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WRRI Annual Conference 2017

Aging Bioretention: Spatial Pollutant Accumulation and Maintenance Implications

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The first BRCs…

- 1990 – "Invention" in Prince George's County, Maryland
- 1993 – First BRC (rain garden) design guidance

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Fast forward 24 years…

- BRCs are one of the most common SCMs in the United States, Australia, and Asia

Rooftop Treatment in Albany, NZ (Courtesy Bill Hunt)

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Fast forward 24 years…

- We know that BRCs work:
  - Hydrologic & nutrient benefits
    - (Davis et al. 2009; Hunt et al. 2012)
  - Metals removal (Pb, Cu, Zn, Cd)
    - (Davis et al. 2003; Gülbaz et al. 2015; Jang et al. 2005; Jones and Davis 2012; Li and Davis 2008; Paus et al. 2013; Sun and Davis 2007)

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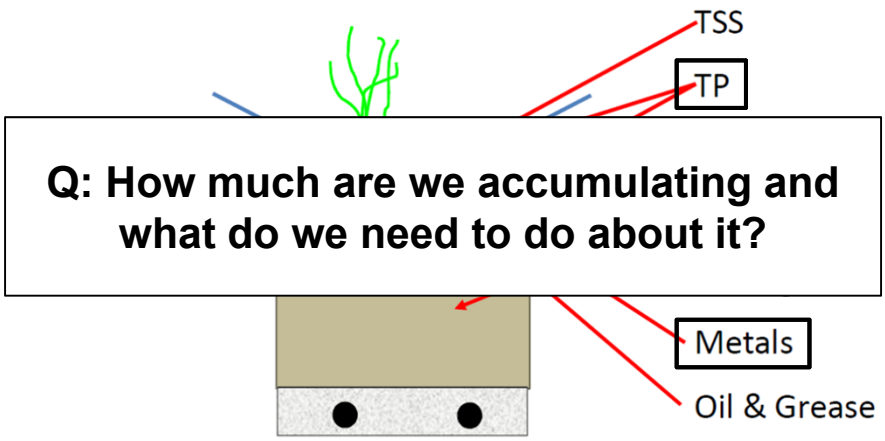
Pollutant Removal



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Research Question

Charlotte, NC – circa 2005

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Research Question

Is this OK?

Charlotte, NC –2015

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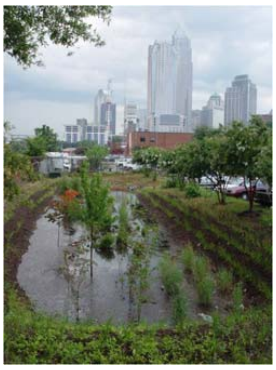
Study Site: Hal Marshall BRC

- Originally studied for hydrology and water quality over 2-year period (2004-2006)
  - Hunt, W. F., Smith, J. T., Jadlocki, S. J., Hathaway, J. M., and Eubanks, P. R. (2008). "Pollutant removal and peak flow mitigation by a bioretention cell in urban Charlotte, NC." Journal of Environmental Engineering, 134(5), 403–408.



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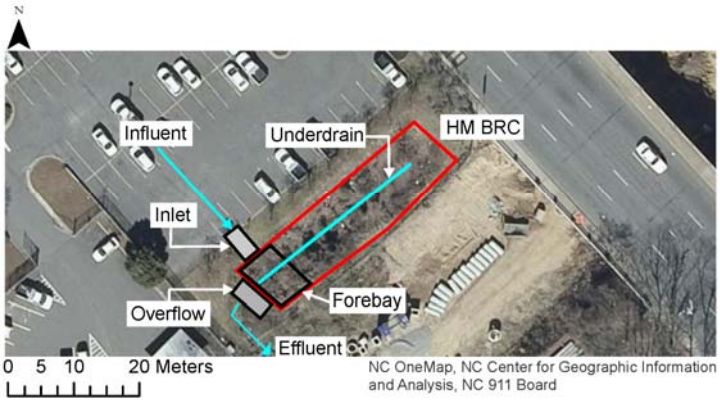
Study Site: Hal Marshall BRC



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Study Site: Hal Marshall BRC

TABLE 1. BRC Characteristics with adaptations from Hunt et al. (2008)

Watershed description	Municipal parking lot
Watershed area	0.37 ha (0.92 ac)
Watershed CN	98
Average Annual Precipitation	110.5 cm (43.5 in.)
BRC surface area	229 m^2 (2,480 ft^2)
BRC storage volume (not including storage within soil)	41 m^3 (1,460 ft^3)
Soil media depth	1.2 m (4 ft)
Underdrain system	0.15 m (6 in.) corrugated plastic pipe
Soil media type[a]	Loamy sand
Soil media silt and clay fraction	5.7%
Soil media permeability[b]	0.0003 cm/s (0.43 in/hr)
Soil media CEC[a]	1.9
Soil media P-Index	7 - 14
Vegetation density (by percent occupied)[c]	85%

[a]Determined from soil samples collected on May 4, 2006
[b]Test conducted on May 4, 2006
[c]Determined from sampling on December 11, 2014

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Study Site: Hal Marshall BRC

- Influent and effluent sampled from 2004 - 2006

TABLE 2. Select Influent and Effluent EMCs from Hunt et al. (2008)

Pollutant	N	Analytical Method	Unit	Inflow	Underdrain	E.R.	Significance
TSS	23	SM 2540D	mg L^{-1}	49.5	20.0	0.60	$P<0.01$
TP	23	SM 4500-P	mg L^{-1}	0.19	0.13	0.31	No. $P=0.078$
Cu	23	EPA 200.8	µg L^{-1}	12.8	5.9	0.54	$P<0.0001$
Zn	23	EPA 200.7	µg L^{-1}	72	17	0.77	$P<0.0001$
Pb	23	EPA 200.8	µg L^{-1}	4.85	3.33	0.31	$P<0.03$
Fe	17	EPA 200.7	µg L^{-1}	1,110	4,710	(3.30)	$P<0.01$[b]

[b]Increase in concentration.

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Study Site: Hal Marshall BRC

- Soil media samples (n = 72) were taken on December 11, 2014
- Taken at depths of 5, 10, and 20 cm (Jones and Davis 2012; Sun and Davis 2007; Turer et al. 2001)
- Analyzed by NC Dept. of Agriculture Soil Testing Lab

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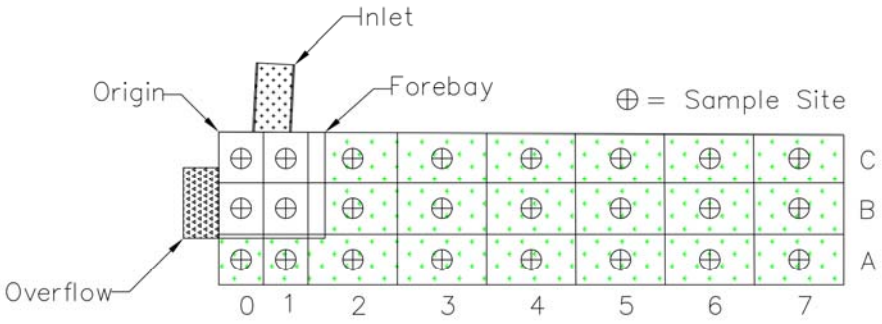
Study Site: Hal Marshall BRC



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Study Site: Hal Marshall BRC

- NCDA&CS Soil Testing reports Zn, Cu, and P as an index value
- Conversion: $c\ (mg\ kg^{-1}) = \frac{K * Index}{\rho}$

Index	Conversion Factor
Phosphorus	1.2
Zinc	0.04
Copper	0.02

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Results

- Phosphorous, Zinc, and Copper significantly decrease with respect to depth and ordinate distance from the inlet

TABLE 3. Summary of *p*-values using Kruskal-Wallis H tests on HM BRC samples. ($\alpha = 0.05$)

Variable	Depth	Feature	Horizontal Distance	Ordinate Distance
CEC	**<0.001**	**0.046**	0.29	**0.003**
Humic Matter (%)	**<0.001**	**0.002**	0.42	**<0.001**
pH	**0.010**	0.079	**0.002**	0.089
Mehlich-3 P	**0.001**	**<0.001**	0.16	**<0.001**
Zn	**<0.001**	**<0.001**	0.10	**<0.001**
Cu	**<0.001**	**<0.001**	0.06	**<0.001**

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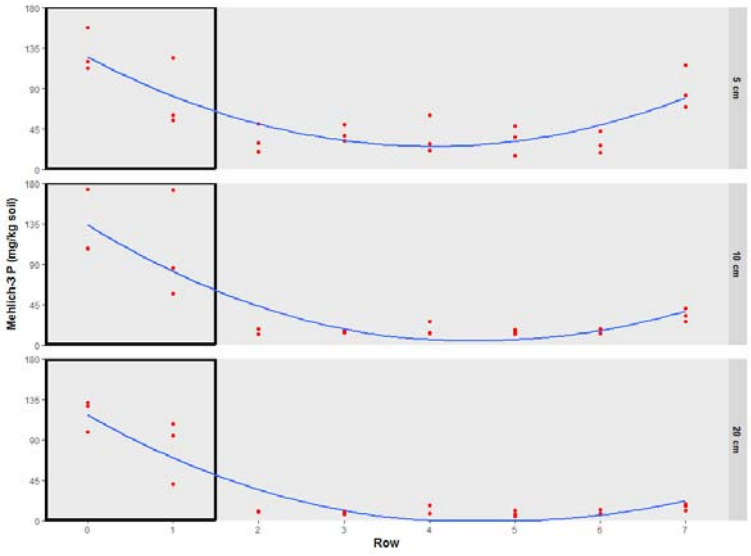
Results – Mehlich-3 P



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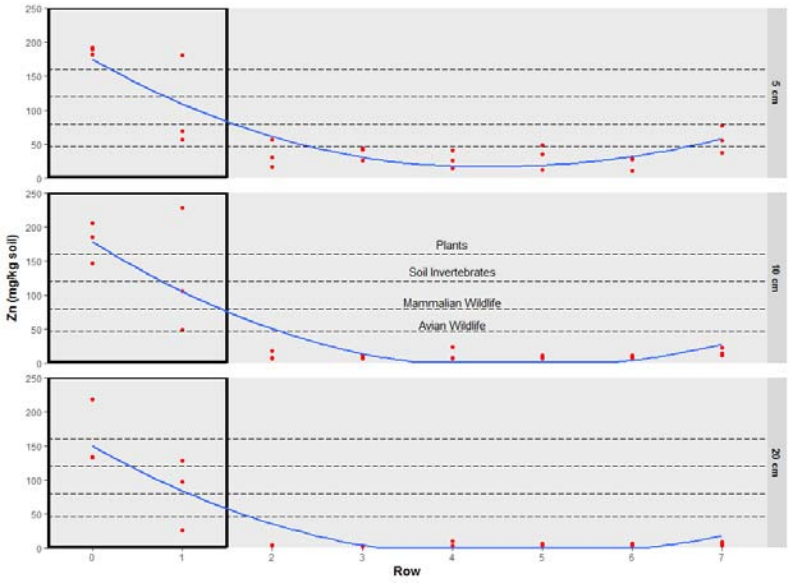
Results - Zinc



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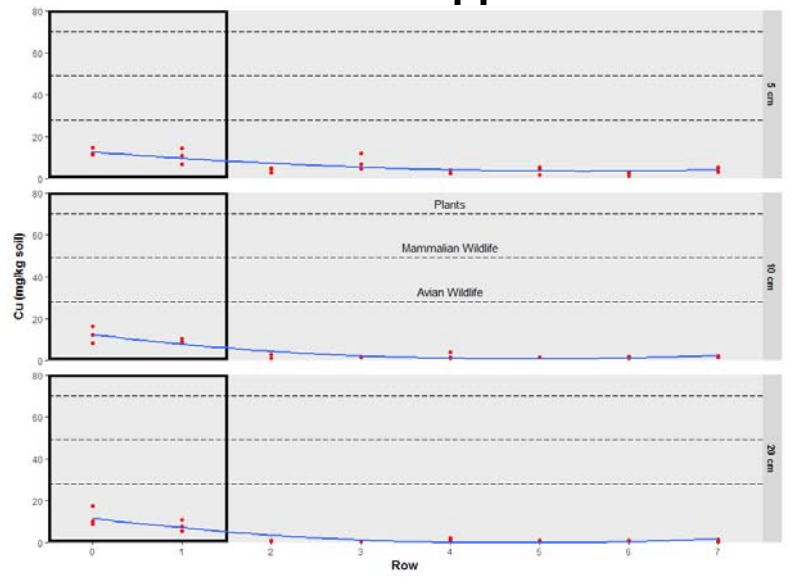
Results - Copper



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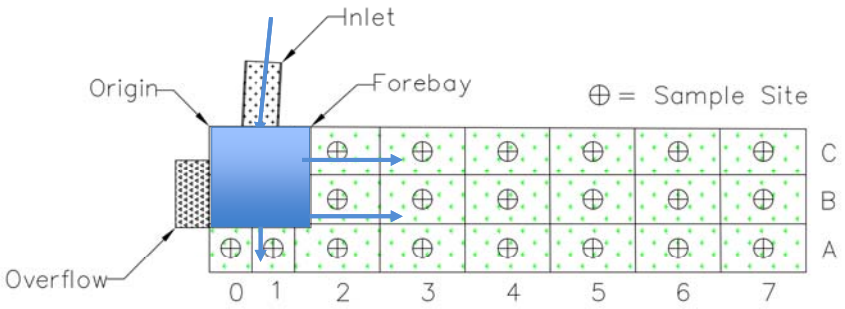
Discussion



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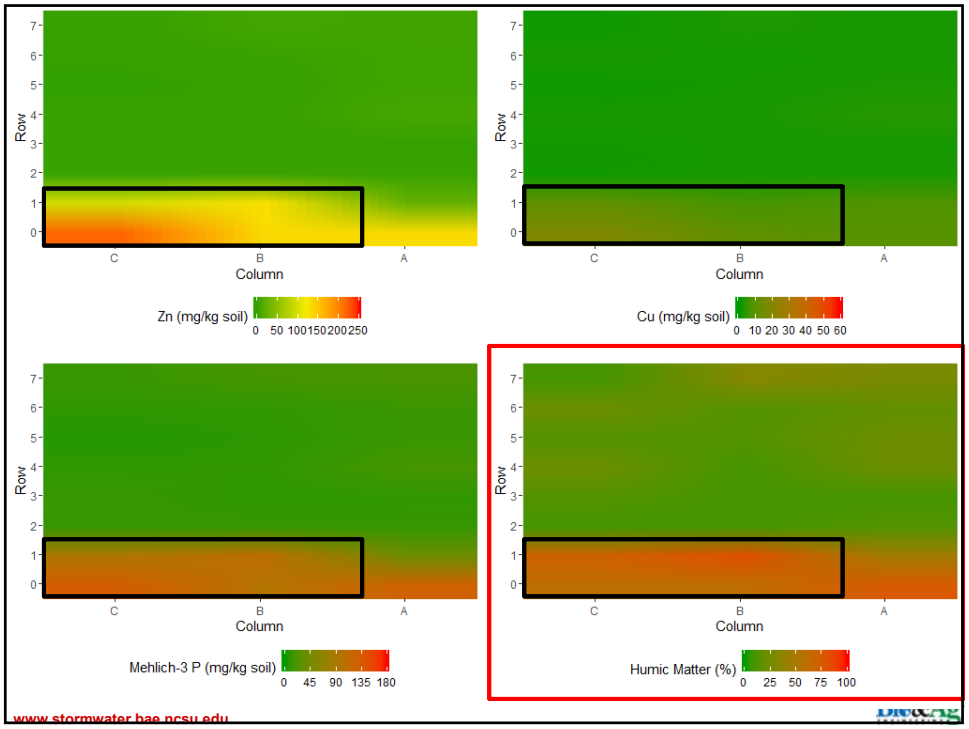

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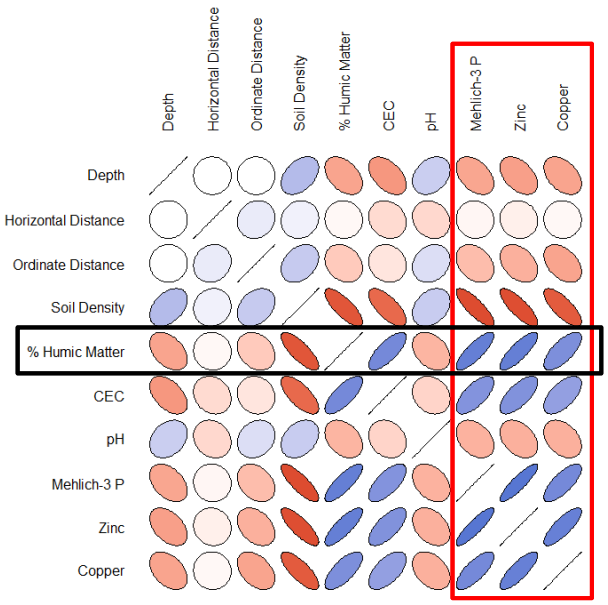

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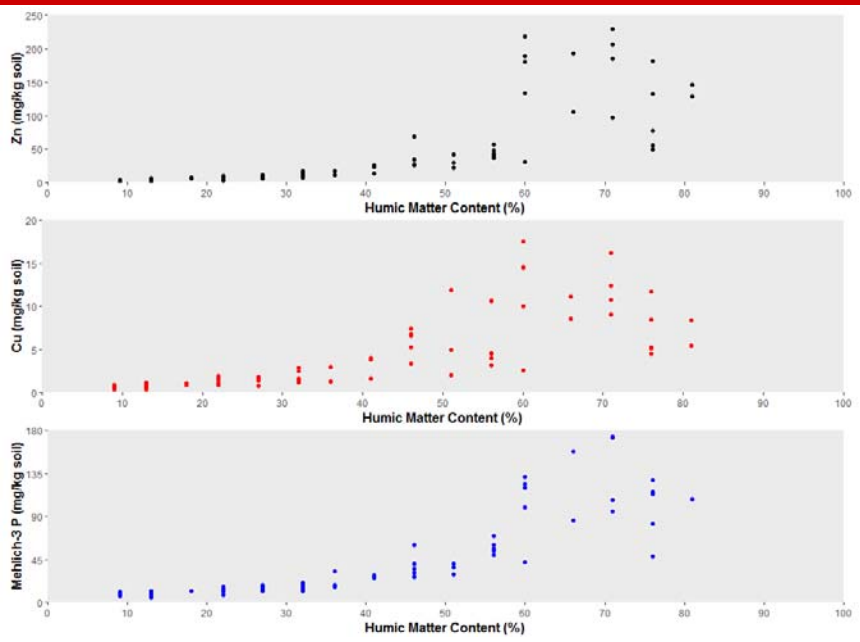

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Discussion

- Good news:
  - Bioretention works!
  - Organic matter binds and complexes metals
    - (Clark and Pitt 2009; Davis et al. 2001; Jang et al. 2005; Sun and Davis 2007; Paus et al. 2014)
    - Affinity: Cu^{2+} >>> Zn^{2+}

TABLE 4. Summary of Zn and Cu annual loads and years to remediation for HM BRC.

Metal	Cu	Zn
Influent EMC ($\mu g\ L^{-1}$)	12.8	72
Effluent EMC ($\mu g\ L^{-1}$)	5.9	17
Annual load[ab] ($mg\ kg^{-1}$ media)	0.04	0.31
Current high conc. ($mg\ kg^{-1}$ media)	17.5	228.6
Low Eco-SSL ($mg\ kg^{-1}$ media)	28	46
Residential Toxicity ($mg\ kg^{-1}$ media)	3,700	28,000
Maximum cumulative load ($kg\ ha^{-1}$)	1500	2800
Years to First Eco-SSL	300	NA
Years to Residential Remediation	1,000+	1,000+
Years to Maximum Load	1,000+	300

[a] Calculated in top 20 cm of soil media
[b] Average soil media density was 1 $g\ cm^{-3}$

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Discussion

- "Bad" news:
  - Careful with accumulation of P
  - As Mehlich-3 P increases in soil, P concentrations in effluent increase (Cox and Hendricks 2000)

TABLE 5. Initial and Sampled Mehlich-3 P in HM BRC

Feature	Initial (mg/kg soil)	Sampled (mg/kg soil)
Forebay		78.1
Mid-Cell	8.4 – 16.8	20.4
Far-Cell		32.0

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Conclusions

- Metal concentrations in soil media remained well below remediation levels following 11 years of service
- Heavy accumulation of Mehlich-3 P in soil media, particularly in the forebay and areas near inlet
- Preferential flow is occurring in areas that are accumulating P → we are realizing less ability to remove P → we're missing treatment opportunities

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Recommendations

- If using a forebay, remove accumulated soil media every 5 years
- Forebay can be amended to include water treatment residuals, iron filings, or locally available amendment

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More Info

Journal of Environmental Management 184 (2016) 363–370

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Evaluating the spatial distribution of pollutants and associated maintenance requirements in an 11 year-old bioretention cell in urban Charlotte, NC

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Acknowledgments

- The research was funded by USEPA grant RD835570
  - Contents do not necessarily represent the official views of the USEPA
  - USEPA does not endorse the purchase of any commercial products or services mentioned
- Assisted by the City of Charlotte, NC, Charlotte-Mecklenburg Stormwater Services, and Kevin Koryto

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Questions

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