CWEA

Fall Seminar
December 14, 2016

Case Study: Evaluating Retrofit Urban Best Management Practice Performance and Lessons Learned

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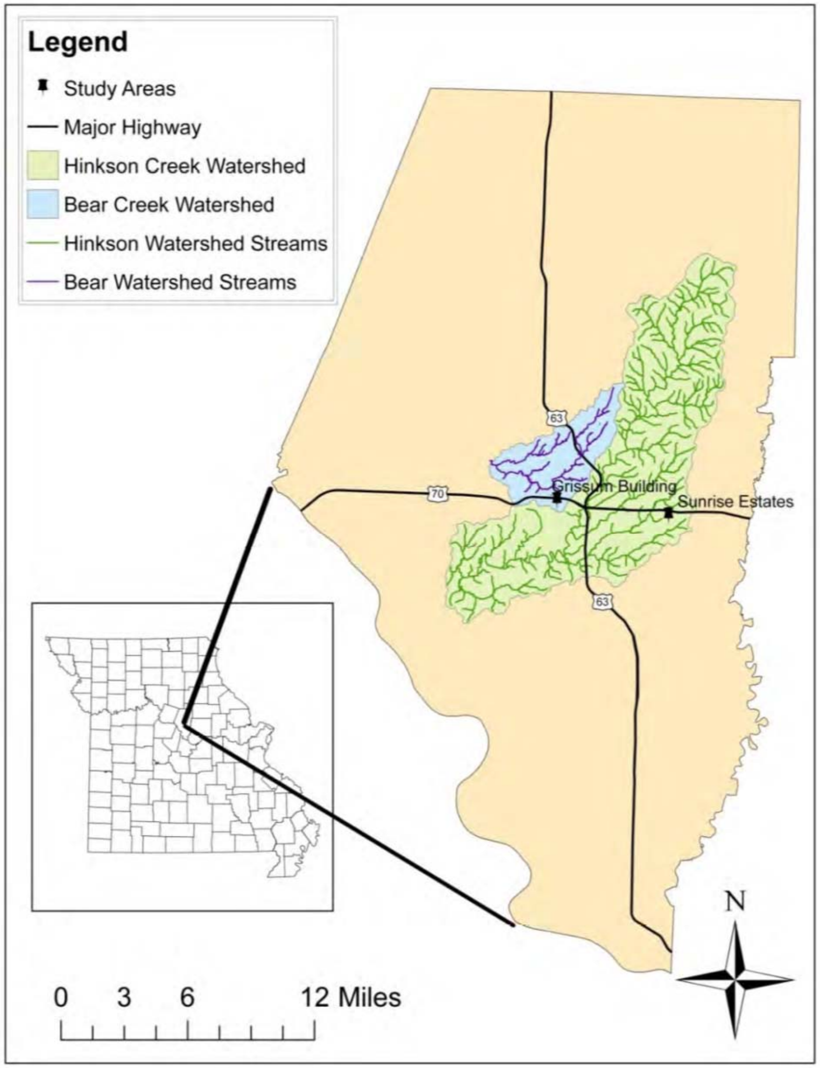
Outline

- Project Background
- Project Objectives
- Project Design – Step Pool
- Project Design – Bioretention
- Field Sampling
- Results
- Lessons Learned

Background

- Hinkson Creek
  - On 303(d) List since 1998
  - Aquatic life impairment
- Impairment Reason
  - Urban runoff sources
  - Pollutants unknown
- TMDL (2011)
  - Reduce stormwater runoff
  - Help "No longer impaired"



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Project Objectives

- Characterize reduction of common urban stormwater pollutants
- Quantify runoff volume reduction
- Implement BMPs and study their performance
  - Pollutant load reductions
  - Hydrologic response
  - Variety of storm events over several years

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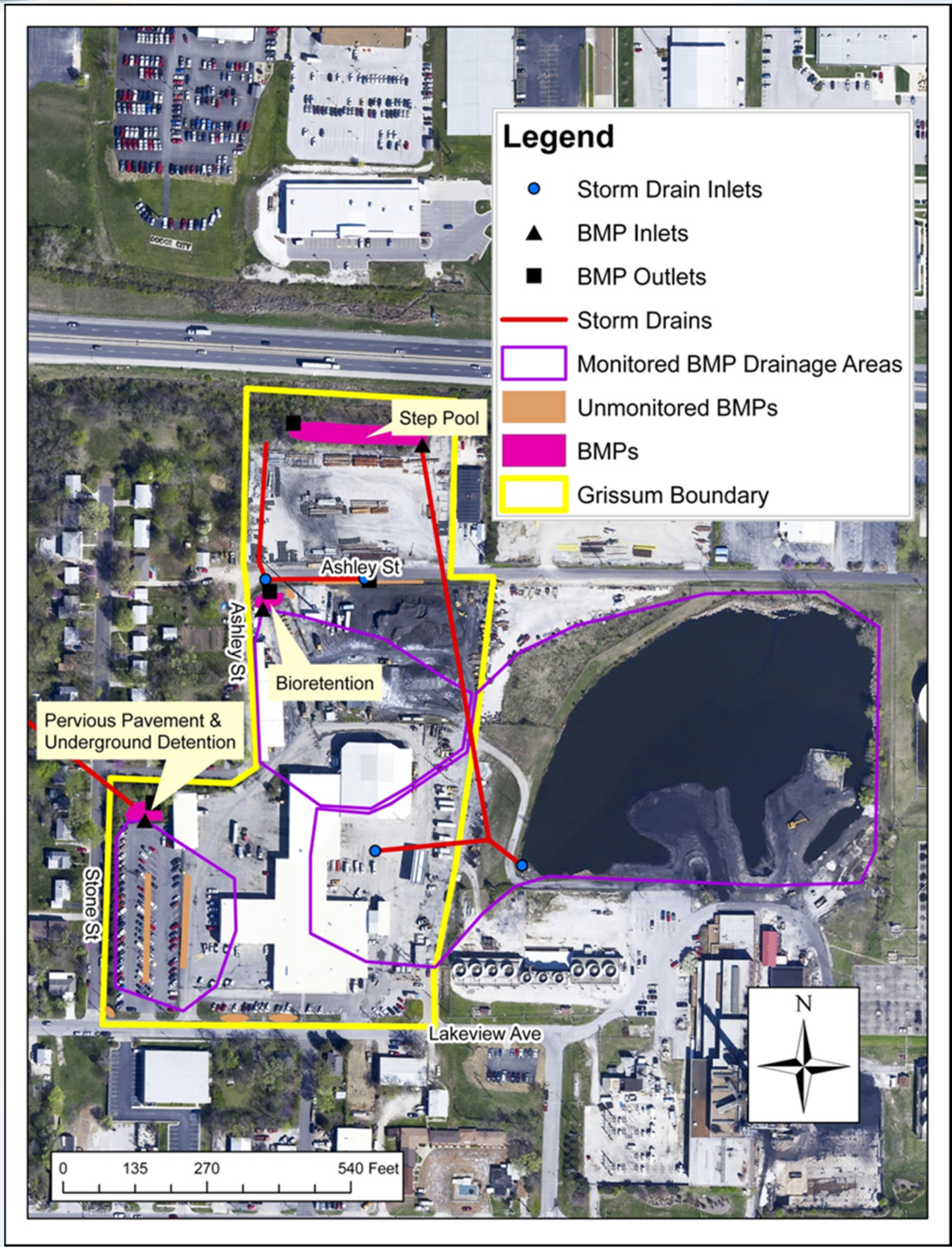
Existing Conditions

- Grissum Building
  - 10 acres
  - Industrial operations
  - No stormwater management
- Owned and operated by the City

Project Design

- Two BMPs implemented
  - Bioretention cell
    - November 2012 – January 2015
    - 11 rainfall events
  - Step pool system
    - September 2012 – December 2014
    - 20 rainfall events



Project Design

- Step pool system
  - Treatment area – 2.2 acres
  - With sand filters
- Bioretention
  - Treatment area – 1.3 acres
  - With underdrains

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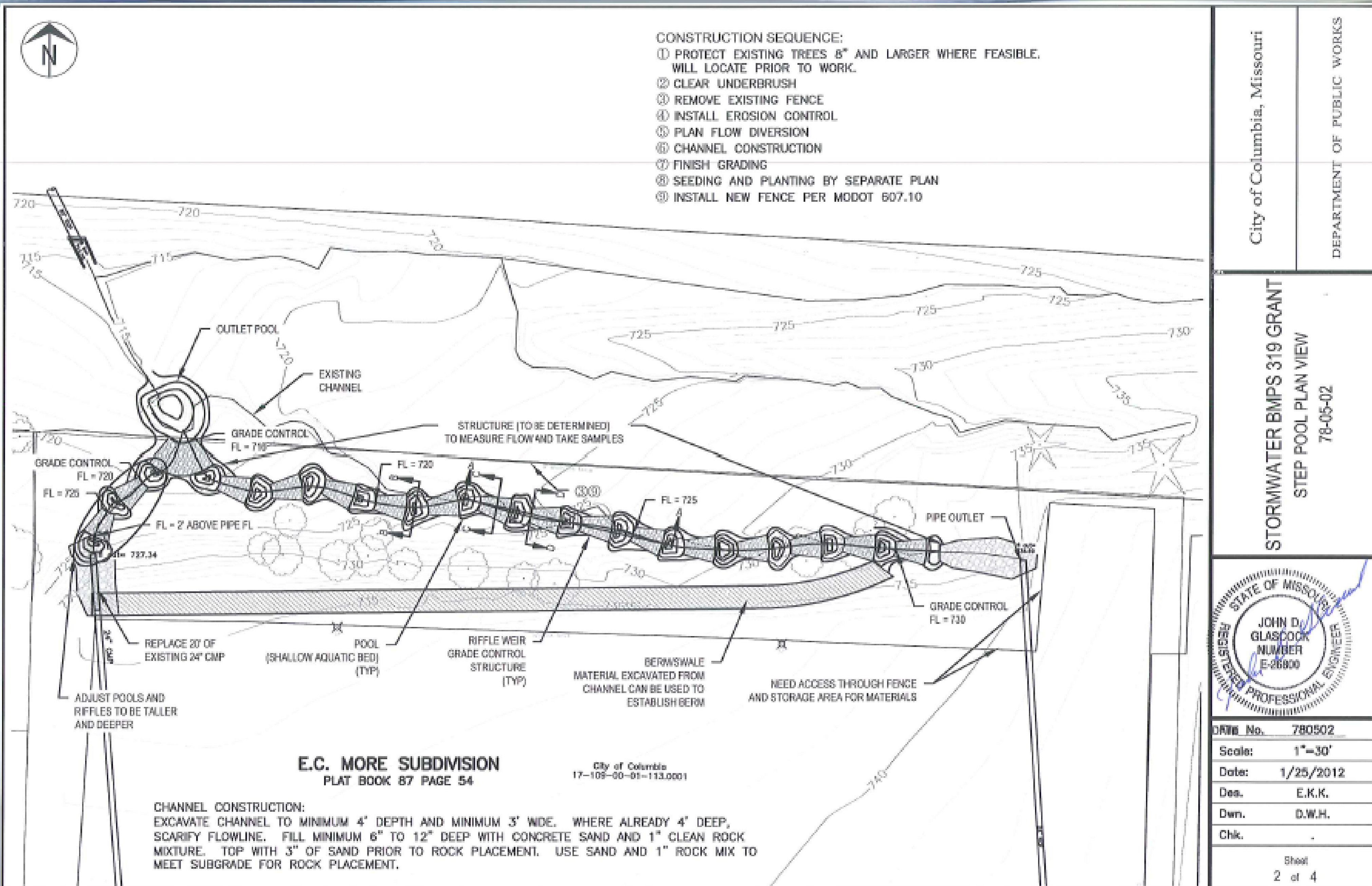
Project Design – Step Pool



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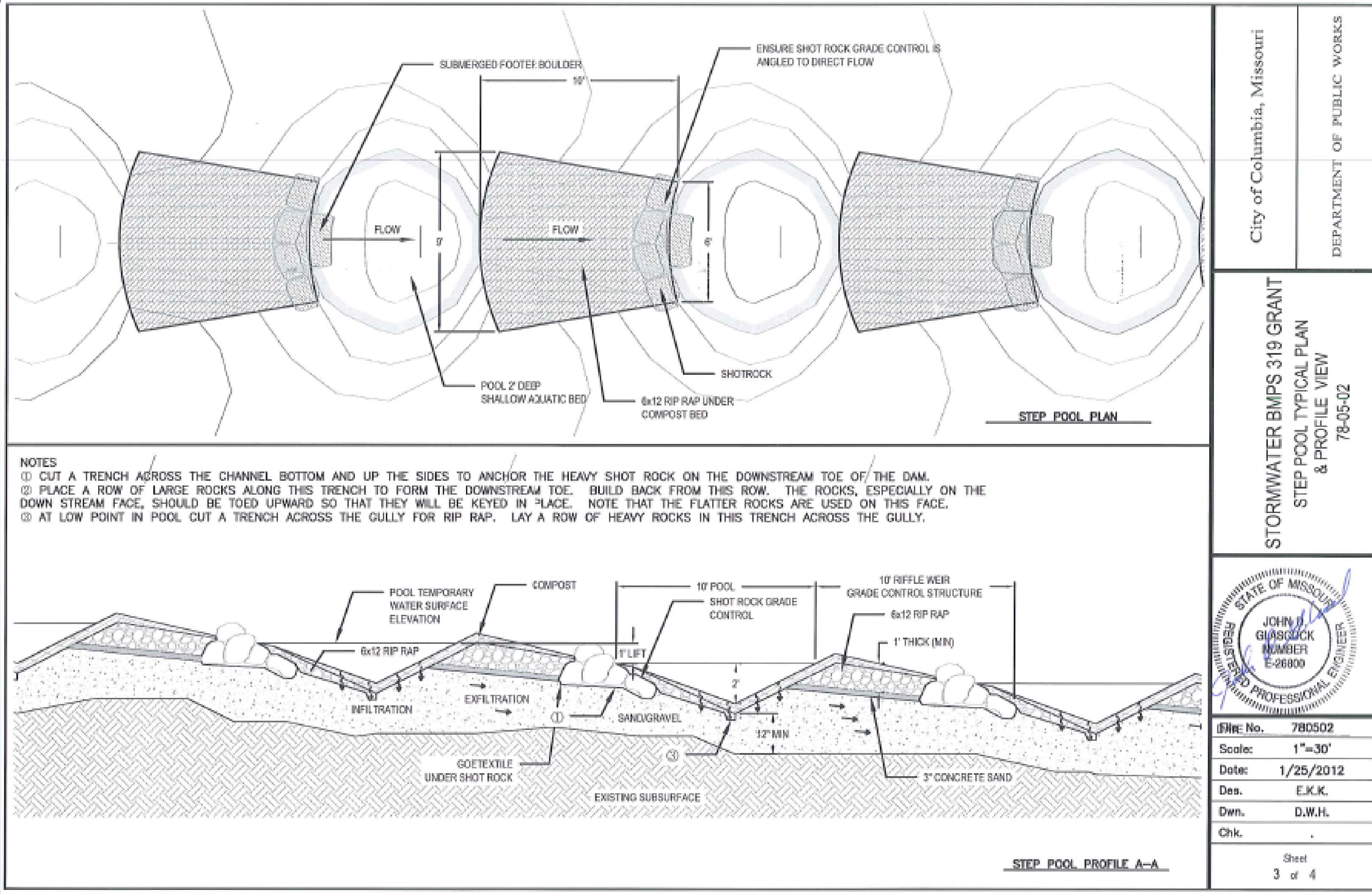
Project Design – Step Pool



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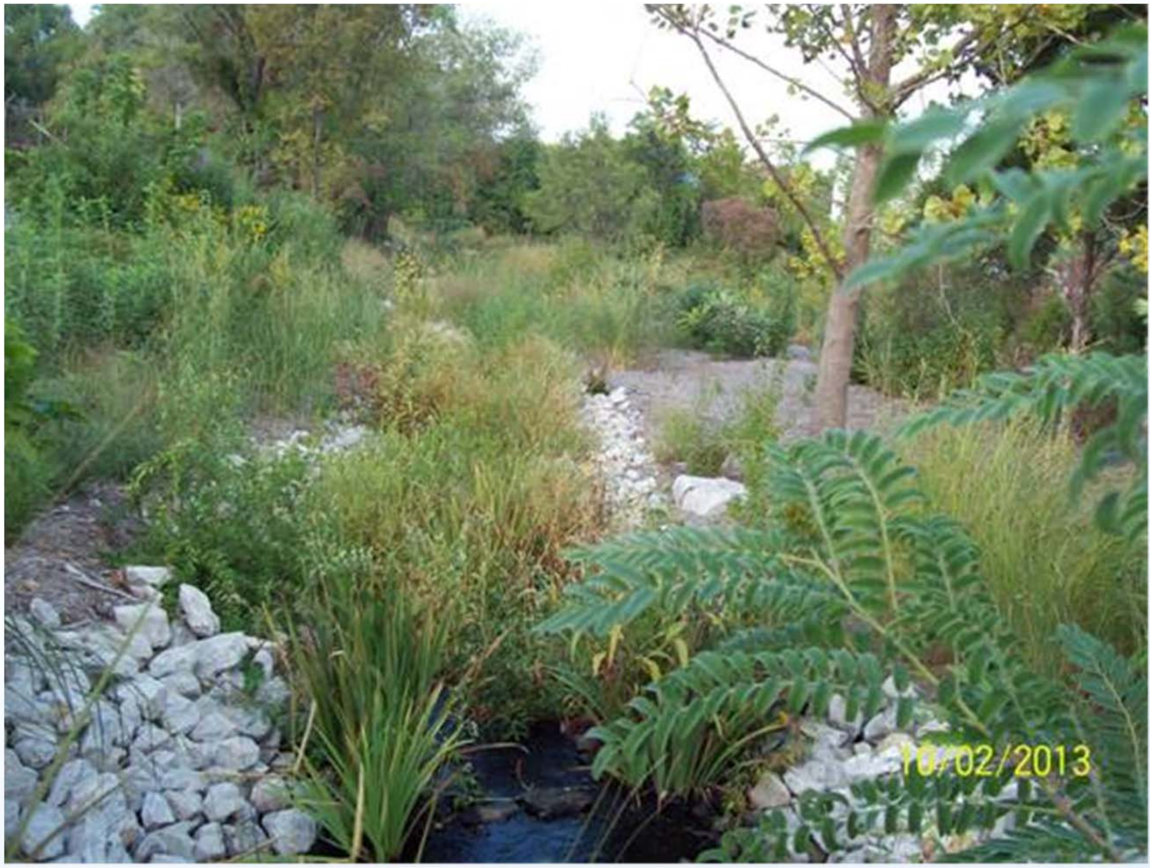
Project Design – Step Pool



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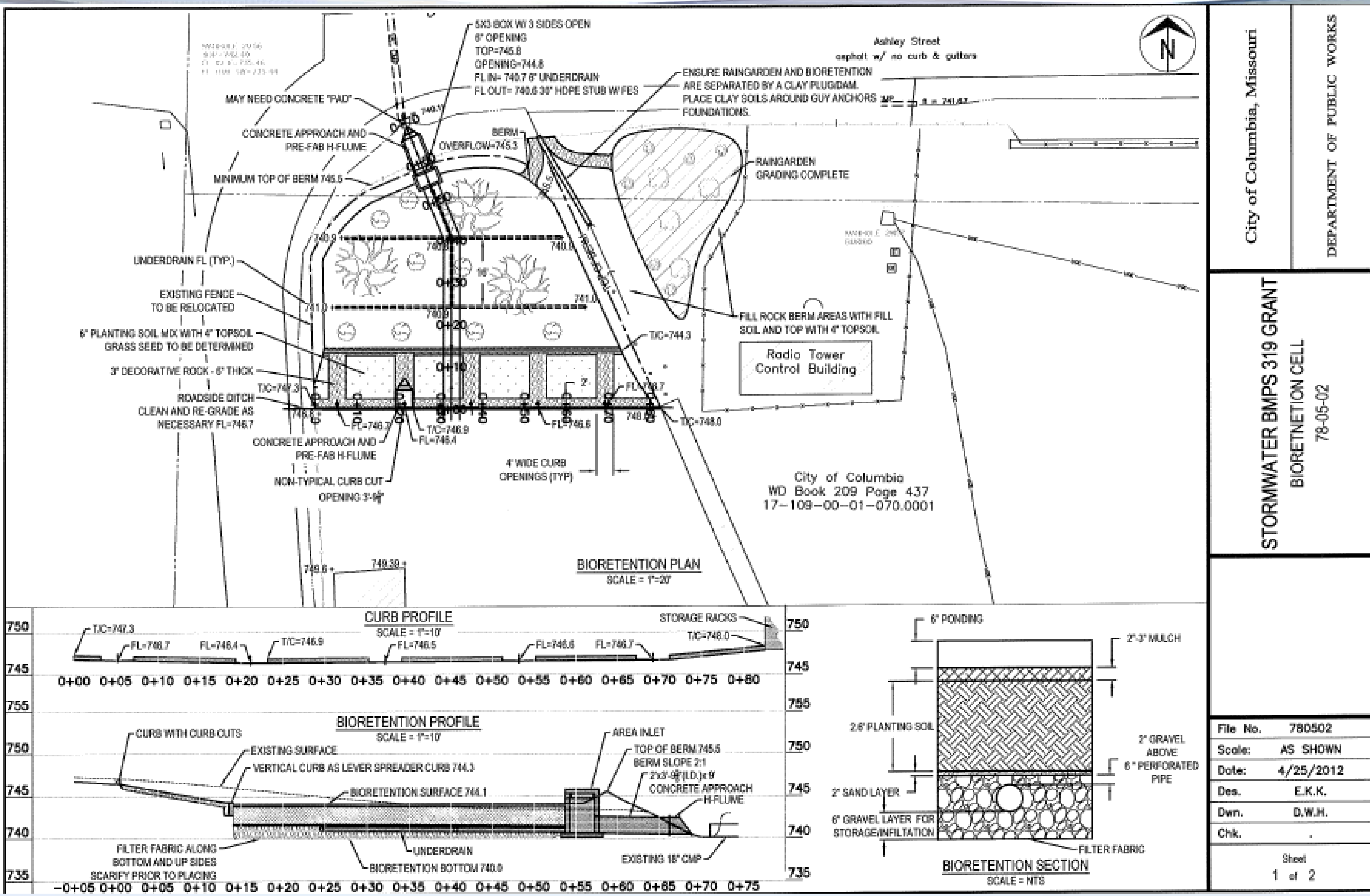
Project Design – Bioretention



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Project Design – Bioretention

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Field Setup

- Auto Sampler
  - Hach Sigma 900 max
  - Installed at inlet and outlet
- H-flumes for flow
- Storm Event
  - >0.2 inches rain in 24-hours
  - Tipping bucket rain gauge
- Min. antecedent dry period
  - 6 hours

Field Setup

- Ultrasonic Sensor
  - To measure depth of water
  - At inlet and outlet
  - For flow computations
- Records collected
  - Water level
  - Flow
  - Precipitation
  - Every 5 minutes

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Field Sampling

- Sampling methodology
  - Flow-weighted composite samples
  - Event mean pollutant concentrations
  - Sample aliquots composited into a 2.5 gal bottle
  - Constant flow volume/ variable time approach
  - All samples were containerized, preserved and handled per QAPP and lab quality control manual.

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Field Sampling

- Target pollutants

Parameter	Analytical Method	Performance Range or Reporting Limit	Reporting Units
Total Recoverable Copper	EPA 6020A	5	µg/L
Total Recoverable Lead	EPA 6020A	5	µg/L
Total Recoverable Zinc	EPA 6020A	5	µg/L
Total Dissolved Solids (TDS)	SM 2540C	1	mg/L
Total Phosphorus (TP)	SM 4500PE	50	µg/L
Total Nitrogen (TN)	SM4500N & EPA 354.1	0.5	mg/L
Total Suspended Solids (TSS)	SM 2540D	1	mg/L
Volatile Suspended Solids (VSS)	SM 2540E	1	mg/L
Chemical Oxygen Demand (COD)	SM 5220D	10	mg/L

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Field Sampling

- Laboratory analyses
  - Standard analytical methods
    - Methods for the Examination of Water and Wastewater
    - 40 CFR 136

Baseline Sampling Results

- Baseline sampling

Event Date	Inlet Flow (cfs)	Inlet Baseline EMC (mg/L)								
		TDS	TSS	VSS	TP	TN	COD	Cu	Pb	Zn
4/17/2014	0.03	1,600	10	1	0.14	5.5	1	**0.003**	**0.003**	**0.003**
7/21/2014	0.79	821	26	15	0.17	19.2	1	0.007	**0.003**	0.045
	Storm Flow (cfs)	Inlet Storm EMC (mg/L)								
Minimum	0.10	132	146	22	0.22	0.3	26	0.003	0.003	0.065
Average	0.88	461	898	80	0.60	2.6	150	0.024	0.029	0.233
Maximum	4.01	908	4,160	275	1.83	6.7	702	0.082	0.143	0.676
Median	0.66	483	369	42	0.43	2.1	84	0.018	0.016	0.180

Event Date	Outlet Flow (cfs)	Outlet Baseline EMC (mg/L)								
		TDS	TSS	VSS	TP	TN	COD	Cu	Pb	Zn
4/17/2014	0.03	1,460	6	2	0.07	8.1	1	**0.003**	**0.003**	**0.003**
7/21/2014	0.76	821	17	12	0.16	14.8	1	0.006	**0.003**	0.033
	Storm Flow (cfs)	Outlet Storm EMC (mg/L)								
Minimum	0.11	174	23	5	0.14	0.3	22	0.003	0.003	0.029
Average	0.88	580	603	61	0.61	2.7	122	0.025	0.025	0.245
Maximum	2.58	1,030	3,860	287	2.63	7.1	726	0.097	0.147	0.767
Median	0.70	563	284	34	0.45	2.4	59	0.019	0.014	0.234

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Precipitation and Flow

Event Date	Antecedant Dry Period (days)	Precipitation		
		Total (in.)	Max Intensity (in./hr.)	Duration (hrs.)
10/5/2012	7.0	0.44	0.48	6.4
10/23/2012	4.1	0.57	0.48	7.6
11/11/2012	6.5	0.97	0.48	6.9
1/29/2013	2.2	0.7	3.36	0.7
3/17/2013	6.5	0.32	0.24	5.0
4/10/2013	3.2	0.42	2.28	3.8
4/17/2013	1.7	0.46	2.16	0.5
4/23/2013	5.2	0.4	0.36	4.0
7/29/2013	3.8	0.25	0.96	1.1
8/2/2013	4.6	1.1	2.88	2.6
8/12/2013	6.4	0.71	2.16	1.7
9/19/2013	2.9	0.85	3.36	2.3
9/28/2013	8.5	0.46	1.68	1.1
10/30/2013	1.1	0.28	0.6	2.2
3/27/2014	0.7	0.41	3.84	1.6
7/8/2014	9.1	1.37	4.2	3.8
8/16/2014	8.6	1.29	1.56	16.3
10/9/2014	6.1	1.67	2.4	3.1
11/24/2014	19.3	0.69	0.6	21.2
12/6/2014	8.4	0.97	0.24	18.0

Step Pool Maturation

July 2013

July 2014

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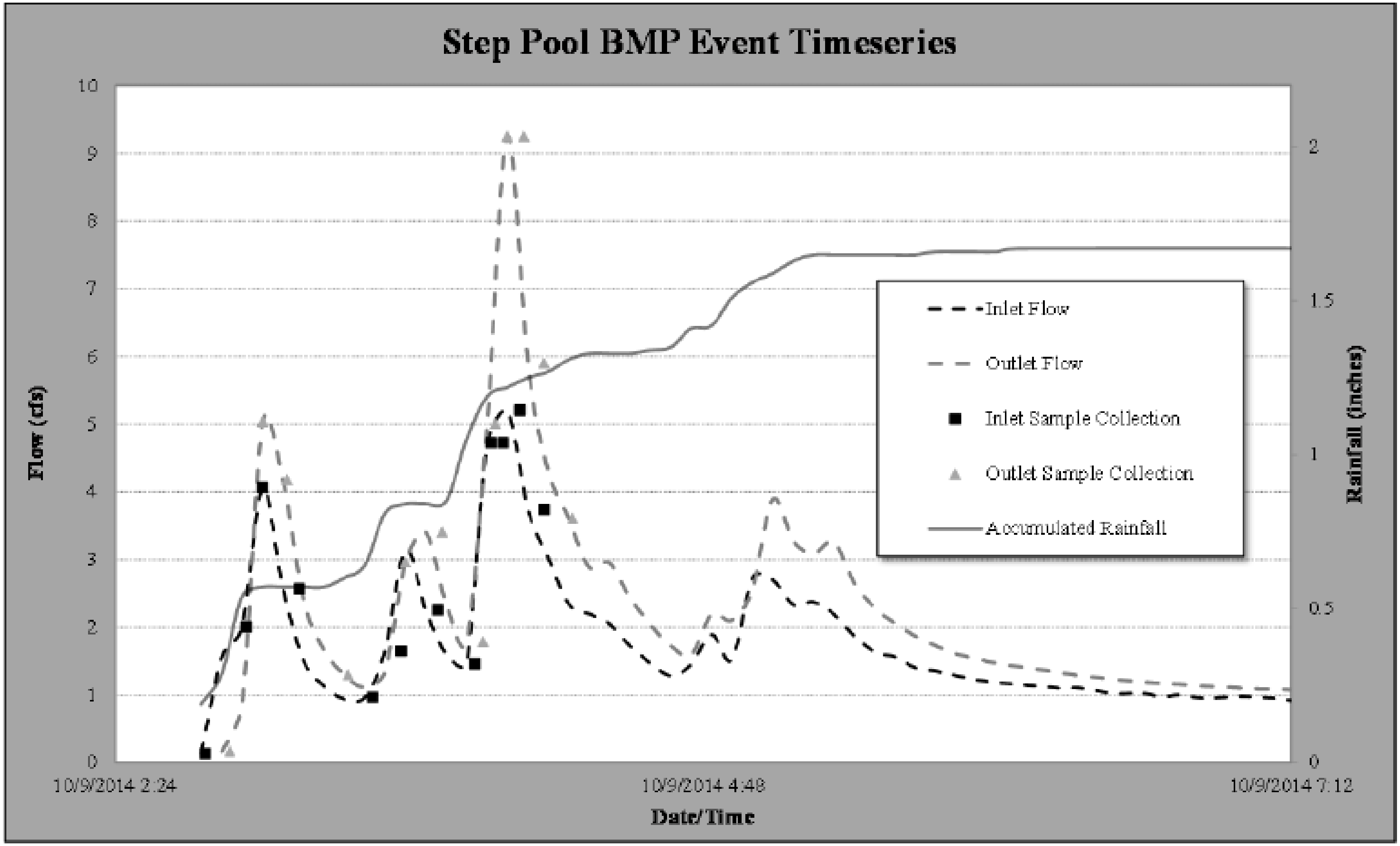
Results – Step Pool

Event Date	Inlet EMC (mg/L)									Outlet EMC (mg/L)								
	TDS	TSS	VSS	TP	TN	COD	Cu	Pb	Zn	TDS	TSS	VSS	TP	TN	COD	Cu	Pb	Zn
10/5/2012	514	252	64	0.97	4.7	98	0.030	0.016	0.162	536	240	31	0.62	2.6	66	0.033	0.011	0.114
10/23/2012	481	151	36	0.42	0.3	38	0.013	0.006	0.155	561	78	21	0.37	0.3	26	0.015	0.006	0.162
11/11/2012	307	278	38	0.68	3.0	66	0.018	0.011	0.159	824	154	50	0.50	3.3	57	0.016	0.008	0.124
1/29/2013	384	4,160	265	1.83	5.4	702	0.082	0.143	0.676	410	3,860	287	2.63	7.1	726	0.097	0.147	0.767
3/17/2013	908	178	32	0.25	1.8	48	0.010	0.006	0.118	1,030	110	30	0.38	3.1	45	0.013	0.005	0.257
4/10/2013	669	2,840	275	1.42	6.7	375	0.053	0.085	0.449	992	1,140	210	1.48	4.2	130	0.047	0.044	0.389
4/17/2013	161	1,540	116	0.88	2.7	91	0.036	0.049	0.316	249	1,110	84	0.83	4.0	89	0.037	0.046	0.314
4/23/2013	505	150	28	0.31	1.5	32	0.010	0.009	0.079	565	104	10	0.40	1.5	26	0.011	0.009	0.081
7/29/2013	642	172	32	0.23	1.3	43	0.011	0.008	0.111	681	81	17	0.15	1.3	27	0.009	0.005	0.075
8/2/2013	144	944	84	0.58	0.3	71	0.020	0.026	0.214	174	968	68	0.63	2.2	90	0.029	0.032	0.324
8/12/2013	333	866	63	0.43	1.8	155	0.019	0.022	0.194	358	786	55	0.54	2.8	156	0.026	0.026	0.264
9/19/2013	620	400	32	0.26	1.8	48	0.020	0.015	0.245	690	780	60	0.47	3.3	61	0.035	0.027	0.478
9/28/2013	554	338	22	0.37	1.5	114	0.018	0.015	0.173	644	328	36	0.45	1.6	115	0.033	0.023	0.400
10/30/2013	570	584	88	0.48	1.5	167	0.016	0.019	0.167	574	408	80	0.44	1.5	134	0.019	0.017	0.210
3/27/2014	343	3,140	240	1.31	5.2	572	0.048	0.078	0.499	389	1,190	108	1.26	5.3	529	0.045	0.065	0.488
7/8/2014	442	638	46	0.45	3.1	78	0.027	0.028	0.356	426	400	24	0.37	3.1	51	0.019	0.021	0.288
8/16/2014	485	253	29	0.22	2.7	47	0.016	0.012	0.227	794	23	5	0.15	1.6	25	0.005	0.003	0.035
10/9/2014	132	652	55	0.33	2.4	123	0.014	0.017	0.186	205	163	13	0.17	0.6	31	0.003	0.008	0.068
11/24/2014	584	146	30	0.35	2.6	26	0.003	0.003	0.065	950	26	8	0.18	1.9	22	0.003	0.003	0.029
12/6/2014	437	270	24	0.23	1.7	101	0.008	0.011	0.099	555	109	20	0.14	1.9	25	0.003	0.003	0.041

Results – Step Pool

Event Date	Antecedant Dry Period (days)	Precipitation			Inlet			Outlet		
		Total (in.)	Max Intensity (in./hr.)	Duration (hrs.)	Mean Flow (cfs)	Peak Flow (cfs)	Total Volume (cf)	Mean Flow	Peak Flow (cfs)	Total Volume (cf)
10/5/2012	7.0	0.44	0.48	6.4	0.11	0.59	7,402	0.12	0.54	7,977
10/23/2012	4.1	0.57	0.48	7.6	0.70	1.22	32,756	0.71	1.24	33,287
11/11/2012	6.5	0.97	0.48	6.9	0.41	1.20	13,040	0.45	1.38	14,168
1/29/2013	2.2	0.7	3.36	0.7	0.65	3.86	9,731	0.82	4.36	12,852
3/17/2013	6.5	0.32	0.24	5.0	0.18	0.33	4,307	0.19	0.33	4,896
4/10/2013	3.2	0.42	2.28	3.8	0.26	2.62	4,879	0.29	2.05	5,511
4/17/2013	1.7	0.46	2.16	0.5	0.98	4.19	9,677	1.18	5.97	11,705
4/23/2013	5.2	0.4	0.36	4.0	0.67	1.13	11,913	0.69	1.24	12,483
7/29/2013	3.8	0.25	0.96	1.1	0.36	1.19	4,582	0.36	0.99	4,657
8/2/2013	4.6	1.1	2.88	2.6	2.14	5.61	14,128	2.58	6.88	17,835
8/12/2013	6.4	0.71	2.16	1.7	1.32	4.54	13,037	1.44	5.34	15,563
9/19/2013	2.9	0.85	3.36	2.3	1.17	4.32	10,218	1.42	5.46	11,908
9/28/2013	8.5	0.46	1.68	1.1	0.89	2.52	5,086	0.94	3.03	5,908
10/30/2013	1.1	0.28	0.6	2.2	0.43	1.16	6,207	0.46	1.21	6,649
3/27/2014	0.7	0.41	3.84	1.6	0.53	4.65	4,309	0.55	4.95	5,316
7/8/2014	9.1	1.37	4.2	3.8	1.63	5.65	13,176	2.16	8.82	16,880
8/16/2014	8.6	1.29	1.56	16.3	0.77	3.35	49,142	0.81	5.19	52,097
10/9/2014	6.1	1.67	2.4	3.1	4.01	5.20	32,514	2.01	9.25	41,703
11/24/2014	19.3	0.69	0.6	21.2	0.10	0.63	14,097	0.11	0.58	15,857
12/6/2014	8.4	0.97	0.24	18.0	0.27	0.75	25,131	0.33	0.89	29,703

Flow Reduction



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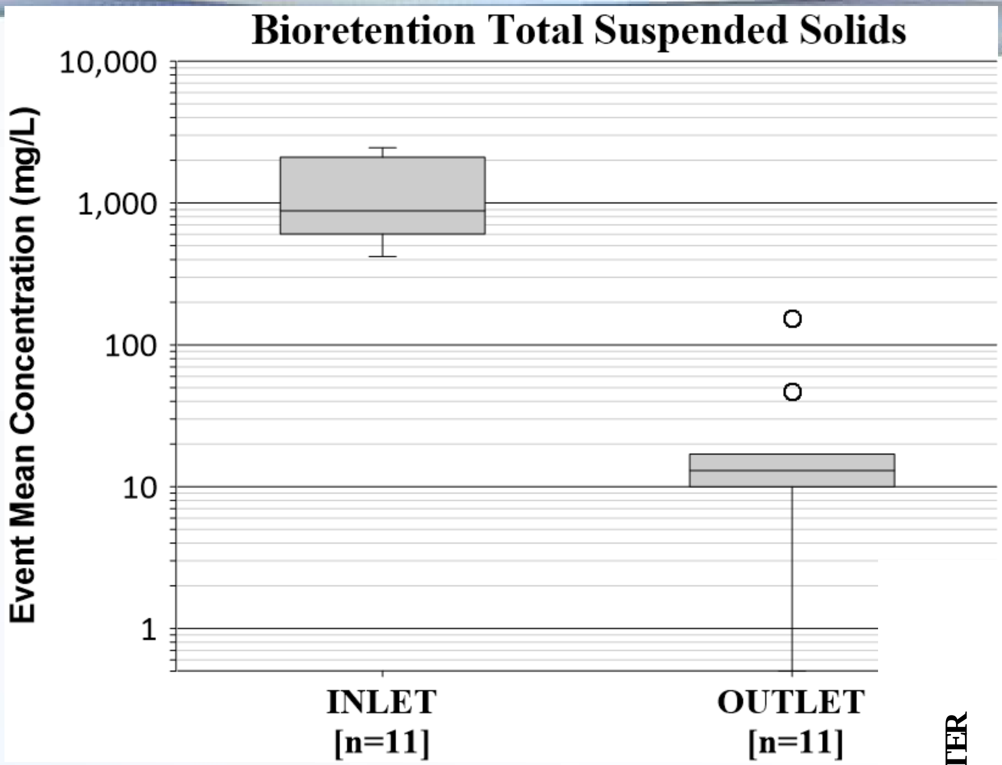
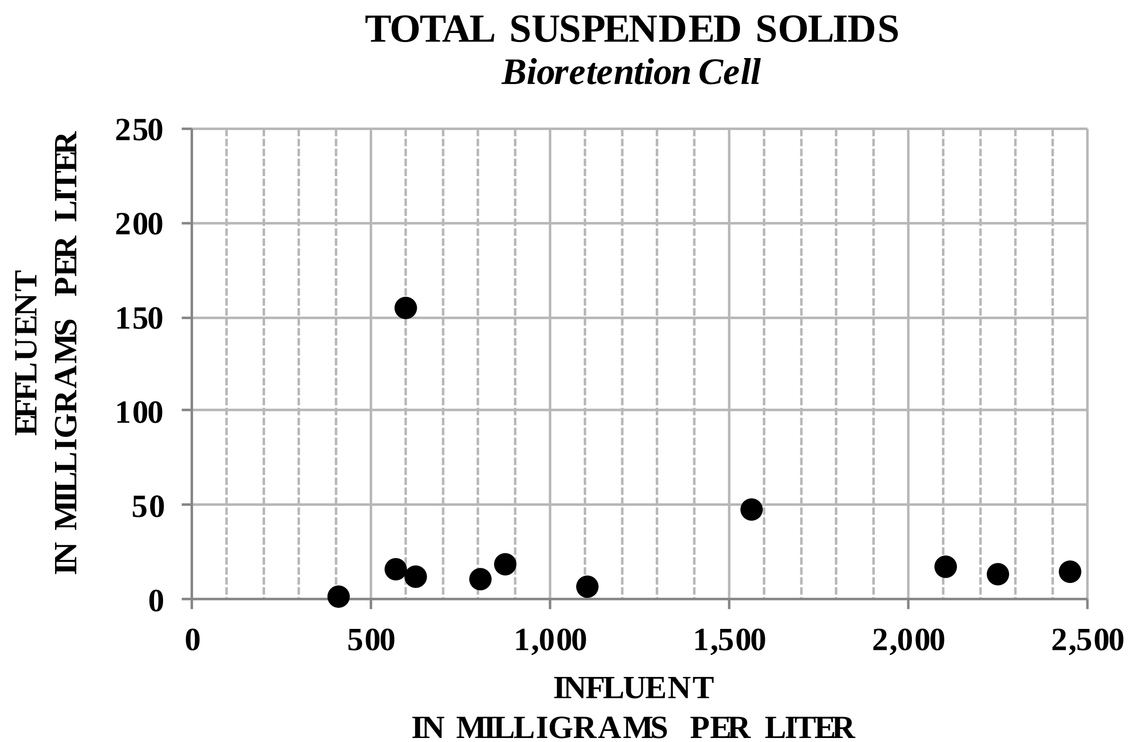
Results – Bioretention





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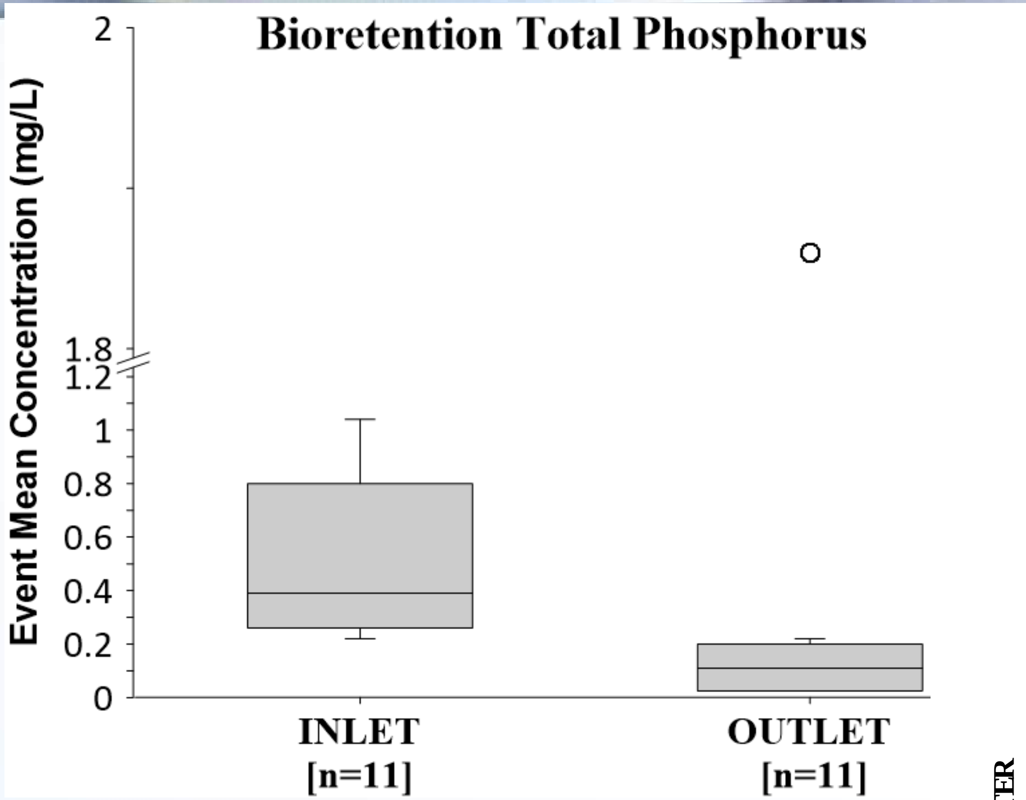

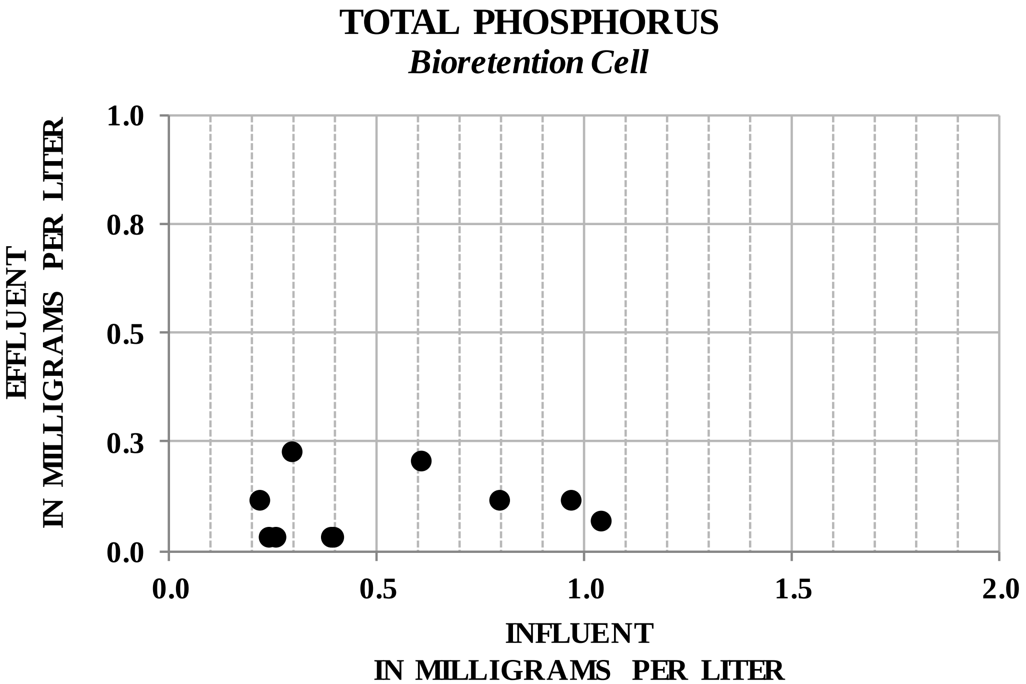

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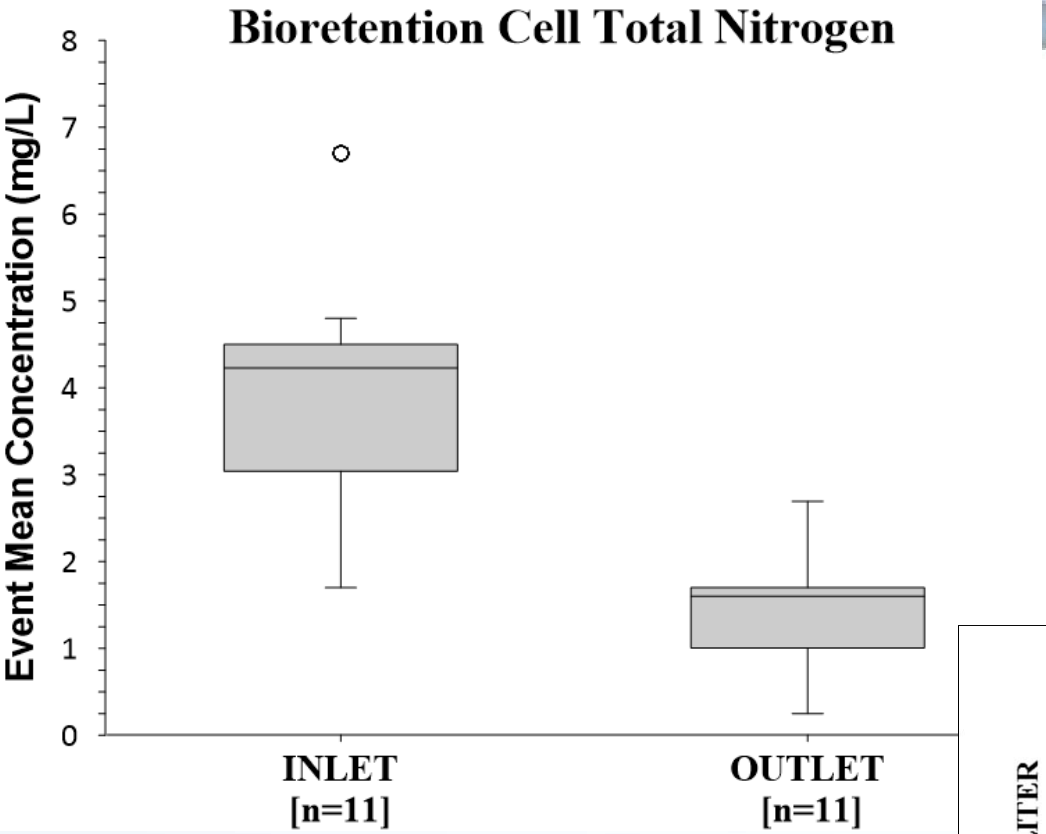

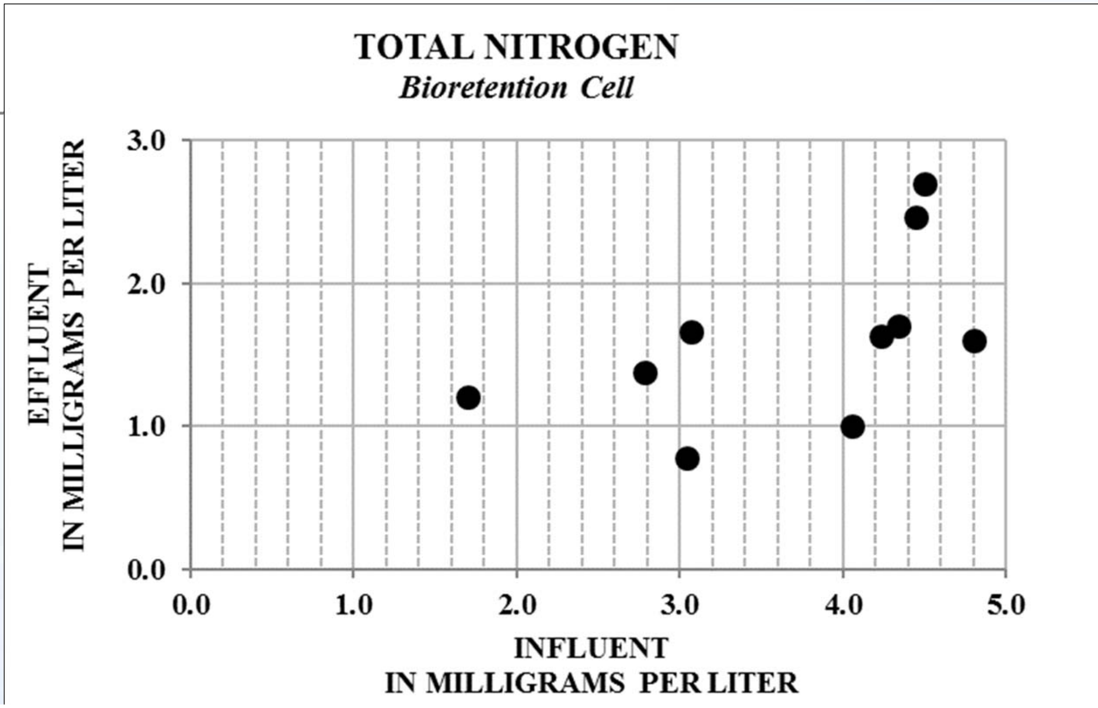

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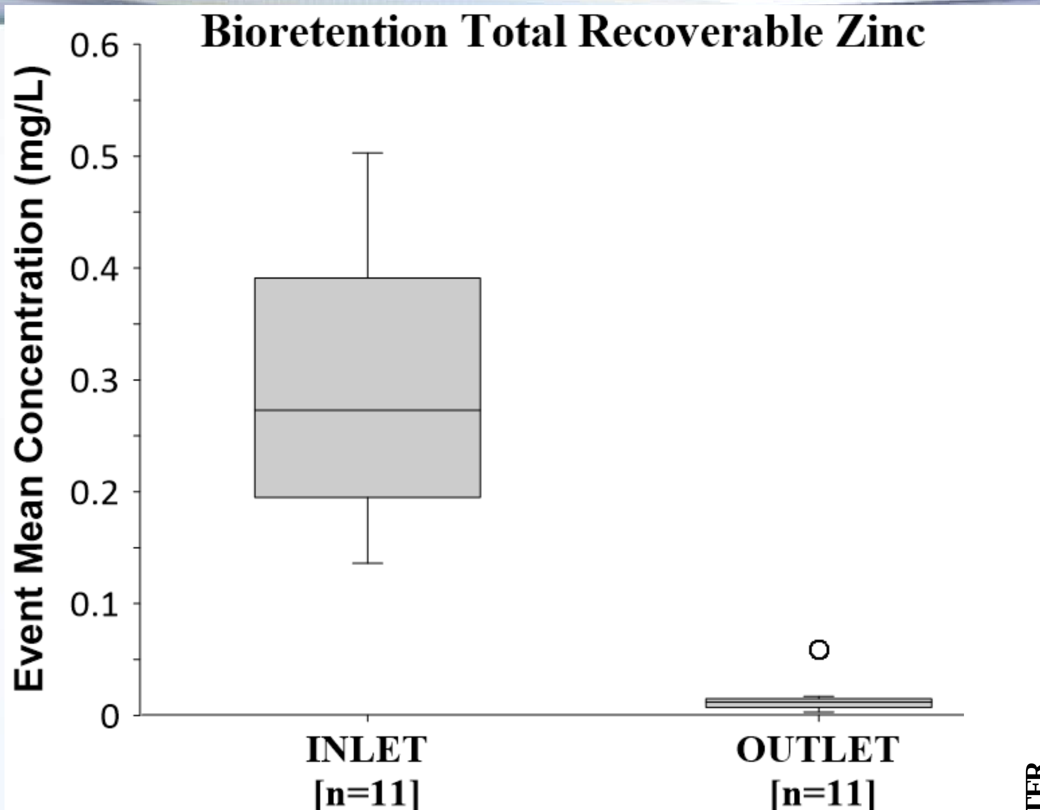

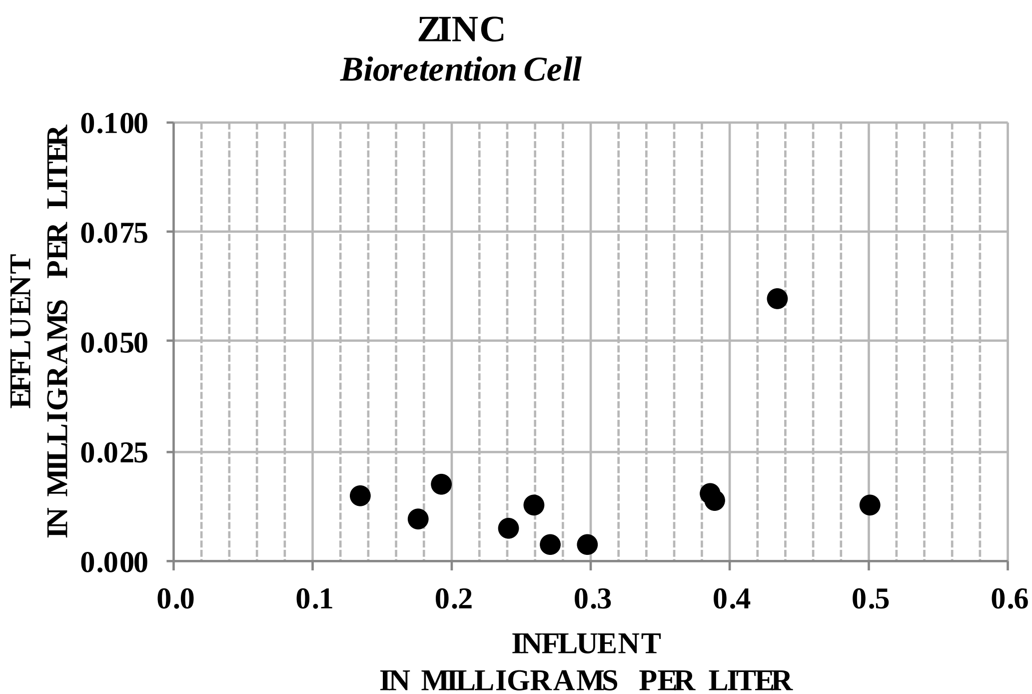

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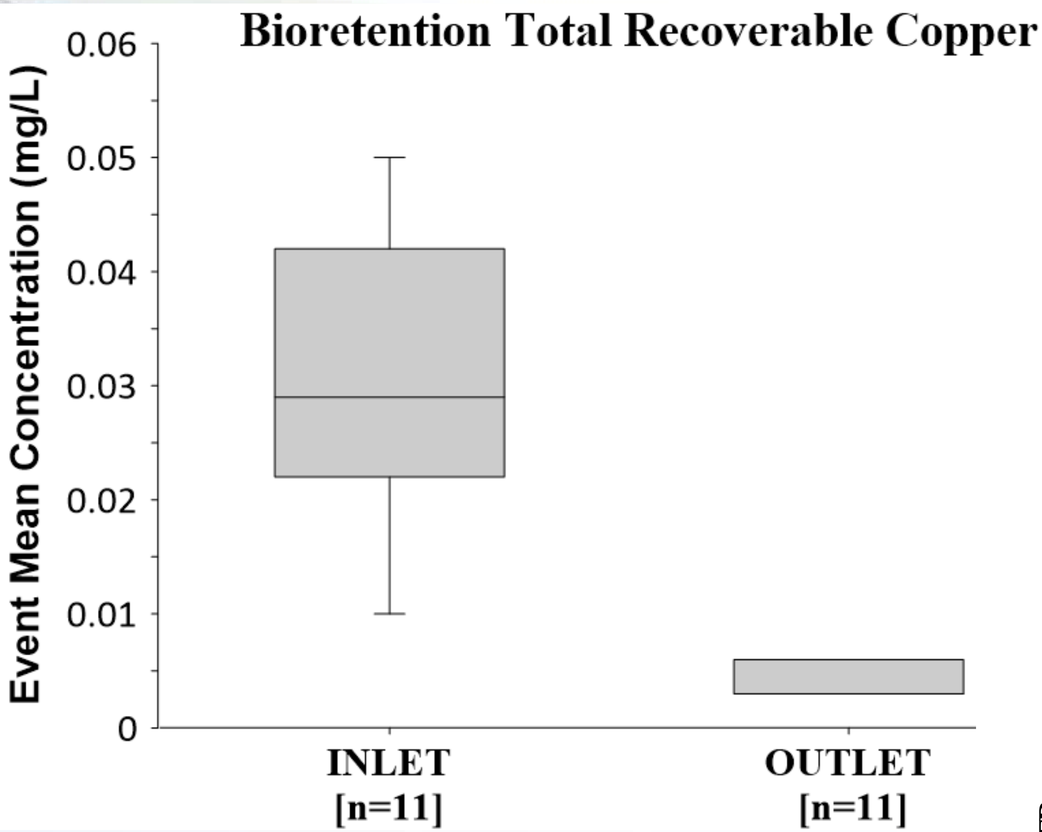
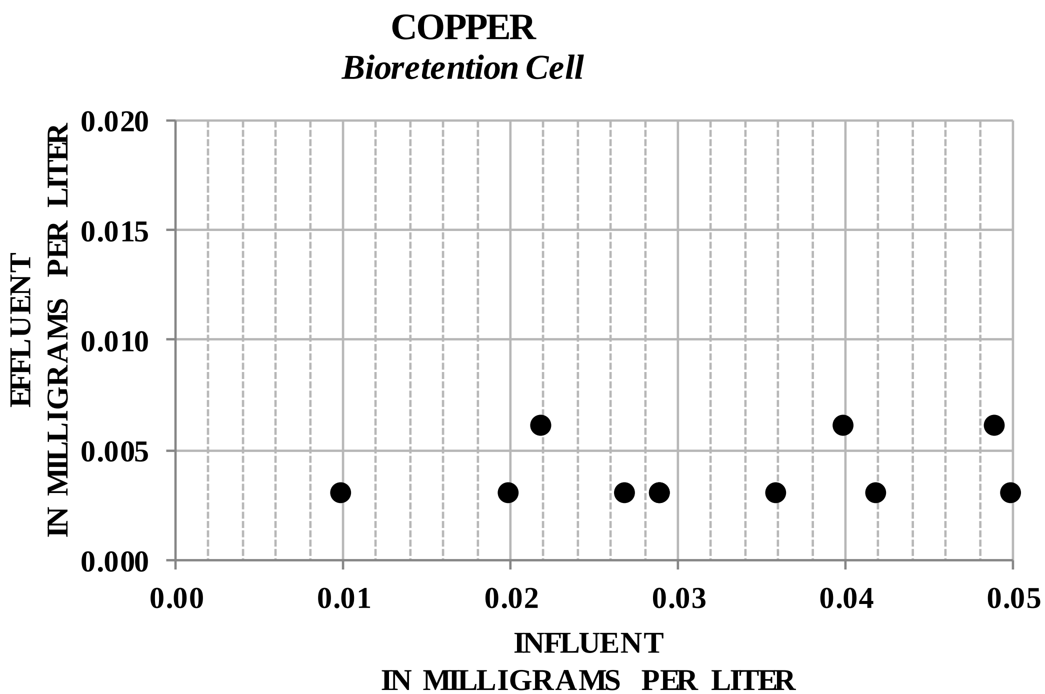
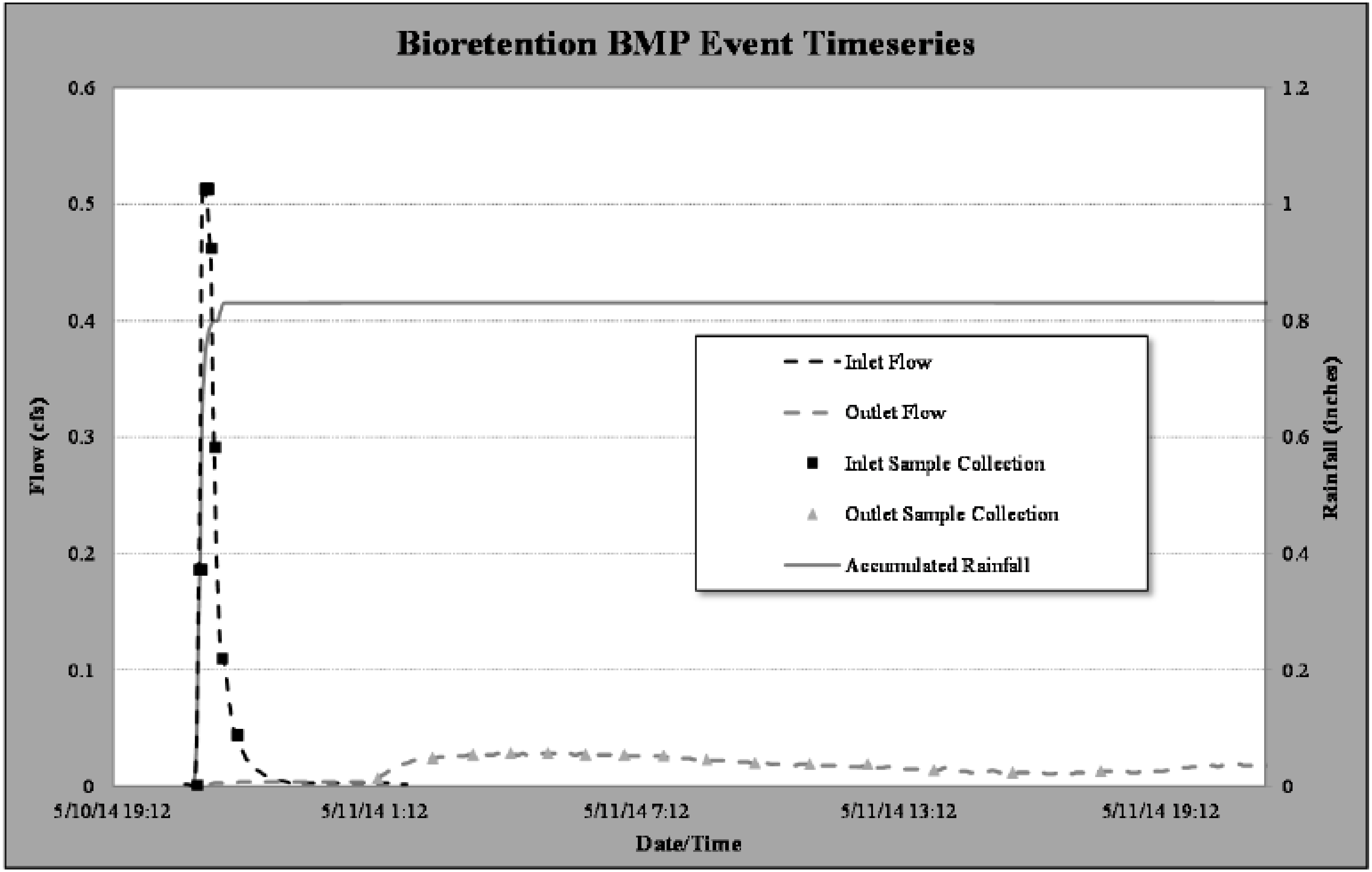




Results – Bioretention

Event Date	Antecedant Dry Period (days)	Precipitation			Inlet			Outlet		
		Total (in.)	Max Intensity (in./hr.)	Duration (hrs.)	Mean Flow (cfs)	Peak Flow (cfs)	Total Volume (cf)	Mean Flow (cfs)	Peak Flow (cfs)	Total Volume (cf)
12/15/2012	11.9	0.56	0.96	4.3	0.071	0.57	1,677	0.013	0.020	2,274
1/11/2013	10.3	0.19	0.36	13.5	0.002	0.04	205	0.002	0.004	314
7/30/2013	3.8	0.23	1.08	1.2	0.045	0.17	381	0.001	0.008	240
4/24/2014	11.7	0.4	0.84	2.0	0.033	0.20	971	0.007	0.017	1,107
5/10/2014	2.9	0.83	4.44	0.8	0.048	0.51	812	0.016	0.028	2,071
8/16/2014	8.6	1.14	1.08	9.3	0.059	0.67	2,859	0.018	0.050	3,239
8/29/2014	12.9	0.29	1.32	0.3	0.156	0.56	516	0.008	0.012	545
9/6/2014	3.6	0.56	0.72	6.1	0.047	0.49	1,007	0.010	0.015	1,328
11/24/2014	19.3	0.67	0.12	23.8	0.017	0.21	1,324	0.013	0.024	1,549
12/5/2014	11.2	0.48	0.12	10.6	0.032	0.12	1,143	0.011	***	1,299
1/4/2015	12.1	0.38	0.12	24.1	0.010	0.11	818	0.012	0.008	941

Flow Reduction



Annual Average Removals

- Monte Carlo simulation was used
- Predicted annual average pollutant reductions

Grissum Building BMP	TSS Load Reduction (tons/yr)	TP Load Reduction (lbs/yr)	TN Load Reduction (lbs/yr)
Step pool	25	24	79
Bioretention	40	399	78

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Lessons Learned

- Step Pool Conveyance System
  - Mature vegetation enhances pollutant removal efficiency
  - Routine maintenance is key for gathering representative data (see images

- Bioretention
  - Establish a robust maintenance program prior to implementation
  - Proper outlet flow monitoring design is important – must consider accurately measuring the entire range of flows (infiltrated vs overflow)
  - Mature vegetation enhances pollutant removal efficiency

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Bioretention - Maintenance

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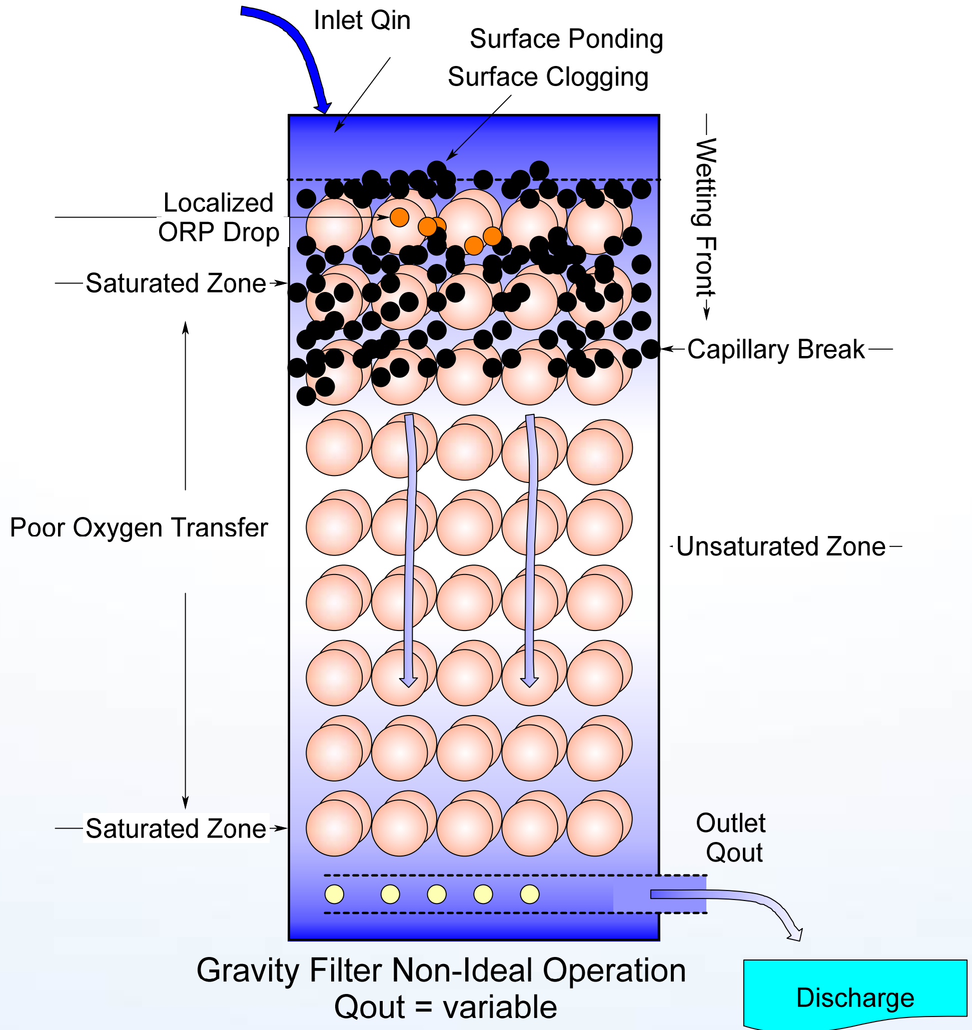
Bioretention - Design

Gravity Flow Media Filter Schematic (hydraulic failure mechanisms)



Gravity Filter Non-Ideal Operation
Qout = variable
CT = variable

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Bioretention – Enhanced Design

1) Empty Media Bed	2) Media Bed Filling