The Hydraulic Performance and Treatment Capabilities of a Hybrid Sand Filter in the Alabama Black Belt

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Speaker Introduction

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- Currently earning MS in Systems Engineering

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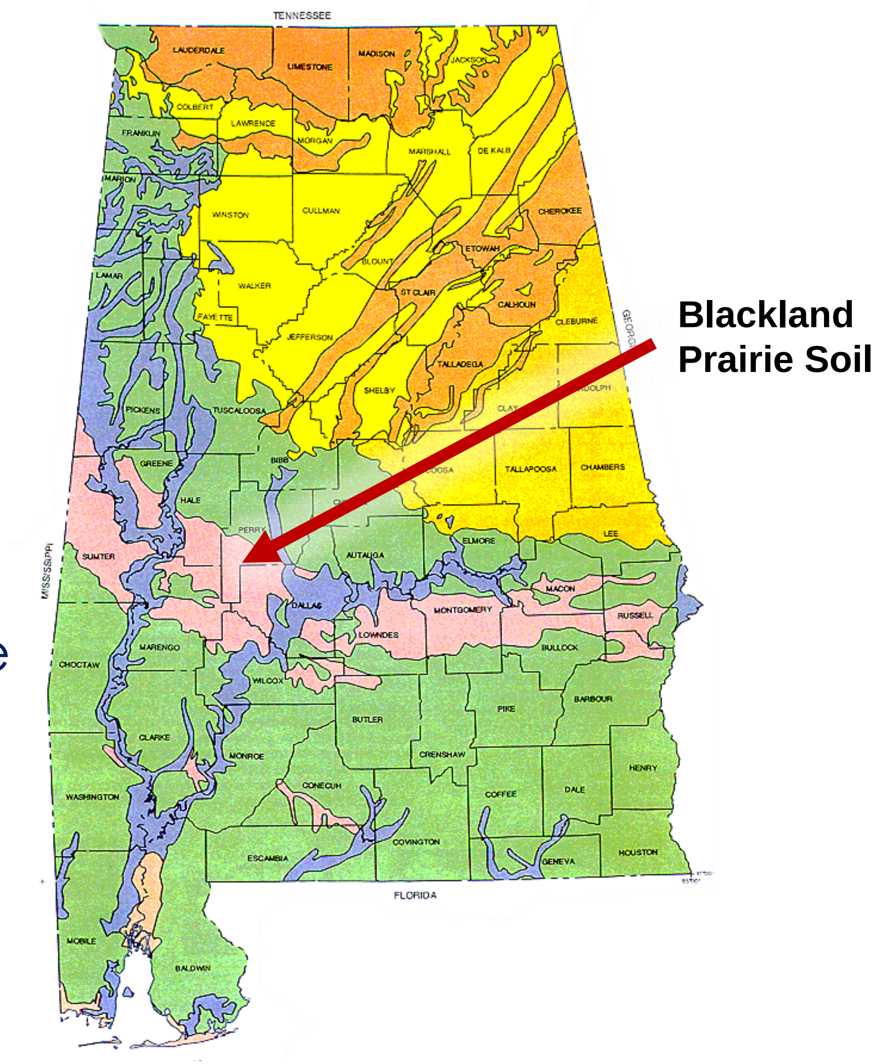
The Alabama Black Belt

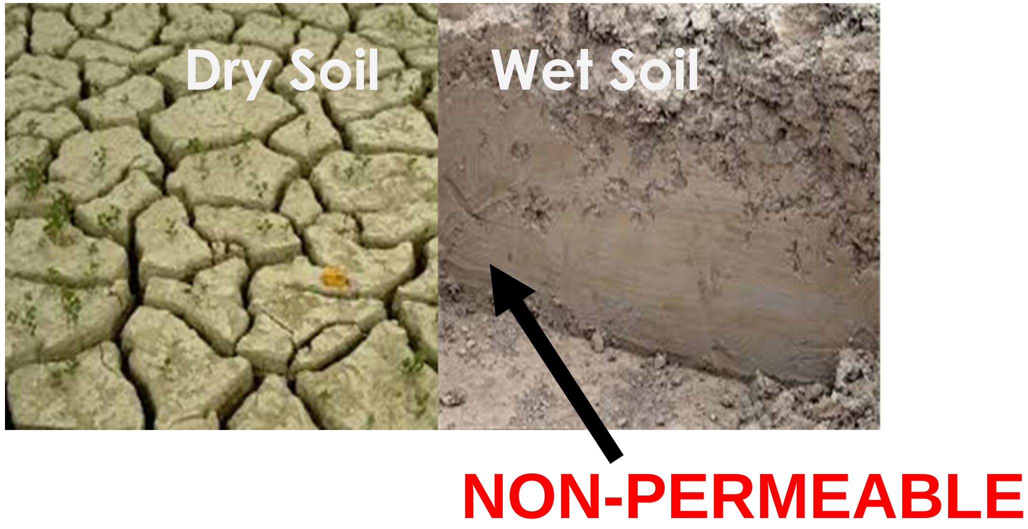
- 17-county region in central Alabama
- Named for fertile black vertisol soils (Blackland Prairie)
- Characteristics:
  - Rural in Nature
  - Population density ⅕ national average
  - Median household income 54% of national average
  - Limited economic development
  - Low educational attainment



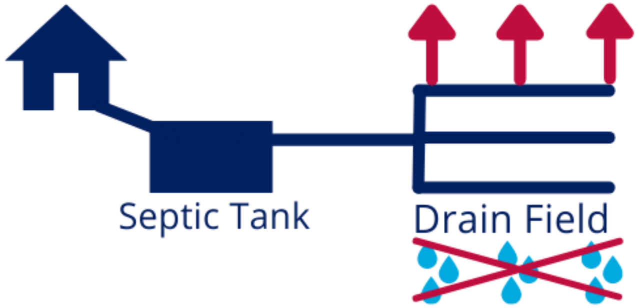
Black Belt Clay Soils

- Inadequate infiltration of water (200+ minutes/inch)
- Traditional septic systems with drain fields rely on the infiltration of wastewater into soils where treatment is accomplished via natural processes
- Inability for water infiltration in Black Belt soils results in septic tank failures

Vertisol Soils

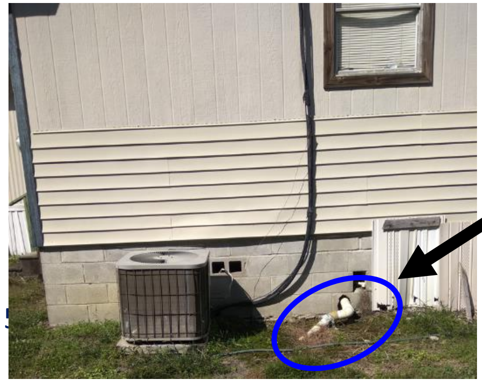


Traditional Septic Tank Situation

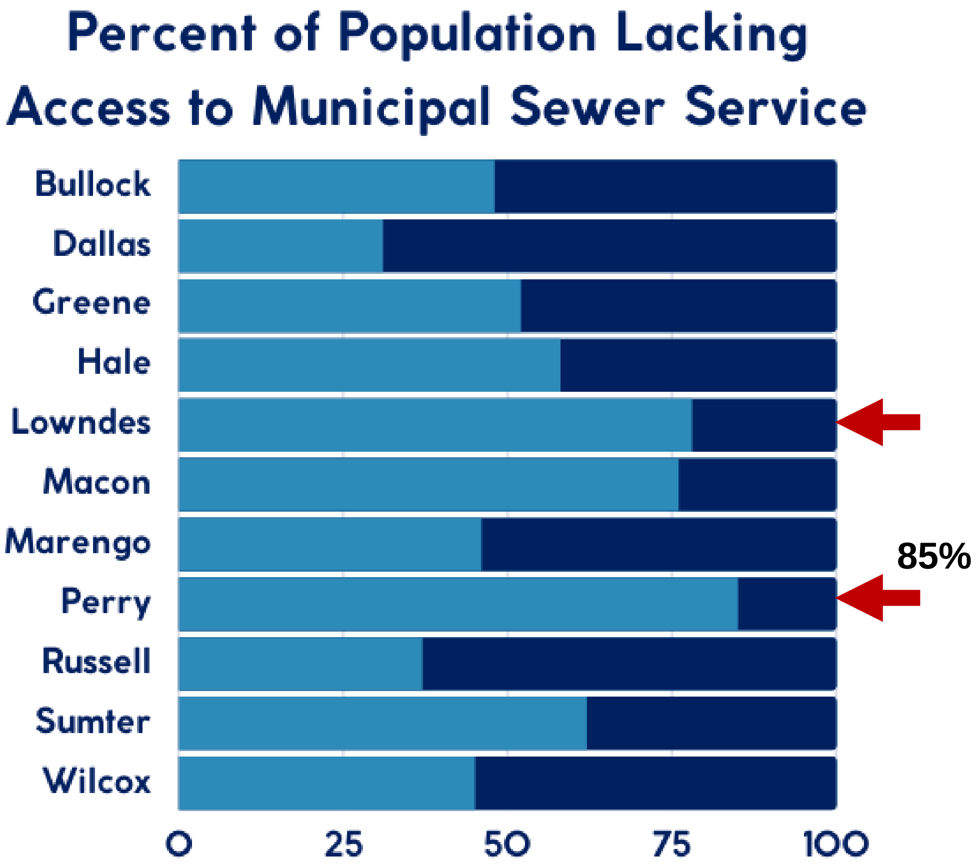


Insufficient Infrastructure

- In a survey of 11 Black Belt counties: Estimated 37% to 85% of residents **lack access to municipal wastewater service**
- Low-income residents sometimes resort to using straight-pipes
- Straight pipes (with or without settling tank) deposit untreated wastewater to the ground surface



Straight Pipes



Health and Environmental Impacts

- Insufficient wastewater management results in community exposures to **bacteria**, **viruses**, and **helminths** via untreated wastewater
  - UNC study in progress to determine the prevalence of pathogen exposure in the Alabama Black Belt
- Hookworm infections are a documented issue in the Alabama Black Belt
  - UAB study underway to determine exact prevalence of hookworm infection in the Alabama Black Belt
- Untreated wastewater flows into local waterways during rain events resulting in:
  - Contamination of waterways
  - Degradation of aquatic ecosystems via oxygen depletion

Developing Sustainable Strategies

Step 1:

Identifying and expanding service areas of existing centralized municipal sewer systems with additional capacity

Step 2:

Establishing decentralized cluster system models of wastewater infrastructure for small clustered communities

Step 3:

Developing and testing cost-effective individual onsite wastewater systems to recommend to residents

Step 4:

Identifying and evaluating applicable management structures for decentralized wastewater treatment models

Step 5:

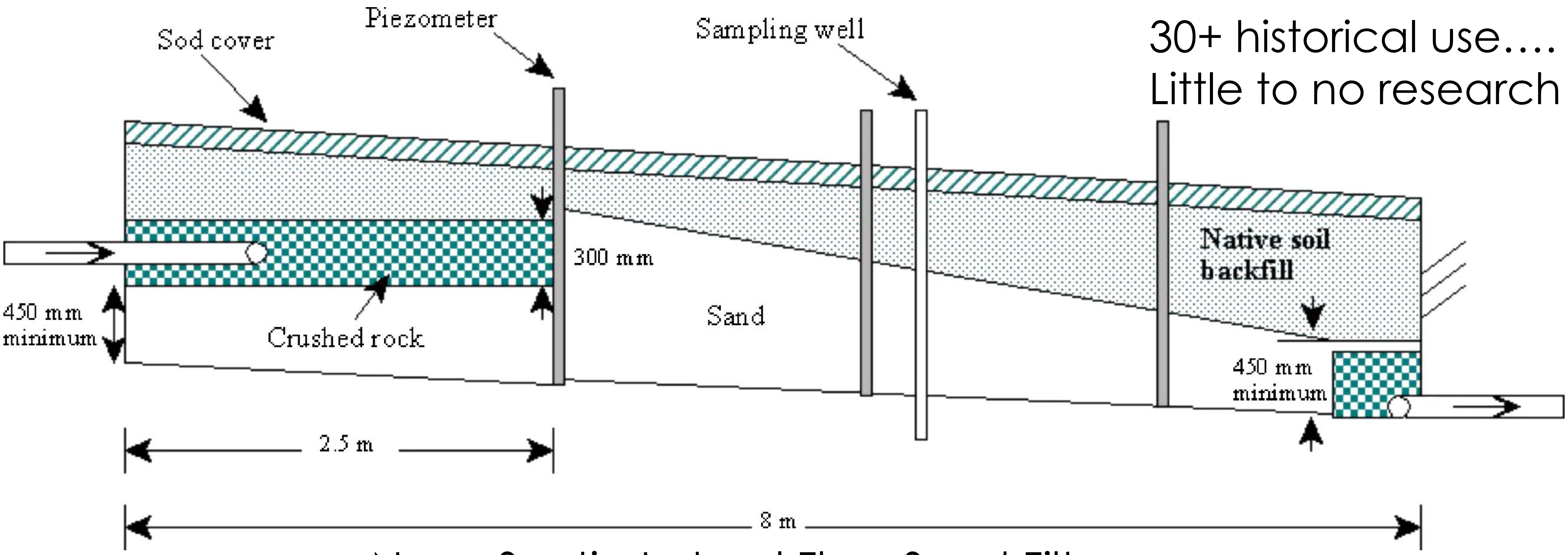
Seeking regulatory changes and "special permitting districts" to meet the unique needs of the region

One Alternative being studied…

Lateral Flow Sand Filters

Bridson-Pateman, E.; Hayward, J.; Jamieson, R.; Boutilier, L.; Lake, C. The Effects of Dosed versus Gravity-Fed Loading Methods on the Performance and Reliability of Contour Trench Disposal Fields Used for Onsite Wastewater Treatment. J. Environ. Qual. 2013, 42 (2), 553–561. https://doi.org/10.2134/jeq2012.0255.

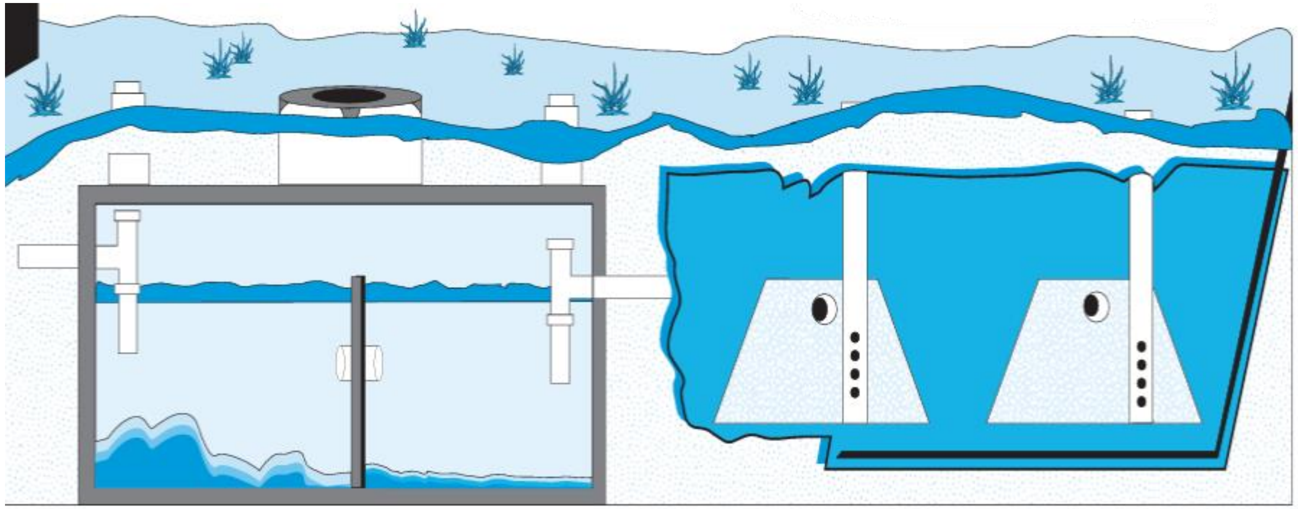
30+ historical use….
Little to no research



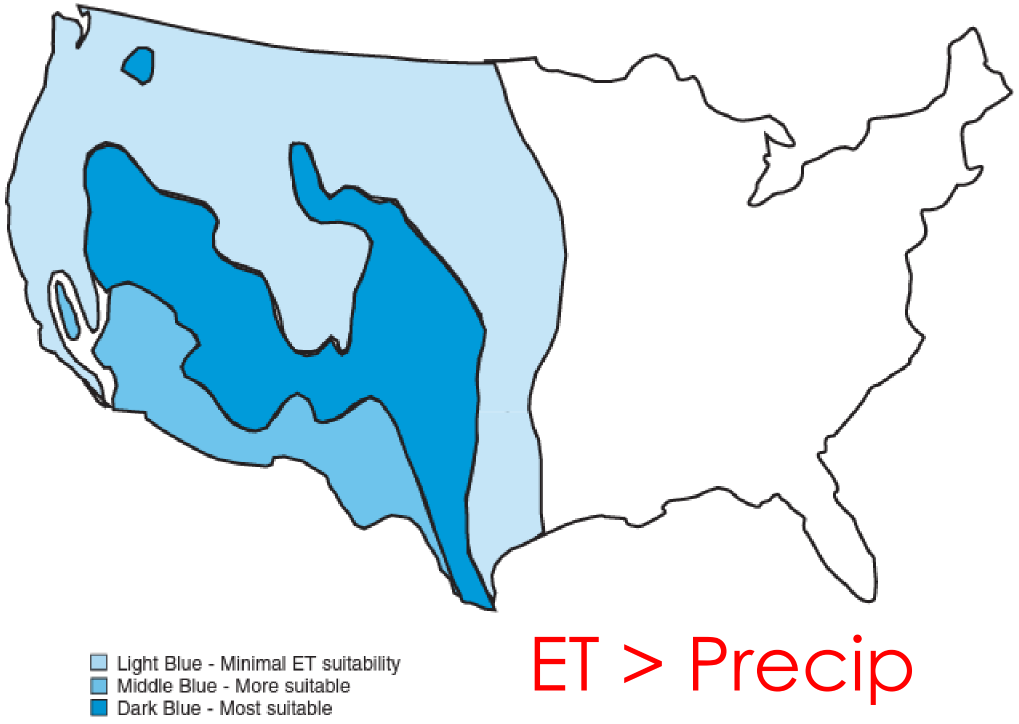
Nova Scotia Lateral Flow Sand Filter

Another Alternative being studied…

Evapotranspiration Sand Filters



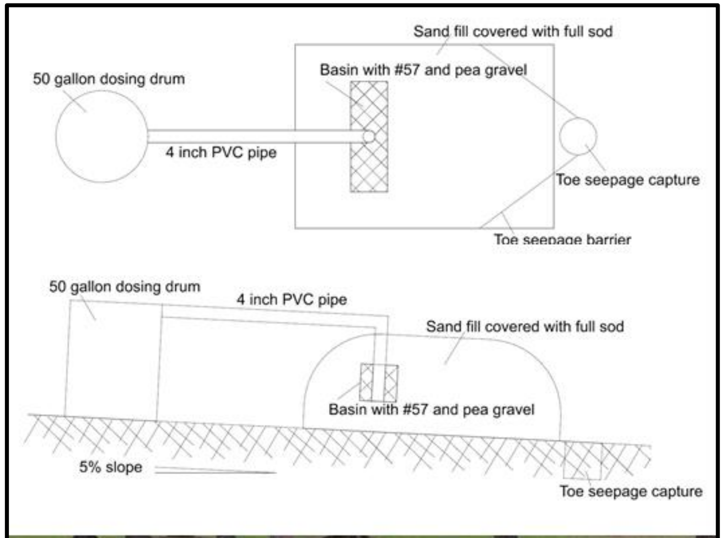
Winter, P.-. Evapotranspiration Systems. Natl. Small Flows - Clear. 2000, 7 (1), 8.



ET > Precip

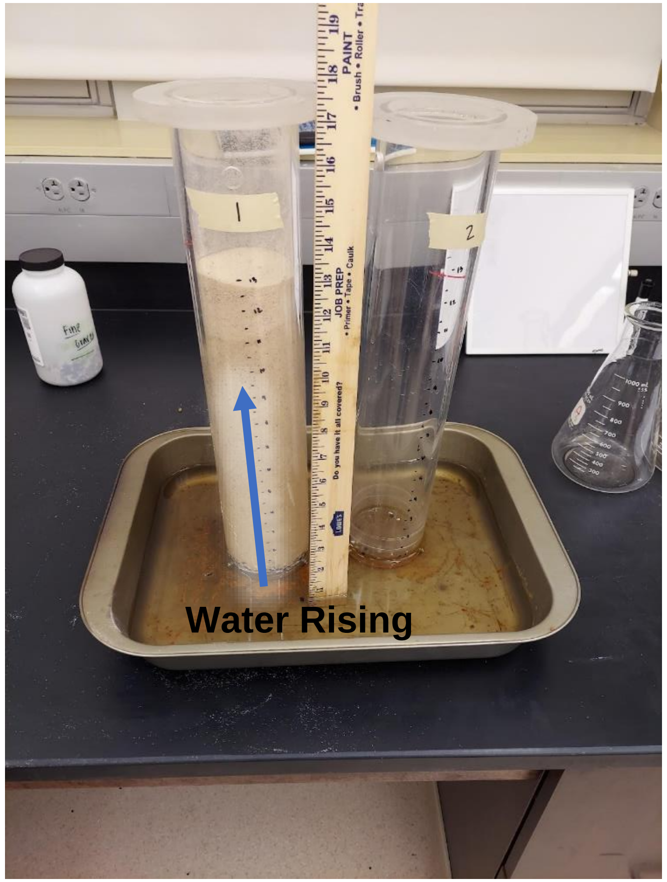
Regions Appropriate for Evapotranspiration Systems
Colored areas represent climates most suitable for ET systems.

Onsite Wastewater Treatment Research: Modified Lateral Flow Sand Filter (Alpha)

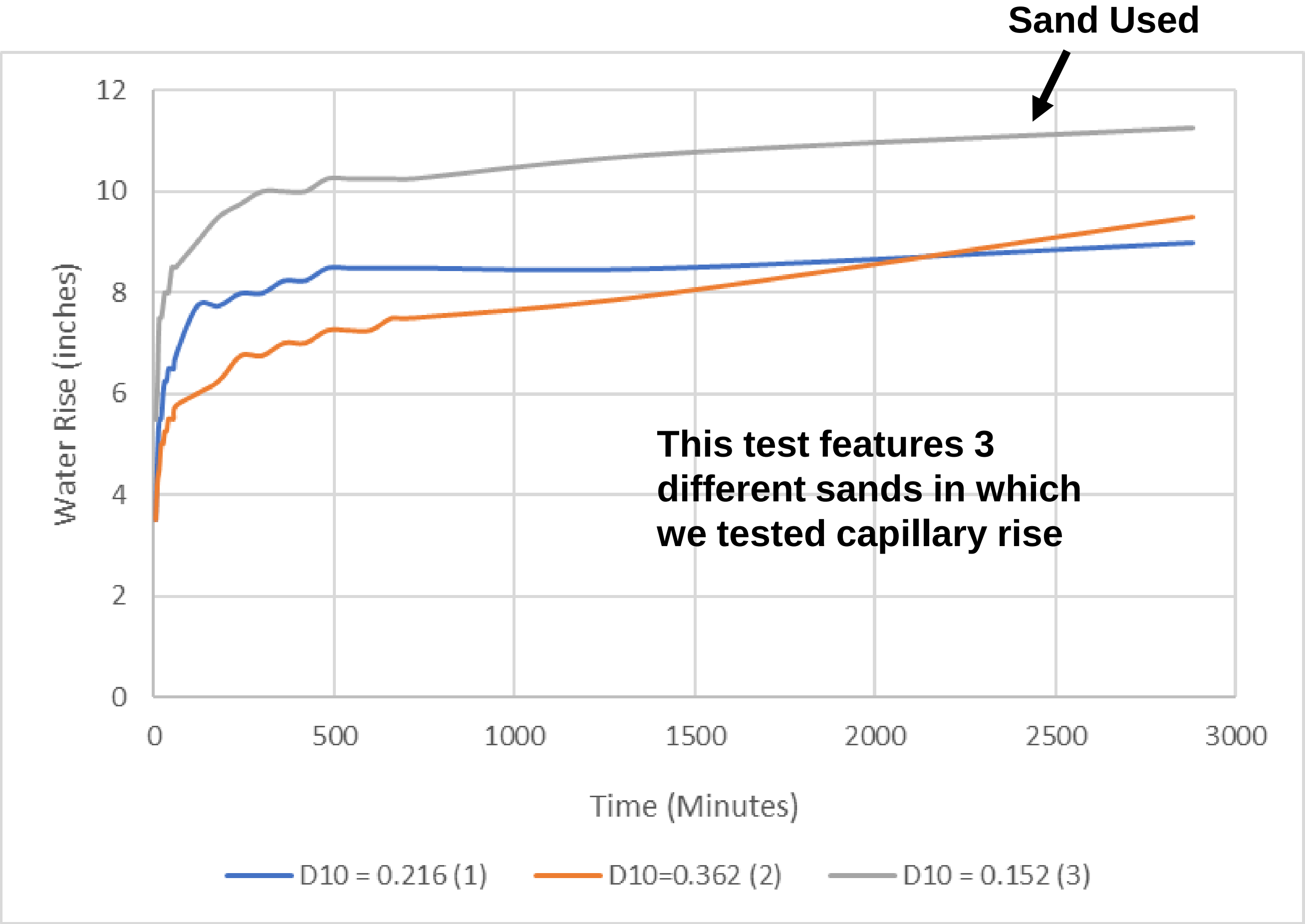


- Pilot scale – 8.5 ft x 12 ft x 3 ft
- Plywood base- 6 ft x 9 ft
- Designed using parameters of a lateral flow sand filter and sand mound system.
- Utilizes **capillary rise**, **evapotranspiration**, sand filtration, and bacterial processes to aid in wastewater treatment and disposal
- Dosed with **51 GPD**
  - Phase 1: Water without additives to track toe seepage
  - Phase 2: Water with dye to observe capillary rise
  - Phase 3: Water with organic matter to synthesize wastewater to observe treatment capacity

Phase 2: Capillary Rise

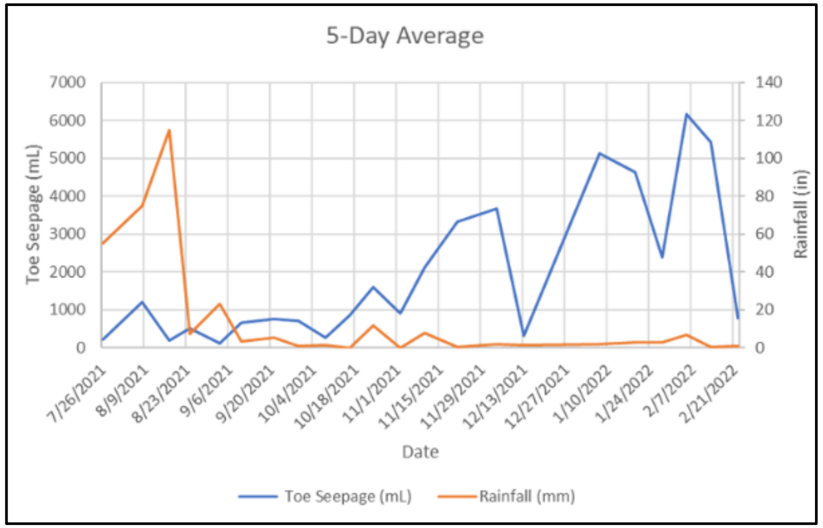


Capillary Rise Set-Up

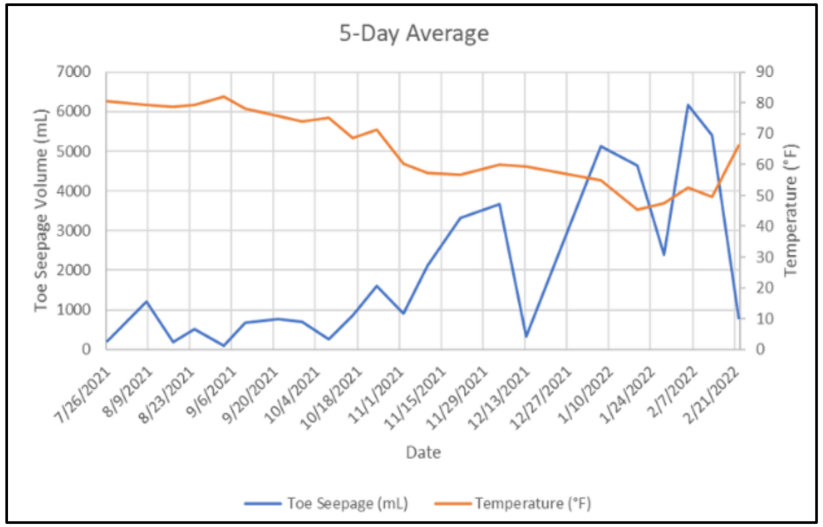


Phase 1: Sand Filter Toe Seepage Data (5-Day)

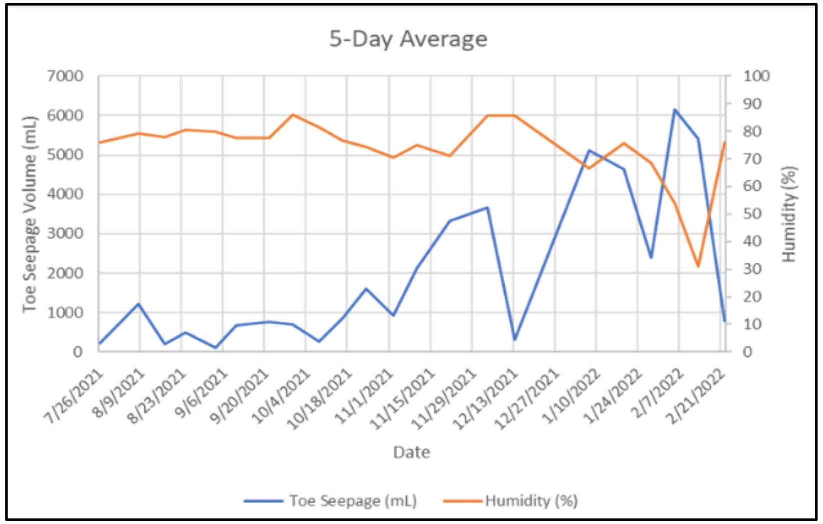
Rainfall



Temperature



Humidity



Correlation Values

	Rainfall	Temperature	Humidity
R^2	0.139	0.687	0.530

Sand Filter Toe Seepage Data Discussion

Correlation Analysis

- Discharge rates were directly proportional to ambient temperature and humidity. **Higher temperatures and humidity lead to lower discharge rates.**
- Rainfall had a lower correlation value

Challenges & Lessons Learned

- Alternative disposal methods for treated effluent should be considered after the sand filter hybrid for impermeable soil types
- Our team installed a second hybrid sand filter to better capture all dosed water/wastewater and to enhance capillary rise.

Phase 3: Wastewater Treatment

- Synthetic wastewater recipe was used to test the sand filter hybrid.
- Samples are taken of the toe seepage effluent.
- Analysis for treatment is on-going. The table consists of data results (4/7/22-8/24/22)

Test Parameter	Influent (mg/L)	Average Effluent (mg/L)	% Reduction	Number of Tests
Nitrate	7.71	31.83	-313%	14
Ammonia	24.80	5.80	77%	14
Phosphorus	4.23	0.33	92%	11
COD	213.00	24.14	89%	13
Total Nitrogen	119.00	40.02	66%	9
BOD	77.05	4.04	95%	14

New Modified Lateral Flow Sand Filter (Bravo)

- Designed using the same parameters as the Alpha model
- Pilot Scale- 13 ft x 9 ft x 3 ft
- Completely confined to a plywood base, with plastic liner
- Bravo model has 2 gravel inflow basins
- Dosed with an average of 55 gallons of synthetic wastewater per day
- Toe seepage and wastewater data is currently being collected
    - Toe seepage is higher than the Alpha model
    - Scope has shifted from disposal to treatment

Bravo Model

Construction Phase

Final Product

Constructed Wetland Addition

For Denitrification of Effluent

- A constructed wetland was added to the Bravo Model
  - Pilot Scale: 6 ft x 4 ft x 1.5 ft
  - Plywood, tarp, PVC pipe
  - 36 cubic feet of #57 gravel,
    48 quarts of biochar
    20 lbs. sawdust
  - Dosed with 50 GPD
- Implemented to further treat effluent wastewater (Denitrification)
- **Bravo sand filter + Constructed Wetland = *Bravo Plus* Treatment System**

Constructed Wetland Addition

Construction Phase

Final Product

Complete System (Bravo Plus)

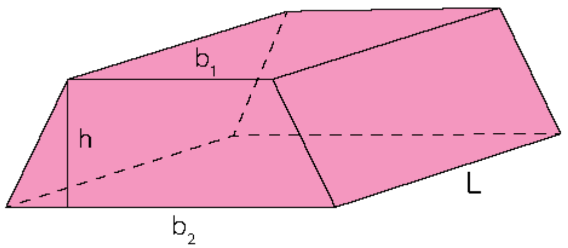
Bravo Plus Treatment Data

- Limited treatment data has been taken on the Bravo Plus system
- Influent: Sample from Wastewater Barrels
- Effluent 1: Sample from Sand Filter toe seepage
- Effluent 2: Sample from Constructed Wetland seepage
- Data analysis is on-going. Table below: 10/8/22-10/26/22
- Nitrate and Ammonia are high because the biology is not yet fully developed in the system

Test Parameter	Average Influent (mg/L)	Average Effluent 1 (mg/L)	Average Effluent 2 (mg/L)	% Reduction (I-E1)	% Reduction (E1-E2)	% Reduction (I-E2)	Number of Tests
Nitrate	7.10	30.04	14.47	-323%	52%	-104%	8
Ammonia	32.16	35.86	37.63	-12%	-5%	-17%	8
TN	95.81	66.51	51.39	31%	23%	46%	8
COD	304.38	24.65	5.80	92%	76%	98%	7
Phosphorus	5.01	0.92	1.74	82%	-89%	65%	8
BOD	63.14	3.46	2.77	95%	20%	96%	6

Cost Estimation for 55-GPD (Sand Filter)

Volume of Trapezoidal Prism



Volume of a Trapezoidal Prism = $\frac{1}{2}(b_1 + b_2) \times h \times L$

$$\text{Soil Volume} = \frac{1}{2}(8.5' + 4.8') \times 2.7' \times 12'$$
$$= 216\ ft^3 = 6yd^3$$

Item	Quantity	Price per Unit	Cost per item
Sand	6 yd^3	14.50/yd^3	$87
Sod	16 sq	$1/sq	$16
Gravel bin (25 gal)	1 bin	$30/bin	$30
River Rock	2.5 ft^3	$4.18/ ft^3	$21
Pea Gravel	0.5 ft^3	$4.68/ ft^3	$5
Wood base	54 ft^2	$1.15/ ft^2	$62
Painters Sheet	1 sheet	$23/sheet	$23
1.25” pipe	30ft	$1.23/ft	$37
DC battery	1 battery	$80/battery	$80
Pump	1 pump	$70/ pump	$70
4” pipe	10ft	$3.90/ft	$39
Programmable timer	1 timer	$13.47/timer	$13
		TOTAL	**~$500**

Cost Estimation for 300-GPD

Item	Quantity	Price per unit	Cost
Sand	42 yd3	$14.50 per yd3	$610
Pea Gravel	0.4 yd3	$39 per ton	$16
#57 Gravel	0.69 yd3	$98 per ton	$68
4" PVC Pipe	20 ft	$5.42/ft	$110
Pump + pump basin	1 pump	$1200 per pump	$1200
Plastic Tub	1 tub	$673 per tub	$673
Sod	570 ft2	$.80/ ft2	$460
		TOTAL	**$3,200**

Cost Estimation for Constructed Wetland

55 GPD Model

Item	Quantity	Price per Unit	Cost per Item
# 57 Gravel	72	$5.18	$372.96
Plywood	2	$54.18	$108.36
Wood Post	2	$11.88	$23.76
Tarp	1	$15	$15
Sawdust	4	$19.99	$79.96
Biochar	6	$16.99	$101.94
4” pipe	10ft	$3.90/ft	$39.00
1.25” pipe	30ft	$1.23/ft	$37
Programmable timer	1	$13.47	$13
DC battery	1	$80	$80
Pump	1	$70	$70
		Total	**$941**

300 GPD Model

Item	Quantity	Price per Unit	Cost per Item
# 57 Gravel	7 Tons	$163.36	$1,143.52
Biochar	2 cubic ft	$375	$375
Sawdust	120 lbs	$10.10	$40.40
		Total	**$1,558.92**

Questions?

Our Team

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- Harry McCaskill IV
- Rachel Chai
- Michael Pitts
- Morgan Rowland
- Lacey Christian
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