Establishing Regulatory Pollutant Removal Credits for Stormwater Control Measures in North Carolina

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Changes in Regulations

- New stormwater rules (15A NCAC 02H) in effect 01/01/2017
  - Minimum Design Criteria (MDC) for SCMs codified in new rules
  - https://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-rules/stormwater-program-rules
  - Available draft version of revised Stormwater Design Manual
- Collaboration between DEQ and Nonpoint Source Planning Programs to update effluent concentrations for SCMs

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SCM Crediting Document

Training and SCM Crediting

Welcome to the MDC Workshops : NCSU and DEQ are cooperating to offer 1.5-day workshops on the MDC if you would like an intensive training on the new rules and manual.

Stormwater Reviewer Certification: The expiration dates for all certifications have been extended until September 1, 2017. People seeking Stormwater Reviewer Certification for the first time should attend a Welcome to the MDC Workshop.

Draft Stormwater Control Measure Credit Document : This document lists all SCM credits together facilitate comparisons between different SCMs for the regulated community. It is a joint effort between DEQ's Stormwater and Nonpoint Source Planning programs. The document is currently in draft form, but will soon be finalized.

- Can find document at: https://deq.nc.gov/sw-bmp-manual

https://stormwater.bae.ncsu.edu/

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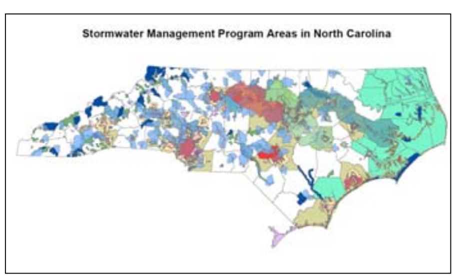
Purpose of Document

- Improve clarity and consistency of SCM crediting
  - Allow for better comparison between SCMs
- Facilitate credit updates using available research
- Meet goals of various state-wide stormwater programs



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Purpose of Document

- Stakeholder meetings with designers, municipal stormwater officials, universities
  - NC DEQ and NCSU drafted document with stakeholder guidance

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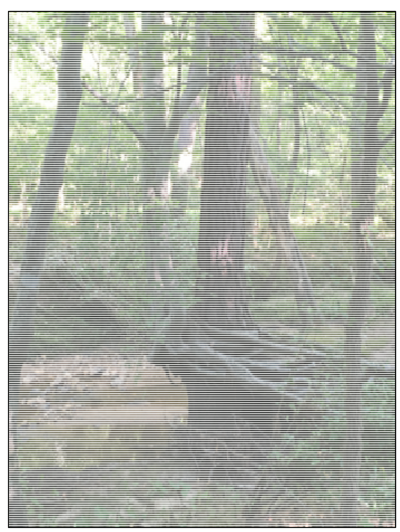
SCM Benefits

- Primary or secondary
- Determine benefits of SCMs for:
  - TN and TP removal
  - Streambank protection
  - Stream temperature
  - Removal of bacteria
  - Annual runoff treated
- Rated either:
  - Excellent, Good, Fair, or Poor
  - Based on previous research



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Primary SCM

From 2H .1002:

A wet pond, stormwater wetland, infiltration system, sand filter, bioretention cell, permeable pavement, green roof, rainwater harvesting, or an approved new stormwater technology that is in accordance with the MDC

Can stand alone when designed per the MDC to treat the design storm depth

From Annette Lucas of NC DEQ

Secondary SCM

From 2H .1002:

An SCM that does not achieve the annual reduction of TSS of a Primary SCM but can be used in a treatment train with a primary SCM to provide pre-treatment or hydraulic benefits

May not stand alone; must be used with another SCM

From Annette Lucas of NC DEQ

SCM Categories

Primary SCMs	Secondary SCMs
Wet Pond	DIS
Stormwater Wetland	LS-FS
Infiltration System	Pollutant Removal Swale
Sand Filter	Dry Pond
Bioretention Cell	
Permeable Pavement	
Rainwater Harvesting	
Green Roof	

From Annette Lucas of NC DEQ

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Primary versus Secondary SCMs

List & Uses	Primary SCMs	Secondary SCMs
List	- Bioretention Cell - Infiltration System - Permeable Pavement - Wet Pond[1] - Stormwater Wetland[1] - Sand Filter - Rainwater Harvesting	- Green Roof - Disconnected Impervious Surface - Level Spreader-Filter Strip - Pollutant removal Swale - Dry Pond
Uses	- As a stand-alone SCM to treat a new development site (when 100% sized). - As a retrofit.	- In series with a primary SCM to reduce the volume of runoff and thus reduce the size of the primary SCM. - In series with a primary SCM to provide pretreatment. - In series with a primary SCM as a hydraulic device to slowly "feed" the stormwater runoff to the primary SCM, to reduce the size of the primary SCM. - In series with another secondary SCM to treat the design storm in a manner that meets or exceeds performance standard. - As a retrofit.

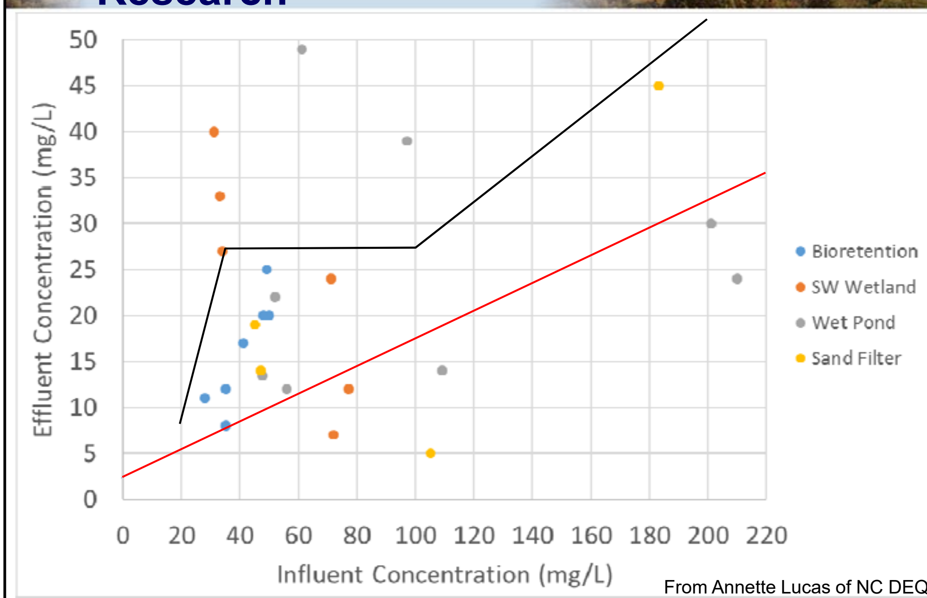
https://stormwa

WHY don't we say
85% TSS removal
any more?

Because it's wrong!

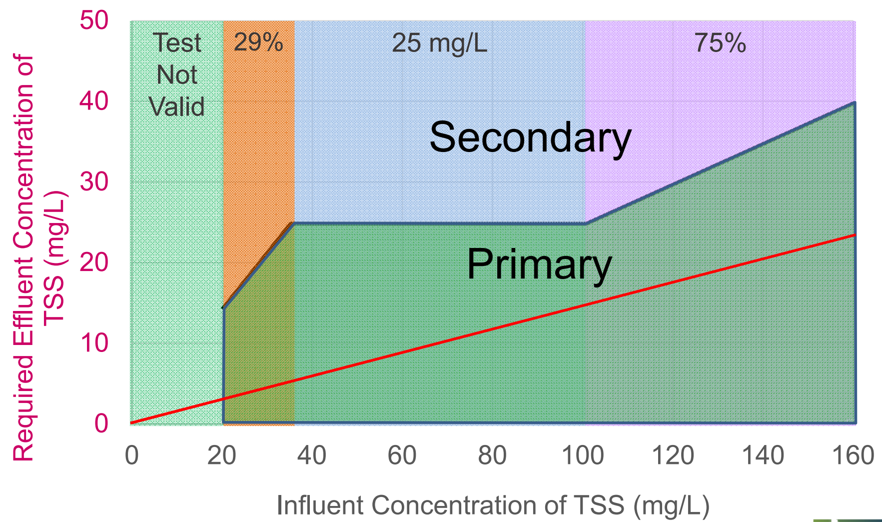
From Annette Lucas of NC DEQ

SCM Performance per Research



From Annette Lucas of NC DEQ

Standards for Primary SCMs



From Annette Lucas of NC DEQ

Options in New Rules

Runoff treatment: the SW runoff from all of the built-upon area of a project at build-out is treated in primary SCMs or a combo of Primary and Secondary SCMs that provides equal or better treatment (one Drainage Area, one Primary SCM)

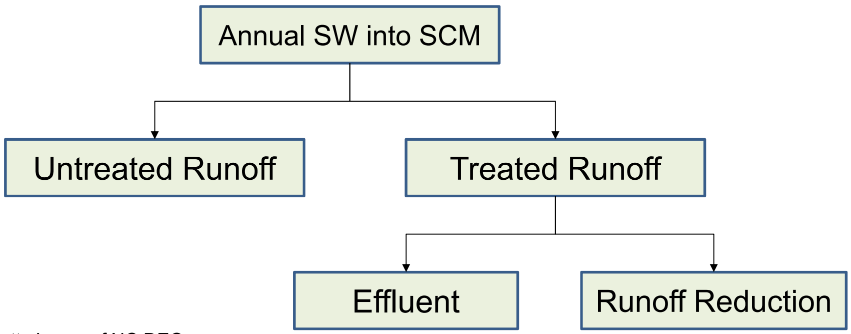
Runoff volume match (aka LID): the annual runoff volume after development does is not more than 10% higher than the amount annual runoff volume before development (5% in SA waters)

From Annette Lucas of NC DEQ

Runoff Volume Match: More Complicated

For SCMs we need to know:

- How much stormwater is treated versus untreated?
- Of the treated stormwater, how much is effluent vs. runoff reduction?
    - What about over/under-sized SCMs?



From Annette Lucas of NC DEQ

Fates of Treated Runoff

Effluent:
Treated discharge from an SCM

Runoff Reduction:
Infiltration, Evaporation, Harvesting

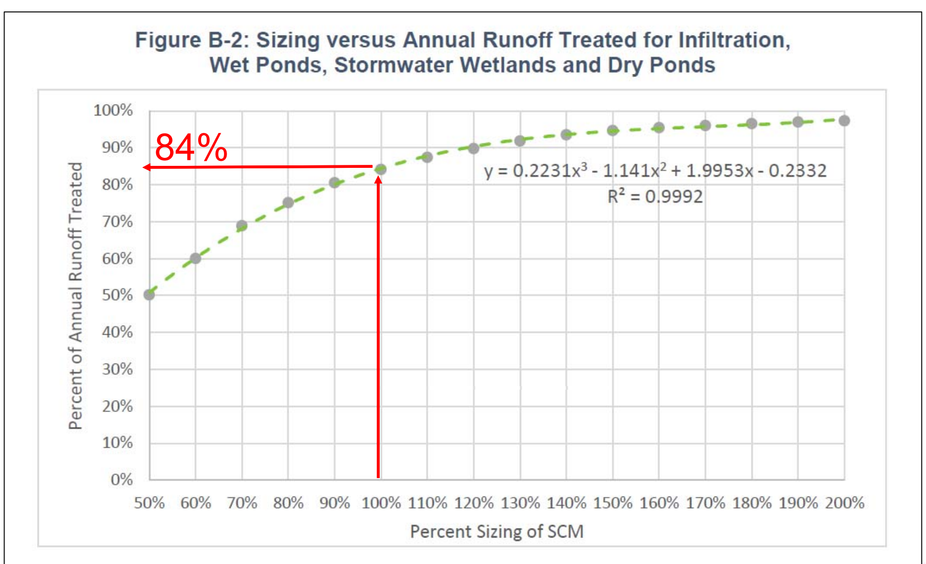
From Annette Lucas of NC DEQ

Annual Runoff Treated

- Modeled using prior work of Smolek et al. (2015) and hypothetical watershed (15 acres, CN = 98)
- Determined annual runoff treated:
  - SCMs 50 to 200% of required size
  - Draw down periods of 12, 60, 72 hours
  - 20 years worth of CRONOS data from Asheville, Raleigh, and Wilmington airports
- Created curves to fit regression equations

Smolek, A.P., Grabow, G.L., & Hunt, W.F. (2015). Influence of drawdown period on overflow volume and pollutant treatment for detention-based stormwater control measures in Raleigh, North Carolina. *Journal of Sustainable Water in the Built Environment, 1*(2) doi:10.1061/JSWBAY.0000798

Annual Runoff Treated



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SCMs (designed per the MDC unless otherwise specified)	% of annual runoff treated if 100% sized
Infiltration Permeable Pavement Wet Pond Stormwater Wetland Dry Pond	84%
Bioretention	94%
Sand Filter (open or closed) StormFilter	90%
LS-FS DIS Pollutant Removal Swale	90%
Rainwater Harvesting	85%

From Annette Lucas of NC DEQ

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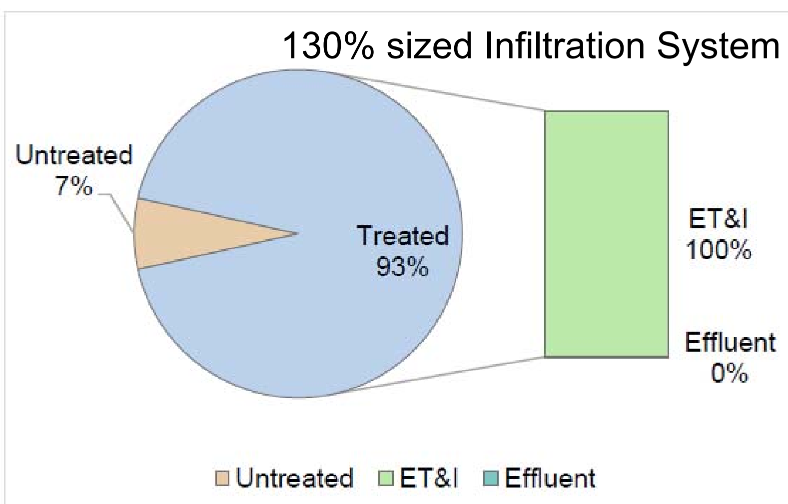
Fates of Runoff



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SCM Pollutant Credits

- Only data from NC and or other comparable regions were used
- When possible used:
  - Published data and submitted articles
    - Monitored SCM designs meet MDCs
  - Exceptions:
    - Sand filters, green roofs, dry ponds
- Paired influent and effluent data
- Performed QA/QC of data
- Data sources provided to NC DEQ

Bioretention

- 10 NCSU studies:
  - Charlotte, Graham (x2), Knightdale (x2), Louisburg (x2), Nashville (x2), Rocky Mount, NC
- For each site calculated average EMCs
- Used average of mean EMCs
  - TN: with and without IWS
  - TP: all studies

Bioretention- Calculation

- For each site: $\overline{x_i} = \frac{1}{n}\sum_{i=1}^{n} C_i$

  Where:

  $\overline{x_i}$ = Average effluent concentration for site (mg/L)

  n = Number of samples from site

  C_i = Effluent concentration from storm event i (mg/L)

Bioretention- Calculation

- For SCM effluent: $\mathrm{E} = \frac{1}{n}\sum_{i=1}^{n} \bar{x}_i$

  Where:

  E = SCM effluent (mg/L)

  n = Number of sites

  $\overline{x_i}$ = Average effluent concentration for site i
- Took average of mean effluent concentrations to avoid bias with different number of samples

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SCM	Role	% Annual Runoff Treated if 100% Sized	% Treated Runoff to Fates			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Bioretention per MDC	Primary	94	A	90	10	0.58	0.12
			B	71	29		
			C	36	64		
			D	14	86		
Bioretention per MDC but without IWS (retrofits and special cases only)	Primary	94	A	51	49	1.20	0.12
			B	20	80		
			C	11	89		
			D	9	91		
Bioretention with design variants per Hyper Tool	Primary	Tool Output	Tool Output			0.58 / 1.20	0.12

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What if I can't remember all of this?

This is all programmed into the Jordan Falls tool!
Storm-EZ needs to be updated….

A goal for 2017 will be to finish the "SNAP" tool that will do both nutrient and LID calculations

Stormwater Nutrient Accounting Tool
Version 4.0.17 beta

STORM-EZ
NCDENR

From Annette Lucas of NC DEQ

What's Next?

Sept. 30 2016: Public notice begins

Oct. 30 2016: Public notice ends

Jan. 1 2017:

- Final SCM Evaluation Document released
- New rules went into effect
- Stormwater Design Manual noticed

Apr. 1 2017: SW Design Manual finalized

From Annette Lucas of NC DEQ

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Questions?


North Carolina
Stormwater Control Measure
Credit Document

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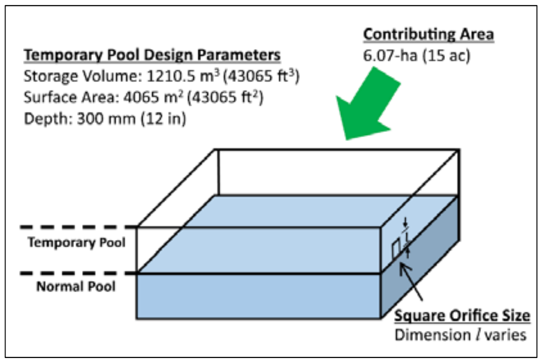
Annual Runoff Treated

Influence of Drawdown Period on Overflow Volume and Pollutant Treatment for Detention-Based Stormwater Control Measures in Raleigh, North Carolina

Alessandra P. Smolek, S.M.ASCE[1]; William F. Hunt III, Ph.D., P.E., D.WRE, M.ASCE[2]; and Garry L. Grabow, Ph.D., P.E.[3]



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Annual Runoff Treated

- Routed using depth of water in SCM rather than volume on hourly basis
- Assumed between hours 0 and 1 drawdown negligible (ponded water = 1 foot) and all of runoff entered SCM
- Inflow:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} * 3630 * A$$

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Annual Runoff Treated

- Outflow:

$$h_{out} = \frac{\left(0.6 * A * \sqrt{2gh_o}\right) * \Delta t}{SA_{SCM}} * C_o, h_1 > \frac{l}{2}$$

$$h_{out} = \frac{(3.33 * (l - 0.2h_w) * h_w^{1.5}) * \Delta t}{SA_{SCM}} * C_w, h_1 \leq \frac{l}{2}$$

Where:
h_{out} = Outflow depth
h_o = Orifice driving head at beginning of Δt
h_1 = Depth of water in SCM at beginning of Δt
h_w = Weir driving head at beginning of Δt
l = Height of rectangular orifice
SA_{SCM} = Surface area of SCM

Annual Runoff Treated

- Overflow (Untreated):

$$h_2 = h_1 + h_{in} - h_{out}$$

$$h_{in} = 0, \qquad P_{cum} \leq I_a$$

$$h_{in} = \frac{P_{\Delta t} * A}{SA_{SCM}}, \qquad P_{cum} > I_a$$

Where:
h_2 = Depth of water in SCM at end of Δt
h_1 = Depth of water in SCM at beginning of Δt
h_{in} = Inflow depth during Δt
P_{cum} = Cumulative depth of rainfall during storm event
I_a = Initial abstraction

Annual Runoff Treated

- Overflow (Untreated):

$$O_i = \begin{pmatrix} 0, & h_2 \leq 12\ in \\ h_2 - 12, & h_2 > 12\ in \end{pmatrix}$$

$$OV = \frac{\sum_{i=1}^{n} O_i}{\sum_{i=1}^{n} h_{in,i}} * 100$$

- Treated:

$$TR = 100 - OV$$

Where:
O_i = Overflow depth that occurred during event i
OV= Overflow (Untreated) depth of runoff
$h_{in,i}$ = Total inflow depth of event i
TR= Treated depth of runoff

Annual Runoff Treated

- Determined overflow for sand filters using:
  - 12 hour drawdown period
  - Rectangular orifice dimensions
  - Surface area of sand filter
  - 20 years of hourly CRONOS data
  - Overflow percentages of 1 or 1.5 inches were normalized by 0.75 to account for sand filter sizing

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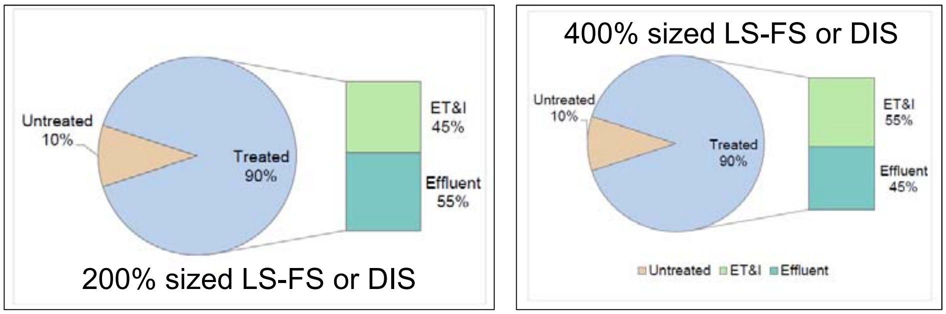
Fates of Runoff

- For level-spreader filter strips and disconnected impervious surfaces
  - Regardless of oversizing (undersizing not allowed) SCMs are designed to treat 90% of annual runoff
  - ET&I increases as vegetated receiving areas increase



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Fates of Runoff

- Bioretention cells runoff fates determined by NCSU HyPerTool model
- Rainwater harvesting runoff fates determined by NCSU Rainwater Harvester model
- Pollutant removal swales and StormFilter runoff fates as stated in document because under/over-sizing not allowed
- Models: https://stormwater.bae.ncsu.edu/resources/

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Infiltration

- Per MDC designed to dewater design volume to bottom of infiltration device within 60 hours or less
- Therefore, no effluent so EMCs are zero

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Infiltration

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% Treated Runoff to Fates			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Infiltration per MDC	Primary	84	A	100	0	0	0
			B	100	0		
			C	100	0		
			D	100	0		

- Excellent protection of stream banks, stream temperature, and removal of bacteria

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Permeable Pavement

- 8 NCSU studies:
  - Fayetteville, Goldsboro, Kinston (x4), Durham, NC
  - Willoughby Hills, OH
- For each site calculated average EMCs
- Used average of mean EMCs
  - Infiltration: designed per MDC, EMCs are zero

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Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% Treated Runoff to Fates			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Permeable pavement (infiltration) per MDC	Primary	84	A	100	0	0	0
			B	100	0		
			C	100	0		
			D	NA	NA		
Permeable pavement (detention, unlined) per MDC	Primary	84	A	10	90	1.08	0.05
			B	5	95		
			C	0	100		
			D	0	100		
Permeable pavement (detention, lined) per MDC	Primary	84	A	0	100	1.08	0.05
			B	0	100		
			C	0	100		
			D	0	100		
Permeable pavement with design variants per the HyPerMod	Primary	Tool Output	Tool Output			1.08	0.05

- Infiltration: Excellent protection of stream banks, stream temperature, and removal of bacteria
- Detention: Fair protection of stream banks; Good protection of stream temperature and removal of bacteria

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Wet Pond and FWI

- 6 NCSU studies:
  - Charlotte (x2), Durham (x2), Fayetteville (x2), NC
- 1 published study:
  - High Point (x2), NC
- For each site calculated average EMCs
- Used average of mean EMCs
  - FWI: applied ratio (post-retrofit: pre-retrofit) to EMCs for wet ponds per MDC

Wet Pond and FWI- Calculation

- For each site: $\overline{x_i} = \frac{1}{n}\sum_{i=1}^{n} C_i$

  Where:

  $\overline{x_i}$ = Average effluent concentration for site (mg/L)

  n = Number of samples from site

  C_i = Effluent concentration from storm event i (mg/L)

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Wet Pond and FWI- Calculation

- For pre and post-retrofit effluent: $\mathrm{E} = \frac{1}{n}\sum_{i=1}^{n} \bar{x}_i$

  Where:

  E = Pre or post-retrofit effluent (mg/L)

  n = Number of sites

  $\bar{x}_i$ = Average effluent concentration for site i
- Found ratio of pre and post-retrofit:

$$Ratio: \frac{E_{post-retrofit}}{E_{pre-retrofit}}$$

- Applied ratios to wet pond effluent concentrations

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Wet Pond and FWI

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% Treated Runoff to Fates			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Wet Pond per MDC	Primary	84	A	25	75	1.22	0.15
			B	20	80		
			C	15	85		
			D	10	90		
Wet Pond per MDC with ≥ 5% covered by FWI per Fig. 1	Primary	84	A	25	75	0.85	0.09
			B	20	80		
			C	15	85		
			D	10	80		

- Fair protection of stream banks and removal of bacteria
- Poor protection of stream temperature

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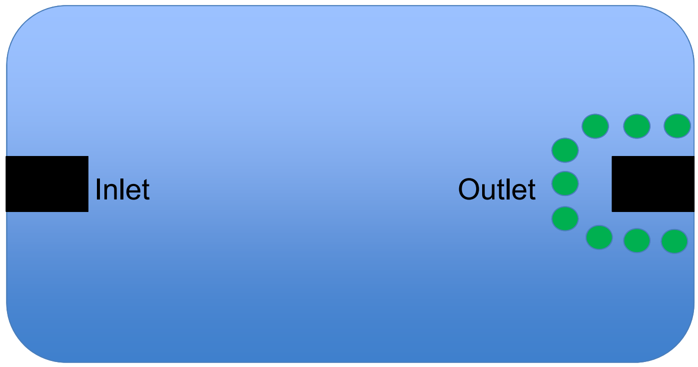
Wet Pond and FWI



- FWI coverage: 5% of wet pond surface area
- Placement: create ring of FWI protecting inlet or outlet structure

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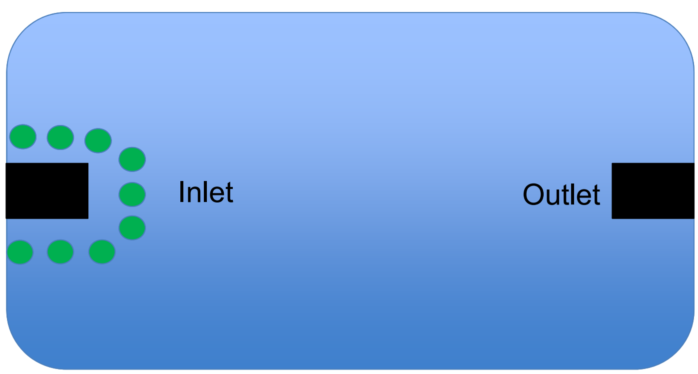
Wet Pond and FWI



- Placement: secure FWI such FWI will not move around wet pond; want to “force” as much runoff through FWI as possible

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Sand Filter

- 6 International Stormwater BMP Database:
  - FL: Orlando, Tallahassee (x2)
  - MD: North Potomac
  - NH: Durham
  - VA: Alexandria
- For each site calculated median EMCs
- Used average of median EMCs
- StormFilter data from manufacturer’s studies

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Sand Filter

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			EMC$_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Sand Filter (open) per MDC	Primary	91	A	10	90	1.33	0.12
			B	5	95		
			C	0	100		
			D	0	100		
Sand Filter (closed) per MDC	Primary	91	A	0	100	1.33	0.12
			B	0	100		
			C	0	100		
			D	0	100		

- Poor protection of stream banks
- Fair protection of stream temperature
- Good removal of bacteria

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StormFilter

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
StormFilter per MDC with PhosphoSorb media™	Primary	91	A	0	100	0.48	0.03
			B	0	100		
			C	0	100		
			D	0	100		

- Poor protection of stream banks
- Fair protection of stream temperature and removal of bacteria

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Rainwater Harvesting

- Determined usage affects EMCs
  - If all harvested water discharged to sanitary sewer do not "see" harvested water
- Use EMCs from Rainwater Harvester model

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Rainwater Harvesting

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			EMC$_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Rainwater Harvesting per MDC	Primary	85	A B C D	Custom based on water usage		Custom based on water usage	

- Excellent protection of stream banks and stream temperature
- Good removal of bacteria

Green Roof

- 2 NCSU studies: Goldsboro (x2), NC
- 1 published study: Storrs, CT
- 3 International Stormwater BMP Database:
  - NZ: Auckland (x3)
- For each site calculated average EMCs
- Used average of mean EMCs

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Green Roof

Credit Table

SCM	Role	% Annual Runoff Treated when sized for Design Storm	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Green Roof per MDC	Secondary	100	N/A	60	40	2.44	0.76

- Good protection of stream banks, stream temperature, and removal of bacteria

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Disconnected Impervious Surface

- 1 NCSU study: Wilmington (x4), NC
- For each site calculated median EMCs
- Used average of median EMCs
- NCSU found concentrations not conservative- use current rooftop concentrations instead

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Disconnected Impervious Surface

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
DIS per MDC	Secondary	90	A	65	35	2.44	0.76
			B	50	50		
			C	40	60		
			D	30	70		

- Good protection of stream banks, stream temperature, and removal of bacteria

Pollutant Removal Swale

- 8 NCSU studies: Duplin County, Johnston County (x2), Knightdale (x3), Sampson County, Wilson, NC
- For each site calculated median EMCs
- Dry conditions: used average of median EMCs for swales without continuous ponding
- Wet conditions: applied ratio (wet conditions: dry conditions) to EMCs for swales with dry conditions

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Pollutant Removal Swale

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Pollutant removal swale with dry conditions	Secondary	90	A	25	75	1.10	0.14
			B	15	85		
			C	5	95		
			D	0	100		
Pollutant removal swale with wet conditions	Secondary	90	A	40	60	0.82	0.11
			B	30	70		
			C	20	80		
			D	10	90		

- Wet: Fair protection of stream banks and stream temperature; Poor removal of bacteria
- Dry: Poor protection of stream banks and removal of bacteria; Fair protection of stream temperature

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Stormwater Wetland

- 9 NCSU studies:
  - Asheville, Charlotte (x2), Edenton, Mooresville, New Bern (x2), Raleigh, Riverbend (x2), NC
- 1 UNCW study:
  - Wilmington, NC
- For each site calculated average EMCs
- Used average of mean EMCs

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Stormwater Wetland

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% Treated Runoff to Fates			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Stormwater wetland per MDC	Primary	84	A	40	60	1.12	0.18
			B	35	65		
			C	30	70		
			D	25	75		

- Good protection of stream banks and removal of bacteria
- Fair protection of stream temperature

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Level Spreader- Filter Strip

- 8 NCSU studies: Apex (x2), Louisburg (x2), Wilson (x4), NC
- For each site calculated median EMCs
- Used average of median EMCs
  - Per MDC: excluded amended LS-FS
  - Virophos: applied ratio (amended: non-amended) to EMCs for LS-FS per MDC

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Level Spreader- Filter Strip

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
LS-FS per MDC	Secondary	90	A	60	40	1.04	0.19
			B	40	60		
			C	25	75		
			D	15	85		
LS-FS with Virophos sand added to the filter strip	Secondary	90	A	60	40	0.87	0.10
			B	40	60		
			C	25	75		
			D	15	85		

- Poor protection of stream banks, stream temperature, and removal of bacteria

Dry Pond

- 2 NCSU studies in Charlotte, NC
- 3 International Stormwater BMP Database:
  - NC: Greenville
  - VA: Charlottesville (x2)
- For each site calculated median EMCs
- Used average of median EMCs

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Dry Pond

Credit Table

SCM	Role	% Annual Runoff Treated if 100% Sized	% of Treated Runoff to Each Fate			$EMC_{effluent}$ (mg/L)	
			HSG	ET&I	Effluent	TN	TP
Dry Pond per MDC	Secondary	84	A	10	90	1.65	0.66
			B	5	95		
			C	0	100		
			D	0	100		

- Poor protection of stream banks, stream temperature, and removal of bacteria

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