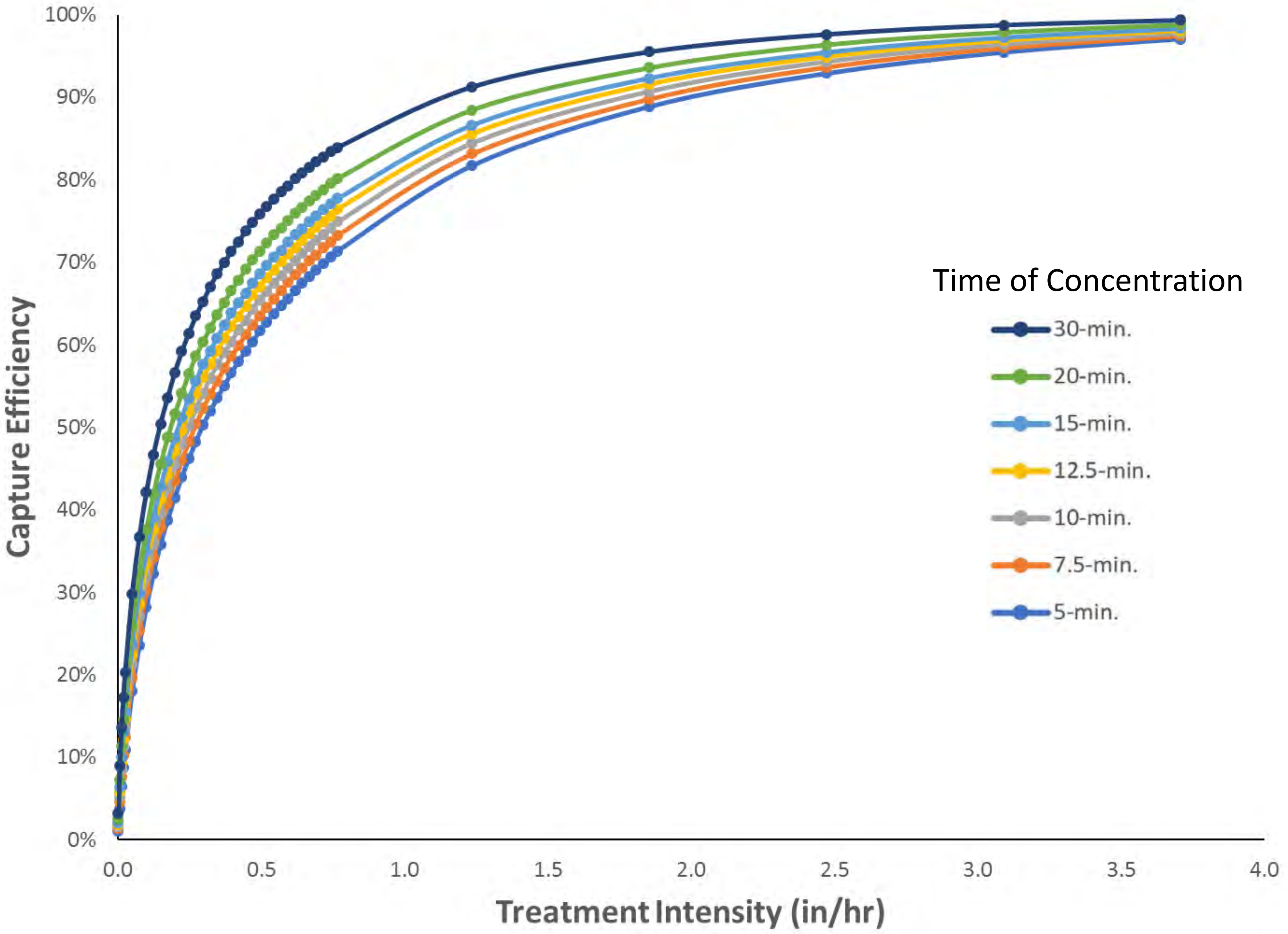
  - Where $I_{treatment}$ = design treatment intensity (in/hr)
  - Q = Modeled flow rate (cfs, ranged from 0.001 to 13.25 cfs, cutoff flow parameter for divider node)
  - A = Catchment area (acre, set to 1 acre)
  - R_v = Average annual runoff coefficient of a 100% DCIA catchment (from Harper & Baker, 2007)

Methodology – Range of Treatment Intensities



Orlando (Rainfall Zone 2) Average Annual Capture Efficiencies [%]							
Treatment Intensity [in/hr]	Time of Concentration [min]						
	5	7.5	10	12.5	15	20	30
0.0012	1.12%	1.40%	1.65%	1.89%	2.10%	2.50%	3.22%
0.0062	3.82%	4.59%	5.24%	5.84%	6.34%	7.34%	8.96%
0.0124	6.49%	7.58%	8.54%	9.32%	10.05%	11.31%	13.63%
0.0185	8.79%	10.18%	11.24%	12.15%	13.03%	14.57%	17.28%
0.0247	10.90%	12.44%	13.60%	14.65%	15.56%	17.30%	20.32%
0.0494	18.01%	19.68%	21.21%	22.51%	23.73%	25.93%	29.80%
0.0742	23.57%	25.42%	27.06%	28.53%	29.89%	32.37%	36.69%
0.0989	28.20%	30.14%	31.87%	33.40%	34.89%	37.57%	42.13%
0.1236	32.25%	34.22%	35.97%	37.60%	39.14%	41.90%	46.64%
0.1483	35.83%	37.81%	39.59%	41.24%	42.79%	45.57%	50.42%
0.1731	38.78%	40.80%	42.63%	44.31%	45.88%	48.77%	53.60%
0.1978	41.49%	43.52%	45.38%	47.11%	48.72%	51.60%	56.60%
0.2225	43.95%	45.99%	47.88%	49.61%	51.21%	54.10%	59.19%
0.2472	46.20%	48.30%	50.16%	51.89%	53.49%	56.54%	61.42%
0.2719	48.30%	50.37%	52.28%	54.01%	55.58%	58.64%	63.48%
0.2967	50.29%	52.33%	54.13%	56.02%	57.59%	60.40%	65.26%
0.3214	51.96%	54.01%	55.99%	57.65%	59.22%	62.04%	67.05%
0.3461	53.52%	55.61%	57.59%	59.22%	60.86%	63.65%	68.59%
0.3708	55.09%	57.16%	59.13%	60.76%	62.37%	65.16%	69.93%
0.3956	56.57%	58.64%	60.37%	62.24%	63.84%	66.60%	71.35%
0.4203	58.02%	59.87%	61.84%	63.45%	65.06%	67.82%	72.52%
0.4450	59.22%	61.29%	62.99%	64.67%	66.25%	69.15%	73.78%
0.4697	60.37%	62.40%	64.33%	65.97%	67.50%	70.27%	74.87%
0.4944	61.68%	63.48%	65.45%	67.05%	68.59%	71.35%	75.88%
0.5192	62.73%	64.57%	66.46%	68.13%	69.63%	72.33%	76.72%
0.5439	63.77%	65.58%	67.50%	69.11%	70.68%	73.34%	77.65%
0.5686	64.82%	66.60%	68.35%	70.12%	71.50%	74.13%	78.58%
0.5933	65.62%	67.61%	69.33%	70.94%	72.44%	75.07%	79.29%
0.6180	66.56%	68.55%	70.23%	71.84%	73.34%	75.96%	80.13%
0.6428	67.47%	69.33%	71.13%	72.74%	74.05%	76.68%	80.79%
0.6675	68.24%	70.19%	71.88%	73.49%	74.95%	77.49%	81.48%
0.6922	69.11%	70.90%	72.74%	74.31%	75.67%	78.18%	82.21%
0.7169	69.85%	71.77%	73.41%	74.99%	76.44%	78.81%	82.82%
0.7417	70.68%	72.48%	74.13%	75.67%	77.08%	79.57%	83.41%
0.7664	71.39%	73.30%	74.91%	76.44%	77.73%	80.17%	83.95%
1.2361	81.73%	83.16%	84.44%	85.57%	86.62%	88.47%	91.28%
1.8541	88.87%	89.79%	90.71%	91.57%	92.32%	93.57%	95.51%
2.4722	92.89%	93.66%	94.33%	94.91%	95.45%	96.36%	97.64%
3.0902	95.46%	95.98%	96.45%	96.88%	97.24%	97.87%	98.77%
3.7083	97.08%	97.44%	97.76%	98.07%	98.33%	98.78%	99.36%

Methodology – Capture Efficiency Curves



Methodology

- Developed 5 tables of results
  - One for each rainfall zone
  - Each efficiency value represents a model run
- Can determine the average annual capture efficiency for any site
  - Need primary treatment flow rate for desired size unit
  - Need to know catchment characteristics
    - TOC
    - Area
    - Average annual runoff coefficient

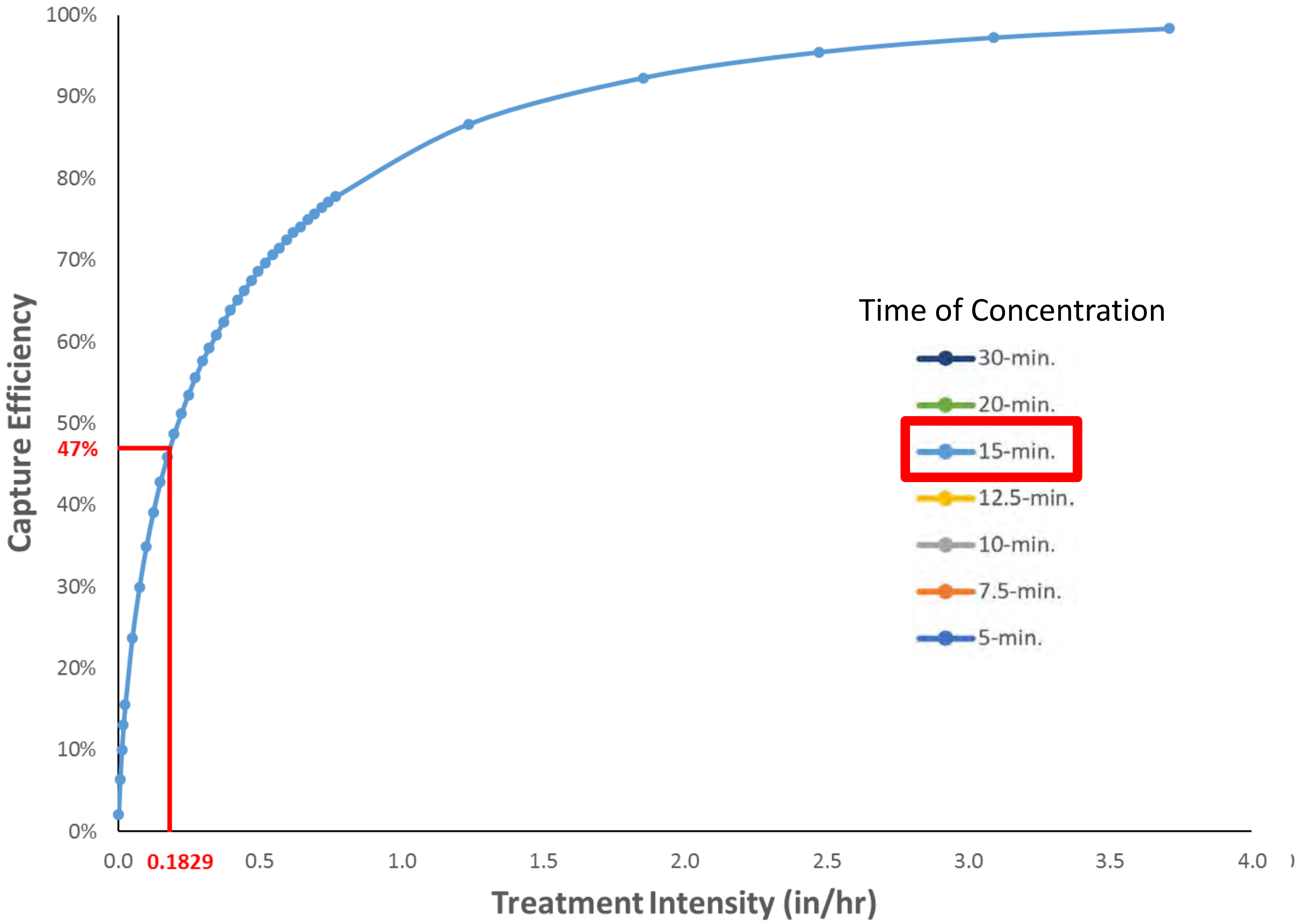
Methodology

- Using the same relationship developed earlier

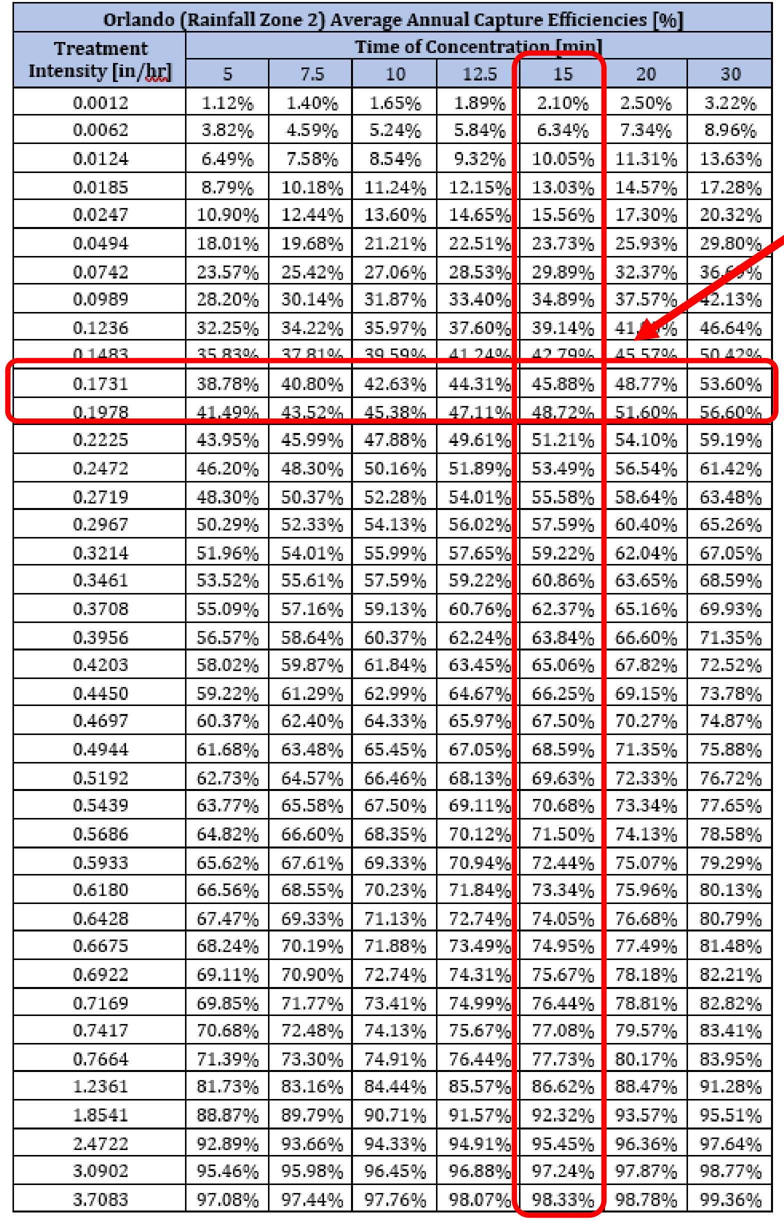
$$I_{treatment} = \frac{Q}{A * R_v}$$

    - Where $I_{treatment}$ = design treatment intensity (in/hr)
    - Q = BMP primary treatment flow rate (cfs)
    - A = Catchment area (acre)
    - R_v = Average annual runoff coefficient for site (from Harper & Baker, 2007)
  - Assume using 8 X 12 X 30 box → 0.24 cfs
  - Assume 2 acre site with R_v = 0.656
    - $I_{treatment}$ = 0.1829 in/hr
  - Assume 15 min TOC

Methodology – Results Example



Methodology – Results Example

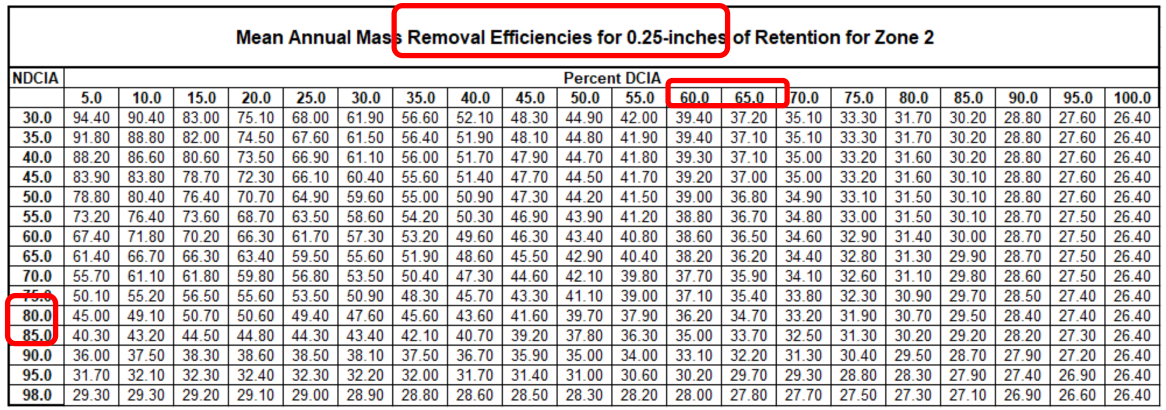


Orlando (Rainfall Zone 2) Average Annual Capture Efficiencies [%]							
Treatment Intensity [in/hr]	Time of Concentration [min]						
	5	7.5	10	12.5	15	20	30
0.0012	1.12%	1.40%	1.65%	1.89%	2.10%	2.50%	3.22%
0.0062	3.82%	4.59%	5.24%	5.84%	6.34%	7.34%	8.96%
0.0124	6.49%	7.58%	8.54%	9.32%	10.05%	11.31%	13.63%
0.0185	8.79%	10.18%	11.24%	12.15%	13.03%	14.57%	17.28%
0.0247	10.90%	12.44%	13.60%	14.65%	15.56%	17.30%	20.32%
0.0494	18.01%	19.68%	21.21%	22.51%	23.73%	25.93%	29.80%
0.0742	23.57%	25.42%	27.06%	28.53%	29.89%	32.37%	36.6[illegible]%
0.0989	28.20%	30.14%	31.87%	33.40%	34.89%	37.57%	42.13%
0.1236	32.25%	34.22%	35.97%	37.60%	39.14%	41.[illegible]%	46.64%
0.1483	35.83%	37.81%	39.59%	41.24%	42.79%	45.57%	50.42%
0.1731	38.78%	40.80%	42.63%	44.31%	45.88%	48.77%	53.60%
0.1978	41.49%	43.52%	45.38%	47.11%	48.72%	51.60%	56.60%
0.2225	43.95%	45.99%	47.88%	49.61%	51.21%	54.10%	59.19%
0.2472	46.20%	48.30%	50.16%	51.89%	53.49%	56.54%	61.42%
0.2719	48.30%	50.37%	52.28%	54.01%	55.58%	58.64%	63.48%
0.2967	50.29%	52.33%	54.13%	56.02%	57.59%	60.40%	65.26%
0.3214	51.96%	54.01%	55.99%	57.65%	59.22%	62.04%	67.05%
0.3461	53.52%	55.61%	57.59%	59.22%	60.86%	63.65%	68.59%
0.3708	55.09%	57.16%	59.13%	60.76%	62.37%	65.16%	69.93%
0.3956	56.57%	58.64%	60.37%	62.24%	63.84%	66.60%	71.35%
0.4203	58.02%	59.87%	61.84%	63.45%	65.06%	67.82%	72.52%
0.4450	59.22%	61.29%	62.99%	64.67%	66.25%	69.15%	73.78%
0.4697	60.37%	62.40%	64.33%	65.97%	67.50%	70.27%	74.87%
0.4944	61.68%	63.48%	65.45%	67.05%	68.59%	71.35%	75.88%
0.5192	62.73%	64.57%	66.46%	68.13%	69.63%	72.33%	76.72%
0.5439	63.77%	65.58%	67.50%	69.11%	70.68%	73.34%	77.65%
0.5686	64.82%	66.60%	68.35%	70.12%	71.50%	74.13%	78.58%
0.5933	65.62%	67.61%	69.33%	70.94%	72.44%	75.07%	79.29%
0.6180	66.56%	68.55%	70.23%	71.84%	73.34%	75.96%	80.13%
0.6428	67.47%	69.33%	71.13%	72.74%	74.05%	76.68%	80.79%
0.6675	68.24%	70.19%	71.88%	73.49%	74.95%	77.49%	81.48%
0.6922	69.11%	70.90%	72.74%	74.31%	75.67%	78.18%	82.21%
0.7169	69.85%	71.77%	73.41%	74.99%	76.44%	78.81%	82.82%
0.7417	70.68%	72.48%	74.13%	75.67%	77.08%	79.57%	83.41%
0.7664	71.39%	73.30%	74.91%	76.44%	77.73%	80.17%	83.95%
1.2361	81.73%	83.16%	84.44%	85.57%	86.62%	88.47%	91.28%
1.8541	88.87%	89.79%	90.71%	91.57%	92.32%	93.57%	95.51%
2.4722	92.89%	93.66%	94.33%	94.91%	95.45%	96.36%	97.64%
3.0902	95.46%	95.98%	96.45%	96.88%	97.24%	97.87%	98.77%
3.7083	97.08%	97.44%	97.76%	98.07%	98.33%	98.78%	99.36%

Need to interpolate between these two values = 47% Average Annual Capture Efficiency

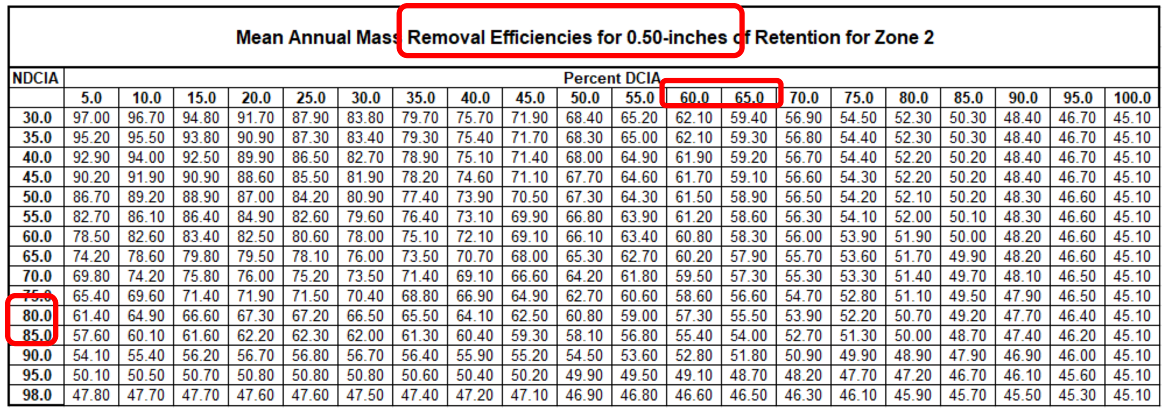
Methodology

- Convert the average annual capture efficiency into an equivalent retention depth
  - Based on Harper and Baker, 2007
  - Required for analysis in BMPTRAINS Model
  - Based on %DCIA and NDCIA CN
    - Interpolate, interpolate, and then interpolate again…



Mean Annual Mass Removal Efficiencies for 0.25-inches of Retention for Zone 2

NDCIA	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	94.40	90.40	83.00	75.10	68.00	61.90	56.60	52.10	48.30	44.90	42.00	39.40	37.20	35.10	33.30	31.70	30.20	28.80	27.60	26.40
35.0	91.80	88.80	82.00	74.50	67.60	61.50	56.40	51.90	48.10	44.80	41.90	39.40	37.10	35.10	33.30	31.70	30.20	28.80	27.60	26.40
40.0	88.20	86.60	80.60	73.50	66.90	61.10	56.00	51.70	47.90	44.70	41.80	39.30	37.10	35.00	33.20	31.60	30.20	28.80	27.60	26.40
45.0	83.90	83.80	78.70	72.30	66.10	60.40	55.60	51.40	47.70	44.50	41.70	39.20	37.00	35.00	33.20	31.60	30.10	28.80	27.60	26.40
50.0	78.80	80.40	76.40	70.70	64.90	59.60	55.00	50.90	47.30	44.20	41.50	39.00	36.80	34.90	33.10	31.50	30.10	28.80	27.60	26.40
55.0	73.20	76.40	73.60	68.70	63.50	58.60	54.20	50.30	46.90	43.90	41.20	38.80	36.70	34.80	33.00	31.50	30.10	28.70	27.50	26.40
60.0	67.40	71.80	70.20	66.30	61.70	57.30	53.20	49.60	46.30	43.40	40.80	38.60	36.50	34.60	32.90	31.40	30.00	28.70	27.50	26.40
65.0	61.40	66.70	66.30	63.40	59.50	55.60	51.90	48.60	45.50	42.90	40.40	38.20	36.20	34.40	32.80	31.30	29.90	28.70	27.50	26.40
70.0	55.70	61.10	61.80	59.80	56.80	53.50	50.40	47.30	44.60	42.10	39.80	37.70	35.90	34.10	32.60	31.10	29.80	28.60	27.50	26.40
75.0	50.10	55.20	56.50	55.60	53.50	50.90	48.30	45.70	43.30	41.10	39.00	37.10	35.40	33.80	32.30	30.90	29.70	28.50	27.40	26.40
80.0	45.00	49.10	50.70	50.60	49.40	47.60	45.60	43.60	41.60	39.70	37.90	36.20	34.70	33.20	31.90	30.70	29.50	28.40	27.40	26.40
85.0	40.30	43.20	44.50	44.80	44.30	43.40	42.10	40.70	39.20	37.80	36.30	35.00	33.70	32.50	31.30	30.20	29.20	28.20	27.30	26.40
90.0	36.00	37.50	38.30	38.60	38.50	38.10	37.50	36.70	35.90	35.00	34.00	33.10	32.20	31.30	30.40	29.50	28.70	27.90	27.20	26.40
95.0	31.70	32.10	32.30	32.40	32.30	32.20	32.00	31.70	31.40	31.00	30.60	30.20	29.70	29.30	28.80	28.30	27.90	27.40	26.90	26.40
98.0	29.30	29.30	29.20	29.10	29.00	28.90	28.80	28.60	28.50	28.30	28.20	28.00	27.80	27.70	27.50	27.30	27.10	26.90	26.60	26.40



Mean Annual Mass Removal Efficiencies for 0.50-inches of Retention for Zone 2

NDCIA	Percent DCIA																			
	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100.0
30.0	97.00	96.70	94.80	91.70	87.90	83.80	79.70	75.70	71.90	68.40	65.20	62.10	59.40	56.90	54.50	52.30	50.30	48.40	46.70	45.10
35.0	95.20	95.50	93.80	90.90	87.30	83.40	79.30	75.40	71.70	68.30	65.00	62.10	59.30	56.80	54.40	52.30	50.30	48.40	46.70	45.10
40.0	92.90	94.00	92.50	89.90	86.50	82.70	78.90	75.10	71.40	68.00	64.90	61.90	59.20	56.70	54.40	52.20	50.20	48.40	46.70	45.10
45.0	90.20	91.90	90.90	88.60	85.50	81.90	78.20	74.60	71.10	67.70	64.60	61.70	59.10	56.60	54.30	52.20	50.20	48.40	46.70	45.10
50.0	86.70	89.20	88.90	87.00	84.20	80.90	77.40	73.90	70.50	67.30	64.30	61.50	58.90	56.50	54.20	52.10	50.20	48.30	46.60	45.10
55.0	82.70	86.10	86.40	84.90	82.60	79.60	76.40	73.10	69.90	66.80	63.90	61.20	58.60	56.30	54.10	52.00	50.10	48.30	46.60	45.10
60.0	78.50	82.60	83.40	82.50	80.60	78.00	75.10	72.10	69.10	66.10	63.40	60.80	58.30	56.00	53.90	51.90	50.00	48.20	46.60	45.10
65.0	74.20	78.60	79.80	79.50	78.10	76.00	73.50	70.70	68.00	65.30	62.70	60.20	57.90	55.70	53.60	51.70	49.90	48.20	46.60	45.10
70.0	69.80	74.20	75.80	76.00	75.20	73.50	71.40	69.10	66.60	64.20	61.80	59.50	57.30	55.30	53.30	51.40	49.70	48.10	46.50	45.10
75.0	65.40	69.60	71.40	71.90	71.50	70.40	68.80	66.90	64.90	62.70	60.60	58.60	56.60	54.70	52.80	51.10	49.50	47.90	46.50	45.10
80.0	61.40	64.90	66.60	67.30	67.20	66.50	65.50	64.10	62.50	60.80	59.00	57.30	55.50	53.90	52.20	50.70	49.20	47.70	46.40	45.10
85.0	57.60	60.10	61.60	62.20	62.30	62.00	61.30	60.40	59.30	58.10	56.80	55.40	54.00	52.70	51.30	50.00	48.70	47.40	46.20	45.10
90.0	54.10	55.40	56.20	56.70	56.80	56.70	56.40	55.90	55.20	54.50	53.60	52.80	51.80	50.90	49.90	48.90	47.90	46.90	46.00	45.10
95.0	50.10	50.50	50.70	50.80	50.80	50.80	50.60	50.40	50.20	49.90	49.50	49.10	48.70	48.20	47.70	47.20	46.70	46.10	45.60	45.10
98.0	47.80	47.70	47.70	47.60	47.60	47.50	47.40	47.20	47.10	46.90	46.80	46.60	46.50	46.30	46.10	45.90	45.70	45.50	45.30	45.10

Methodology

- Several assumptions were required in the development of this methodology
  - Based on Florida conditions
  - Free discharge assumed, i.e. no tailwater conditions
  - Only the primary treatment is considered
    - Potential to add high flow treatment once data collected to support performance
  - Orifice is downstream of media
  - Orifice equation used to calculate flow through the system
  - Output treatment depth intended to be used in conjunction with BMPTRAINS Model
  - No upstream storage provided, i.e. flow through system
  - 5 minute time step assumed appropriate to evaluate BMP

Methodology

- Assumptions (cont.)
  - Calculated efficiencies based on hypothetical 1 acre 100% DCIA catchment
    - Treatment intensity is used to determine efficiency of catchments with different characteristics
  - Linear interpolation is appropriate for determining results between modeled values
  - Reported capture efficiencies based on properly maintained and operating systems
    - As defined by product manufacturers
  - No significant erosion/sedimentation issues in catchment (clogging)
  - CN refers to the non-DCIA CN
  - Calculations based on SWMM models that assume Green-Ampt method of infiltration and Kinematic Wave flow routing method

Conclusions

Conclusions

- Flow-through BMPs provide flexible treatment options where other BMPs may not be practical
- Need consistent method to evaluate and compare performance
- Continuous simulation results can be used to generate input for familiar, existing software
- Using results consistent with the assumptions used for BMPTRAINS allows for additional analysis of alternative combinations
- Incorporating with industry standard software assists with regulatory buy-in

Geosyntec
consultants

Thank you!
Questions?

Mike Hardin, PhD, PE, CFM
mhardin@Geosyntec.com
(321)244-1464

Mark Ellard, PE, CFM, D.WRE, ENV. SP
mellard@Geosyntec.com
(407)321-7030