

Steel Furnace Slag for Phosphorus Remediation

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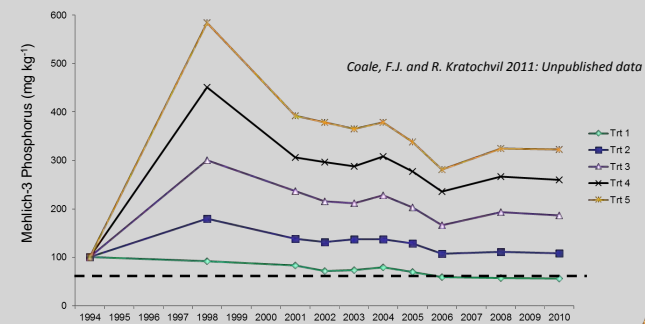
Target: Dissolved P

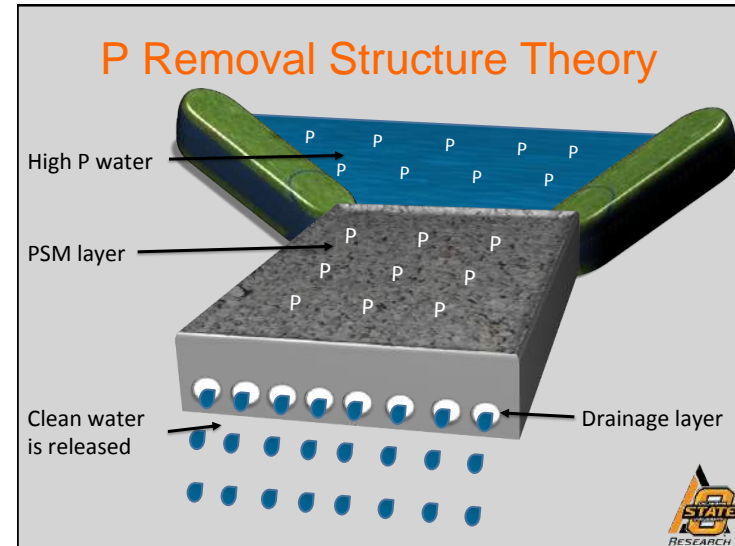
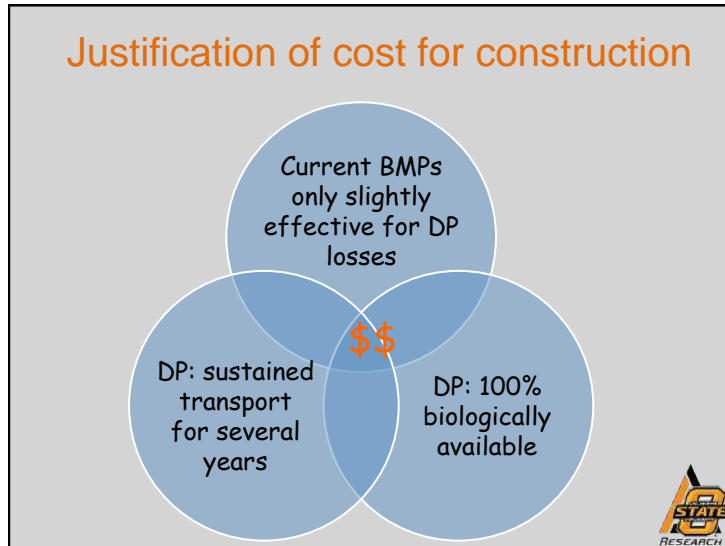
- Soils built up with “legacy” P will continue to release dissolved P for many years
 - Conventional best management practices do little for DP
- Objective: construct P removal structures to trap dissolved P in runoff and tile drainage



Need for P filters

- High soil P concentrations contribute to long-term, slow P leak
- This is referred to as a “legacy” P issue





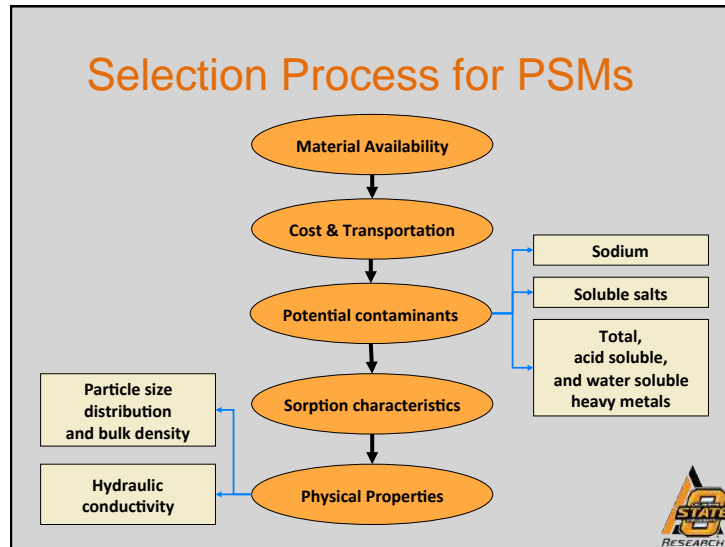
3 Necessary Components

- Effective PSM in sufficient quantity
- P-rich water must flow through PSM
- Ability to retain and replace PSM




Example by-product PSM's

	Acid mine drainage treatment residuals		Drinking water treatment residuals
	Bauxite mining and production waste (red mud)		Fly ash
	Steel slag waste		Foundry Sand
			Waste recycled gypsum



Cartridge Filter?

- Portable, easy to install
- Does not work!
- Limited amount of PSM

Confined Bed

- Good for large filter
- Ideal for drainage swales that require high peak flow and non restricted drainage
- Achieved through shallow PSM with large surface area

Tile Drain

- Similar to bed, but without confinement
- Allows large amount of material to be used
- Use flow control to build head
- Low cost
- Probably best option for ditches

Box Filter

- Easily switch out material
- Modular design – integrates with flow control
 - Agri-Drain
- Small ditches or pond overflow
- Drawback: Small amount of material

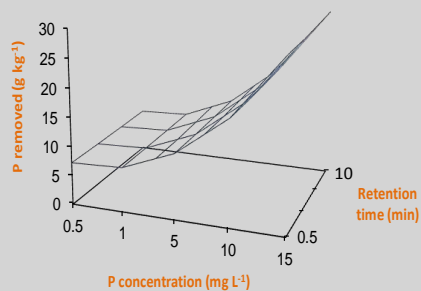


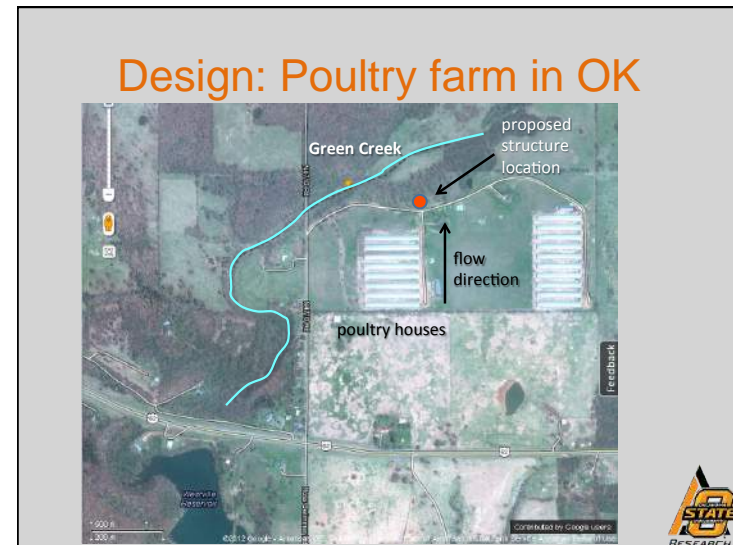
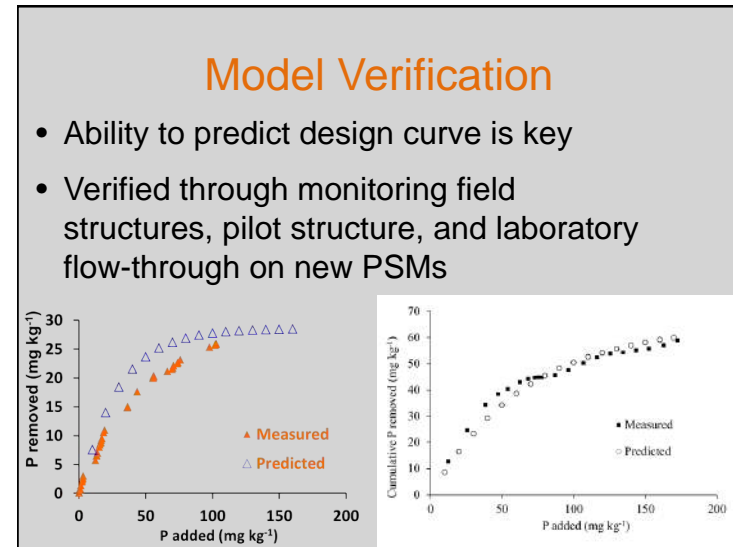
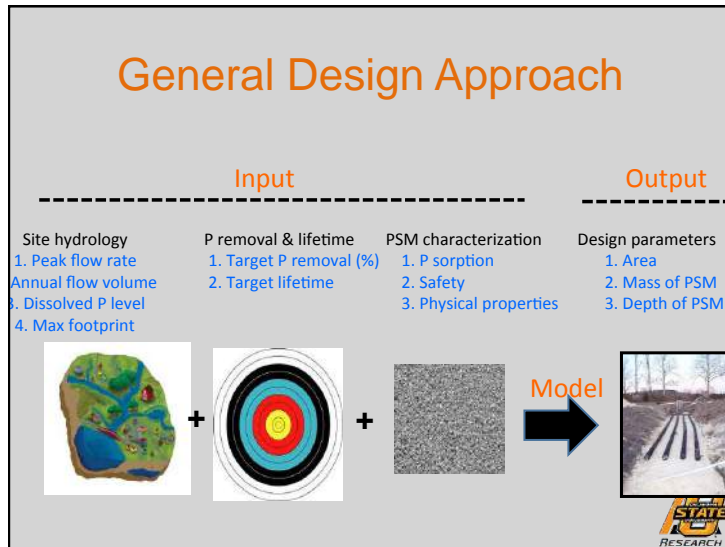
Storm Drain Filter



Performance and Lifetime

- It depends:
 - Site conditions
 - PSM
 - Design



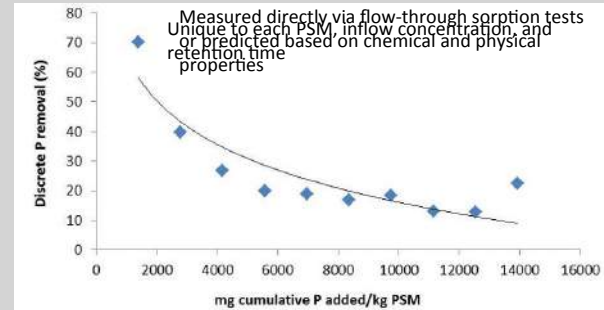


Site Conditions

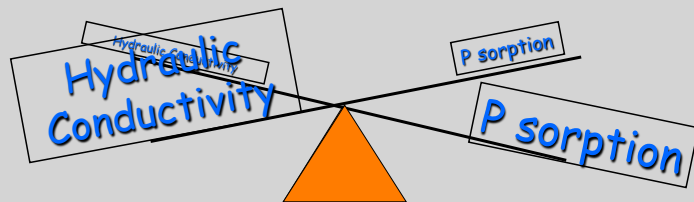
- Drainage area: 9 acres
 - Slope: 6%
- Curve #: 78
 - Peak flow rate, 2yr-24hr storm: 16 cfs
 - Annual flow volume: 9 acre-ft
- Typical dissolved P: 1 to 2 mg L⁻¹
 - Annual dissolved P load: 49 lbs (22 kg)
 - Average of 2 mg P L⁻¹
- Goal: remove 45% of annual P load



Sizing the Structure: design curve for potential PSMs



Structure design: impact of PSM characteristics



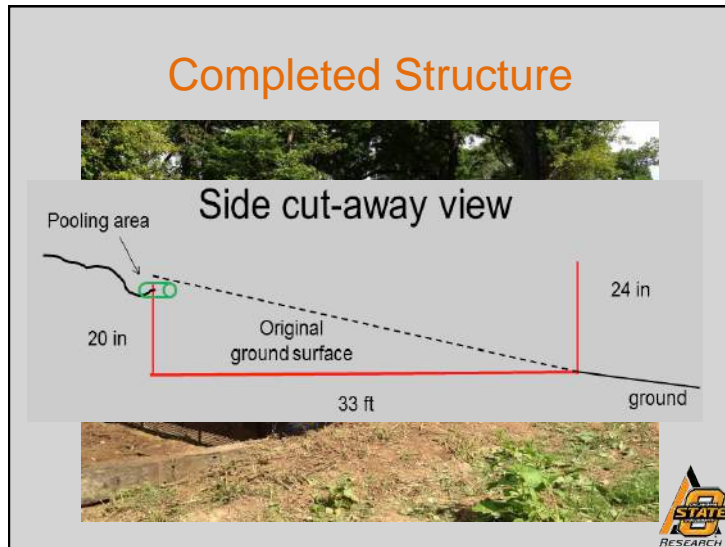
- Need to handle peak flow rate
- Need to handle P load



Design options to meet given P removal and 16 cfs flow

PSM	Mass (Mg)	Cumulative year 1 removal (%)	Lifetime (yrs)	Hydraulic conductivity (cm s ⁻¹)	Area (m ²)	PSM depth (cm)
WTR ^a	7	37	21	0.01	286	2.3
AMDR ^a	4	50	7	0.009	225	2.2
Fly ash ^a	3 (plus 95% sand)	50	3.6	0.03 (mixed with 95% sand)	406	13
>6.35 cm slag ^b	171	21	1.4	1.0	190	50
Treated > 6.35 cm slag ^{**}	36	45	3.5	1.0	40	50





Advantage of Slag

- Large HC = high flow rates
 - However, slag must be sieved to remove fines
 - Decreased flow rate with time
 - Loss of flocs containing P





Additional Support

- Design software currently being created
 - Provide interactive design guidance based on user inputs
- NRCS Standard will be completed after software is completed
 - NRCS cost-share
- Commercialization may be key to dissemination



Example of Software

Manually Input Design Curve ($y=e^{-mx}$)

Slope (m)

Intercept (x)

Option 1 (RT Not Met)

Mass Required (tons)	4.603
Area Required (sq ft)	491.8
Depth of Material (inches)	3.6
Lifetime (years)	29.3
Actual RT (min)	0.371086
Actual Removal (%)	19.1997
Phosphorus Removed during Specified Lifetime (pounds)	0.931217
Cumulative Phosphorus Removed (pounds)	9.09317


Total Iron (mg/kg)

Material Physical Characteristics (Required)

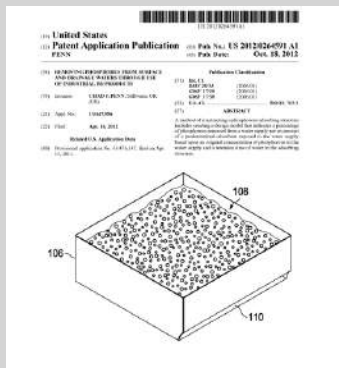
Bulk Density (g/cm³)

Hydraulic Conductivity (cm/sec)


Porosity



Software Availability



- Oklahoma State University is currently licensing the software for designing P removal structures
 - Commercial organizations
- NRCS will retain a free license





Economics Example: Westville

- Metal & custom fabrication: \$2677
– 1/4" carbon steel
- Slag transportation, sieving, coating: \$853
- Earth work for pad & berms: \$846
- Paint, seed, & erosion mat: \$613
- TOTAL Construction: ~ \$5000
- Annual renewal estimated at \$1213
- Includes profit from private companies except for metal painting and installation



Economics Example: Westville

Year	\$	P removal (lbs.)	Cumulative P removal cost (\$/lb P)
1	4989	22	226.77
2	1213	22	140.95
3	1213	22	112.35
4	1213	22	98.05
5	1213	22	89.46
6	1213	22	83.74
7	1213	22	79.66



Re-use of Spent Slag

- Not a highly soluble P source
– Ex: Spent slag filter
- WSP: 0.03 mg L⁻¹
- Removed 59 kg sediment
- Extraction of P is possible: not economical
– Issue of scale
– XANES showed several P forms depending on PSM
- Good road base material



