

low impact development technical workshop series

Water Quality Treatment in Bioretention

Topics

Mechanisms

Performance

Special considerations

WASHINGTON STATE UNIVERSITY
PIERCE COUNTY EXTENSION

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All primary pathways for removing pollutants from storm flows are active in bioretention

Stormwater volume reduction.

Sedimentation.

Filtration.

Phytoremediation.

Thermal attenuation.

Adsorption.

Volatilization.

Some characteristics of urban pollutants

PAH's product of incomplete combustion and sealers. Coal tar emulsions may be 5-600x higher in PAH's concentrations than asphalt emulsion.

Annual loading of oil to Puget Sound ~22,580 metric tons (Exxon Valdez spilled ~33,500 metric tons).

Many pollutants associated with fines (particularly metals), many <0.45 microns (dissolved).

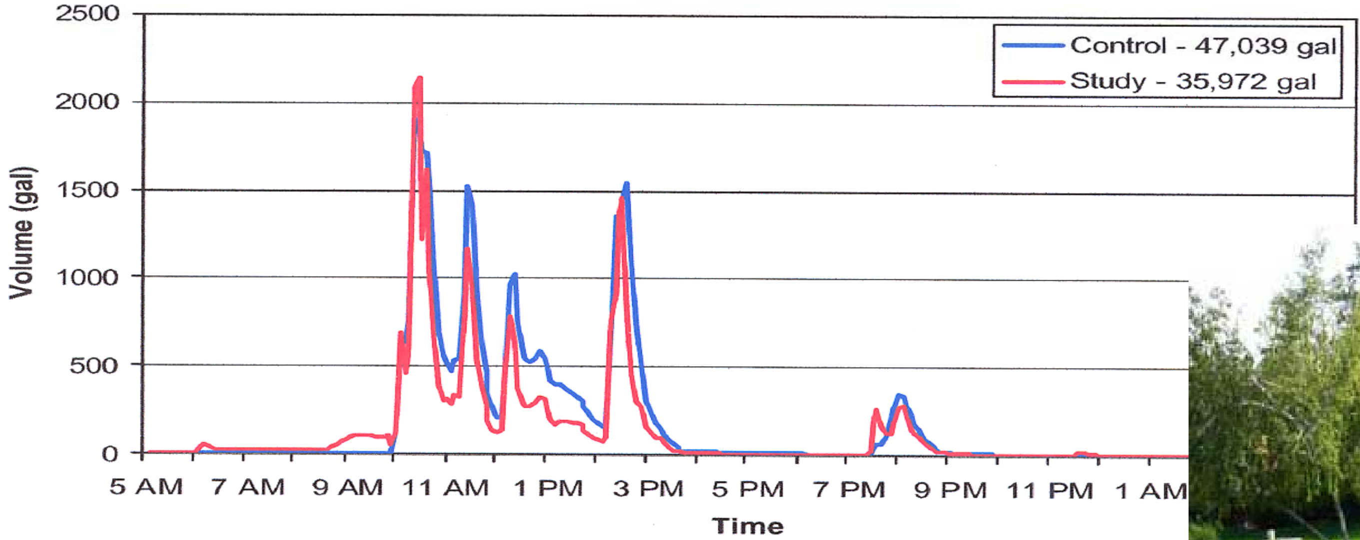
Ranges of metals from various studies:
Zn (20-2000 µg/l)> (~344 metric tons/yr to PS)
Cu ~Pb (5-200 µg/l) >
Cd (<12 µg/l)
(Davis et al 2001)

Flow volume reductions in bioretention

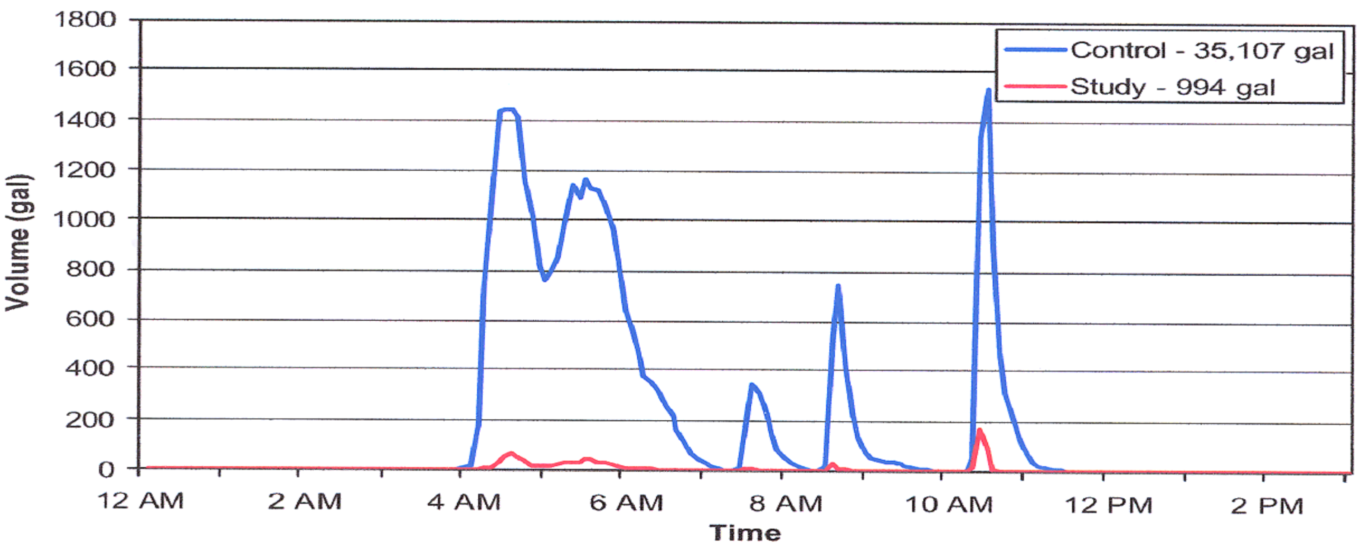
	Completed	Infiltration	Sizing	Volume Reduction (%)
Siskiyou Green Street	Oct 2003	1.5 -2.0 in/hr	6%	*(1/04 – 12/05) 83%
Glencoe Rain Garden	Oct 2003	1.8 - 3.0 in/hr	6%	(1/04 – 12/05) 94%
Greensboro NC	2001	0.2 – 0.6 in/hr	5%	(2002) 78%
Sea Street	2001	variable		(2001 – present) 98%
110th Cascade	2003			(10/04 – 06) 74%
Meadow on the Hylebos	2006	0.0 – 0.8 in/hr	15%	(10/07 – 5/08) 99.99%

water quality treatment

Pre-Construction Runoff Data
June 6, 2003
0.50" Rainfall



Post-Construction Runoff Data
May 29, 2004
0.71" Rainfall



Soil sampling in bioretention facilities

	e. Coli (mpn/g)	Cu (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
Siskiyou Green Street					
0-6”	280	34.4	56.8	0.103	170
6-12’	--	17.0	12.2	0.032	100
12-18”	--	17.6	10.9	0.054	96
SW 12th & Montgomery					
0-6”	7	30.1	29.9	0.043	120
12-18”	--	22.2	18.9	0.082	92

MTCA
Pb: 250 mg/kg
Hg: 2 mg/kg

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Percent removal of metals and TSS in bioretention and grass bioswales

	TSS (mg/L)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
Davis etal 2001*		89% (u) 92% (l)	>98% (u) >98 (l)	>98% (u) >98 (l)
Davis etal 2003**		>99%	>99%	>99%
Greenbelt		97%	>95%	>95%
Largo		43%	70%	64%
Hunt etal 2006				
Greensboro	-180%	99%	81%	98%
Chapel Hill	--	--	--	--
Hsieh, Davis 2005	91%			
Multhanna etal 2007		63%	93%	87%
PNW Bioswales (Herrera 2006)	64%			47%
National Bioswales (Herrera from Barrett)	43%			53%

Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)

** Percent mass removal (lab)

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Percent removal of nutrients in bioretention and grass bioswales

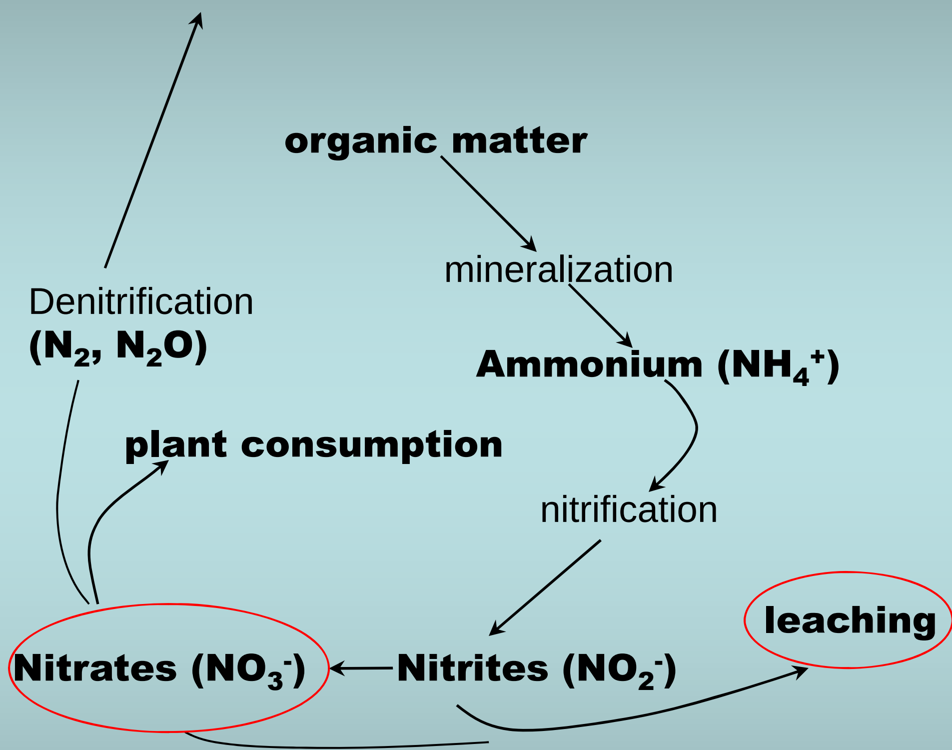
	TKN (mg/L)	NO_3 (mg/L)	TP (mg/L)	Hydrocarbons (µg/L)
Davis etal 2006*	38% (u) 68% (l)	-96% (u) 24% (l)	1% (u) 81% (l)	
Greenbelt	57%	16%	65%	
Largo	67%	15%	87%	
Mass removal	97%	97%	99%	
Hunt etal 2006				
Greensboro	-4.9%	75%	-240%	
Chapel Hill	45%	13%	65%	
Hsieh 2005				>97%
PNW Bioswales (Herrera 2006)			18%	-10%
Nat'l Bioswales**				-88%

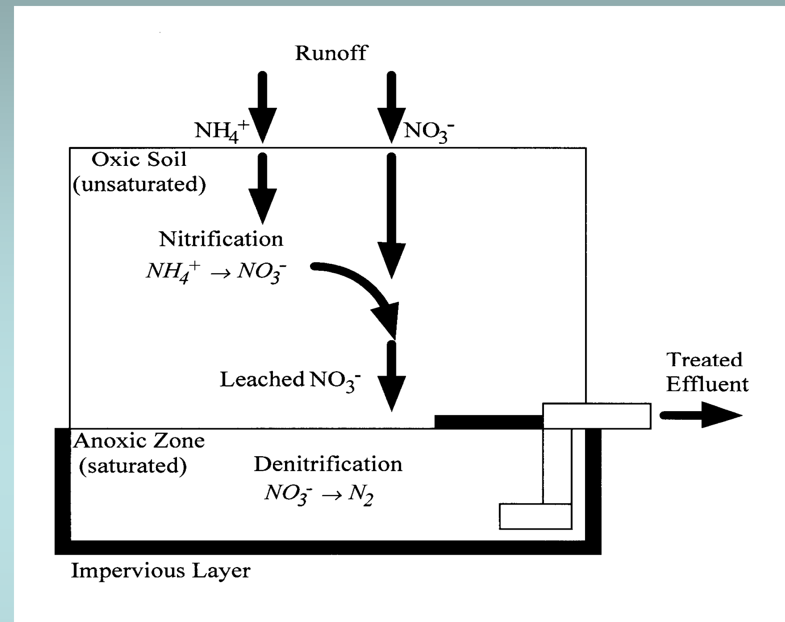
Event mean concentrations

* Percent reduction at 18 cm (upper) and 61 cm (lower) depths (lab)

**Herrera from Barrett

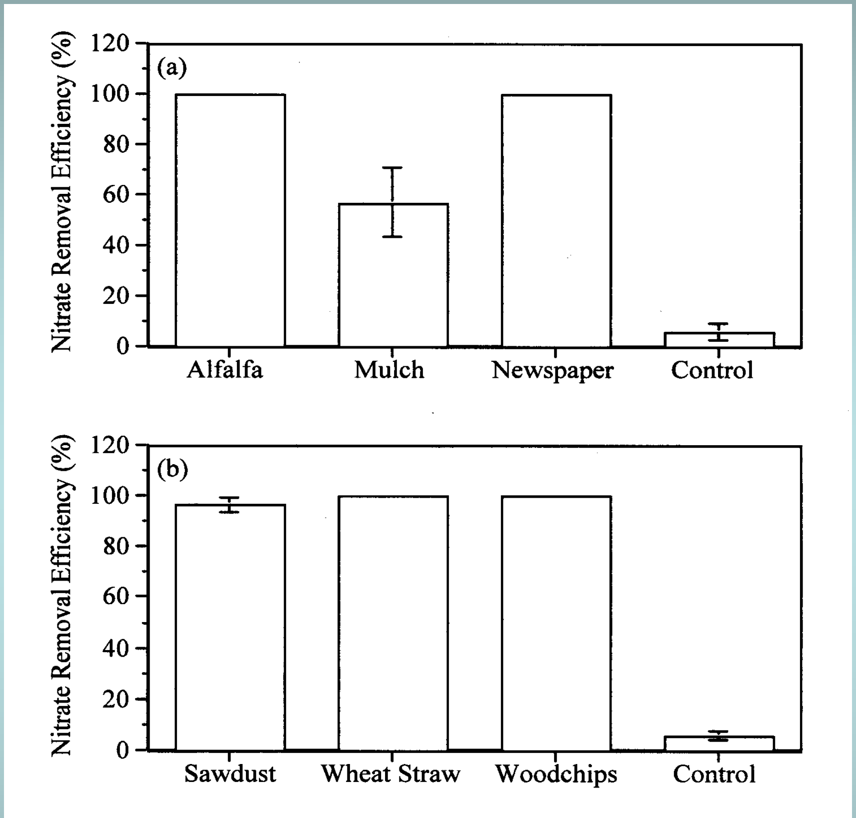
Methods for managing nitrate

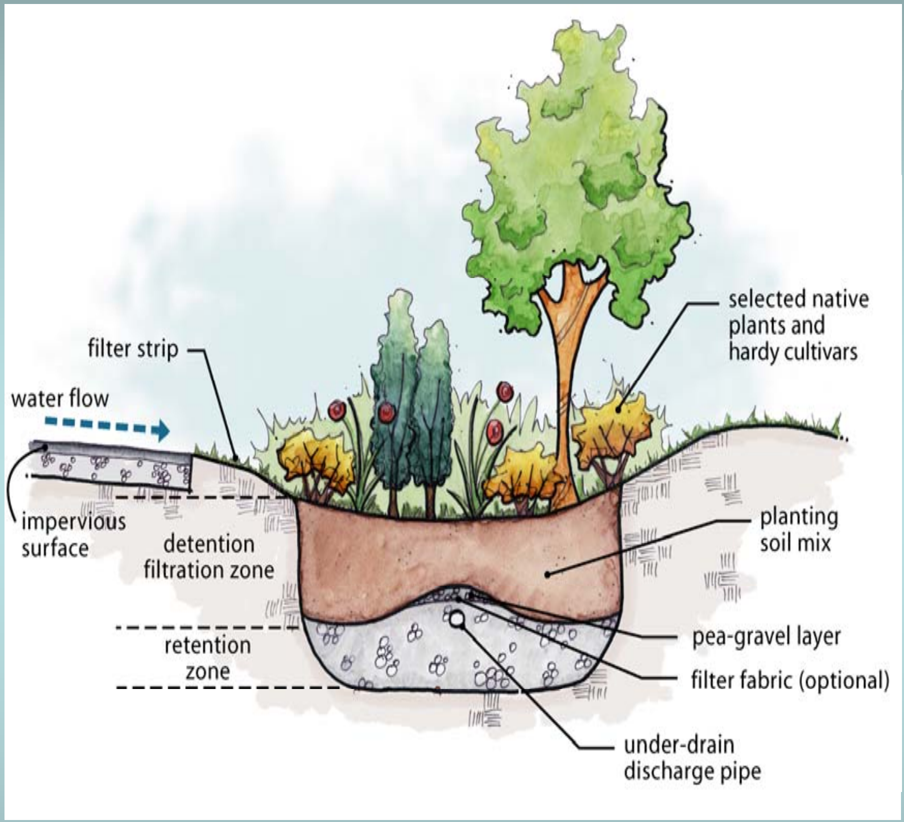




NO_3^- electron acceptor not O_2 in anaerobic conditions
$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$
Electron donor may be sugar, hydrocarbon (simple) or complex (mulch).

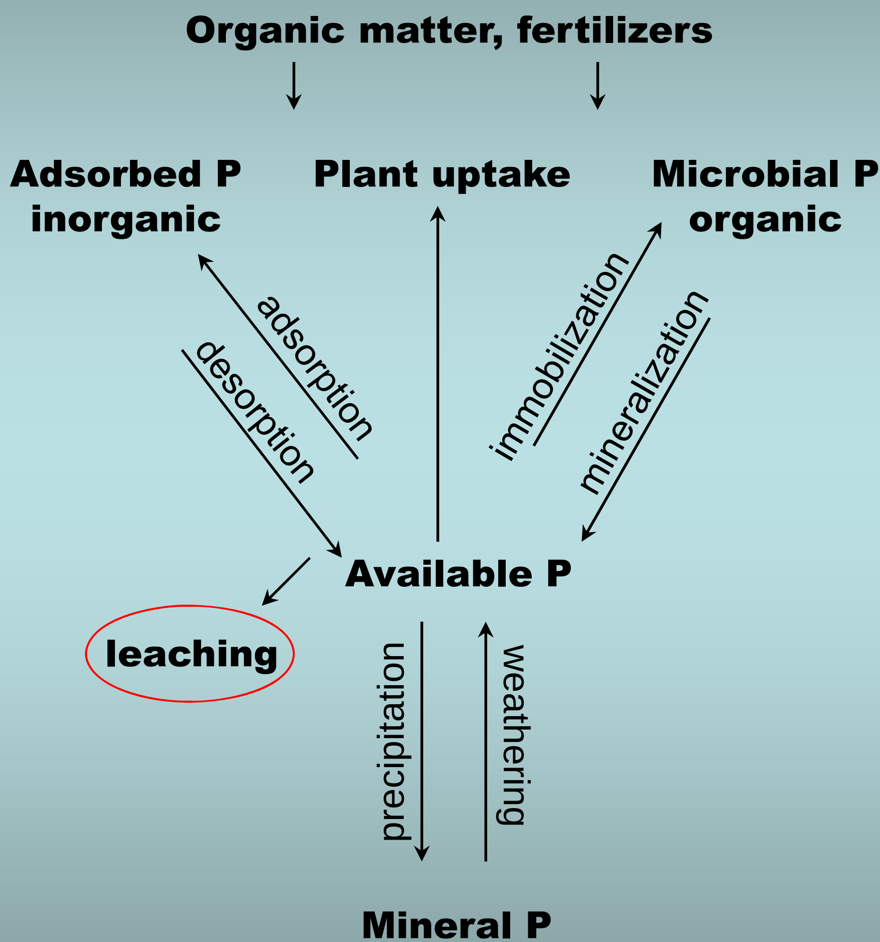
Methods for managing nitrate

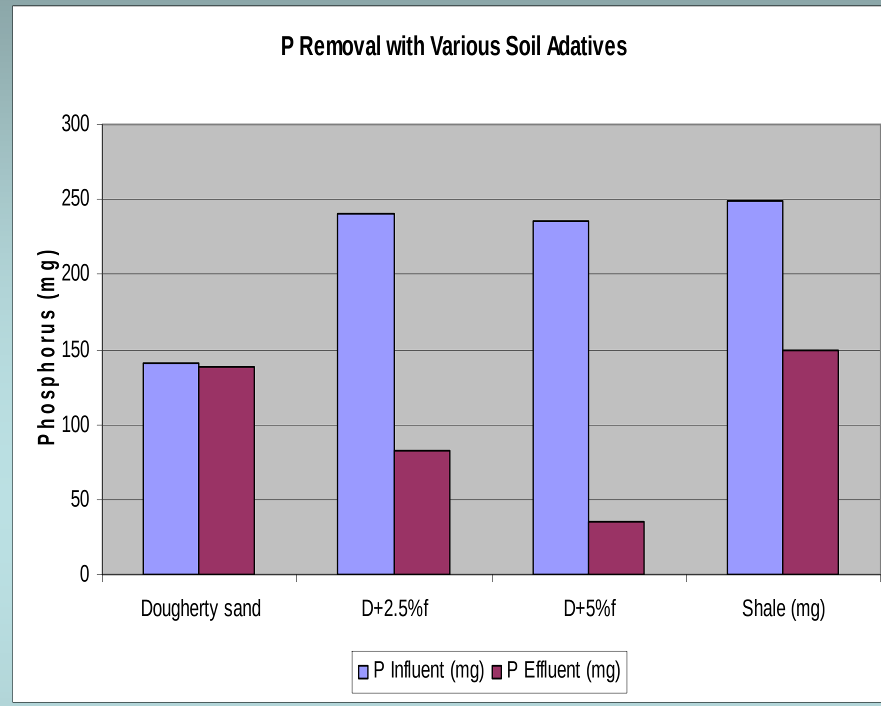




Newspaper and woodchips good electron donor and carbon source for denitrification. (Kim Seagren, Davis, 2000)

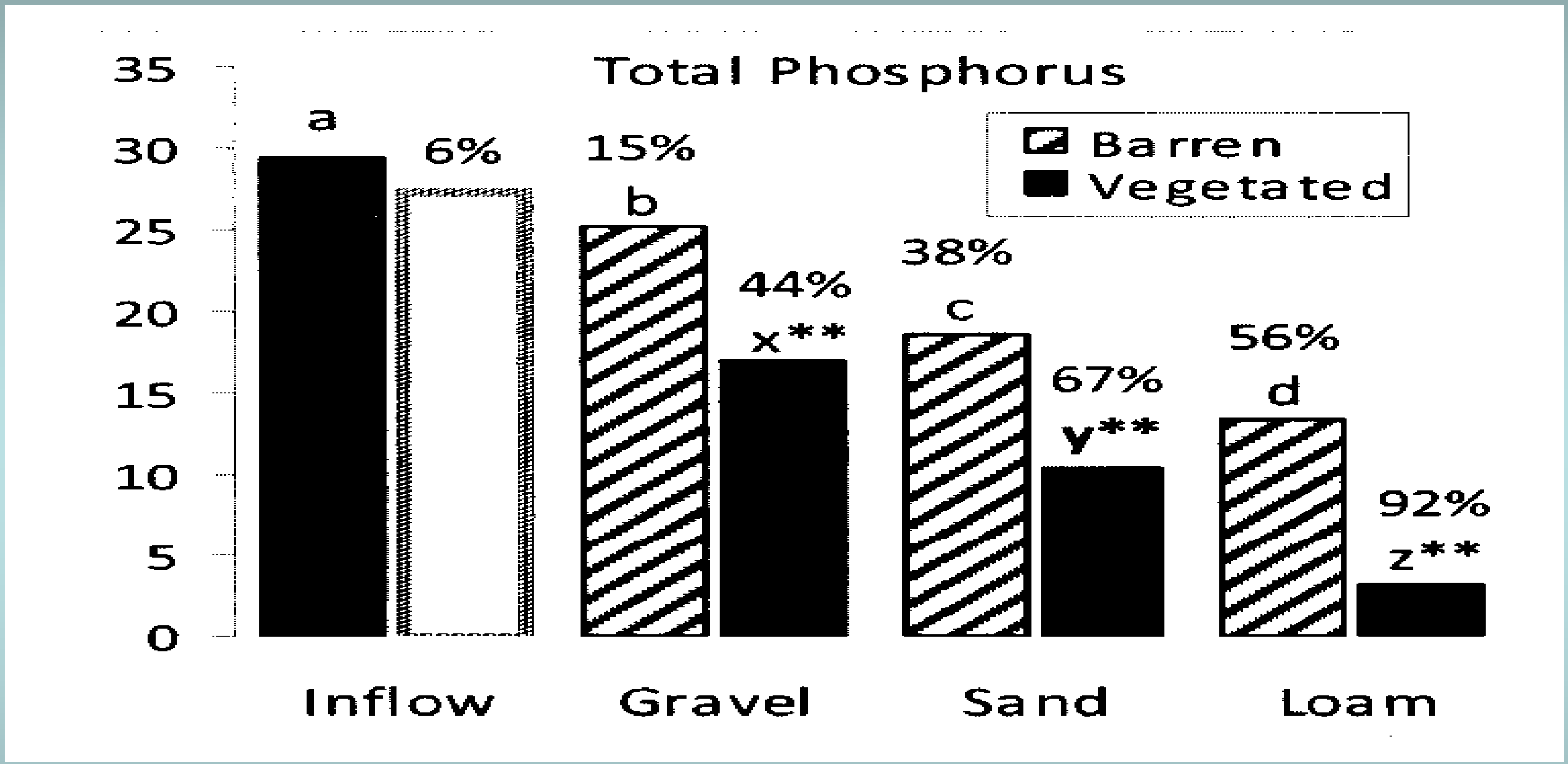
Methods for retaining phosphate





Fly ash significantly improves P retention, but significantly reduces K. (Zhang 2000)

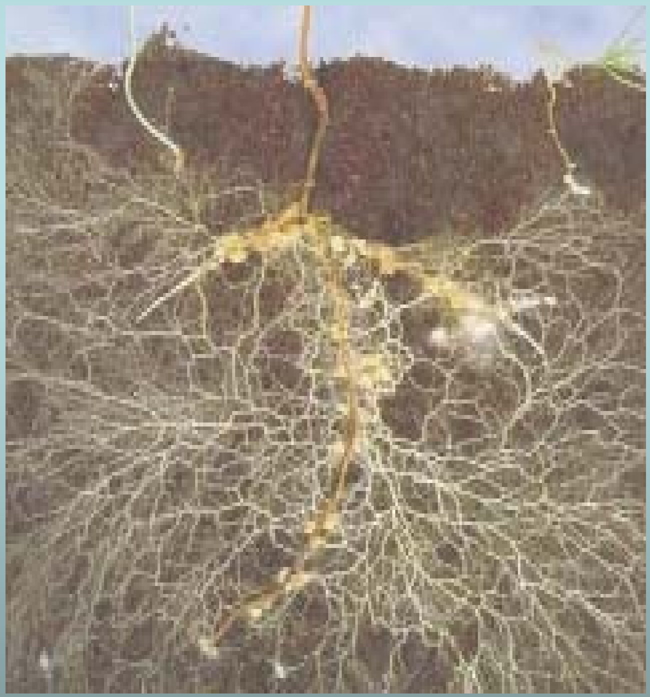
Methods for retaining phosphate



P-sorption increased significantly in vegetated vs non-vegetated plot. Increased O_2→oxidizes Fe and arbuscular mycorrhizal fungi possible mechanisms.
(Lucas, Greenway 2007)

Plants play a critical role in bioretention flow and water quality treatment performance

- **Plant roots penetrate soil creating flow paths, exude saccharides and dead material that feed soil organisms and create soil aggregates.**



- **Treatment mechanisms:**
  - **Nutrient uptake.**
  - **Metal uptake.**
  - **Uptake, volatilization, transformation of organics.**

- **Plants influence water quality directly (e.g. uptake) and indirectly through physical an chemical changes to rhizosphere.**

Summary and recommendations

- Bioretention areas provide excellent metal, hydrocarbon and TSS removal.
- Metal, hydrocarbon and TSS removal primarily in upper few centimeters. Hydrocarbons transformed within a few days. Mulch layer most important for metal and hydrocarbon removal.
- Phosphorus and nitrogen removal is variable. Nitrate and phosphate export is possible. Removal likely improves with facility depth.
- Nitrate removal dependent on O_2. Use raised under-drain to create an anaerobic zone and improve NO_3 for effluent release to marine water. Controlling HRT with under-drain orifice has not examined adequately yet.

Summary and recommendations

- Phosphate removal primarily driven by sorption capacity (other factors include HRT, BSM depth, and possibly plants and microbial activity).
- More research needed for optimizing for phosphate and nitrate removal. WSU starts research program winter 2009.
- Discussion focused on percent removal and concentrations. When considering volume reduction in rain gardens, loads dramatically reduced for all constituents.