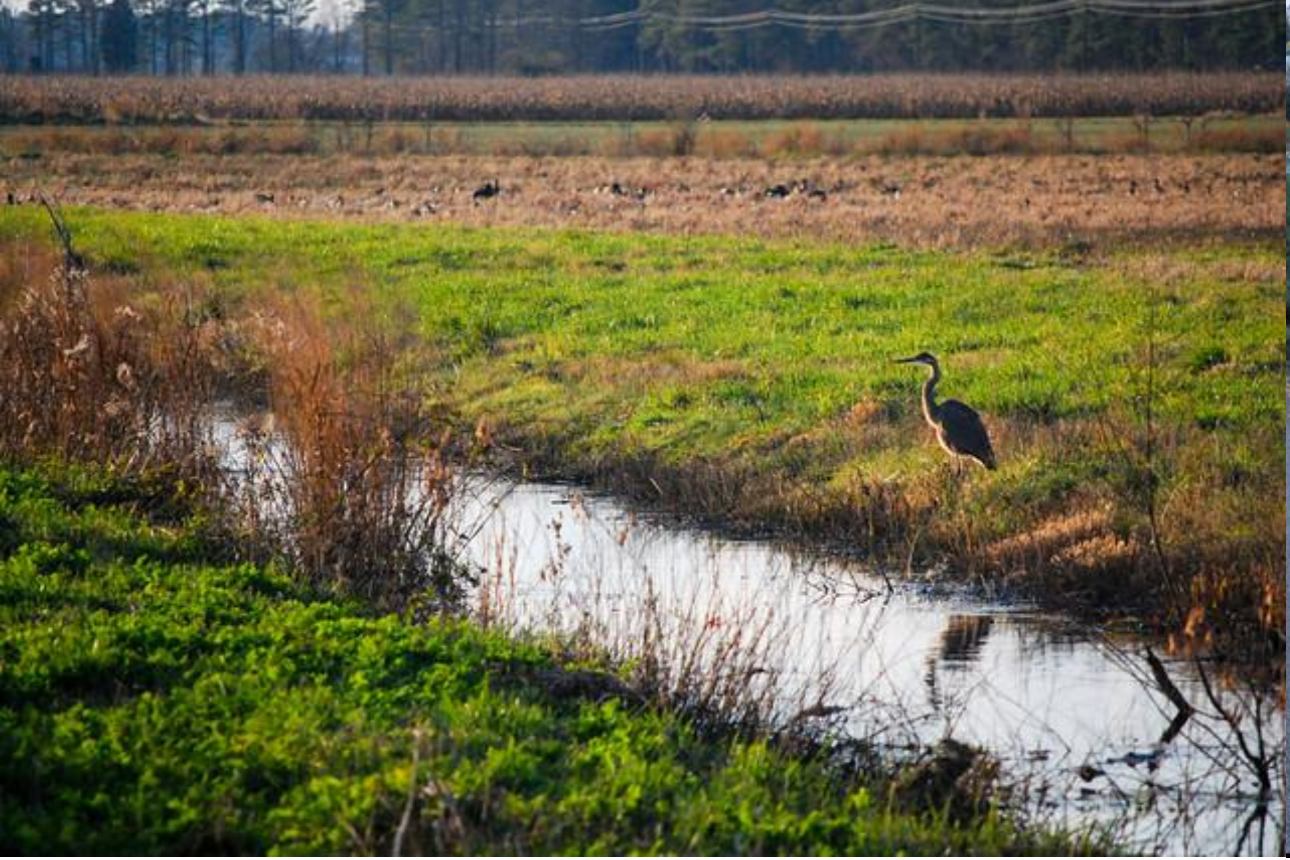


Recommendations of the BMP Expert Panel for Agricultural Ditch Management Practices

Wednesday, September 18, 2019

Welcome to the webcast! Everyone is currently muted. We will begin at 1:00pm.
This webcast will be recorded.

Chesapeake Bay Program
Science. Restoration. Partnership.

VIRGINIA TECH

Photos: Chesapeake Bay Program, https://flic.kr/ps/rYeEj

Getting started

- **If you can’t hear me right now, please double-check your audio!**
- Click the “start audio” button in your Zoom control panel and follow the prompts to connect audio through either your computer or conference line
  - If Zoom control panel is hidden, hover your mouse over the minimized control panel at the bottom or top of your screen; “start audio” is on left-hand side of panel
- Participants are muted automatically to avoid disruptions.
- Please enter your questions for the speakers into the chat box throughout the webinar.
  - We will note your questions and pose them later in the webcast, or at pauses as able. Therefore, please provide a slide number if your question refers to a specific slide.
- We are recording this session and will post the link to the CBP event calendar entry for this webcast (along with slides and all other materials): https://bit.ly/2k4HXgk

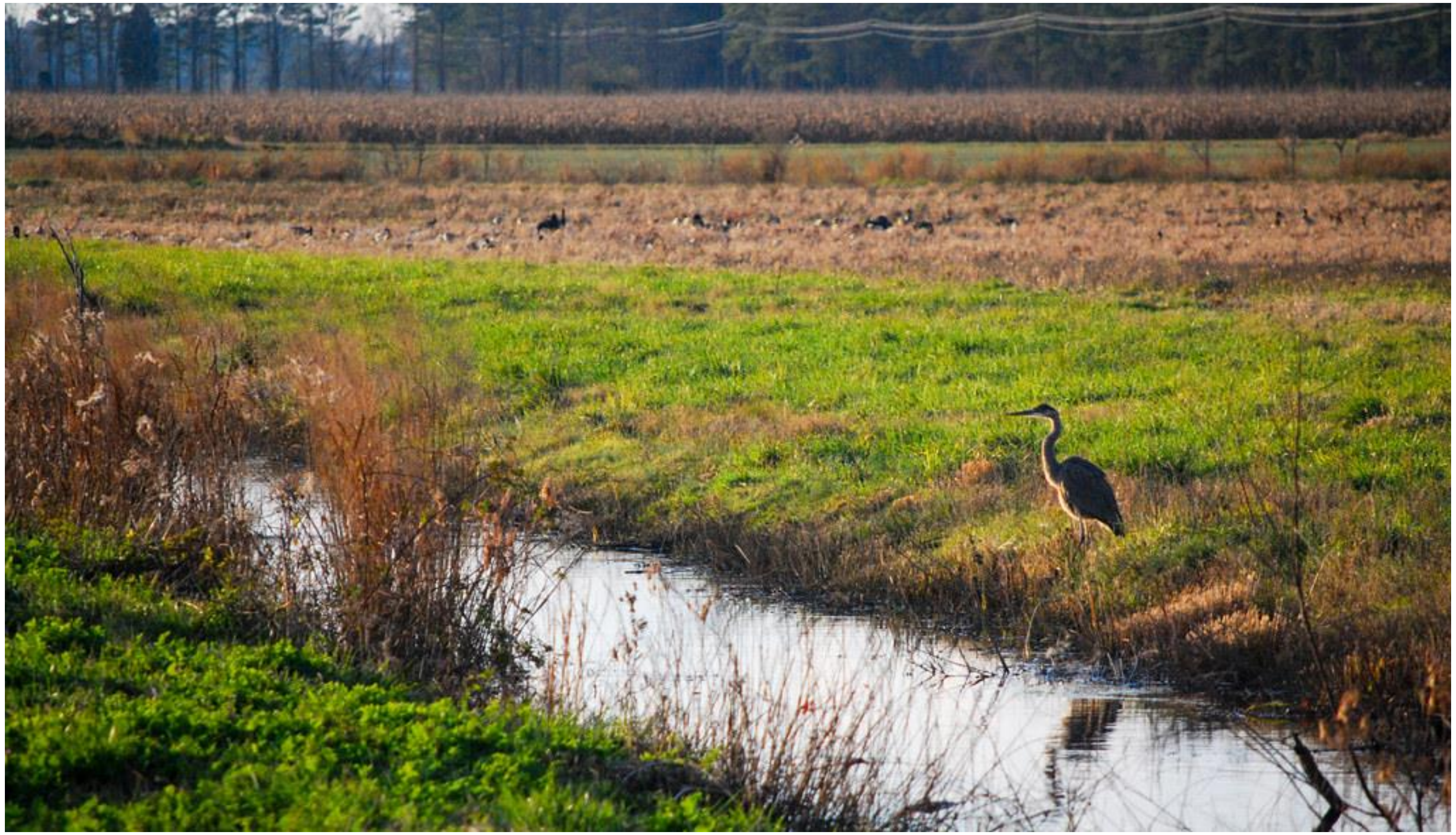
Jeremy Hanson
Virginia Tech, Panel Coordinator

(Right) Photo credit: Sabrina Klick, Univ. of Maryland Eastern Shore

Webcast Agenda

- Introduction and Overview of the Panel Process
- Scope, Charge and Membership of the Expert Panel
- Summary of panel recommendations
- Panel recommendations
    - Blind Inlets
    - Denitrifying Bioreactors
    - Drainage water management
    - Phosphorus removal systems
    - Saturated buffers
- Future research and management needs
- General Q&A (30 mins)

Photo credit: Sabrina Klick, Univ. of Maryland Eastern Shore



What is a BMP Expert Panel?

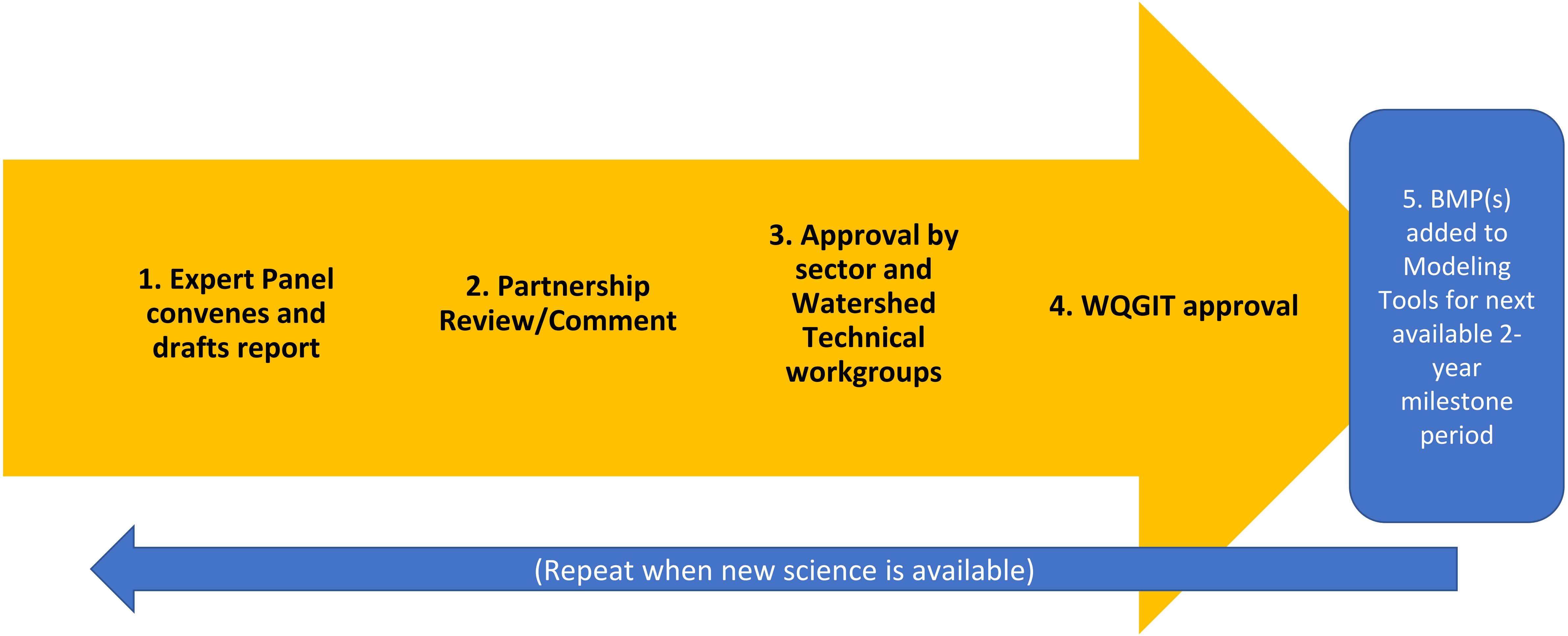
Best Management Practices (BMPs) are practices or technologies that reduce pollution loads when implemented or installed (can be structural, non-structural, programmatic)

Expert panels use the best available science and best professional judgment to inform the Chesapeake Bay Program partnership how much a BMP reduces pollution

- The panel writes a report with a lot of information in it
- They follow the BMP Protocol

Expert panels focus on the water quality benefits – specifically, the nitrogen, phosphorus and sediment reductions – associated with BMPs. They consider ancillary effects, too.

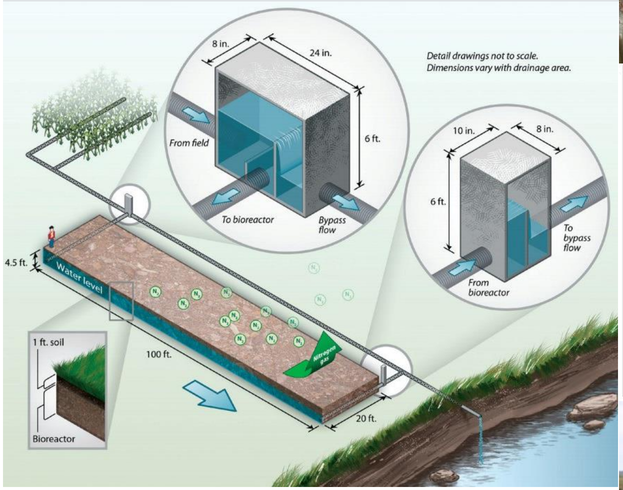
The “BMP Protocol” process (simplified)

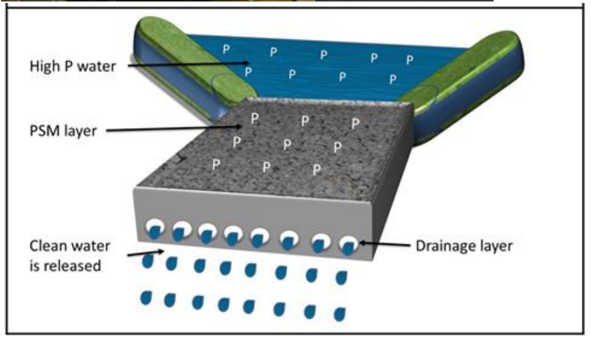


Panel Charge and Membership

Panel Charge

- Formed to evaluate nitrogen, phosphorus and sediment reduction benefits of several management practices associated with agricultural ditches/drainage:
  - ✓ Blind Inlets
  - ✓ Denitrifying Bioreactors
  - ✓ Drainage water management
  - ✓ Phosphorus removal systems
  - ✓ Saturated buffers
  - ❑ Gypsum curtains
  - ❑ Two-stage ditches
  - ❑ Denitrifying curtains
  - ❑ Ditch dipouts (dredging)
  - ❑ Bioreactors that treat springs/seeps





Panel membership and support roster

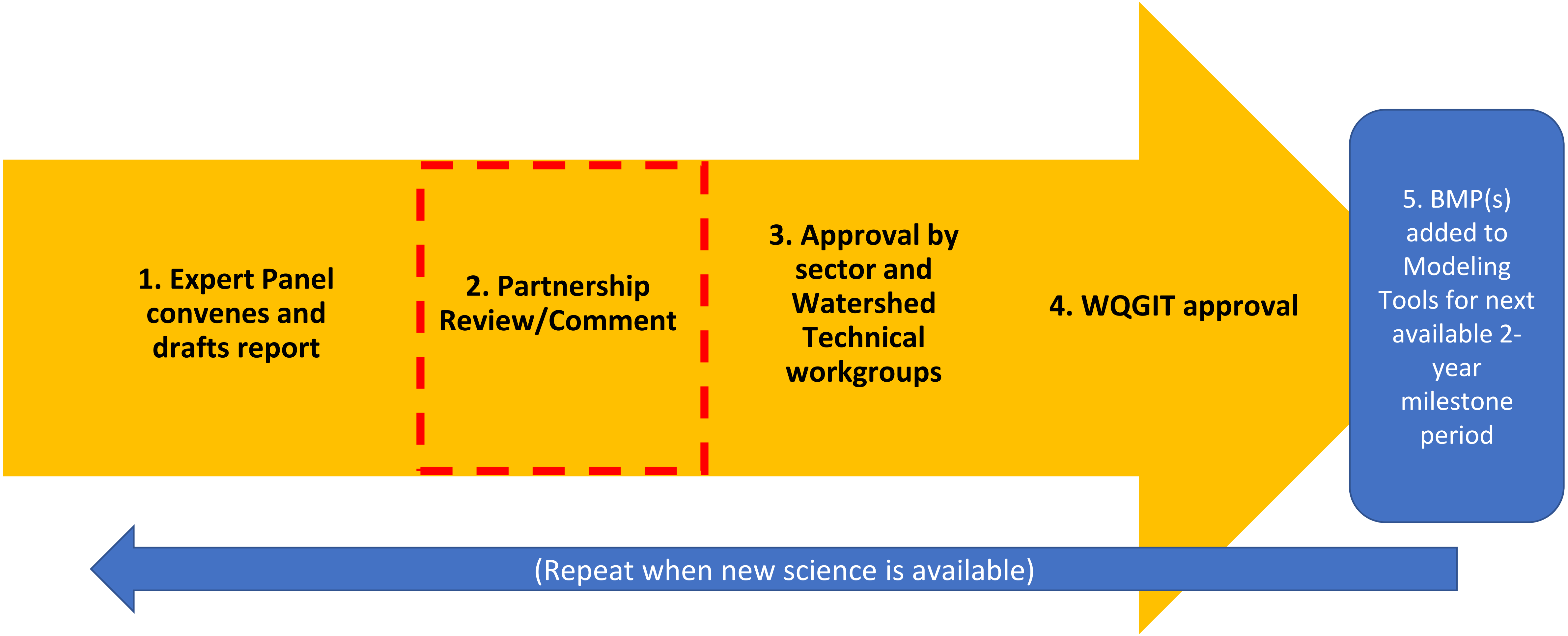
Name	Affiliation
Ray Bryant, PhD, Panel Chair	**USDA Agricultural Research Service**
Ann Baldwin, PE	**USDA Natural Resources Conservation Service**
Brooks Cahall	**Delaware Department of Natural Resources and Environmental Control**
Laura Christianson, PhD PE	**University of Illinois**
Dan Jaynes, PhD	**USDA Agricultural Research Service**
Chad Penn, PhD	**USDA Agricultural Research Service**
Stuart Schwartz, PhD	**University of Maryland – Baltimore County**
Panel Support	
Loretta Collins	*University of Maryland, AgWG Coordinator*
Clint Gill	*Delaware Department of Agriculture*
Jeremy Hanson	*Virginia Tech, CBPO*
Brian Benham	*Virginia Tech*
Mark Dubin	*University of Maryland*
Jeff Sweeney	*EPA CBPO*
Allie Wagner	*CRC, CBPO*
Lindsey Gordon	*CRC, CBPO*

Panel Timeline

- Charge approved by Agriculture Workgroup: Feb. 2016
- Membership approved by AgWG: April 2016
- Convened for first call in May 2016
- Open stakeholder session: August 31, 2016 (https://bit.ly/2mdb2a0)
- Panel calls and deliberations thru July 2019
- Report posted and distributed: September 4-5, 2019
- “Roll-out” webcast: September 18, 2019 (today)
- **Feedback requested by COB October 7, 2019**
- Tentative timeline for decision/approval:
  - Agriculture WG: November
  - Watershed Technical WG: Early December
  - WQGIT: December

Photo credit: USDA NRCS

The “BMP Protocol” process (simplified)



Some notes for the audience

- “Roadside ditch” versus “agricultural ditch”
  - No firm or comprehensive distinctions, but some general differences (for current purposes, but can be refined for future CBP efforts)
    - Roadside ditches are adjacent to roads/highways, often managed by local/state transportation or highway agencies but can also be privately managed
    - Agricultural ditches help manage drainage from cropland or adjacent agricultural land uses; publicly managed by PDAs (MD) and Tax Ditch Associations (DE), or privately-owned.
    - Both can be adjacent to roads, so not mutually exclusive.
- We won’t be able to replicate the detail of this presentation at subsequent workgroup/GIT meetings

Cut for time: see report for more information

- Basic background about Watershed Model and agriculture loads
- Appendix A: Technical appendix, including info about reporting for NEIEN, application within CAST scenarios
- Ancillary benefits, potential hazards or unintended consequences

Today’s speakers

Ray Bryant, PhD

Panel Chair

USDA, ARS

Laura Christianson, PhD, PE

Panel Member

Univ. of Illinois

Ann Baldwin, PE

Panel member

USDA NRCS

Loretta Collins

CBP AgWG Coordinator

Univ. of Maryland

Agricultural Ditch Management BMP Expert Panel

Photos: Chesapeake Bay Program

Outline: Ag ditches management panel

I. Summary of panel recommendations

II. Panel recommendations, such as the following for each category of practices:
   - Overview and main findings
   - Definitions
   - Key factors
   - Review of science (inside/outside watershed)
   - Recommendations
   - Specific gaps or research needs

III. Future research and management needs

Outline: Ag ditches management panel

I. Summary of panel recommendations
II. Panel recommendations
   a) Blind Inlets
   b) Denitrifying Bioreactors
   c) Drainage water management
   d) Phosphorus removal systems
   e) Saturated buffers
III. Future research and management needs

Summary of Recommendations

I. Summary of Recommendations

BMP	NRCS P Code	Reduction efficiency	Application	Credit duration
Blind inlets	620, 606	0% TN, 40% TP, 60% Sed.	Drained area (ac.)	5 Yr
Blind inlets w/ P-sorbing materials		0% TN, 50% TP, 60% Sed.	Drained area (ac.)	5 Yr
Denitrifying bioreactors	605	20% TN, 0% TP, 0% Sed.	Drained area (ac.)	10 Yr
WC Structures	587	0% TN, 0% TP, 0% Sed.	Drained area (ac.)	N/A
Drainage Water Management	554	30% TN, 0% TP, 0% Sed.	Drained area (ac.)	Annual
P removal systems	782	0% TN, 50% TP, 60% Sed.	Drained area (ac.)	4 yr
Saturated buffers	604	20% TN, 0% TP, 0% Sed.	Drained area (ac.)	10 Yr

Outline: checking in

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II. Panel recommendations
   a) Blind Inlets
   b) Denitrifying Bioreactors
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   d) Phosphorus removal systems
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III. Future research and management needs

Panel recommendations

Photos: Chesapeake Bay Program

Blind Inlets

The blind inlet acts to filter drainage water prior to it entering the subsurface tile drain. Blind inlets are used to drain depressions in poorly drained locations within a field.

From the perspective of water quality, the benefit from installation of a blind inlet is only realized when the blind inlet replaces an existing open inlet (e.g., tile riser).

Blind Inlets

Main Findings

- 60% Sediment reduction
- 40% TP load reduction
  - No credit for TN load reduction

Based on:

- Peer-reviewed research from outside of the watershed
- Current research from inside and outside of the watershed
- NRCS conservation practice standard

Definitions and concepts

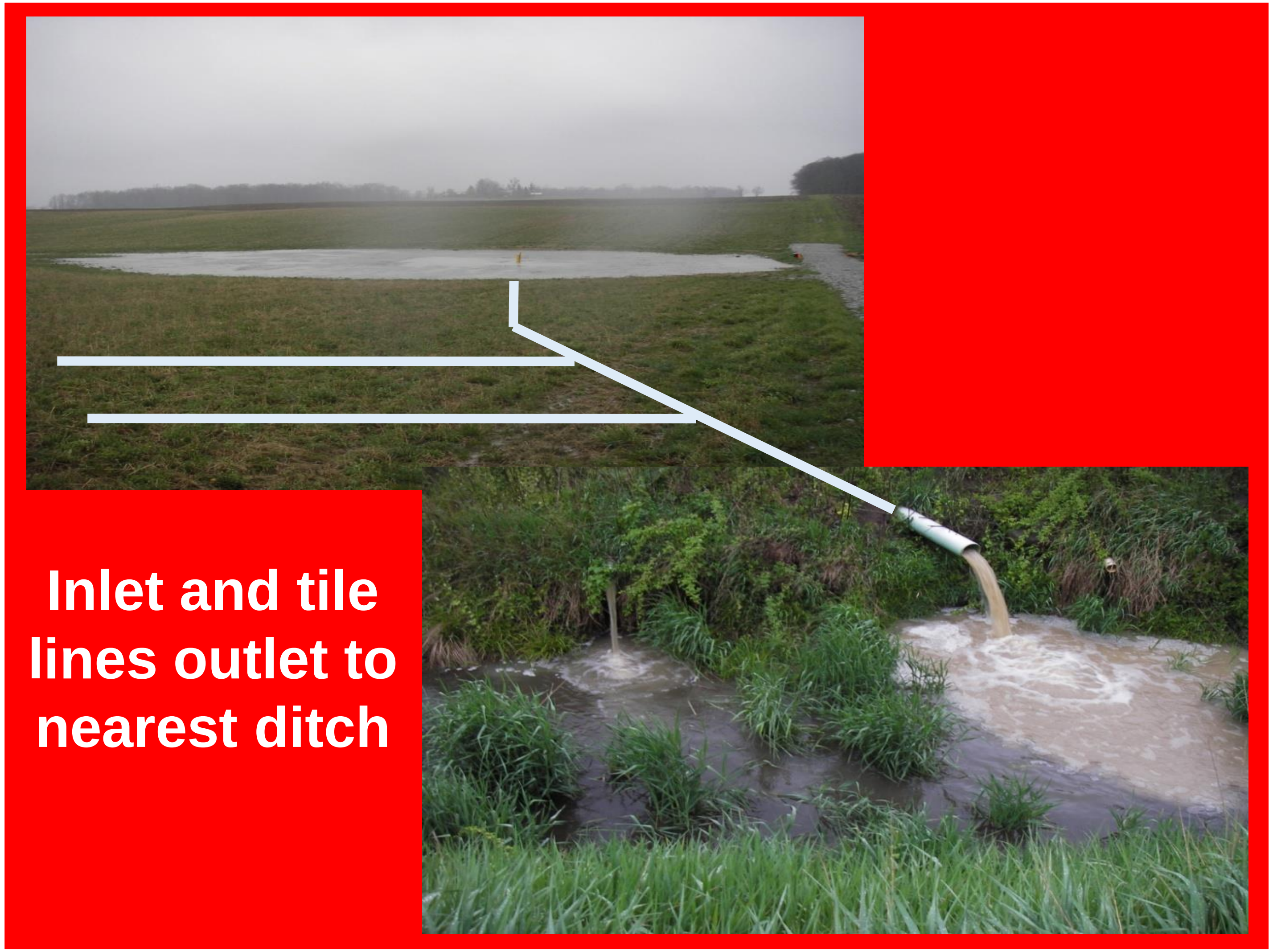
Traditional Tile Well and Tile Riser

A perforated pipe or open inlet extending vertically out of the ground that is connected to a subsurface tile drain pipe. These are used to drain depressions in poorly drained locations within a field.

Definitions and concepts

Subsurface Tile & Tile Inlet Flow

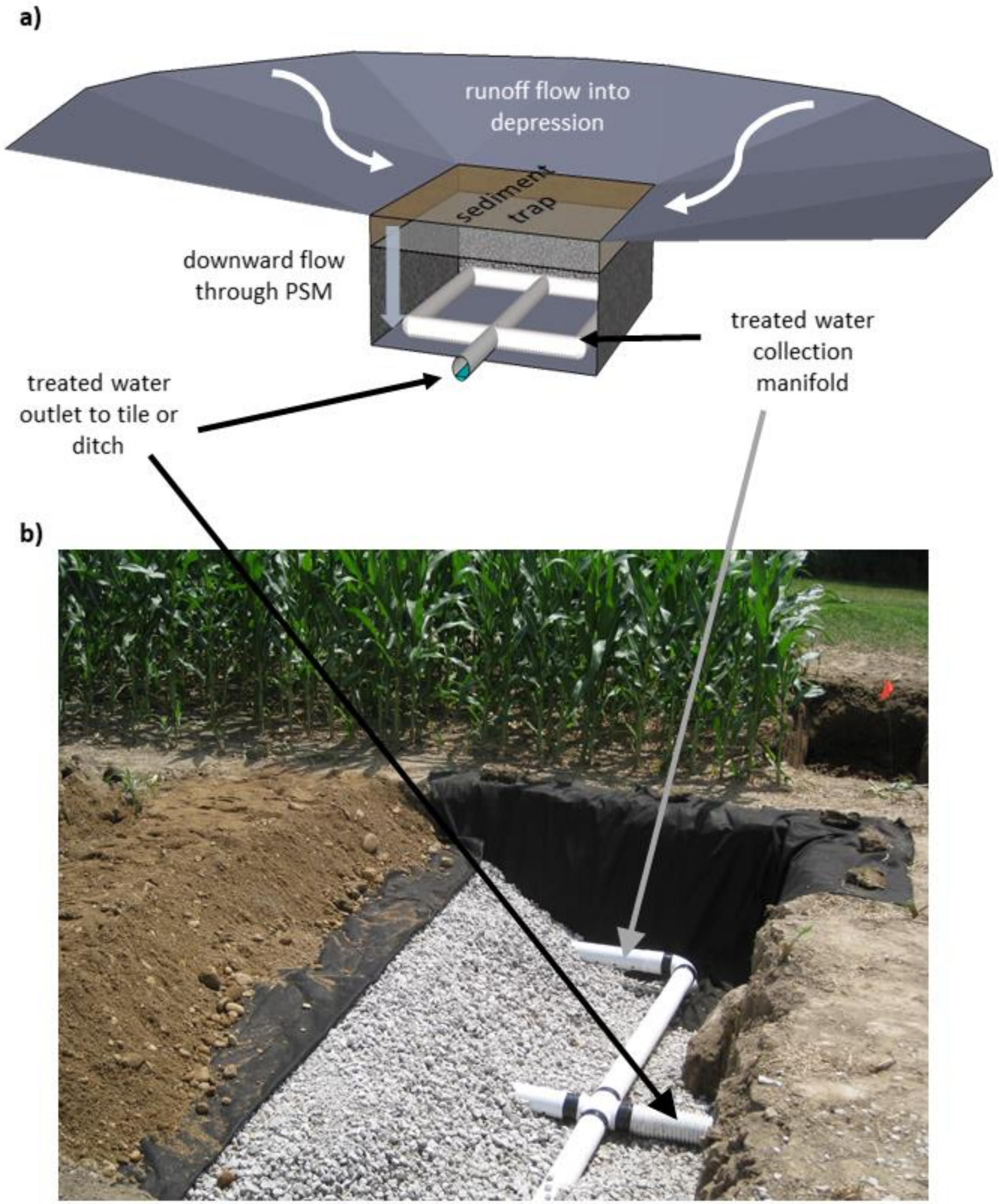
In much of the Coastal Plain, planting a crop would not be possible without drainage.



Definitions and concepts

Blind Inlet

A type of French drain attached to a subsurface tile drain, where perforated pipe is placed at the bottom of an excavated hole that is then backfilled with pervious material (gravel and sand). The uppermost gravel or sand layer is covered with soil. The blind inlet acts to filter drainage water prior to it entering the subsurface tile drain.



Definitions and concepts

Blind Inlet Construction

Definitions and concepts

Gravel Inlets

Rock inlets have been tested in other locales as an alternative to tile risers:

- Not as effective at decreasing contaminant loads initially
- Silt in with time to become as effective as a blind inlet
- Panel makes no distinction between blind inlets and gravel inlets

Key factors

Blind Inlets

Blind inlets are designed to be farmed over

- Reductions are applied to the size of the drained area (ac)
- Small areas may be subject to drought stress

The benefit from installation of a blind inlet is only realized when the blind inlet replaces an existing open inlet

United States Department of Agriculture

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

SUBSURFACE DRAIN

(Ft.)

CODE 606

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

UNDERGROUND OUTLET

(Ft.)

CODE 620

Use blind inlets where the installation of an open or above ground structure is impractical. Design the blind inlet with a graded granular filter around the conduit. Design the filter based on the particle size of the surrounding soil and the desired flow rate. Refer to NEH Part 650, Engineering Field Handbook, Chapter 14 for the design of blind inlets.

Review of science (inside/outside watershed)

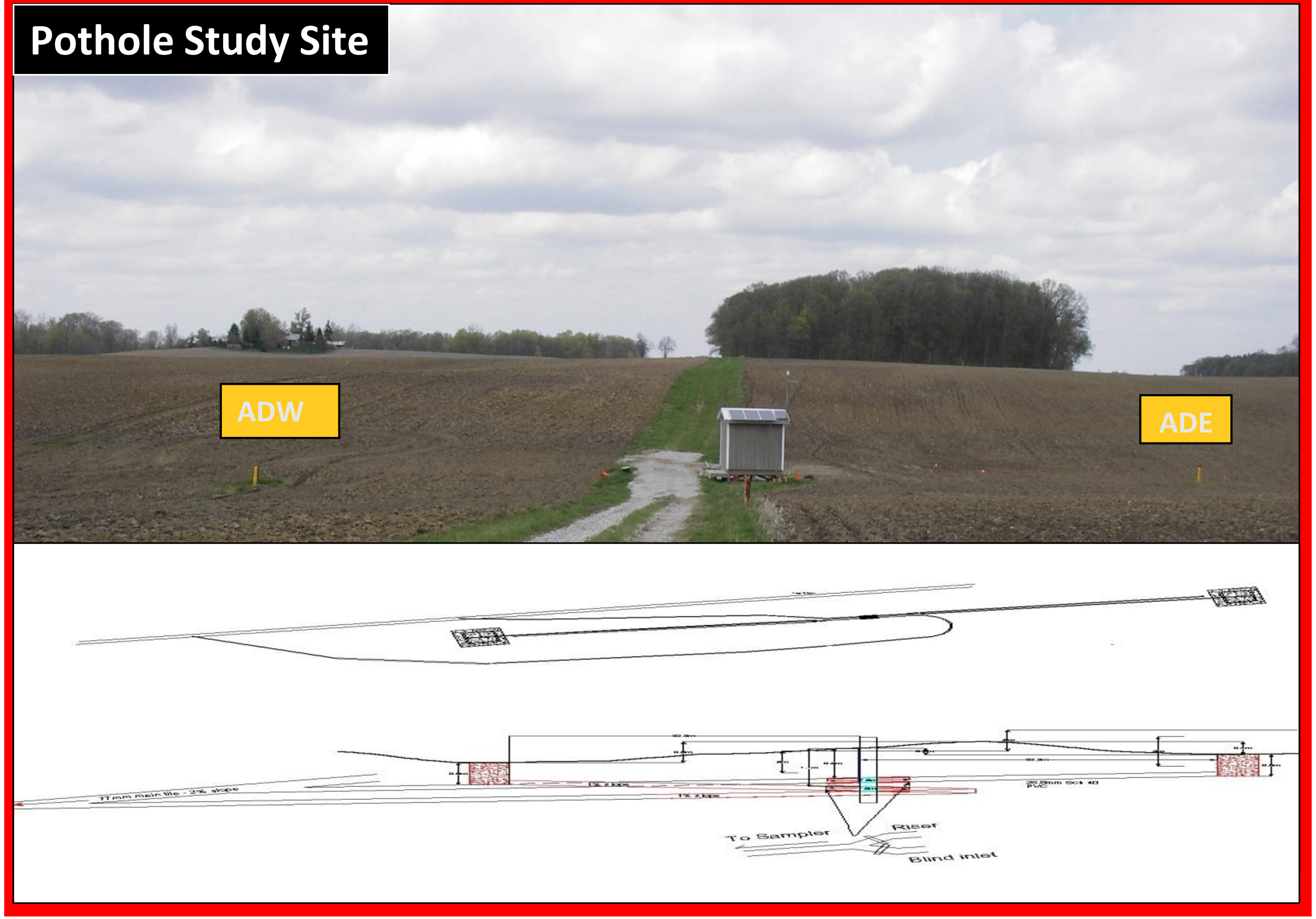
References

Feyereisen, et al. 2015. JEQ 44(2):594-604.

Ryan & Elimelech. 1996. Colloids and surfaces 107: 1-56.

Smith & Livingston. 2013. Soil Use and Mgmt. 29: 94-102.

Williams, et al. 2018. J. Soil Water Cons.



Blind Inlets Recommendations

- 60% Sediment reduction
- 40% TP load reduction
    - No credit for TN load reduction
- Application: Drained area (acres)
- Credit Duration: 5 yr
- Based on:
    - Peer-reviewed research from outside of the watershed
    - Current research from inside and outside of the watershed
    - NRCS conservation practice standards 620, 606
- ***The benefit from installation of a blind inlet is only realized when the blind inlet replaces an existing open inlet (e.g., tile riser).***

Recommendations for Blind Inlets Constructed with P-sorbing Materials

- 60% Sediment reduction
- 50% TP load reduction (10% more P removal)
  - No credit for TN load reduction
- Application: Drained area (acres)
- Credit Duration: 5 yr
- Based on:
  - Peer-reviewed research from outside of the watershed
  - Current research from inside and outside of the watershed
  - NRCS conservation practice standards 620, 606
- ***The benefit from installation of a blind inlet is only realized when the blind inlet replaces an existing open inlet (e.g., tile riser).***

Specific gaps or research needs

Better field assessments of the blind inlet are needed in order to better quantify their effectiveness. **Sites should continue to be installed and monitored within the watershed which would require monitoring open inlets prior to replacing them with blind inlets and continued monitoring to assess sediment and nutrient reductions.**

Outline: checking in

I. Summary of panel recommendations

II. Panel recommendations

  a) Blind Inlets
  b) Denitrifying Bioreactors
  c) Drainage water management
  d) Phosphorus removal systems
  e) Saturated buffers

III. Future research and management needs

Denitrifying Bioreactors

Main findings:

- 20% TN load reduction
  - No credit for P or TSS load reductions

Based on:

- Measured data from inside and outside of the watershed
- NRCS conservation practice standard

What is a denitrifying woodchip bioreactor?

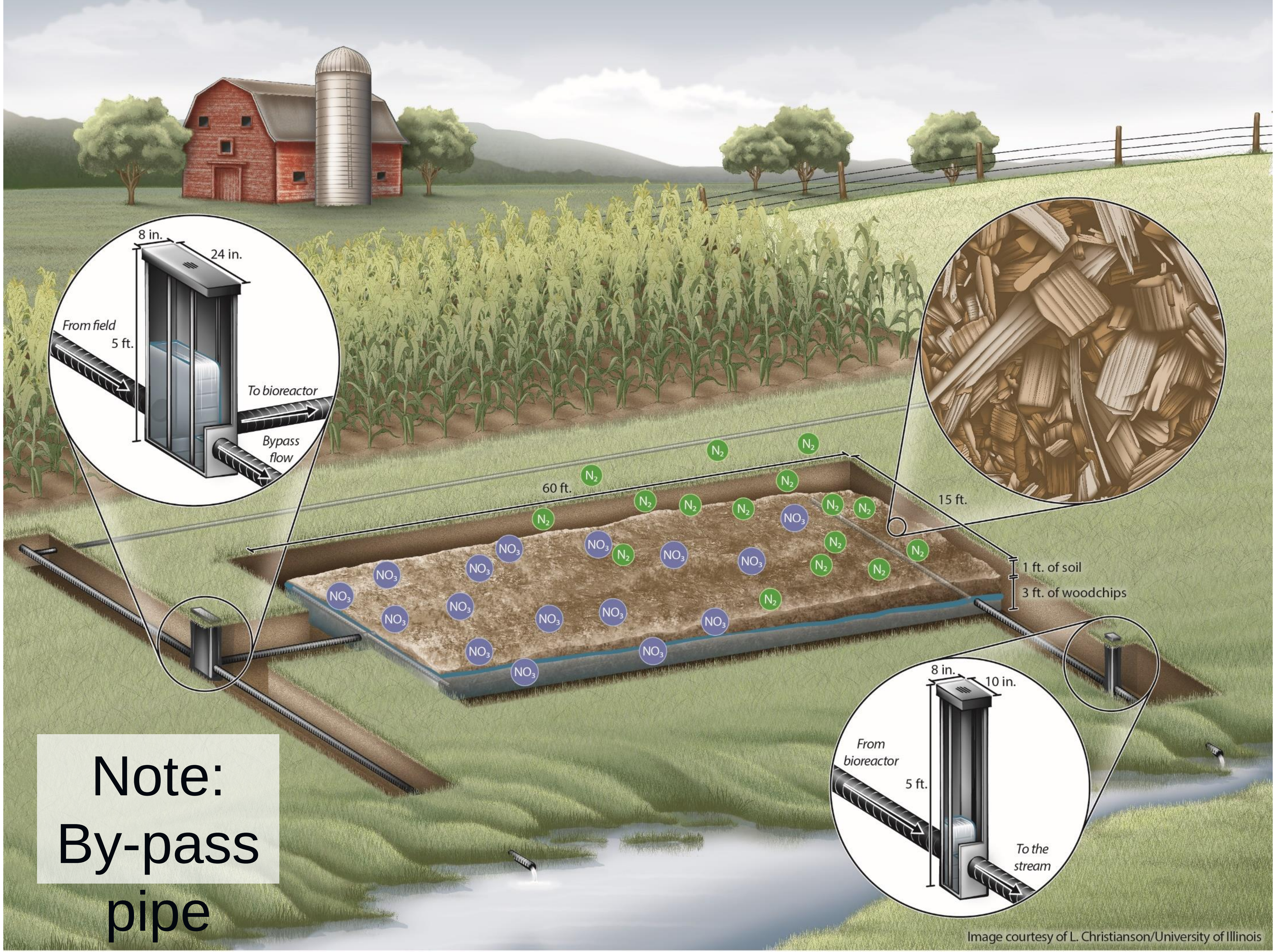
Drainage area	17 ac
L x W x D (ft)	50 x 12 x 3
Total volume	1800 ft^3
L:W ratio	4.2
Inlet tile size	4 inch

What is a denitrifying woodchip bioreactor?

Drainage area	50 ac
L x W x D (ft)	44 x 11 x 3
Total volume	1450 ft^3
L:W ratio	4.0
Inlet tile size	6 inch

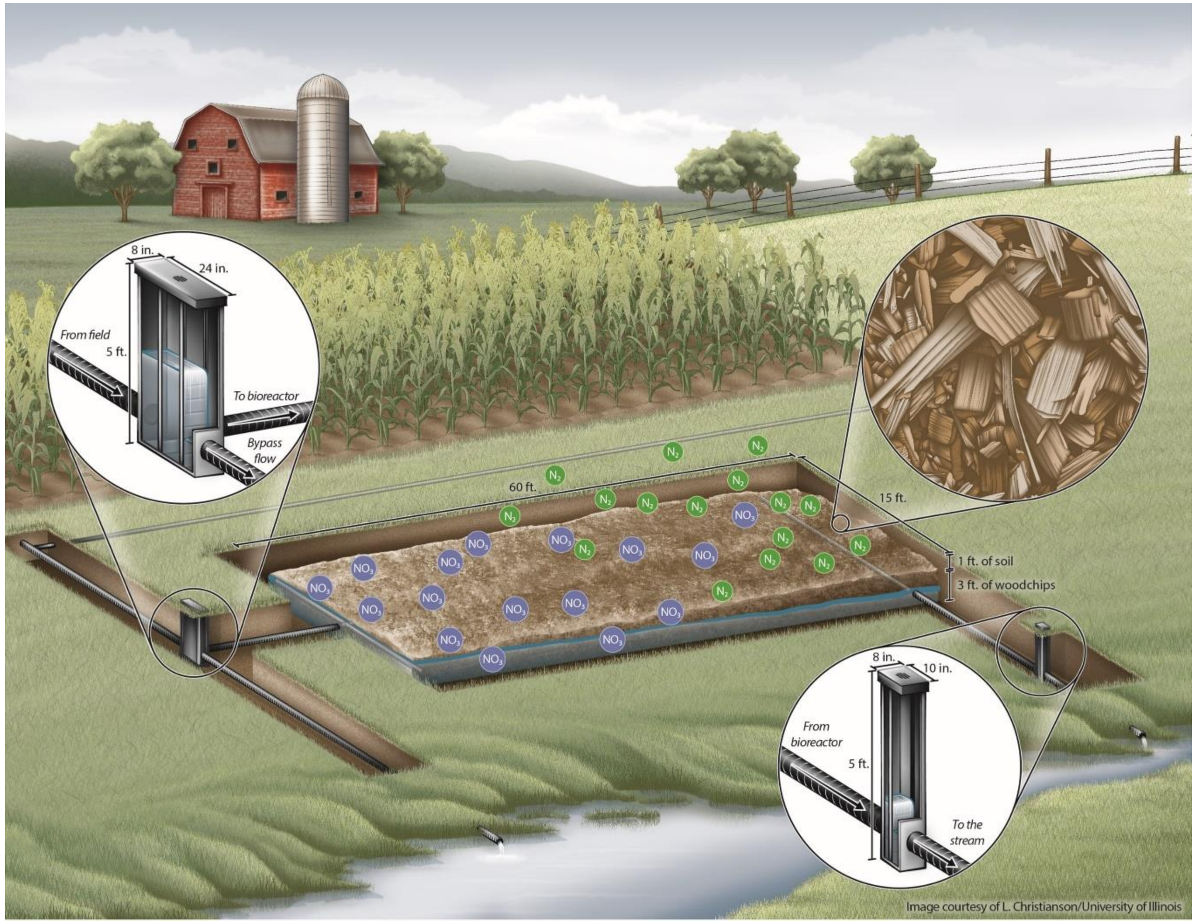
What is a denitrifying woodchip bioreactor?

Drainage area	50 ac
L x W x D (ft)	76 x 19 x 4
Total volume	5340 ft^3
L:W ratio	4.0
Inlet tile size	10 inch



Note: By-pass pipe

What impacts a bioreactor's N load reduction?

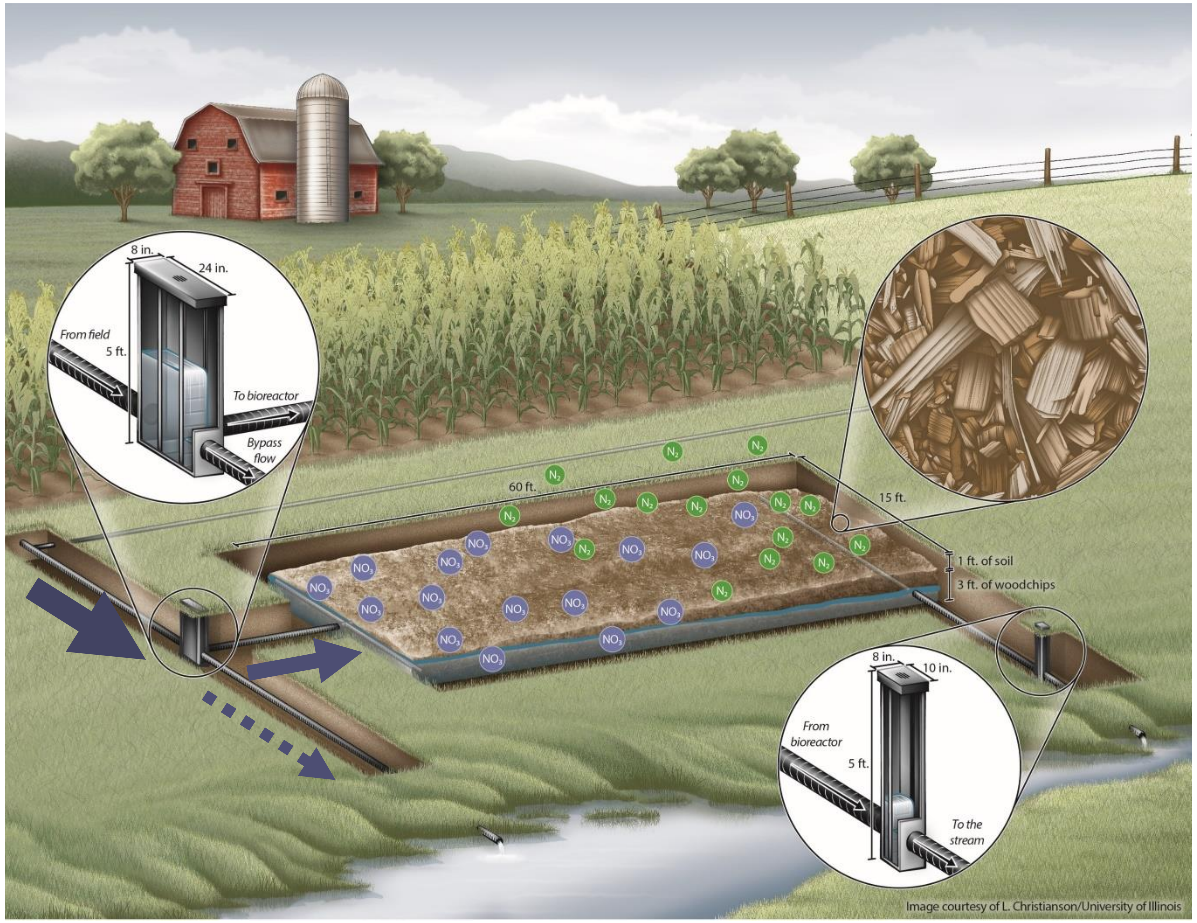


Generalized bioreactor illustration; not to USDA NRCS CPS 605

What impacts a bioreactor's N load reduction?

Two factors:

1. How much flow coming from the field is being treated?



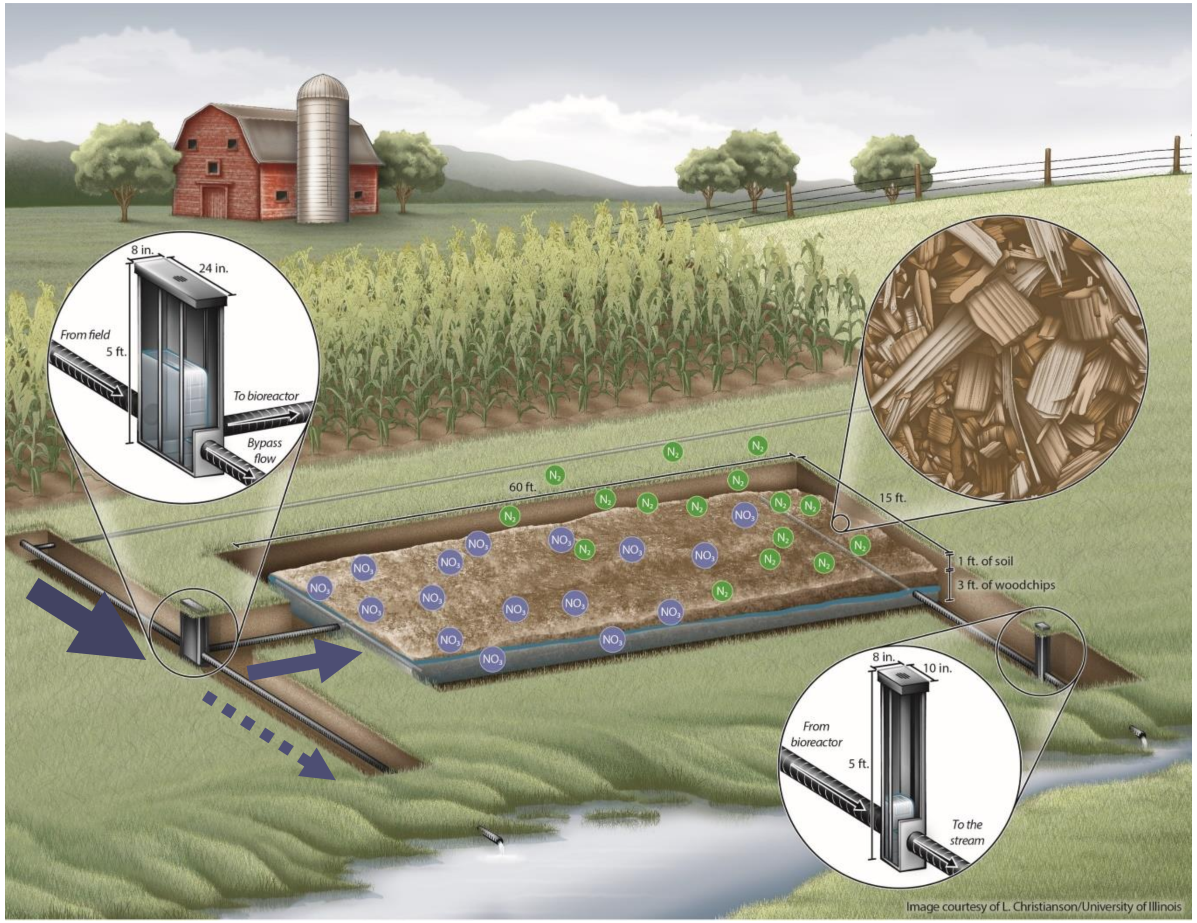
Generalized bioreactor illustration; not to USDA NRCS CPS 605

What impacts a bioreactor's N load reduction?

Two factors:

1. How much flow coming from the field is being treated?

USDA NRCS Conservation Practice Standard:
Aim to treat **≥60%** of long-term average annual flow volume.

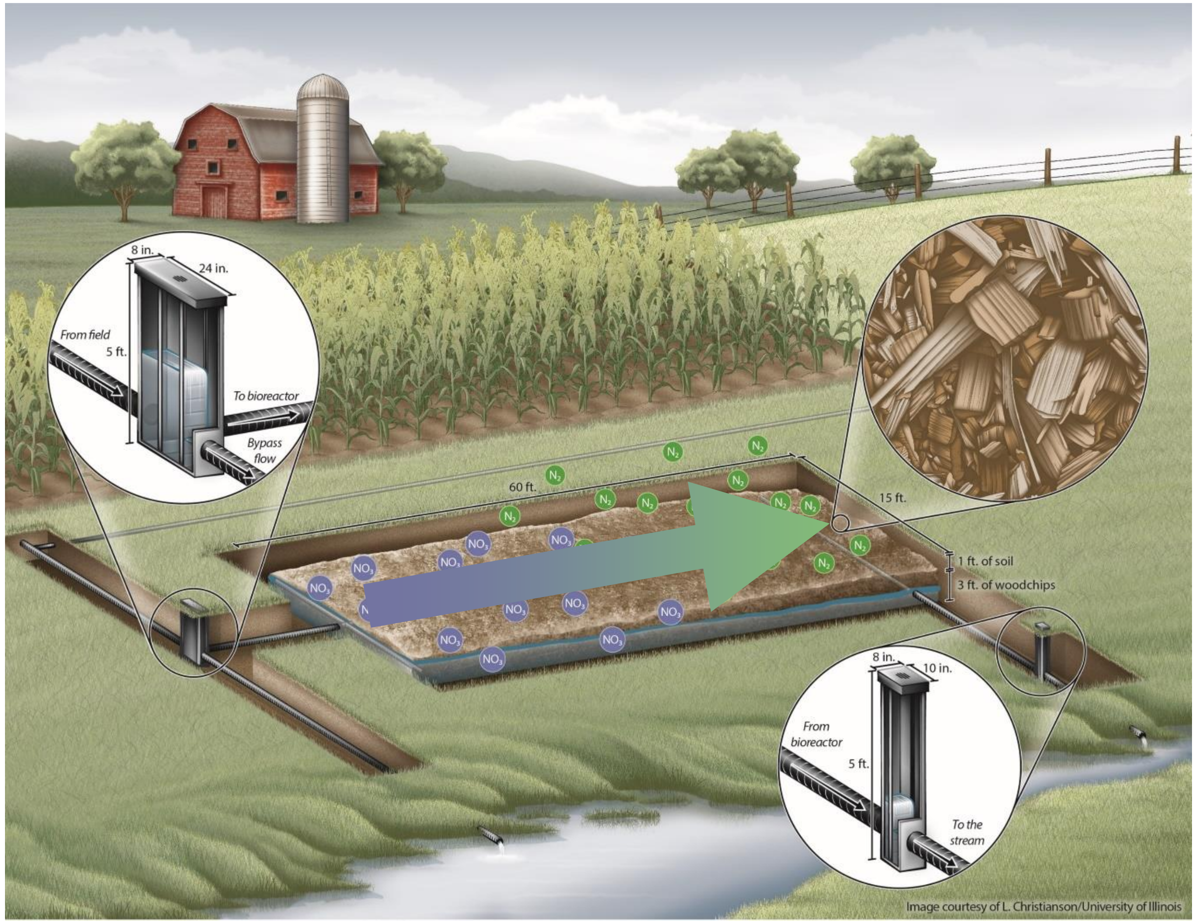


Generalized bioreactor illustration; not to USDA NRCS CPS 605

What impacts a bioreactor's N load reduction?

Two factors:

2. How much nitrogen is being removed from the water that is treated?



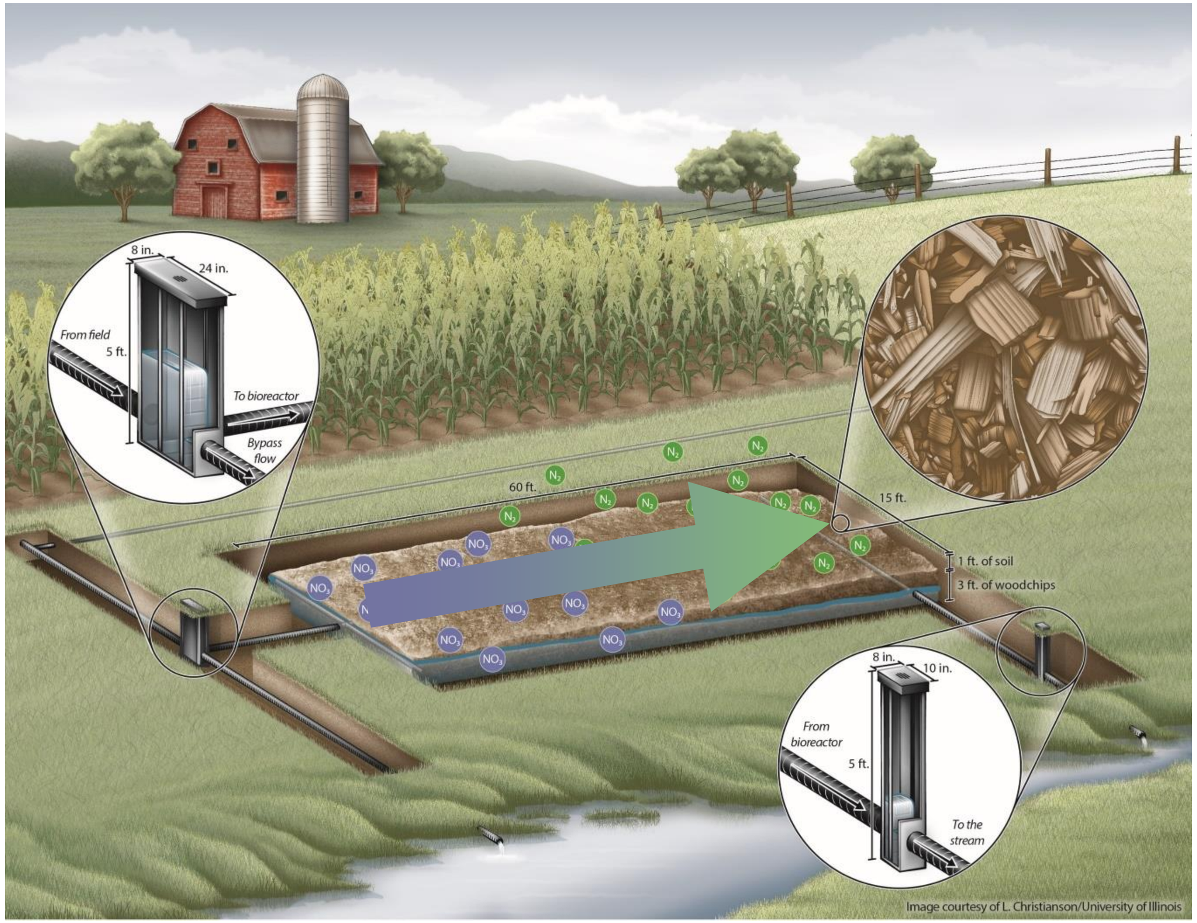
Generalized bioreactor illustration; not to USDA NRCS CPS 605

What impacts a bioreactor's N load reduction?

Two factors:

2. How much nitrogen is being removed from the water that is treated?

USDA NRCS Conservation Practice Standard:
Aim for **≥30%** nitrogen load reduction for the treated water



Generalized bioreactor illustration; not to USDA NRCS CPS 605

United States Department of Agriculture

605-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

DENITRIFYING BIOREACTOR

Code 605

Performance and Capacity. Design the capacity of the bioreactor based on one of the following:

- Treat peak flow from a 10-year, 24-hour drain flow event.
- Treat at least 15 percent of the peak flow from the drainage system.
- Treat at least 60 percent of the long-term average annual flow from the drainage system using locally proven criteria (e.g., drainage coefficient).

Design the bioreactor to achieve at least a 30-percent annual reduction in the nitrate nitrogen load of the water flowing through the bioreactor.

United States Department of Agriculture

605-CPS-1

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

DENITRIFYING BIOREACTOR

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Performance and Capacity. Design the capacity of the bioreactor based on one of the following:

- Treat peak flow from a 10-year, 24-hour drain flow event.
- Treat at least 15 percent of the peak flow from the drainage system.
- Treat at least 60 percent of the long-term average annual flow from the drainage system using locally proven criteria (e.g., drainage coefficient).

Design the bioreactor to achieve at least a 30-percent annual reduction in the nitrate nitrogen load of the water flowing through the bioreactor.

60% of the flow x 30% N reduction for the treated flow

= **at least 18% N load reduction at the tile outlet**

What has been found within the watershed?

Table 6 - Summary of flow treated and nitrate removal within the bioreactor and considering bypass flow ("Total") for three bioreactors in Maryland. Source: Rosen and Christianson (2017)

	Flow				Bioreactor				Total (Including Bypass 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		%
Ridgely Farm 8 August 2014–6 August 2015	37,000	13%	4.65	0.06	23	0.3	99%	**0.40**	251	229	**9.0%**
6 August 2015–4 May 2016 ‡	5860	21%	7.64	0.30	9.6	0.4	96%	**0.21**	58	48	**16%**
Queen Anne Farm 8 August 2014–6 August 2015	24,400	59%	9.22	0.08	134	1.1	99%	**5.36**	214	81	**62%**
6 August 2015–13 April 2015 ‡	24,800	50%	8.60	0.23	106	2.9	97%	**5.12**	219.0	115.92	**47%**
Voorhees Farm 19 December 2104–20 July 2015 ‡	49,700	98%	13.46	11.57	677	607	10%	**1.53**	688	618	**10%**

† Removal rate based only on dates when flow was occurring and calculated using the entire bioreactor volume (L × W × D).
‡ Not annual periods due to the grant timeline.

What has been found within the watershed?

Published online November 30, 2017

Agricultural & Environmental Letters

Research Letter

Enhanced Denitrification Bioreactors Hold Promise for Mid-Atlantic Ditch Drainage

L. E. Christianson,* A. S. Collick, R. B. Bryant, T. Rosen, E. M. Bock, A. L. Allen, P. J. A. Kleinman, E. B. May, A. R. Buda, J. Robinson, G. J. Folmar, and Z. M. Easton

Core Ideas

- Bioreactors can be designed to remove nitrate from drainage ditches.
- Designing bioreactors for ditch drainage requires site-specific flexibility.
- All mid-Atlantic ditch bioreactors tested removed nitrate from drainage water.
- Practical concerns will require adjustments to design and installation.

Abstract: There is strong interest in adapting denitrifying bioreactors to mid-Atlantic drainage systems to help address Chesapeake Bay water quality goals. Three ditch drainage-oriented bioreactors were constructed in 2015 in Maryland to evaluate site-specific design and installation concerns and nitrate (NO_3–N) removal. All three bioreactor types removed NO_3–N, as measured by load and/or concentration reduction, showing promise for denitrifying bioreactors in the mid-Atlantic's low gradient Coastal Plain landscape. The ditch diversion bioreactor (25% NO_3–N load reduction; 0.97 g NO_3–N removed m^{-3} d^{-1}) and the sawdust denitrification wall adjacent to a ditch (>90% NO_3–N concentration reduction; 1.9–2.9 g NO_3–N removed m^{-3} d^{-1}) had removal rates within range of the literature. The in-ditch bioreactor averaged 65% NO_3–N concentration reduction, but sedimentation is expected to be one of the biggest challenges. A robust water balance is critical for future assessment of bioreactors' contribution to water quality improvement in low gradient mid-Atlantic landscapes.

Denitrifying Bioreactors

Main findings:

- 20% TN load reduction
  - No credit for P or TSS load reductions

Based on:

  - Measured data from inside and outside of the watershed
  - NRCS conservation practice standard

Denitrifying bioreactors: Future research is important

- **Continued and increased monitoring of denitrifying bioreactors**: "*…the panel recommends that flow and nitrate concentrations continue to be monitored on bioreactor installations throughout the watershed ...*"
- Future research should account for different types of bioreactors such as in-ditch bioreactors and sawdust walls.
- Monitoring and reporting of TSS and P load reductions
  - Bioreactors can remove TSS, but there is little documented research of this.
  - Woodchips can serve as a source of leached P, but under certain conditions, bioreactor removal of both TP and DP has been documented.

Photo: courtesy of Tim Rosen, ShoreRivers, used with permission

Denitrifying bioreactors: Future research is important

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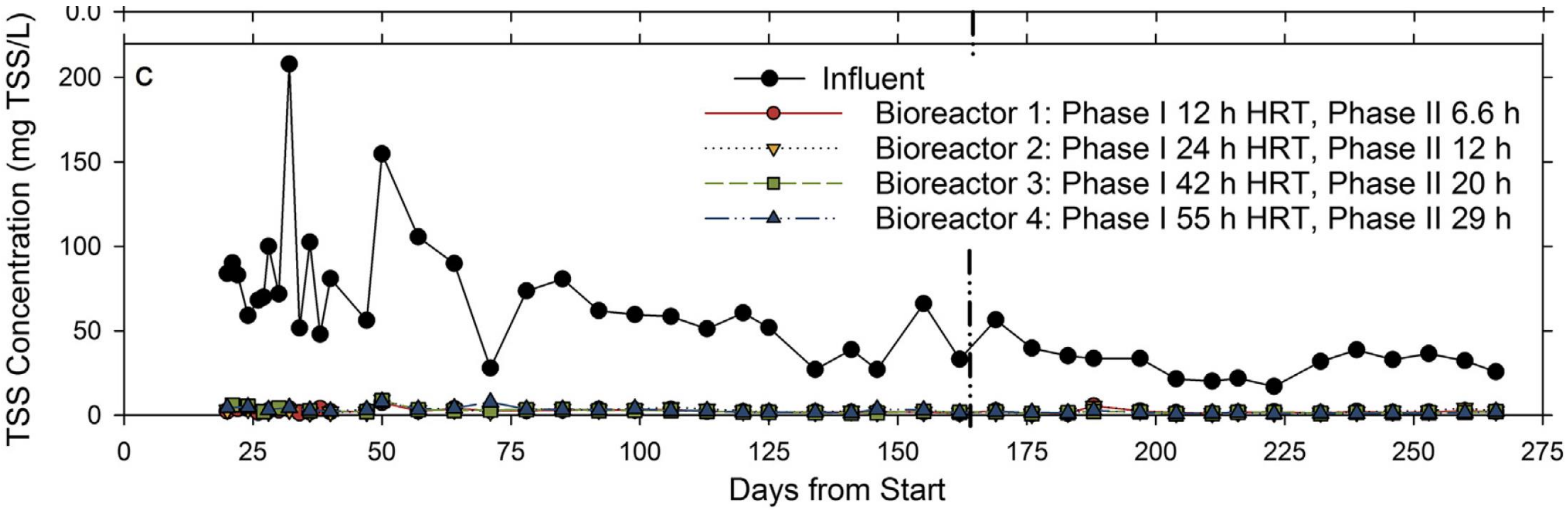
Denitrifying bioreactors: Future research is important



- **Monitoring and reporting of TSS and P load reductions**
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From: Christianson, L., C. Lepine, K. Sharrer, and S. Summerfelt. 2016. Denitrifying bioreactor clogging potential during wastewater treatment. *Water Research* 105:147-156.

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Based on:

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Drainage water management

To receive credit for nutrient reduction in the CBWM, water control structures must be a component of a drainage water management system designed and operated for the primary purpose of reducing nutrient loading from drainage systems into downstream receiving waters by restricting subsurface drainage from leaving the field.

Drainage water management

Main findings:

- Water Control Structures (CP code 587)
  - No credit for TN, TP or TSS load reductions
- Drainage water management (CP code 554)
  - 30% TN load reduction
  - No credit for TP or TSS load reductions
  - Credit for effective drainage control area (ac)
  - Credit duration: Annual

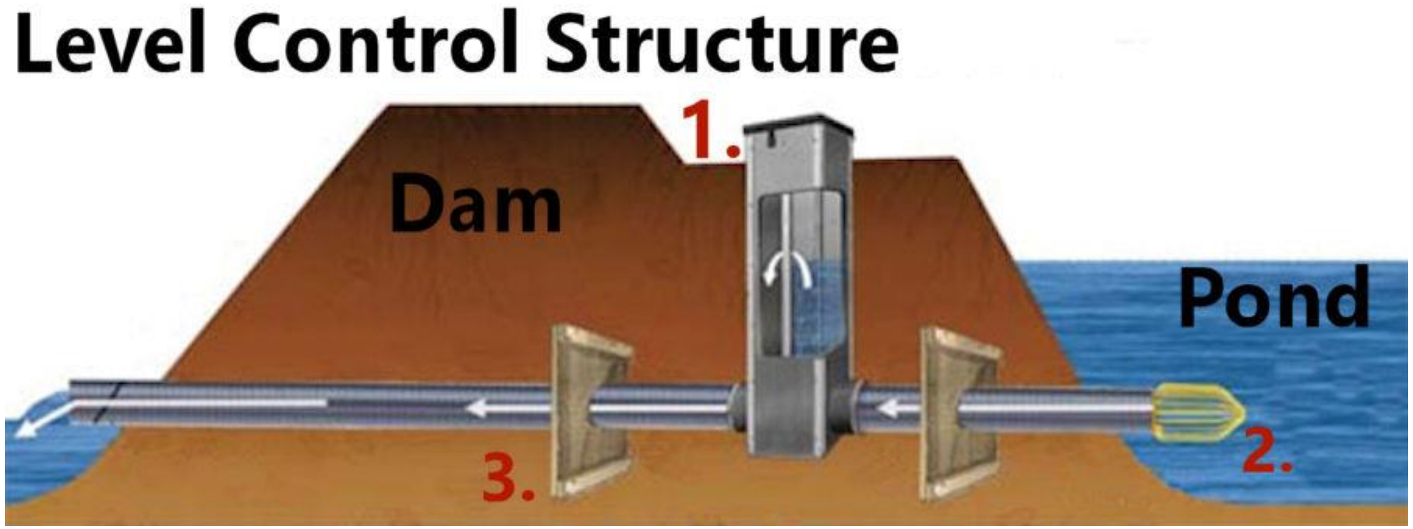
To receive credit for nutrient reduction in the CBWM, water control structures must be a component of a drainage water management system designed and operated for the primary purpose of reducing nutrient loading from drainage systems into downstream receiving waters by restricting subsurface drainage from leaving the field.

Definitions and concepts

- **Water Control Structure** (WCS)- A structure in a water management system that conveys water, maintains a desired water surface elevation, and controls the direction or rate of flow. For research purposes, it may also be designed to measure rate of water flow.

- **Drainage Water Management** (DWM) – Generally, the process of managing water discharges from surface and/or subsurface agricultural drainage systems. This section discusses the use of Drainage Water Management for "controlled drainage" (CD) of agricultural fields to raise and lower the water levels within the soil profile throughout the year following an operation and maintenance plan.

Key factors



Water Control Structures

May be used for a variety of purposes unrelated to drainage water management, such as:

- Control the direction of flow entering a denitrifying bioreactor
- Control the measurement of irrigation water
- Keep trash, debris or weed seeds from entering pipelines
- Control the direction of channel flow resulting from tides or back-flow from flooding: tide gates
- Convey water over, under or along a ditch, canal or road: culverts, flumes, inverted siphons
- Flood land for frost protection
- Manage water levels for wildlife or recreation
- Control the water level in a pond

Key factors

Drainage Water Management

The process of managing the drainage volume and water table elevation by regulating the flow from a surface or subsurface agricultural drainage system.

The purpose of this practice is to –

- Reduce nutrient, pathogen, and pesticide loading from drainage systems into downstream receiving waters.
- Improve productivity, health, and vigor of plants.
- Reduce oxidation of organic matter in soils.

Key factors

Drain Layout to optimize cost vs. controlled drainage (Cooke et al., 2008)

United States Department of Agriculture

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

STRUCTURE FOR WATER CONTROL

(No.)

CODE 587

DEFINITION

A structure in a water management system that conveys water, controls the direction or rate of flow, maintains a desired water surface elevation or measures water.

PURPOSE

The practice may be applied as a management component of a water management system to control the stage, discharge, distribution, delivery or direction of water flow.

United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

DRAINAGE WATER MANAGEMENT

Code 554

(Ac)

DEFINITION

The process of managing the drainage volume and water table elevation by regulating the flow from a surface or subsurface agricultural drainage system.

PURPOSE

The purpose of this practice is to—

- Reduce nutrient, pathogen, and pesticide loading from drainage systems into downstream receiving waters.
- Improve productivity, health, and vigor of plants.
- Reduce oxidation of organic matter in soils.

Review of science (inside/outside watershed)

- CD commonly reduces annual drain water discharge and nitrate loads to receiving waters.
- Most commonly, the nutrient load reduction is comparable to the reduction in drain water discharge, suggesting a limited influence of denitrification.
- Drain water reduction from CD results from vertical seepage and, to a more limited extent, ET (<10%).
- Drain water reductions may also result from increased surface runoff and lateral seepage that can discharge to receiving waters beyond the drain outlet.

Table 1

Summary of results of field studies of effectiveness of drainage water management in reducing drainage volumes and nitrogen loads (modified from Skaggs et al. 2010).

Reference	Location	Soil	Years observed	Area (ha)	Drain spacing (m)	Drain depth (m)	Control depth* (m)	Percent drainage	Reduction nitrogen loss
Gilliam et al. 1979	North Carolina	Portsmouth sandy loam	3	5 to 16	30 and 80	1.2	0.3 to 0.5	50	50
	North Carolina	Goldsboro sandy loam	3	3	30	1	0.3	85	85
Evans et al. 1989	North Carolina	Ballanhack sandy loam	2	4	18	1	0.6	56	56
	North Carolina	Wasda muck	2	4	100	1.2	0.6	51	56
	North Carolina	Wasda muck	2	4	18	1	0.6	17	18
Lalonde et al. 1996	Ontario	Bainesville silty loam	2	0.63	18.3	1	0.75	49	69
							0.5	80	82
Breve et al. 1997†	North Carolina	Portsmouth	1.2	1.8	22	1.2	0.4 to 0.5	16	20
Tan et al. 1998	Ontario	Brookston clay loam	2	2.2	9.3	0.65	0.3	20	19
Gaynor et al. 2002‡	Ontario	Brookston clay loam	2	0.1	7.5	0.6	0.3	16	
Drury et al. 2009§	Ontario	Brookston clay loam	4	0.1	7.5	0.6	0.3	29	31 to 44‖
Wesstrom and Messing 2007	Sweden	Loamy sand	4	0.2	10	1	0.2 to 0.4	80	80
Fausey 2005	Ohio	Hoytville silty clay	5	0.07	6	0.8	0.3	41	46
Jaynes 2012	Iowa	Kossuth/Ottosen	4	0.46	36	1.2	0.6	18	21
Helmers et al. 2012	Iowa	Taintor/Kalona	4	1.2 to 2.4	18	1.2	0.3	37	36
Adeuya et al. 2012	Indiana	Rensselaer	2	3	21	1	0.15 to 0.6	19	23
	Indiana	Rensselaer	2	6 to 9	43				18
Cooke and Verma 2012	Illinois	Drummer	2	15	30	1.15	0.15	44	51
		Drummer/Dana	1 to 2#	8.1	15	1.15	0.15	44	52
		Orion Haymond	1 to 2#	5.7	18 to 21	1.15	0.15	89	79
		Patton/Montgomery	1 to 2#	16.2	12	0.85	0.15	38	73

* Control typically removed during seedbed preparation, planting, and harvesting periods.
† Controlled drainage (CD) during the growing season only. CD reduced subsurface drainage volume by 16%; Nitrogen loss from subsurface drain + runoff by 20%.
‡ CD reduced subsurface drainage by 35%, increased surface runoff by 28%, and reduced total outflow by 16%. Nitrogen results were not reported and effects on pesticide loss were reported.
§ CD reduced subsurface drainage by 29%, increased surface runoff by 38%, and reduced total outflow by 11%.
‖ CD reduced nitrogen loss by 44% for recommended nitrogen application rates and by 31% for elevated nitrogen rates.
\# Drainage volume measured for two years and nitrogen losses measured for one year for these locations.

Recommendations

- Water Control Structures (CP code 587)
  - No credit for TN, TP or TSS load reductions
- Drainage water management (CP code 554)
  - 30% TN load reduction
  - No credit for TP or TSS load reductions
  - Credit for effective drainage control area (ac)
  - Credit duration: Annual

To receive credit for nutrient reduction in the CBWM, water control structures must be a component of a drainage water management system designed and operated for the primary purpose of reducing nutrient loading from drainage systems into downstream receiving waters by restricting subsurface drainage from leaving the field.

Specific gaps or research needs

- The need for improved, more reliable, field-scale understanding of all of the flow paths responsible for observed drain water reductions was a common theme identified in these CD review and synthesis papers.
- In a recent review, Ross et al. (2016) observed that TP and DP loads were also reduced by CD, but the review recommended that future research focus on P reductions as there is a paucity of research on the topic.

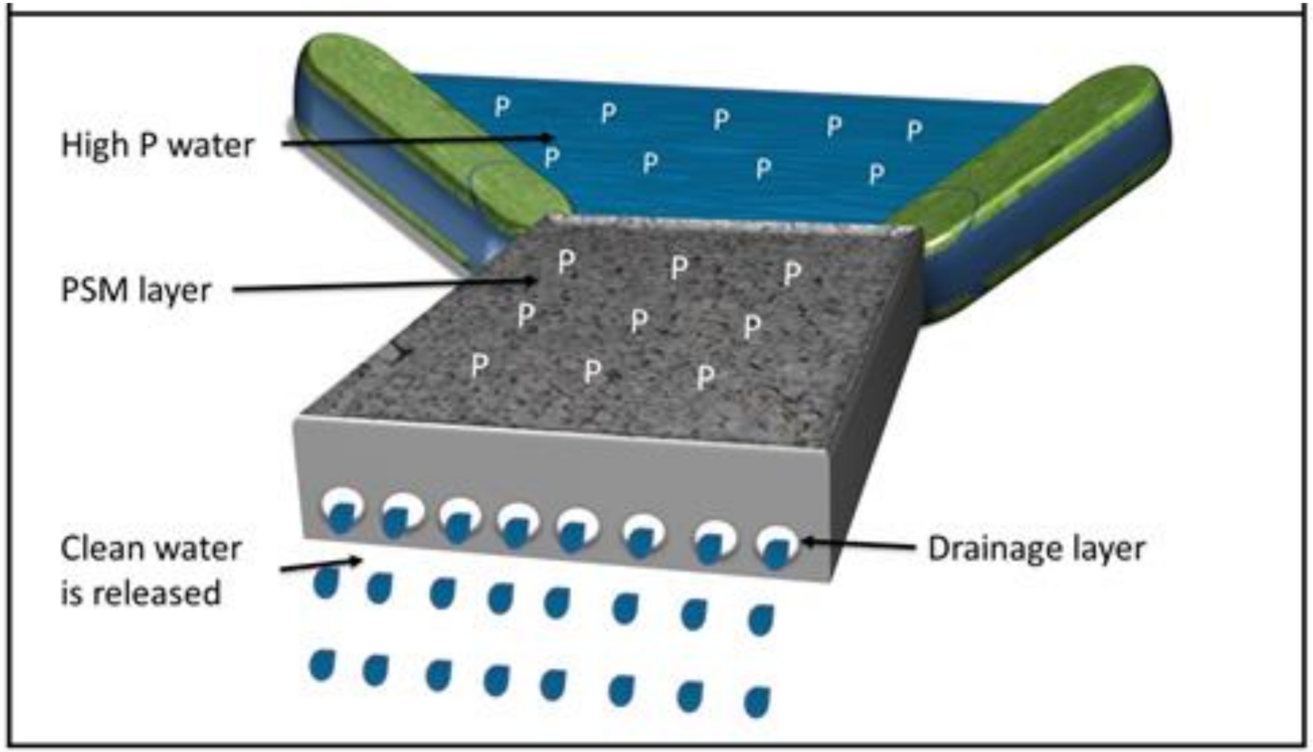
Outline: checking in

I. Summary of panel recommendations

II. Panel recommendations

  a) Blind Inlets
  b) Denitrifying Bioreactors
  c) Drainage water management
  d) Phosphorus removal systems
  e) Saturated buffers

III. Future research and management needs



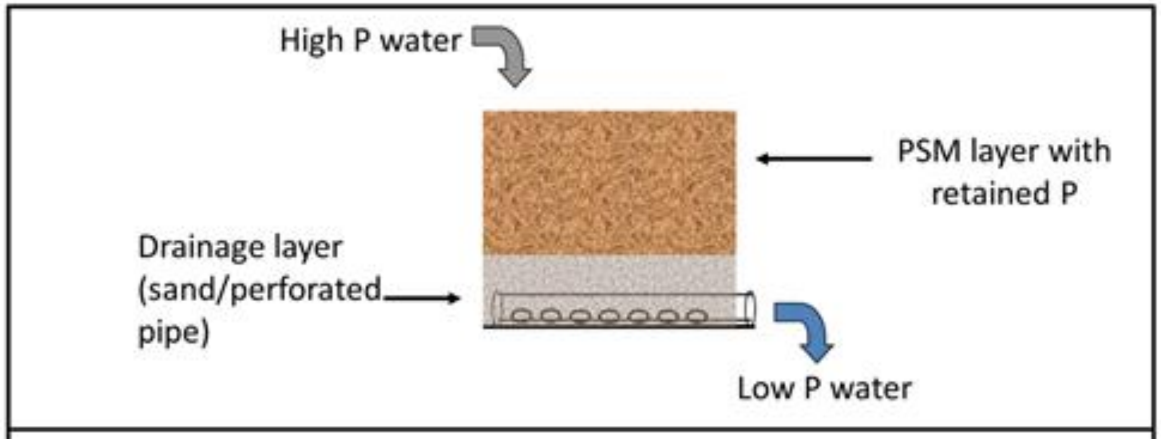
Phosphorus removal systems

A P removal system (NRCS Code 782) is a landscape-scale filter for trapping DP in drainage water. There are many designs for P removal structures depending on the landscape and hydrologic conditions.

Phosphorus Removal Systems

Main Findings

- 50% TP load reduction
- 60% Sediment reduction
  - No credit for TN load reduction
- Credit for drainage area (ac)
- Credit duration: 4 yr



Based on:

- Peer-reviewed research from outside and inside of the watershed
- NRCS conservation practice standard code 782

Definitions and concepts

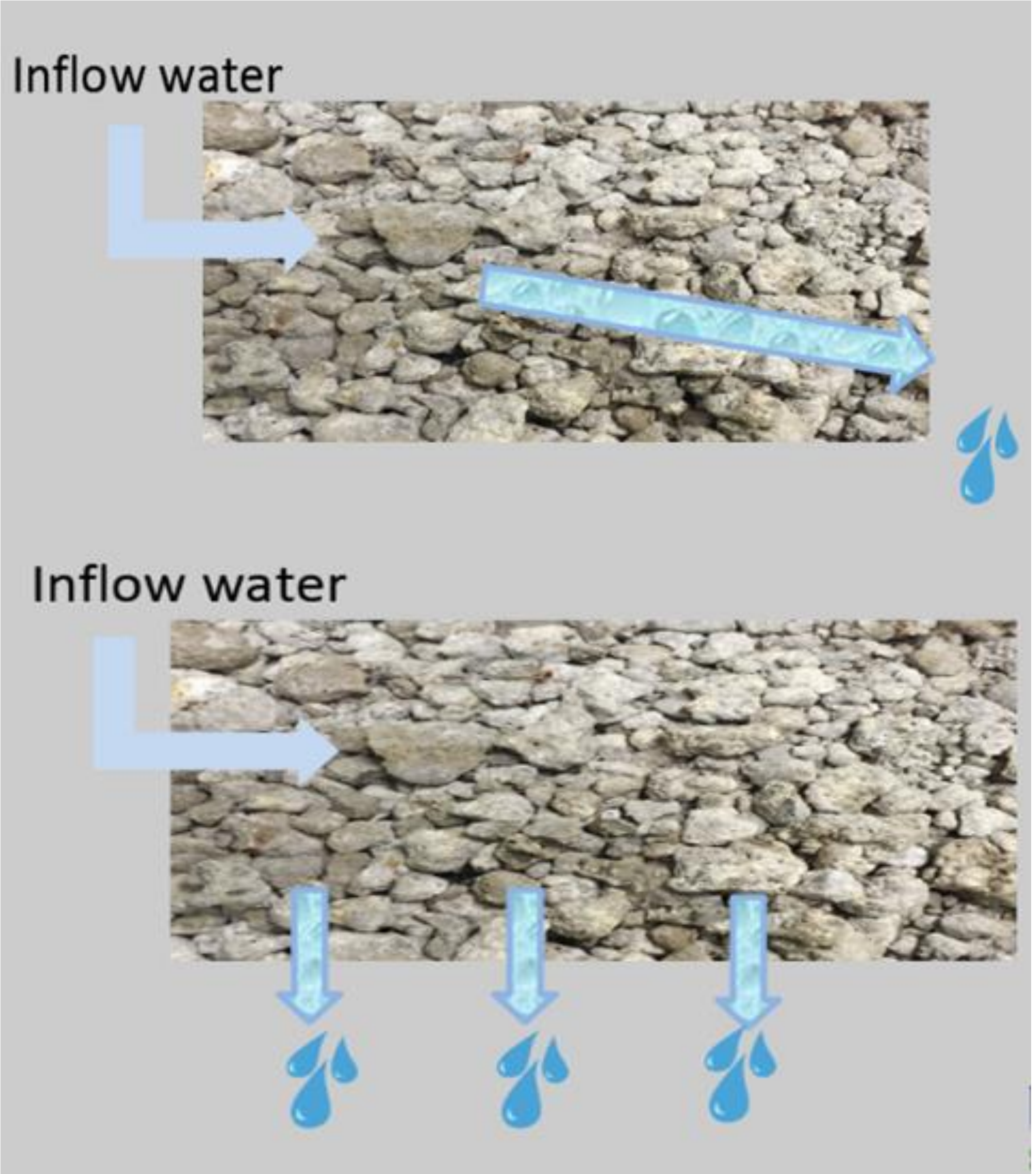
Phosphorus Sorption Material (PSM)

- Solid media that has an affinity for dissolved P.
- Used as a filter material in P removal structures and potentially, blind inlets.
- PSMs are often industrial by-products rich in iron, aluminum and/or calcium and magnesium.

Key factors

Core Components

- Contains a sufficient mass of an unconsolidated P sorption material.
- The PSM is contained and placed in a hydrologically active area that receives dissolved P (DP) concentrations greater than 0.2 mg L^{-1}.
- High DP water is able to flow *through* the contained PSM at a suitable flow rate.
- The PSM can be removed and replaced after it is no longer effective at removing P at the minimum desired rate.



Key factors

Design Input

Input

Site hydrology
1. Peak flow rate
2. Annual flow volume
3. Dissolved P level
4. Max footprint

P removal & lifetime
1. Target P removal (%)
2. Target lifetime

PSM characterization
1. P sorption
2. Safety
3. Physical properties

Output

Design parameters
1. Area
2. Mass of PSM
3. Depth of PSM
4. Pipe reqmt

+

+

Model →

Key factors

Phosphorus Removal System Designs

United States Department of Agriculture

782-ICPS-1

Natural Resources Conservation Service

Interim Conservation Practice Standard

PHOSPHORUS REMOVAL SYSTEM

Code 782

(No.)

DEFINITION

A system designed to reduce dissolved phosphorus (P) from surface runoff, subsurface flow, or groundwater.

PURPOSES

To improve water quality by reducing dissolved phosphorus loading to surface water through the sorption or precipitation of phosphate phosphorus from drainage and runoff water.

Review of science (inside/outside watershed)

References

64 refereed publications

Inside and outside of the watershed

Study	Notes	PSM	Mass (Kg)	Particle Size (mm)	Retention Time	Influent DP Concentration (mg L⁻¹)	Cumulative P Added (mg kg⁻¹)	Cumulative P Removed (mg kg⁻¹)	Cumulative P Removed (%)
Wastewater: Ca-Rich Materials									
Szögi et al. [42]	Bed filter for swine effluent	Marl	1237	4.7–19	15.8 h	82	71	36	37–52
Gray et al. [43]	Artificial wetland (pilot scale) for treating wastewater	Marl	21	NA	5 d	7	48	47.6	99
Wastewater: Steel Slag									
Shilton et al. [49]	Column field test for wastewater	Iron slag	24	NA	12 h	10	1168	210	18
Shilton et al. [14]	Confined bed for wastewater treatment	Steel slag	17,773,695	10–20	72 h	8.4 (total P)	3400	1200	35
Wastewater: Mine Drainage Residuals (MDR) and Fe-Rich Materials									
Wood and McAtamney [54]	Pilot-scale constructed wetland for landfill leachate	Laterite	3000	2–3.5	8 d	1.46	2.45	2.28	93
Dobbie et al. [15]	Wastewater treatment plant	MDR (granular)	Initially 2100, then 1075 after	0.002–5	26 m (theoretical)	4	57,566	21,900	38
Non-Point Drainage: Non-Steel Slag Materials									

P Removal System Recommendations

Main Findings

- 50% TP load reduction
- 60% Sediment reduction
  - No credit for TN load reduction
- Credit for drainage area (ac)
- Credit duration: 4 yr

Based on:

  - Peer-reviewed research from outside and inside of the watershed
  - NRCS conservation practice standard code 782

Specific gaps or research needs

- The panel recommends that flow and P concentrations continue to be monitored on P removal structures throughout the watershed in order to better document their overall effectiveness in this region.
- Data on sediment entrapment within the P removal structure and particulate bound P in that sediment is also needed.

Outline: checking in

I. Summary of panel recommendations

II. Panel recommendations

   a) Blind Inlets

   b) Denitrifying Bioreactors

   c) Drainage water management

   d) Phosphorus removal systems

   e) Saturated buffers

III. Future research and management needs

Pre-installation

Installation

Post-installation

Saturated buffers

Unless otherwise attributed, pictures in this section are credited to Lynn Betts, IA NRCS and SWCS, downloaded from Conservation Media Library album on Flickr: https://flic.kr/s/aHsm2PEhL5

Saturated Buffer

An edge-of-field practice that removes nitrate from tile drainage water before it enters ditch, stream, or other surface waters.

Diversion of tile-line flow to subsurface, perforated distribution pipe used to divert and spread drainage system discharge to a vegetated area to increase soil saturation.

NRCS CPS 604

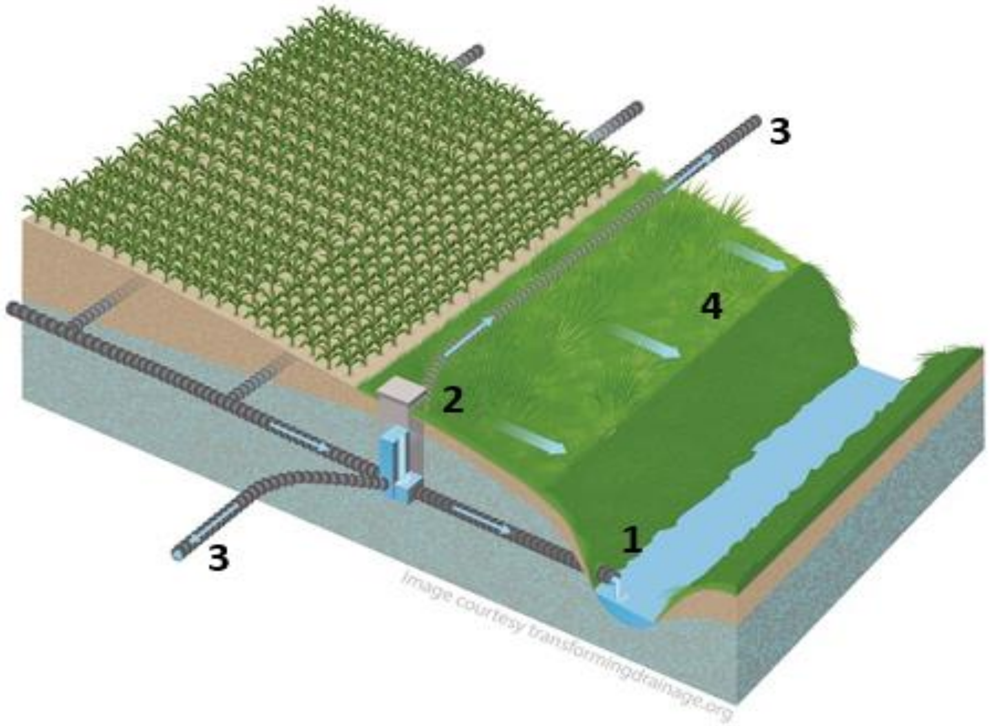


Figure 15 in report. Basic components of a saturated buffer: 1. tile outlet, 2. water control structure, 3. perforated distribution tile or pipe, and 4. riparian buffer with established perennial vegetation. Adapted from https://transformingdrainage.org/

Saturated buffer

Main findings:

- 20% TN reduction
- Insufficient data and thus no TP or TSS reduction is recommended

Based on:

- Peer-reviewed research from outside of the watershed
- NRCS conservation practice standard (5% or more of drainage system capacity or as much as practical based on available buffer length)

Figure 14 in report. Installation of a saturated buffer. Source: USDA ARS 2015. Photographer: Dan Jaynes.

Definitions and concepts

Tile drain: subsurface conduit to collect and convey excess water

Tile outlet: outlet pipe that conducts water from tile drain to ditch or surface water

Water control structure: structure that conveys waters, maintains desired water elevation, and control direction or rate of flow.

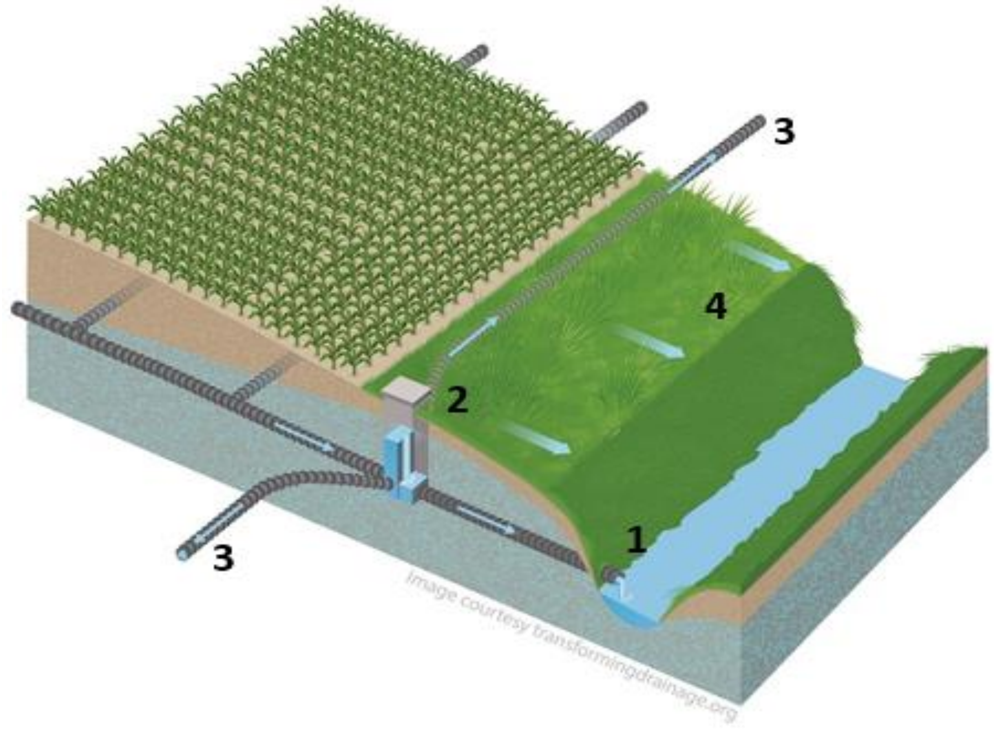


Figure 15 in report. Basic components of a saturated buffer: 1. tile outlet, 2. water control structure, 3. perforated distribution tile or pipe, and 4. riparian buffer with established perennial vegetation. Adapted from https://transformingdrainage.org/

Definitions and concepts

Tile drain: subsurface conduit to collect and convey excess water

Tile outlet: outlet pipe that conducts water from tile drain to ditch or surface water

Water control structure: structure that conveys waters, maintains desired water elevation, and control direction or rate of flow.

Key factors

- Nitrate removal occurs primarily through denitrification
- Immobilization w/in buffer by microorganisms or sequestration within vegetation may also remove nitrate
- Key factors include the saturated buffer's length and width, soil properties and drainage area.

United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SATURATED BUFFER

Code 604

(ft)

DEFINITION

A subsurface, perforated distribution pipe used to divert and spread drainage system discharge to a vegetated area to increase soil saturation.

PURPOSE

Install the practice to achieve one or more of the following purposes:

- To reduce nitrate loading from subsurface drain outlets.
- To enhance or restore saturated soil conditions in riverine, lacustrine fringe, slope, or depression hydrogeomorphic landscape classes.

Review of science (outside watershed)

References

Addy, K.L., A.J. Gold, P.M. Groffman, and P.A. Jacinthe. 1999. Ground water nitrate removal in subsoil of forested and mowed riparian buffer zones. J. Environ. Qual. 28: 962–970. doi:10.2134/jeq1999.00472425002800030029x

Brooks, F., and Jaynes, D. Quantifying the effectiveness of installing saturated buffers on conservation research program to recued nutrient loading from tile drainage waters. Final Report to Farm Services Agency, 30 Apr., 2017.

Gulliford, J. 2017. Looking for agricultural water quality protection practices: Saturated buffers. Journal of soil and water conservation 72:36A-37A. doi:10.2489/jswc.72.2.36A

Jaynes, D.B. and T.M. Isenhart. 2011. Re-Saturating Riparian Buffers in Tile Drained Landscapes. A Presentation of the 2011 IA-MN- SD Drainage Research Forum. November 22, 2011. Okoboji, IA.

Jaynes, D.B. and T.M. Isenhart. 2014. Reconnecting Tile Drainage to Riparian Buffer Hydrology for Enhanced Nitrate Removal. Journal of Environmental Quality 43:631-638. Doi:10.2134/jeq2013.08.0331

Jaynes, D.B. and T.M. Isenhart. 2019. Performance of Saturated Riparian Buffers in Iowa, USA. Journal of Environmental Quality 48:289-296.

Utt, N., S.W. Baker, D. Jaynes, and J. Albertsen. (2015). Demonstrate and Evaluate Saturated Buffers at Field Scale to Reduce Nitrates and Phosphorus from Subsurface Field Drainage Systems. NRCS CIG Grant Report.

Review of science (outside watershed)

Table 11 from report. Review of nitrate removal results for Saturated Buffers. First six sites are from Jaynes and Isenhart, 2019. Last four sites are from Utt et al., 2015.

Location	Drainage Area, ha	Saturated Buffer Length, m	Saturated Buffer Width, m	% of Tile Flow Diverted to Saturated Buffer	Nitrate Removed, kg-N	% of Total NO_3 Load Removed	NO_3 Removal Rate, g-N m^{-1} d^{-1}
Hamilton Co., IA	10.1/5.91*	305	21	42%	97	39%	1.5
Hamilton Co., IA	5	308	24	94%	52	84%	1.3
Tama Co., IA	7	115	4	51%	24	48%	2.0
Story Co., IA	22	124	14	26%	55	25%	1.7
Hamilton Co., IA	40	168	22	21%	118	8%	2.6
Boone Co., IA	3	266	19	49%	22	17%	0.4
Benton Co., IA	60	366	135	30%	408	29%	6.6
Edgar Co., IL	15	178	75	32%	68	29%	3.3
Rock Island CO., IL	60	219	120	26%	161	11%	3.0
Dodge Co., MN	20	280	80	22%	26	16%	4.2
avg.	**25**	**233**	**51**	**39%**	**103**	**30%**	**2.7**

***Additional tile installation in 2013 changed the area drained to the outlet. Adjoining fields were predominantly planted to corn and soybean. The Utt et al., 2015 data includes only sites that met the CPS 604 standard and had at least one year of data.**

Recommendations

- 20% TN load reduction for drainage system it is applied to
- Insufficient data or evidence and thus no TP or TSS removal is recommended at this time.
  - No appreciable removal of suspended solids by the saturated buffer; in fact, they should be placed where minimal suspended solids will enter the buffer to avoid plugging the system.
  - Mixed evidence of P removal. Utt et al. (2015) suggests that soil can either adsorb or release P as indicated by measured declines and increases in total dissolved P within the buffers.
- Recommended 10-year credit duration

Specific gaps or research needs

- Currently no published research for saturated buffers within the Chesapeake Bay Watershed; monitoring of nitrate flow and concentrations from saturated buffers in the CBW would better document their effectiveness.
- Potential for P removal needs further study. Some studies have shown removal of measurable amounts of P, but neither the duration of the removal nor the soil characteristics that contribute to P removal are known.

Reminder: Unless otherwise attributed, pictures used in this Saturated Buffer section are credited to Lynn Betts, IA NRCS and SWCS, downloaded from Conservation Media Library album on Flickr: https://flic.kr/s/aHsm2PEhL5

Outline: checking in

I. Summary of panel recommendations
II. Panel recommendations
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   e) Saturated buffers
III. Future research and management needs

Future research needs

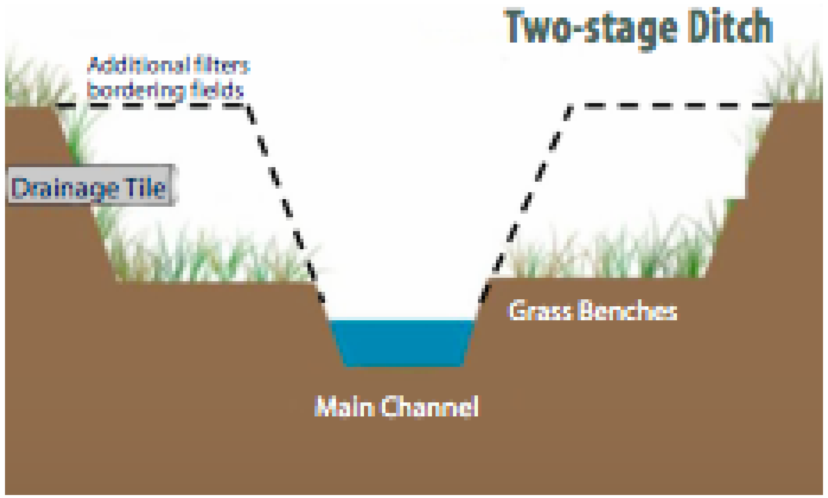
Including practices that currently do not have sufficient research to recommend efficiency values for nitrogen, phosphorus or sediment

Gypsum curtains

- Collected data indicates up to 90 % reduction in P concentrations in water that passes through the curtains, but load calculations are difficult since the rate of groundwater flow can only be estimated.
- Recent data suggest that there may be failures in some spots along the curtain, suggesting that animals, such as muskrats, may be burrowing through the curtain and providing a path for bypass flow.
- The length of effectiveness of the practice and the need for maintenance needs further investigation.

Two-stage ditches

- Replaces the traditional trapezoidal ditch common in drainage systems with a ditch more consistent with natural stream processes.
  - First stage = Channel forming discharges/flows
  - Second stage = floodplain within the ditch that provides bank stability and conveyance capacity
- Some published research outside the region suggests that the mini-floodplain can increase denitrification.
- Currently, no design criteria for this practice exists for the specific soil and landscape conditions of the Delmarva.



Cross-sectional of 2-stage ditch.
Source: Wikimedia Commons

Ditch dipouts (dredging or clean-out)

- The removal of sediment and vegetation from the channel of a ditch; occurs when the conveyance of drainage water is slowed and inadequate.
- Some research inside and outside the region, most studies published 2009 or earlier. Some evidence that dipouts can lower ability of the ditch to buffer nutrient concentrations in the ditch flow. Disruption by dipout may also make sediments in the ditch more susceptible and increase sediment loss.
- More studies are needed to assess whether dipouts are a BMP for water quality.

Traditional drainage ditch after a cleanout. Source: Ohio State University Extension, https://agditches.osu.edu/image-galleries/drainage-channels

Denitrifying curtains

- Denitrifying walls are filled with mixtures of native soil and sawdust that range from 20 to 50% sawdust by volume.
- The only peer-reviewed study of a sawdust denitrifying wall within the Chesapeake Bay region reported this type of bioreactor was simple to design and construct, inexpensive, and resulted in >90% NO_3–N concentration reductions at the one monitored site (Christianson et al., 2017).

Documenting NO_3–N removal effectiveness for the sawdust wall was difficult due to the challenge of measuring lateral groundwater flow rates. To give credit for NO_3–N reduction with this practice, a practical solution would be to develop regional estimates of groundwater flow rates and accept those as applicable to certain soil and landscape conditions."

Denitrifying Bioreactors for springs/seeps

- New/emerging use of DNBRs to treat groundwater when it surfaces in a spring/seep, particularly in areas with elevated groundwater nitrate levels.
- Some initial efforts in Shenandoah Valley (VA) have promising initial anecdotal results.
- No published research currently available.

Q&A

Please enter your questions in the chat box.

If you are familiar with Zoom and wish to ask your question verbally, please use the “raise hand” feature and wait to be called on. Un-mute and ask your question when prompted and re-mute when done speaking.

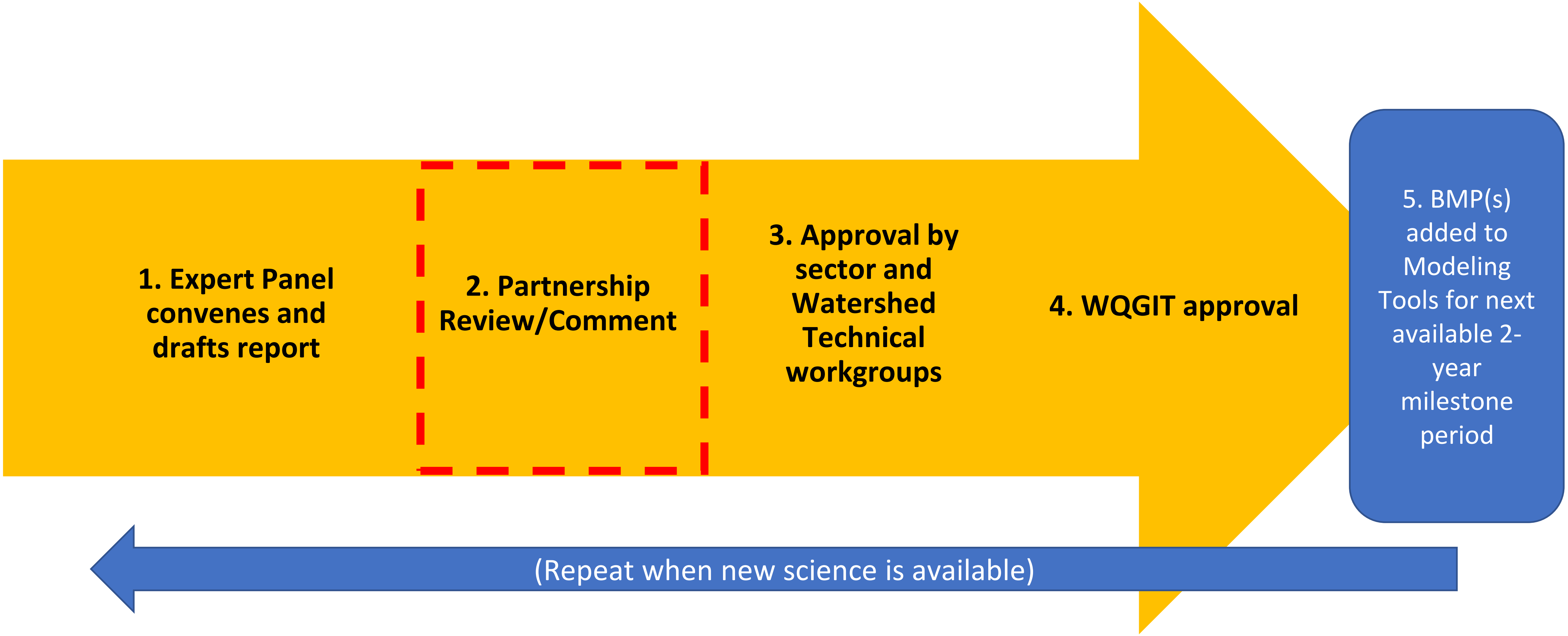
Photos: Lynn Betts, IA NRCS and SWCS, downloaded from Conservation Media Library album on Flickr: https://flic.kr/s/aHsm2PEhL5

Panel Timeline (reprised)

- Charge approved by Agriculture Workgroup: Feb. 2016
- Membership approved by AgWG: April 2016
- Convened for first call in May 2016
- Open stakeholder session: August 31, 2016 (https://bit.ly/2mdb2a0)
- Panel calls and deliberations thru July 2019
- Report posted and distributed: September 4-5, 2019
- “Roll-out” webcast: September 18, 2019 (today)
- **Feedback requested by COB October 7, 2019**
- Tentative timeline for decision/approval:
    - Agriculture WG: November
    - Watershed Technical WG: Early December
    - WQGIT: December

Photo credit: USDA NRCS

The “BMP Protocol” process (simplified)



Next steps

- Reminder: the full report, appendices and this recorded webcast are available on the CBP calendar page:
- **Feedback requested by COB October 7**
  - Send written feedback about the report to Jeremy Hanson, Panel Coordinator (jchanson@vt.edu)
  - Call or email with questions or requests (410-267-5753)

Photo: Chesapeake Bay Program


Q&A

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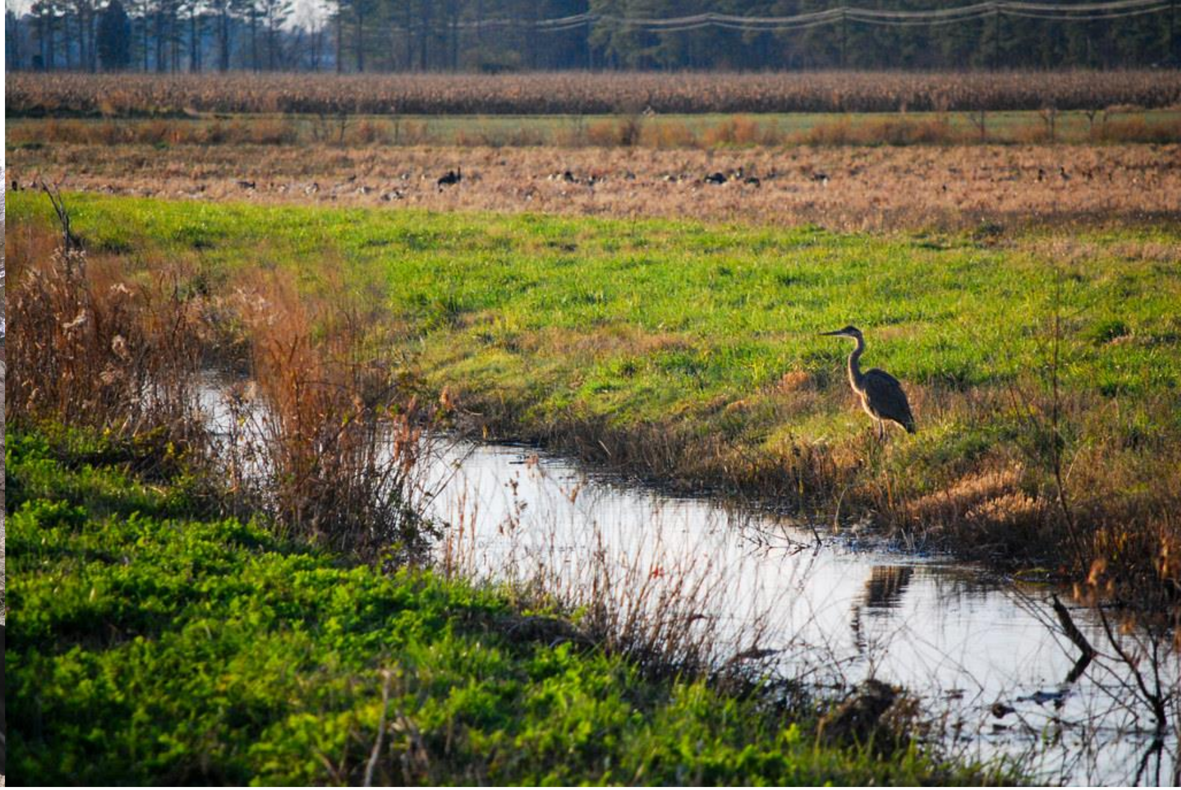

Thank you for joining us!

Contact Jeremy Hanson with follow-up questions or comments: jchanson@vt.edu; 410-267-5753

New or updated materials will be posted when available to the CBP calendar entry for this webcast:
https://bit.ly/2k4HXgk

Photos: (Left) courtesy of Tim Rosen, ShoreRivers, used with permission; (Right) Chesapeake Bay Program