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Green Infrastructure Options for Nitrogen Removal in the Barnegat Bay Watershed

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Introduction

- Barnegat Bay, like many coastal areas in the country, is undergoing water quality problems that affect both its use and ecology.
- The most pressing issue affecting the Bay is over-enrichment by nutrients, primarily nitrogen, from surface runoff.
- Approximately half of the nitrogen loads to Barnegat Bay originate from surface runoff.
- Increased nitrogen can lead to a variety of water quality problems: eutrophication and hypoxia (lowered dissolved oxygen), increased harmful algal blooms, loss of submerged aquatic habitat, altered benthic communities, and loss of fisheries.

Green Infrastructure

. . .is an approach to stormwater management that is cost-effective, sustainable, and environmentally friendly.

Green infrastructure projects capture, filter, absorb, and reuse stormwater to maintain or mimic natural systems and treat runoff as a resource.

Green Infrastructure Effectiveness

Best Management Practice (BMP)	Total Phosphorous Removal Rate (%)	Total Nitrogen Removal Rate (%)
Bioretention Basin	60	30
Constructed Stormwater Wetland	50	30
Extended Detention Basin	20	20
Infiltration Basin	60	50
Manufactured Treatment Devices	See N.J.A.C. 7:8-5.7(d)	See N.J.A.C. 7:8-5.7(d)
Pervious Paving[2]	60	50
Sand Filter	50	35
Vegetative Filter	30	30
Wet Pond	50	30

Source: NJ Stormwater BMP Manual (NJDEP, 2004; revised 2017)

Green Infrastructure Options in Barnegat Bay

1. Modified Rain Garden for Enhanced Nitrogen Removal

2. Subsurface Gravel Wetlands Design Alternative Evaluation

Nitrogen Removal from Rain Gardens

- Installed rain garden next to Georgian Court University dining hall to capture roof runoff in November 2011.
- Began monitoring nutrients (nitrogen and phosphorus) in the inflow and outflow to determine removal rates (project completed in October 2014).

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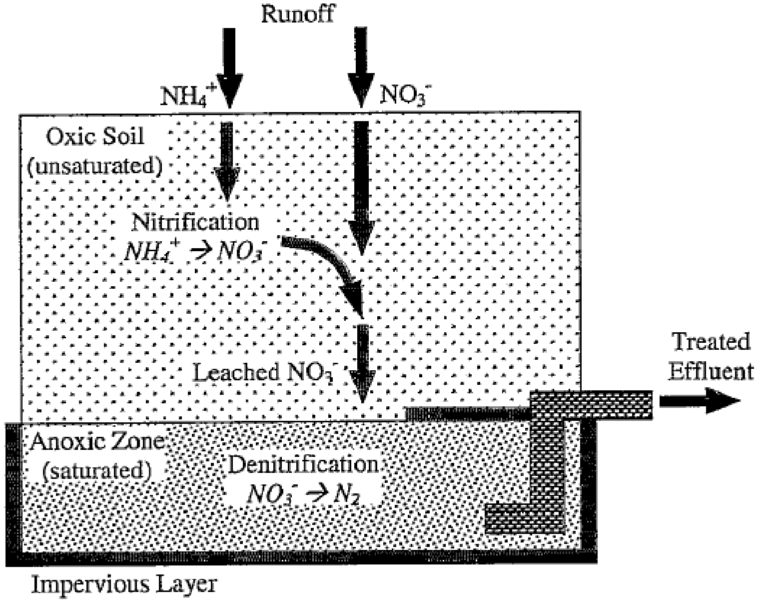
Nitrogen Removal from Rain Gardens

- Project involves alteration of the ‘traditional’ rain garden design in order to maximize removal of nitrogen from stormwater runoff.
- Maintaining saturated conditions in the rain garden increases nitrogen removal.

Nitrogen Removal from Rain Gardens



Source: Kim *et al.* 2003

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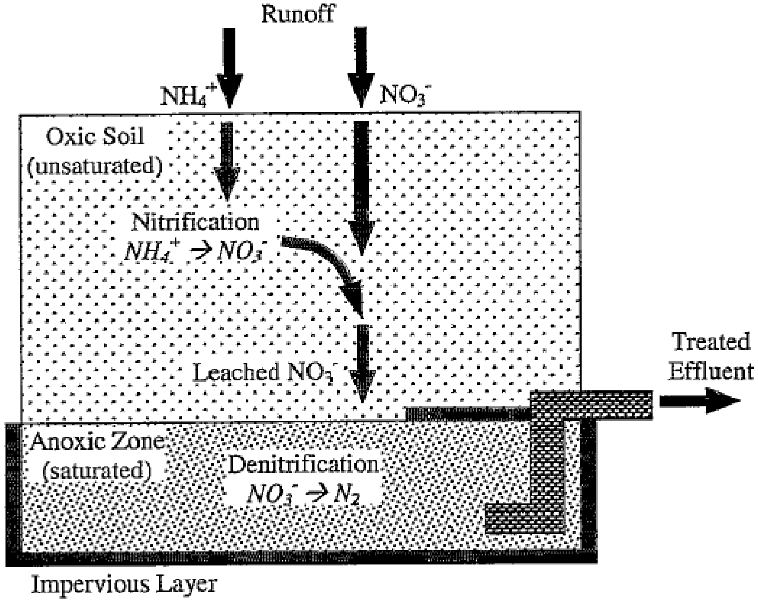
Nitrogen Removal from Rain Gardens



Source: Kim *et al.* 2003

Methods

Stormwater collected over the course of a storm event at the inlet and outlet of the rain garden.

Samples were analyzed for nutrients (N & P series) and total suspended solids (TSS).

Methods

- **Pollutant removal was calculated as percent removal (%R) of the measured target analytes (TA) using the following formula:**

$$\%R = \frac{TA_{IN} - TA_{OUT}}{TA_{IN}} X\, 100$$

- **Data (both sample concentration and %R) were analyzed for significance ($p < 0.05$) using analysis of variance (ANOVA: single factor).**

Results

- **14 storm events samples from September 2012 through October 2014.**
- **Mean total phosphorus (TP) outlet concentration (0.125 mg/L) was higher than the inlet (0.016 mg/L).**
- **Mean TP %R efficiency was -686% (export).**
- **About ½ of the inlet TP samples were below the detection limit; this indicates that the organic planting medium and mulch are leaching phosphorus.**

Results

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)
Inlet (Mean)	0.074	0.013	0.290
Outlet (Mean)	0.037	0.011	0.144
Std Dev – Inlet	0.084	0.004	0.529
Std Dev – Outlet	0.018	0.003	0.249

- **Mean NH_3 %R efficiency was 50%; NO_2 %R was 15.2%; NO_3 %R was 50.4%.**
- **%R for some species of N was higher than the estimated 30% removal for total nitrogen (TN) bioretention basins.**

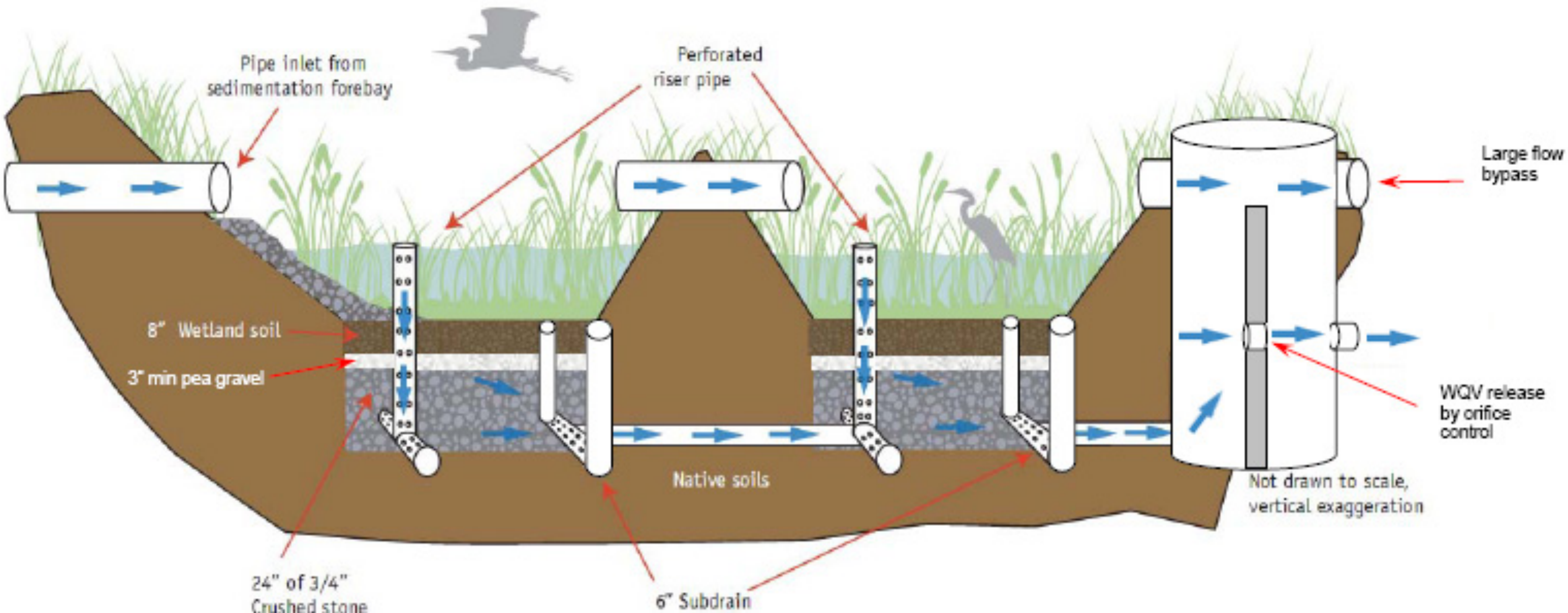
Results

- Many of the inlet samples were found to be below the detection limit for NH_3, NO_2 and NO_3.
- This may indicate that the first flush was missed by the grab samples, or that there was an insufficient load in the source water (i.e., roof runoff).
- More research needed to validate the levels seen and %R calculated.

Subsurface Gravel Wetland

- **The University of New Hampshire's Stormwater Center (UNHSC) has established guidelines for the design of subsurface gravel wetlands as a BMP. Results from their work indicate that such gravel wetlands can achieve a median annual removal of at least 95% of NO3, and TP removal was 55%.**
- **Modified designs are being used in the Barnegat Bay Watershed.**

Subsurface Gravel Wetland



From: UNHSC 2010

Subsurface Gravel Wetland

- **Received funding to install a series of four subsurface gravel wetlands with different designs to evaluate design alternatives for Barnegat Bay.**
- **Finished construction in May 2016 and started monitoring nutrients (N & P series) afterwards.**

Four designs being installed and tested on campus of Georgian Court University

3’ NJDEP Design: 3’ gravel; 3” pea gravel; 9” wetland soil

Advanced Bioretention System: 2’ gravel; 2’ bioretention media

UNH Design: 2’ gravel; 3” pea gravel; 9” wetland soil; 2 cells

2’ NJDEP Design: 2’ gravel; 3” pea gravel; 9” wetland soil

Methods

- Stormwater to collected from 14 storm events at the inlet and outlets of each subsurface gravel wetland design. Autosamplers were used for collection of water samples.
- Samples analyzed for nutrients (N & P series) and TSS.
- Vegetation sampled for growth (density, height, species richness) and underwent tissue analyses for nutrients to determine plant uptake of nitrogen.
- Sampling ran from May 2016 through October 2017.

Results – UNH Design

	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)
Inlet (Mean)	0.28	0.02	0.19
Outlet (Mean)	0.18	0.03	0.43
Std Dev – Inlet	0.12	0.01	0.16
Std Dev – Outlet	0.09	0.03	0.40

- Mean NH3 %R efficiency was 36.0%; NO2 %R was -38.4%; NO3 %R was -130.7%.
- %R is estimated at -2.9% for TN for this system.

DRAFT DATA

Results – NJDEP 2’ Design

	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)
Inlet (Mean)	0.28	0.02	0.19
Outlet (Mean)	0.21	0.02	0.18
Std Dev – Inlet	0.12	0.01	0.16
Std Dev – Outlet	0.12	0.02	0.13

- Mean NH3 %R efficiency was 26.6%; NO2 %R was -33.4%; NO3 %R was 1.8%.
- %R is estimated at -28.0% for TN for this system.

DRAFT DATA

Results – NJDEP 3’ Design

	NH3 (mg/L)	NO2 (mg/L)	NO3 (mg/L)
Inlet (Mean)	0.28	0.02	0.19
Outlet (Mean)	0.16	0.02	0.15
Std Dev – Inlet	0.12	0.01	0.16
Std Dev – Outlet	0.07	0.01	0.11

- Mean NH3 %R efficiency was 43.7%; NO2 %R was -4.0%; NO3 %R was 18.1%.
- %R is estimated at 24.6% for TN for this system.

DRAFT DATA

Results – ABS Design

	NH_3 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)
Inlet (Mean)	0.28	0.02	0.19
Outlet (Mean)	0.17	0.01	0.38
Std Dev – Inlet	0.12	0.01	0.16
Std Dev – Outlet	0.12	0.01	0.17

- **Mean NH_3 %R efficiency was 41.2%; NO_2 %R was 16.7%; NO_3 %R was -104.0%.**
- **%R is estimated at 24.8% for TN for this system.**

DRAFT DATA

Results

- Many of the inlet samples were found to be below the detection limit for NH_3, NO_2 and NO_3.
- Of the four designs tested, the NJDEP 3' and ABS designs were most efficient when using the raw data. More analyses needed to refine and verify these results.
- More research needed to validate the levels seen and %R calculated.

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