Conservation Drainage

Denitrifying Bioreactor

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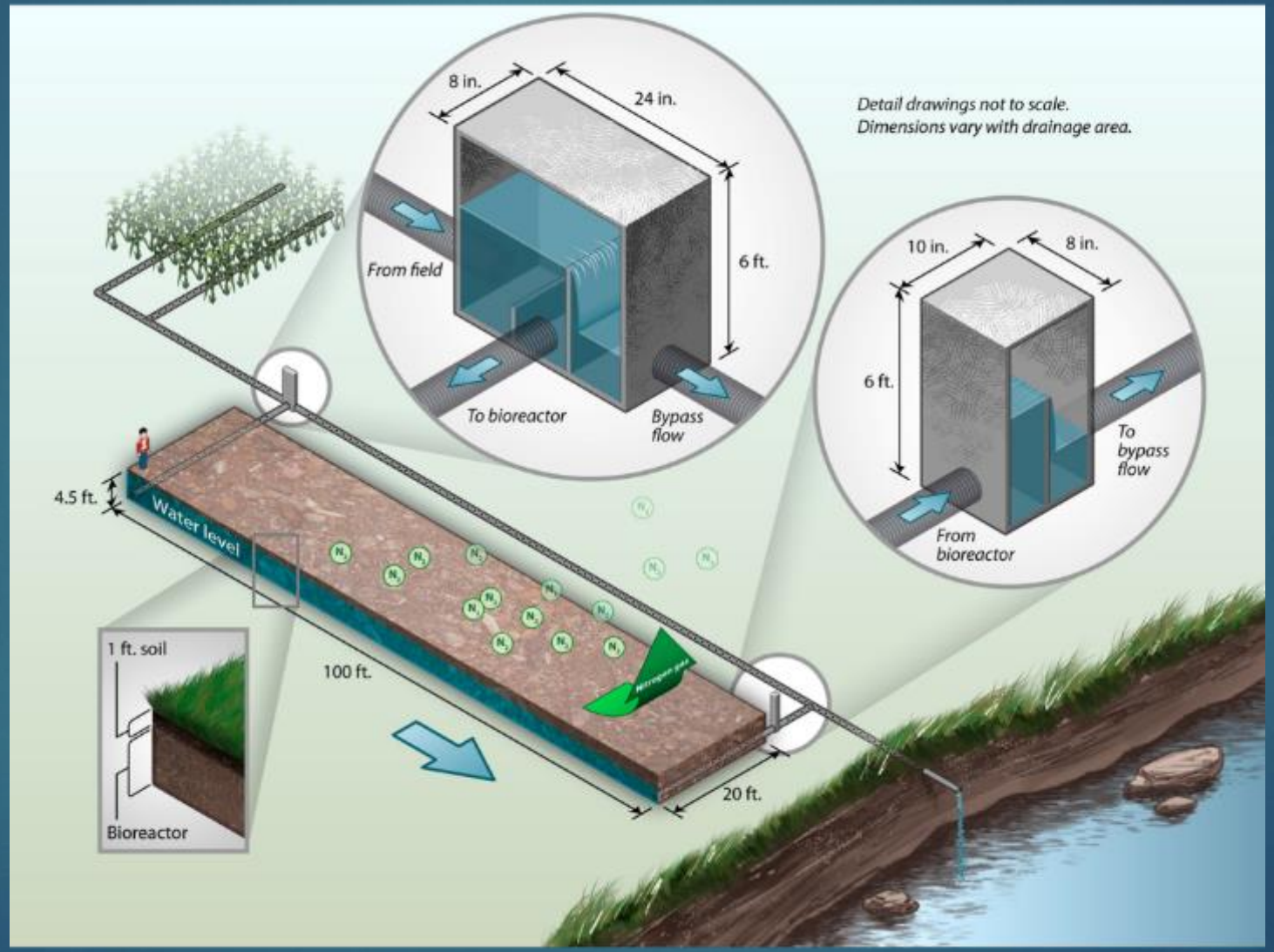
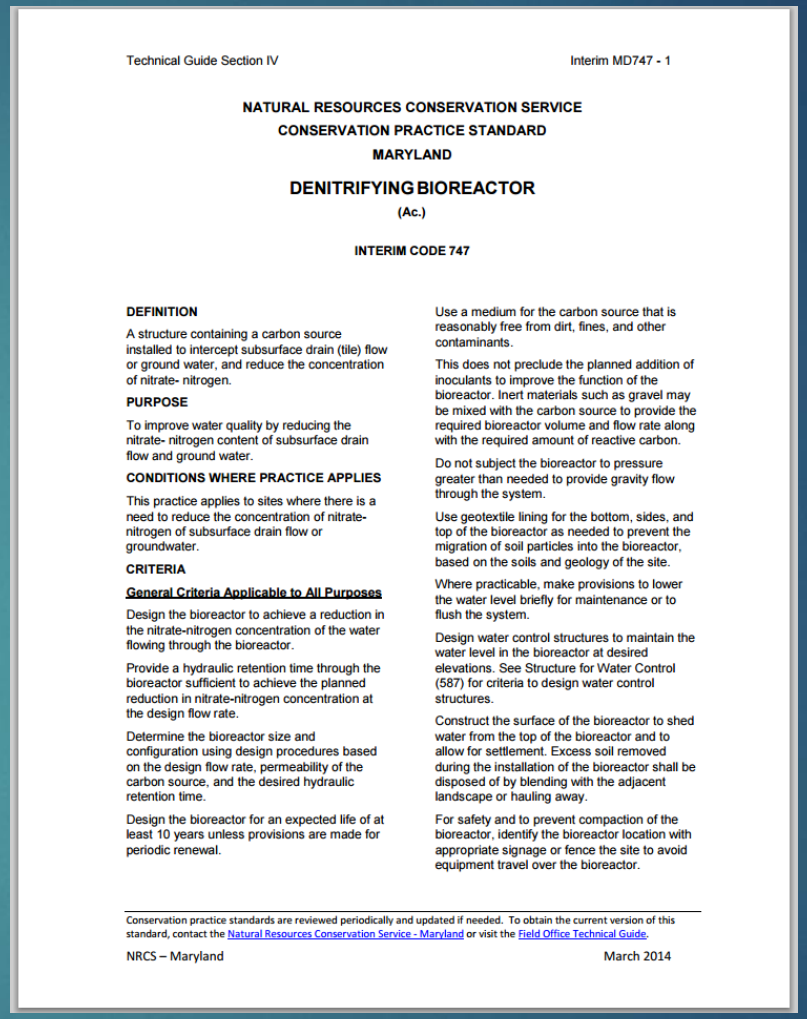
Midshore Riverkeeper Conservancy

Denitrifying Bioreactor



Overview

- Implemented/studied in Midwest
- NRCS Standard
- 10 year lifespan
- Data collection at 7 sites on the eastern shore of Maryland
- Implemented in 3 Chesapeake Bay states: NY, VA, MD



Technical Guide Section IV — Interim MD747 - 1

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD
MARYLAND

DENITRIFYING BIOREACTOR

(Ac.)

INTERIM CODE 747

DEFINITION

A structure containing a carbon source installed to intercept subsurface drain (tile) flow or ground water, and reduce the concentration of nitrate- nitrogen.

PURPOSE

To improve water quality by reducing the nitrate- nitrogen content of subsurface drain flow and ground water.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to sites where there is a need to reduce the concentration of nitrate-nitrogen of subsurface drain flow or groundwater.

CRITERIA

General Criteria Applicable to All Purposes

Design the bioreactor to achieve a reduction in the nitrate-nitrogen concentration of the water flowing through the bioreactor.

Provide a hydraulic retention time through the bioreactor sufficient to achieve the planned reduction in nitrate-nitrogen concentration at the design flow rate.

Determine the bioreactor size and configuration using design procedures based on the design flow rate, permeability of the carbon source, and the desired hydraulic retention time.

Design the bioreactor for an expected life of at least 10 years unless provisions are made for periodic renewal.

Use a medium for the carbon source that is reasonably free from dirt, fines, and other contaminants.

This does not preclude the planned addition of inoculants to improve the function of the bioreactor. Inert materials such as gravel may be mixed with the carbon source to provide the required bioreactor volume and flow rate along with the required amount of reactive carbon.

Do not subject the bioreactor to pressure greater than needed to provide gravity flow through the system.

Use geotextile lining for the bottom, sides, and top of the bioreactor as needed to prevent the migration of soil particles into the bioreactor, based on the soils and geology of the site.

Where practicable, make provisions to lower the water level briefly for maintenance or to flush the system.

Design water control structures to maintain the water level in the bioreactor at desired elevations. See Structure for Water Control (587) for criteria to design water control structures.

Construct the surface of the bioreactor to shed water from the top of the bioreactor and to allow for settlement. Excess soil removed during the installation of the bioreactor shall be disposed of by blending with the adjacent landscape or hauling away.

For safety and to prevent compaction of the bioreactor, identify the bioreactor location with appropriate signage or fence the site to avoid equipment travel over the bioreactor.

Conservation practice standards are reviewed periodically and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service - Maryland or visit the Field Office Technical Guide.

NRCS – Maryland — March 2014

MIDSHORE RIVERKEEPER® CONSERVANCY

Engineering Guide

Subsurface Drainage Bioreactor Design

Developed by M. Helmers & L. Christianson, ABE, Iowa State University

Modified for NRCS use by B. Atherton, P.E., Agricultural Engineer

IaDenitrifyingBioreactor.xls Ver 1.0

Producer -->

Township/Section -->

Designed by -->

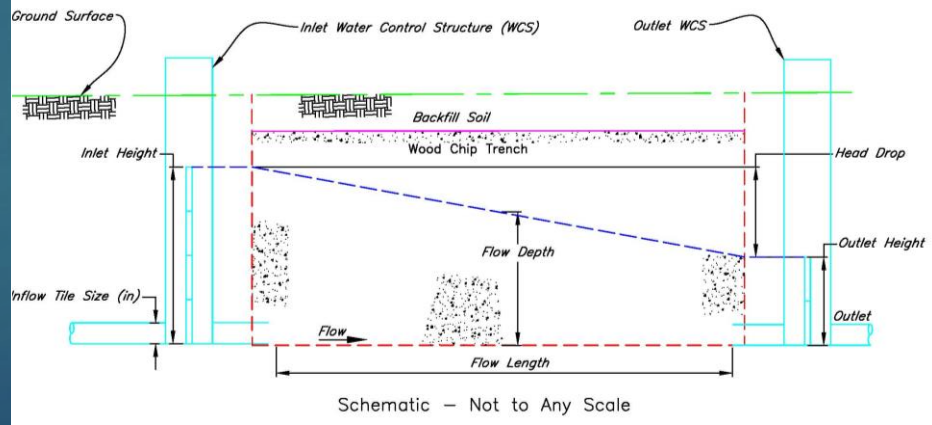
Date -->

Checked by -->

Date -->

Instructions: Enter values in gray cells

Field Information:		
Tile Size (in)	6	Size of inflow tile; known from site
Tile Grade (%)	0.50	Limiting Grade of inflow tile; known from site
Manning's "n" value	0.015	3" - 6" Corrugated Plastic Pipe (tubing), single wall
Velocity in Pipe (ft/s)	1.76	Mannings Gravity Driven Flow Equation = $1.49 \times \sqrt{\left(\frac{Tile\,Grade}{100}\right)} \times \frac{\left(\frac{Tile\,Size}{(Conversion)}\right)^{\frac{2}{3}}}{0.012(for\,dual\,wall)OR\,0.015(for\,non-dual\,walled)}$
Peak Flow from Tile Size (cfs)	0.345	Flow rate = Velocity x Area of Tile
Media Information:		
Conductivity of Wood Media (ft/s) (K)	0.15	Converted from 4.5 cm/s per Laura Christianson; (original value 9.5 cm/s to ft/s; value determined in Porous Media Lab, AB
Porosity of Wood (ρ)	0.7	Taken from van Driel et al., 2006
Bioreactor Inputs and Calculations:		
Flow Length (ft) (L)	100	Iteratively choose to the nearest foot
Trench Width (ft) (W)	10	Iteratively choose to the nearest foot; should be less than 25% of the flow length
Inlet Height (ft)	2.5	Iteratively choose to the nearest 0.1 foot
Outlet Height (ft)	0.3	Iteratively choose to the nearest 0.1 foot
Head Drop (ft) (ΔH)	2.2	Calculated based on diffference between inlet and outlet
Flow Depth (ft) (d)	1.4	Calculated to be in bioreactor middle (average of inlet and outlet height)
Hydraulic Gradient (i)	0.022	Head Drop / Flow Length
Results:		
Bioreactor Flow Rate (cfs) (Q)	0.045	Darcy's Law for Porous Media Flow = $Hyd.Conductivity \times Hyd.Gradient \times Flow\,Area = KiA = Ki(W \times d)$
Hydraulic Retention Time (hours) (HRT)	**6.0**	HRT = $\tau = \frac{Volume \times porosity}{Flow\,rate} = \frac{V\rho}{Q} = \frac{l \times w \times d \times \rho}{Q}$ (conversions included); 4 hour min., should be 6 to 8 hours
% of peak flow that can be passed through bioreactor	**13.2**	Bioreactor Flow Rate / Peak Flow from Tile ; minimum 15%



Schematic – Not to Any Scale

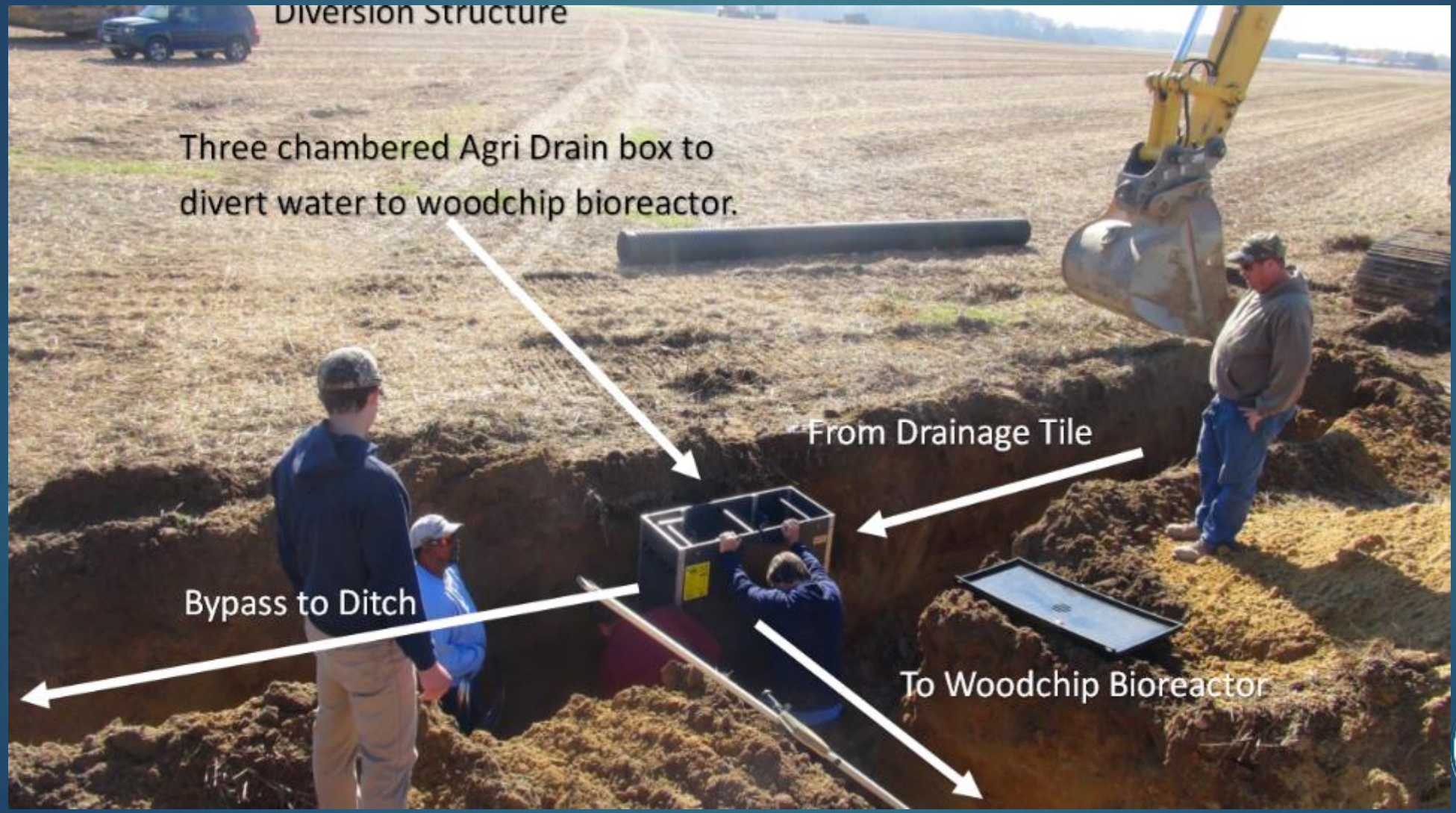
This Bioreactor design is based on treating a minimum of 15% of the peak flow capacity of the drainage system.
The design retention time is between 4 - 8 hours (Robertson et al., 2000; van Driel et al., 2006).

Notes:

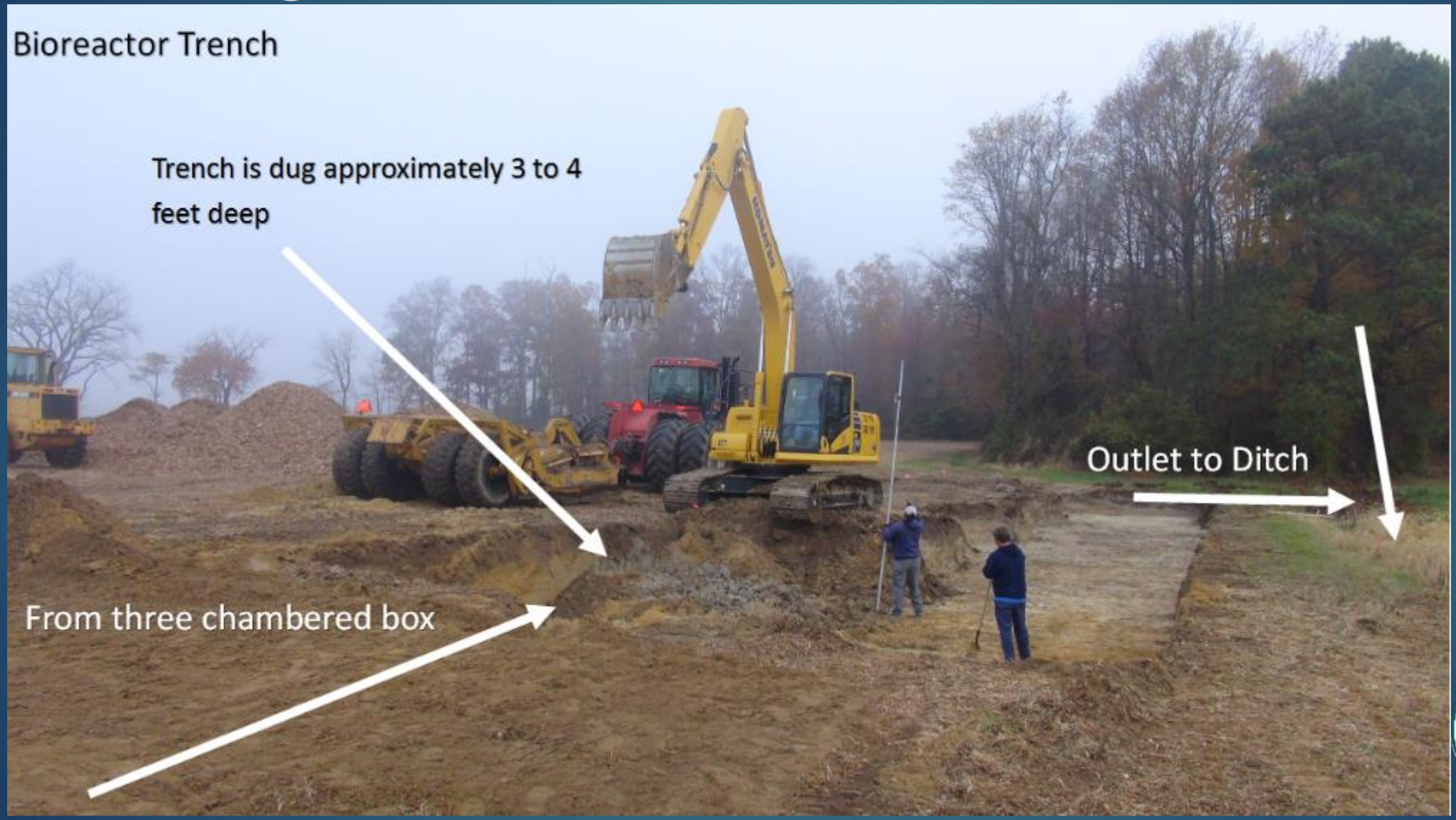
Background


Before Construction
Drainage Tile Outlet
Ditch
Woodchip Bioreactor
Location
Woodchips

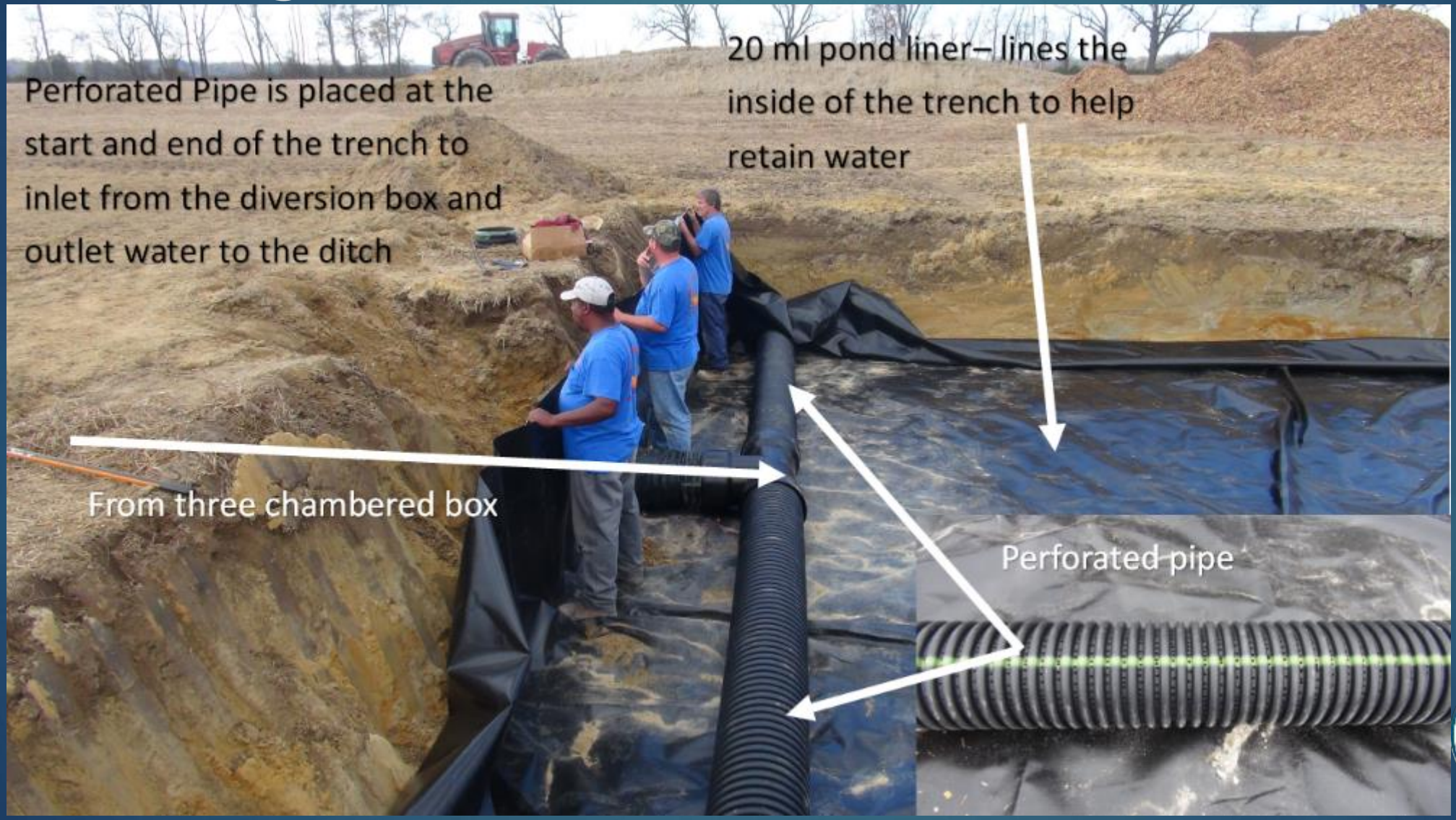
Background


Diversion Structure
Three chambered Agri Drain box to divert water to woodchip bioreactor.
From Drainage Tile
Bypass to Ditch
To Woodchip Bioreactor

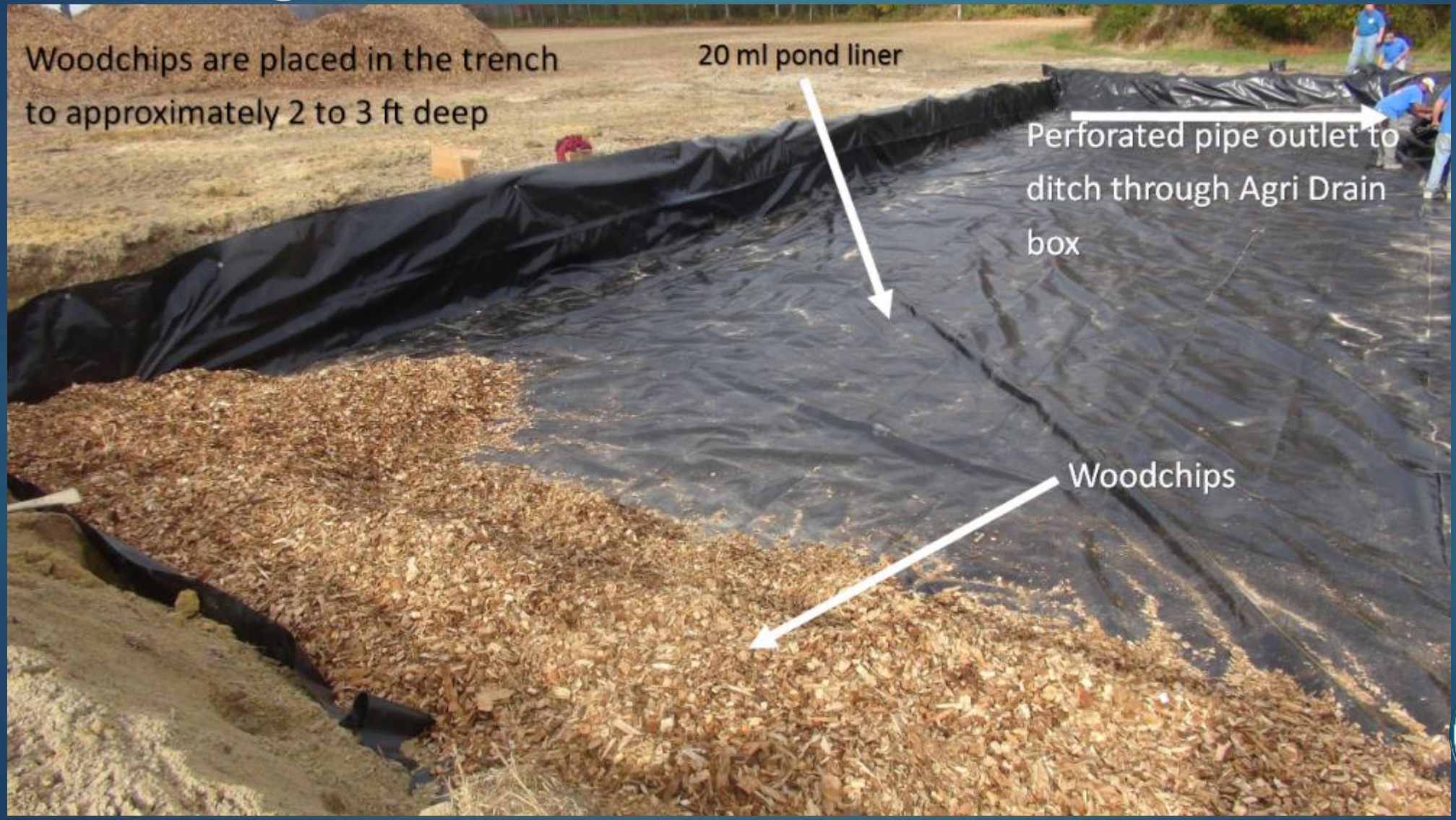
Background


Bioreactor Trench
Trench is dug approximately 3 to 4 feet deep
Outlet to Ditch
From three chambered box

Background


Perforated Pipe is placed at the start and end of the trench to inlet from the diversion box and outlet water to the ditch
20 ml pond liner– lines the inside of the trench to help retain water
From three chambered box
Perforated pipe

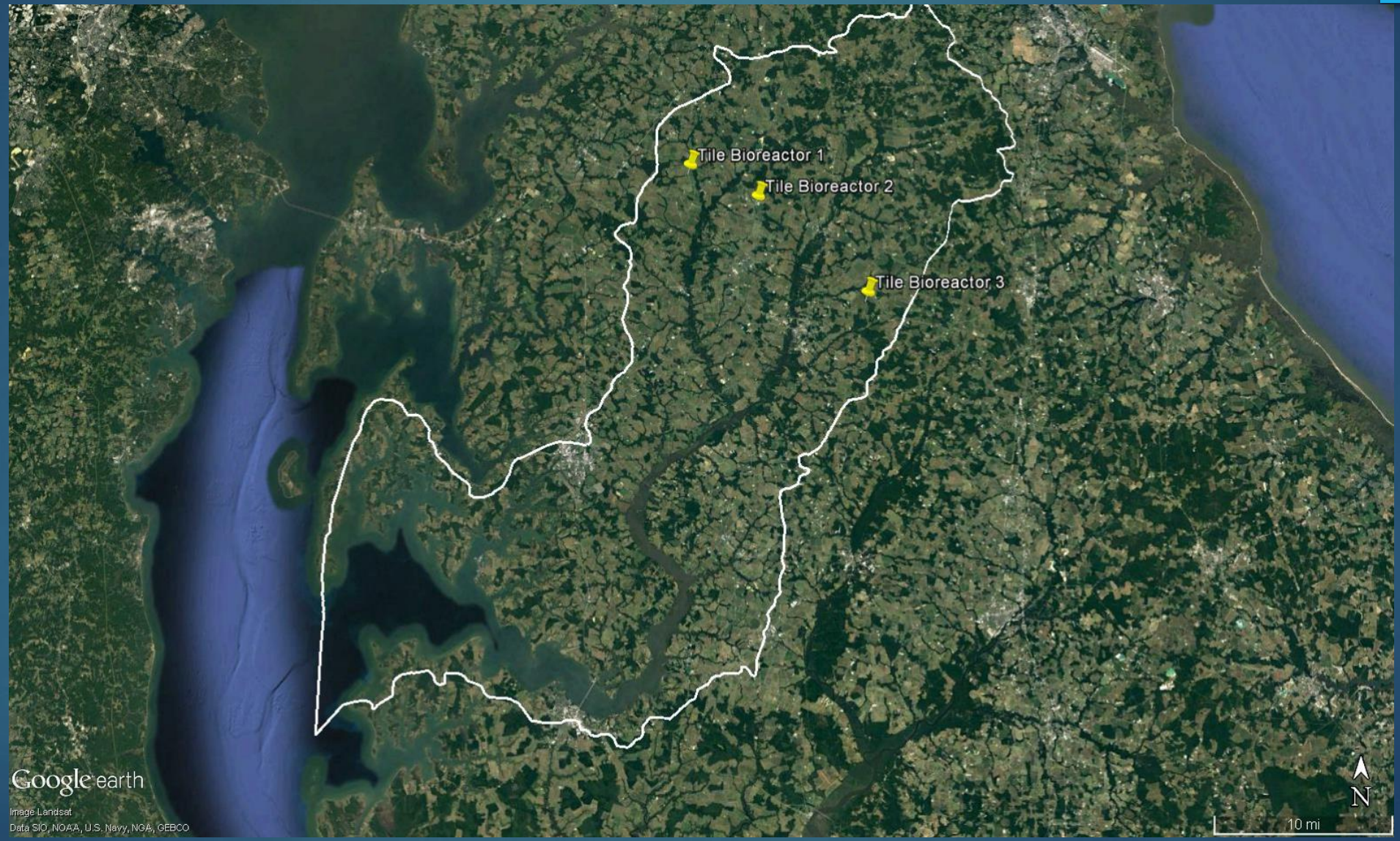
Background


Woodchips are placed in the trench to approximately 2 to 3 ft deep
20 ml pond liner
Perforated pipe outlet to ditch through Agri Drain box
Woodchips

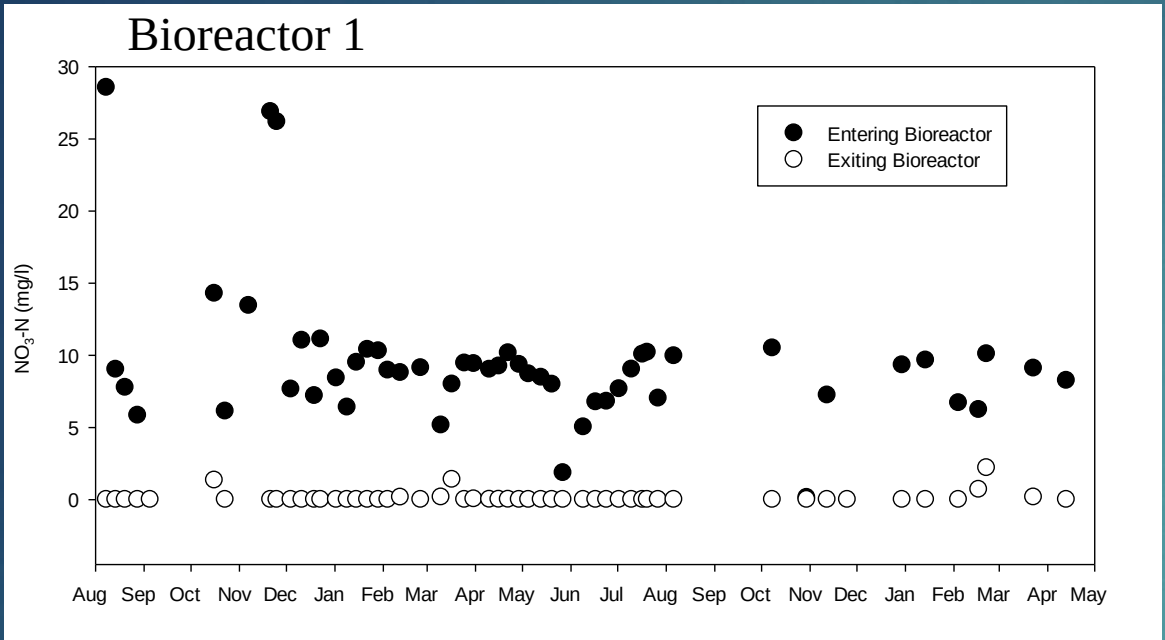
Background

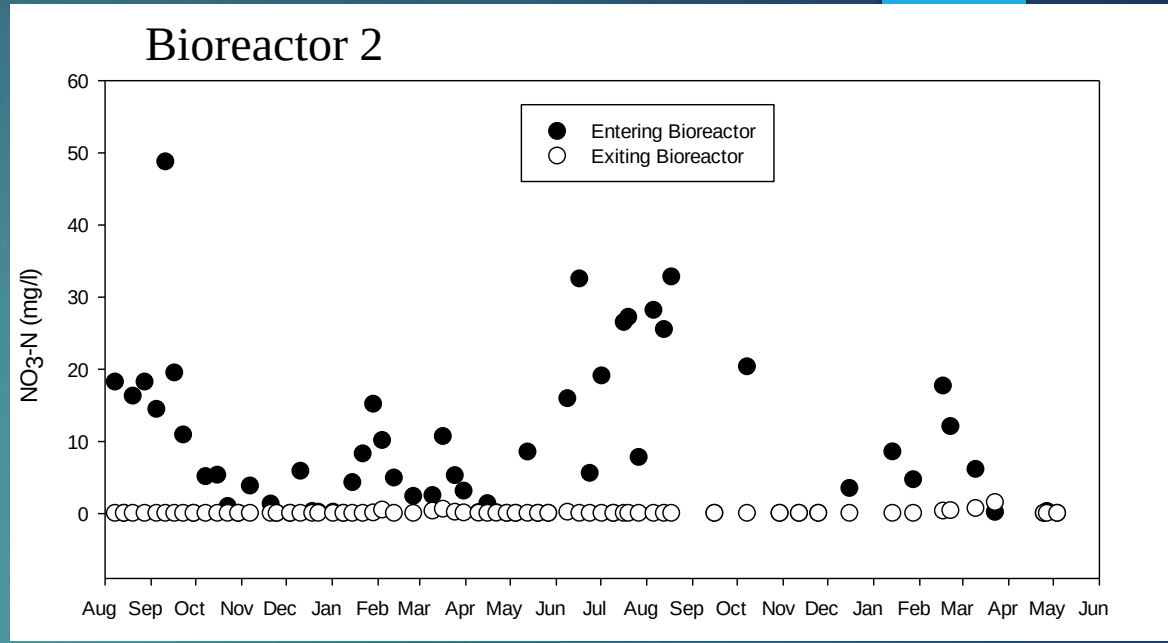
Trench is backfilled to surface elevation on the edge with slight crown in center

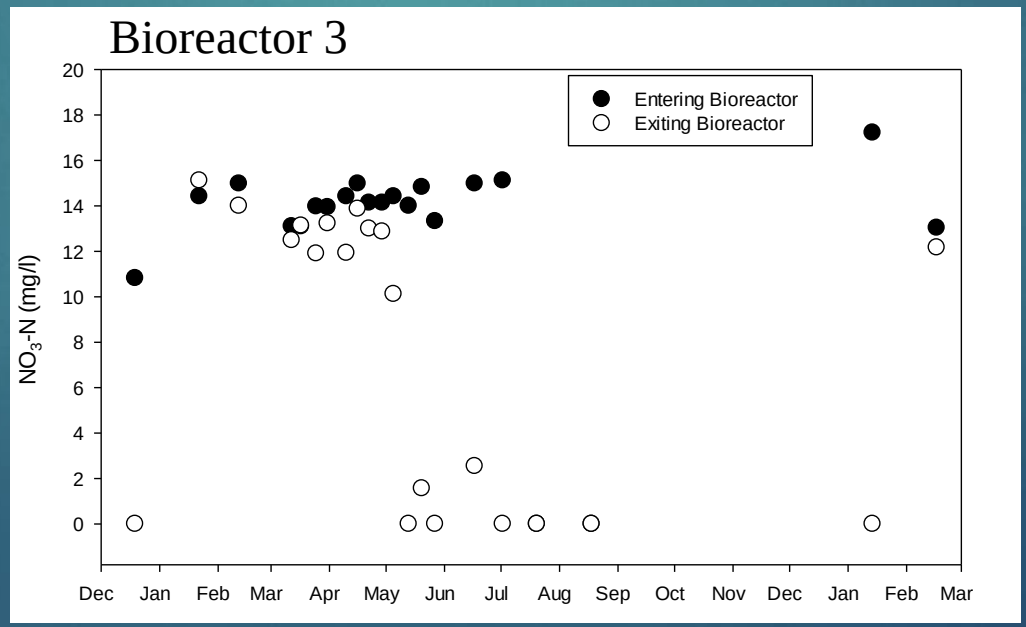
Locations


Tile Bioreactor 1
Tile Bioreactor 2
Tile Bioreactor 3
Google earth
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
N
10 mi

Results- Nitrate







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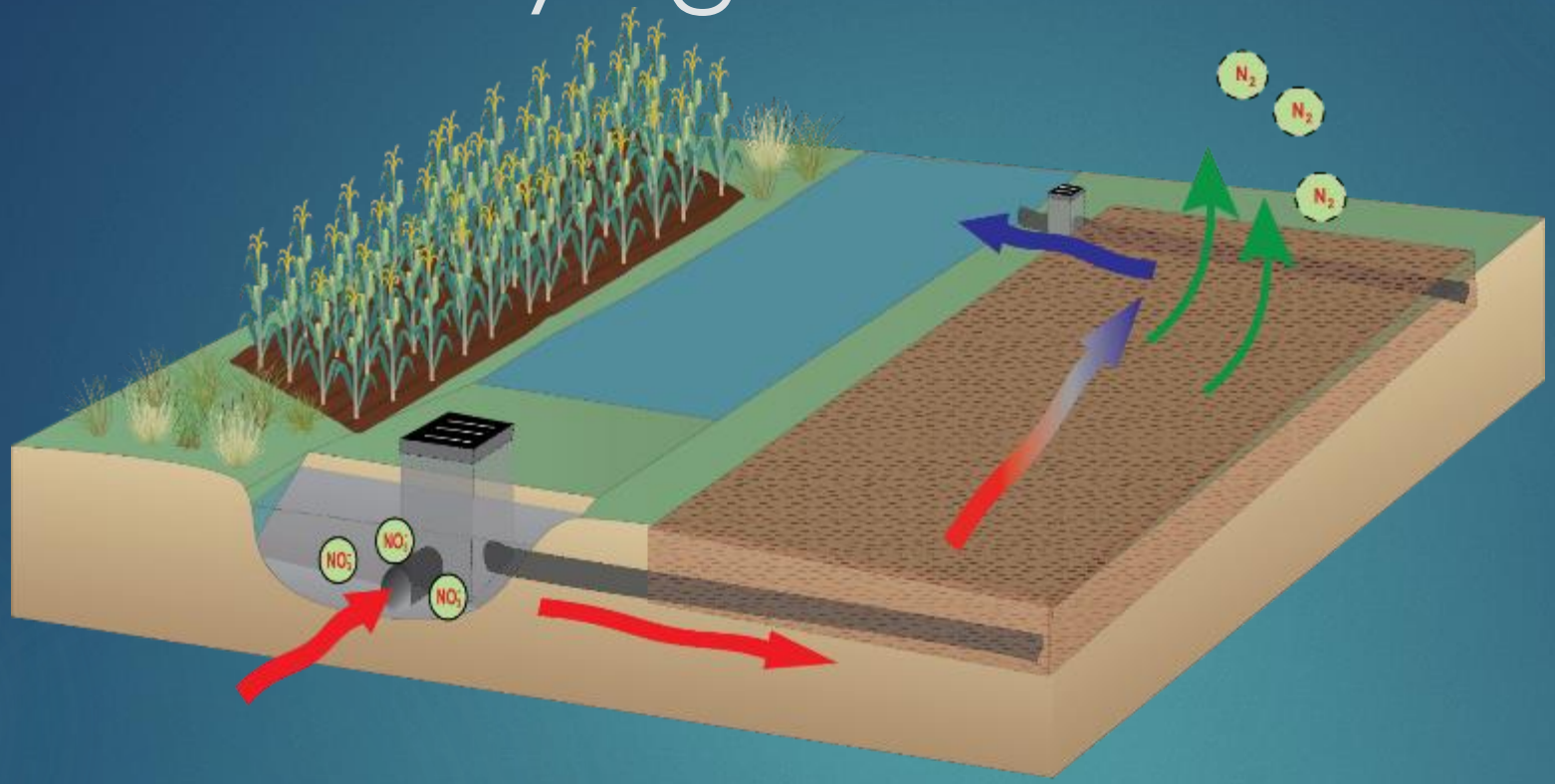
Results

	Flow		Bioreactor						Total (including by-pass flow)		
	Total volume from field	Percent treated in bioreactor	Flow weighted concentration: IN	Flow weighted concentration: OUT	Nitrate load: IN	Nitrate load: OUT	Nitrate removal efficiency	**Nitrate removal rate†**	Nitrate load: IN	Nitrate load: OUT	**Nitrate removal efficiency**
	m^3	%	mg NO_3-N/L		kg N		%	**g N removed per m^3 bioreactor per d**	kg N		**%**
Bioreactor 2											
8 Aug 2014-6 Aug 2015	37,000	13%	4.65	0.06	23	0.3	99%	**0.40**	251	229	**9.0%**
6 Aug 2015-22 Feb 2016 ‡	4,460	18%	9.43	0.11	7.7	0.1	99%	**0.24**	51	43	**15%**
Bioreactor 1											
8 Aug 2014-6 Aug 2015	18,400	63%	8.94	0.10	103	1.1	99%	**3.43**	158	57	**64%**
6 Aug 2015-30 Oct 2015 ‡	870	77%	7.69	0.39	31	1.6	95%	**2.23**	8.7	2.1	**76%**
Bioreactor 3											
19 Dec 2104-20 Jul 2015‡	49,700	98%	13.46	11.57	677	607	10%	**1.53**	688	618	**10%**

Results

	---------- Nitrate-N ----------		---------- Ammonium ----------		-------- Total Nitrogen --------		-- Orthophosphate --		----- Total Phosphorus -----	
	---------- mg N/L ----------						-------- mg PO_4/L -------		---------- mg TP/L --------	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Bioreactor 2	8.73 ± 10.7 (61) †	0.04 ± 0.1 (61) †	9.74 ± 11.1 (36)	14.3 ± 16.9 (36)	28.3 ± 20.6 (18) †	12.3 ± 7.3 (18) †	2.33 ± 2.7 (36)	1.61 ± 2.1 (36)	4.77 ± 4.8 (18)	3.22 ± 3.0 (18)
Bioreactor 1	9.52 ± 5.1 (50) †	0.12 ± 0.4 (51) †	0.23 ± 0.7 (30)	0.27 ± 0.5 (30)	11.7 ± 6.1 (14) †	2.47 ± 2.2 (14) †	0.16 ± 0.3 (30)	0.22 ± 0.4 (30)	0.61 ± 0.7 (14)	0.61 ± 0.8 (14)

Ditch Denitrifying bioreactor



Locations

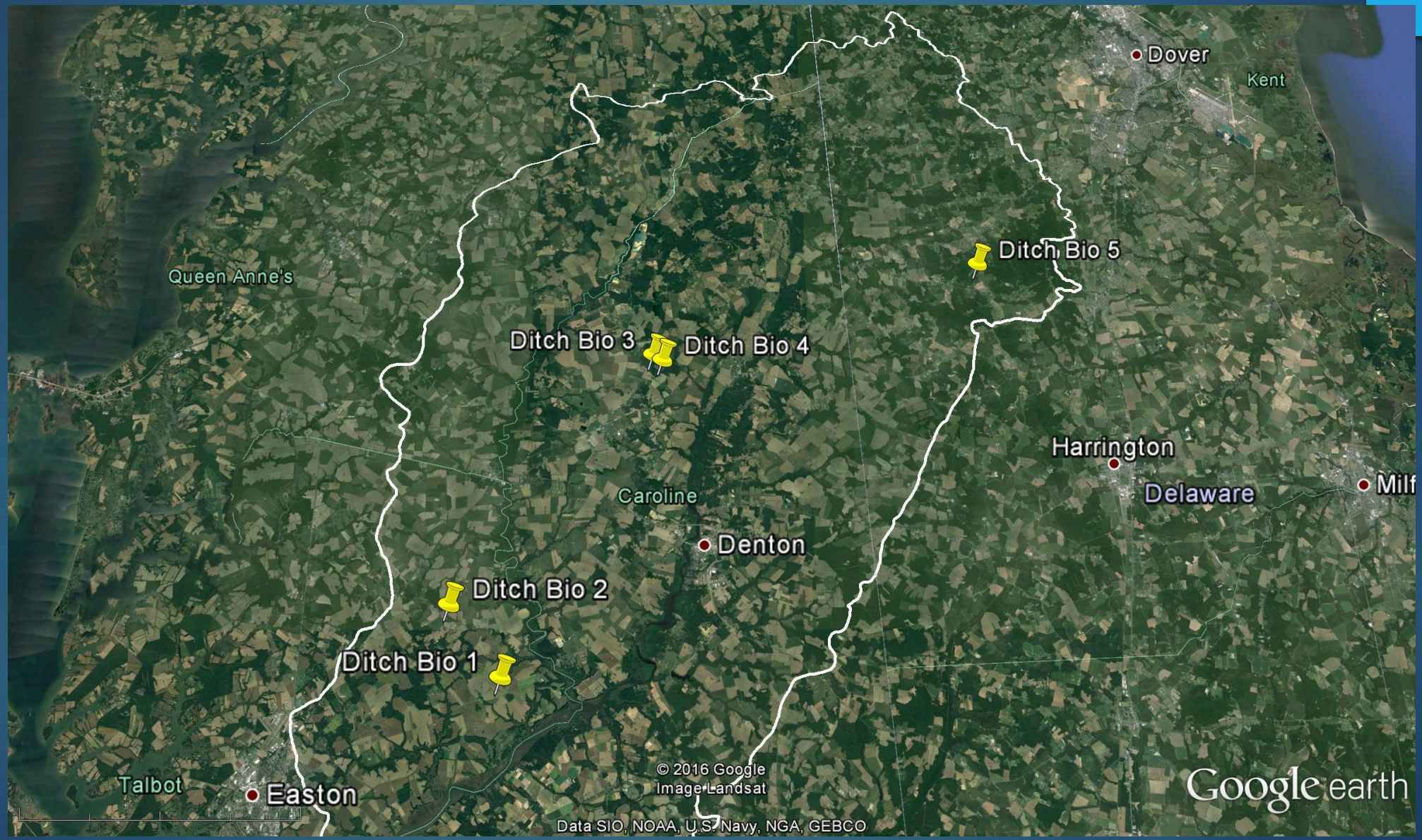

Dover
Kent
Queen Anne's
Ditch Bio 5
Ditch Bio 3
Ditch Bio 4
Harrington
Delaware
Caroline
Denton
Ditch Bio 2
Ditch Bio 1
Talbot
Easton
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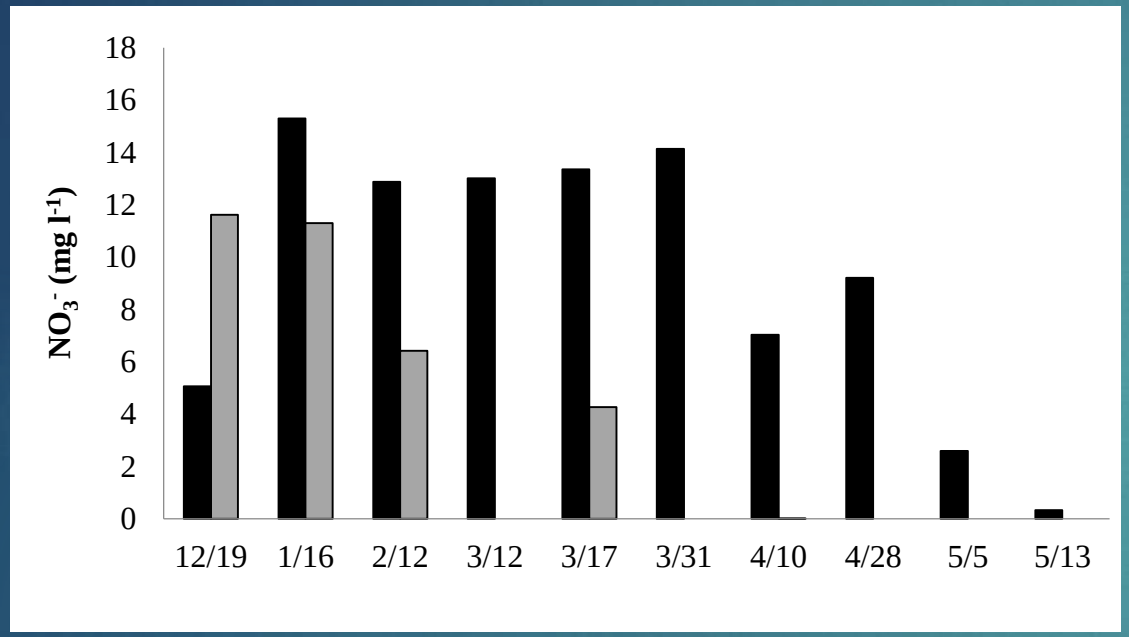
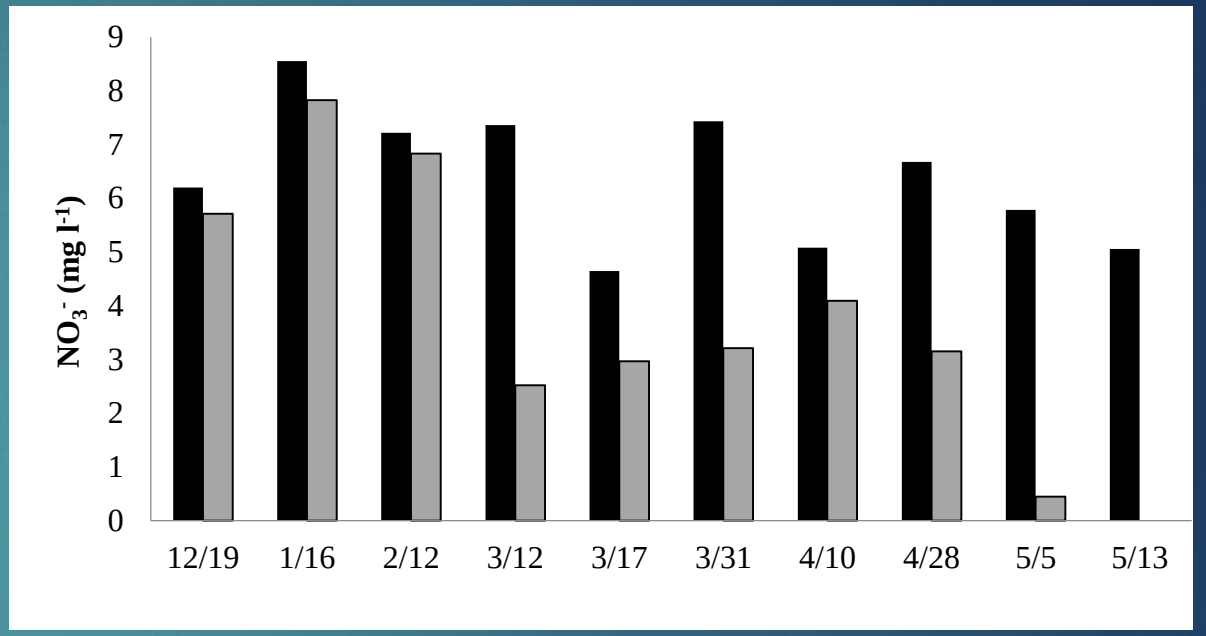
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth

First and Second Generation

First Generation

Nitrate Reduction (mg/l)-Base Flow

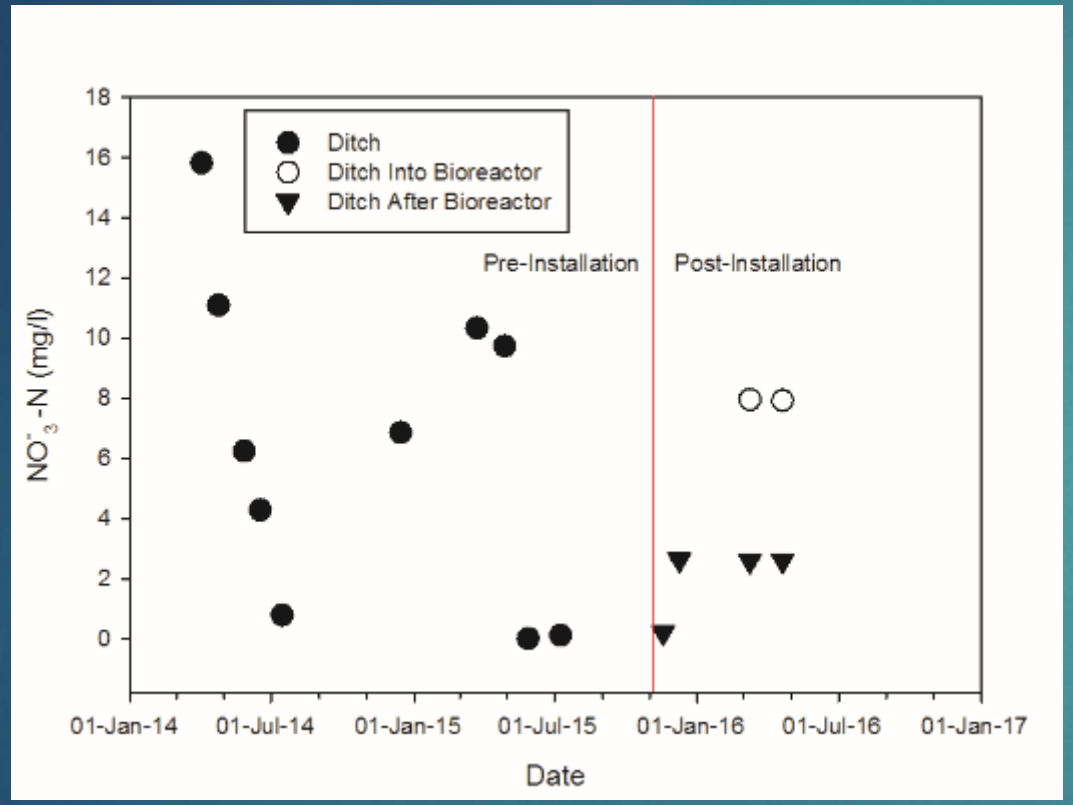


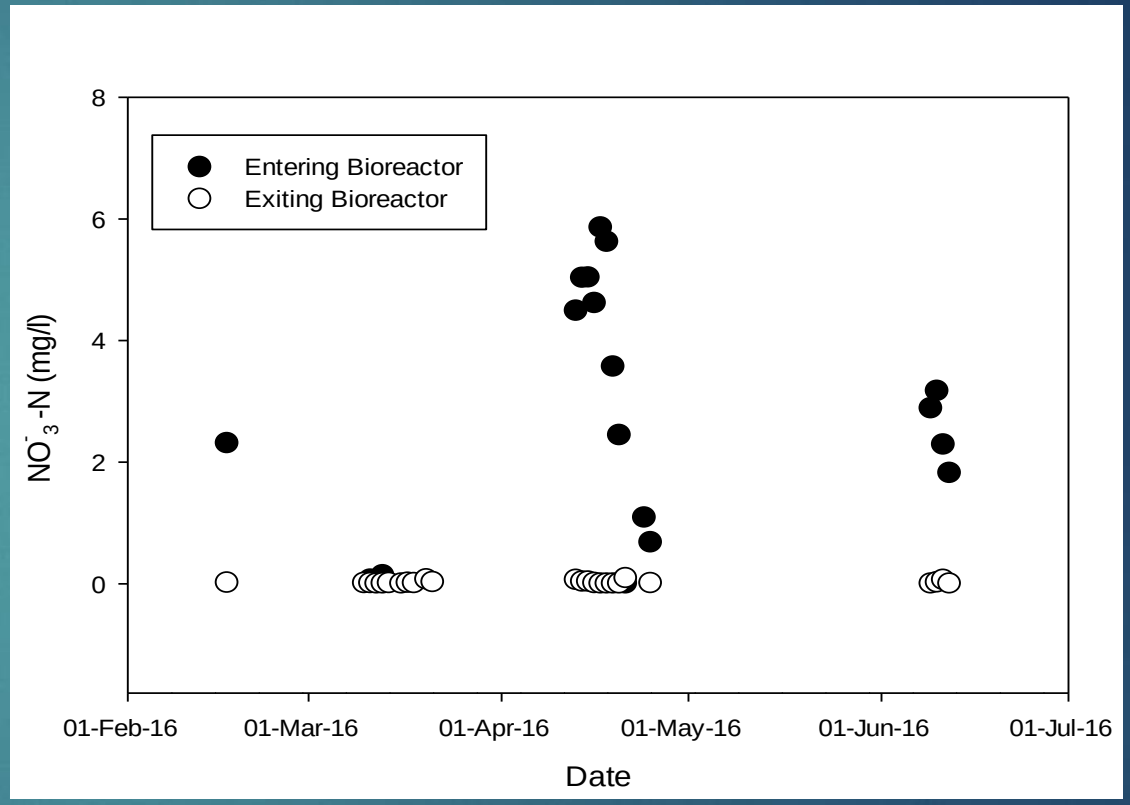


	Nitrate (mg/l)
Before	9.29
After	3.36
Reduction	63.8%

	Nitrate (mg/l)
Before	6.40
After	3.68
Reduction	42.6%

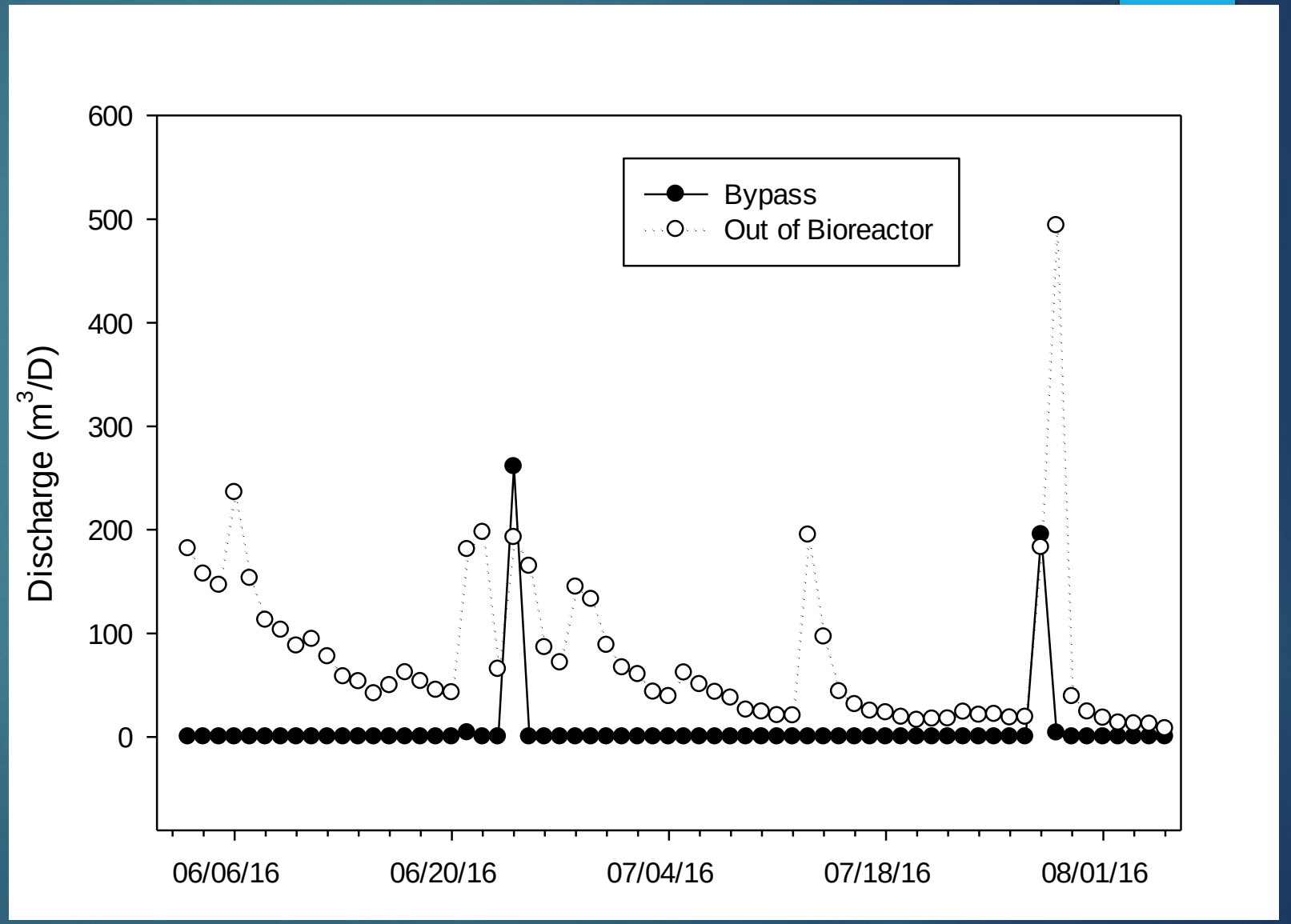
Second Generation





	Nitrate (mg/l)
Before	3.6
After	0.02
Reduction	99%

Second Generation



Questions?

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