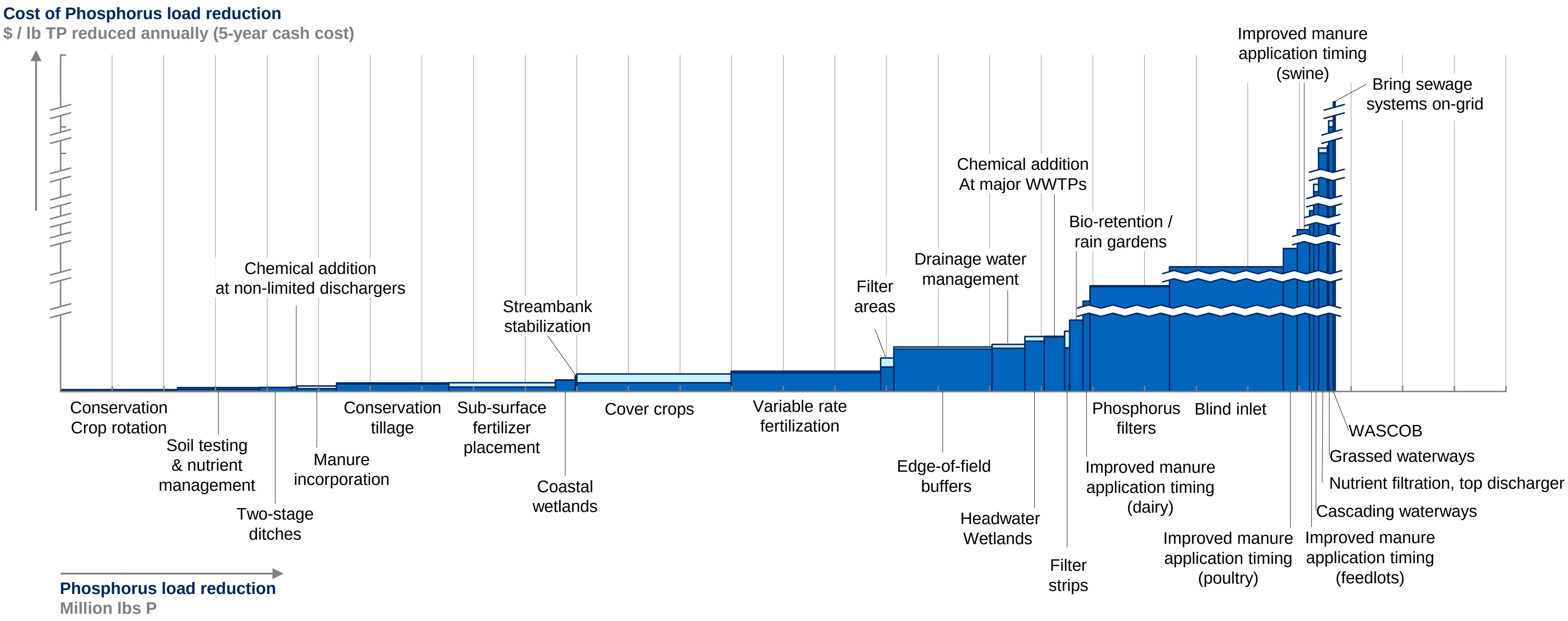
H2Ohio

Graphics for inclusion in DAP Appendix C

Estimated P load reduction through prioritized best practices

Using 2018 5-year trailing annual Spring TP in Maumee basin as baseline



Element	Description	Unit
Impact	Share of P load the intervention reduces	% P load reduced per unit (i.e., acre)
Cost	Cost of implementing and maintaining given intervention	$ / lb P load reduced
Applicability	Incremental units to which interventions can be applied	# incremental units (i.e., acre)

BMP Category: Name of BMP

Basic definition of the BMP

Impact

Range of phosphorus reduction efficiencies per unit

Detailed description of how BMP reduces phosphorus

Cost

Range of costs to implement BMP per unit

$/acres

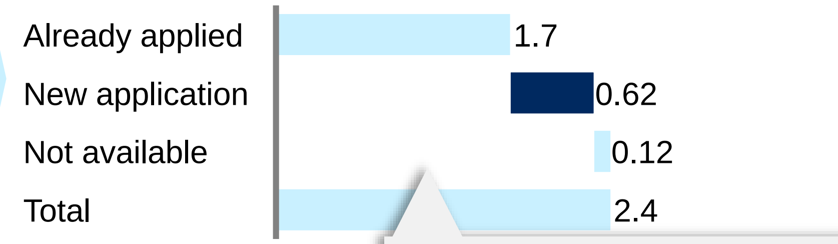
	Cost	Benefit
Recurring	$1 – $13 Soil testing	$(15) - $ 0 Reduced P applied
One-time	$4 – $6 Plan development	

Red $ in benefit box is $ saved

New application

Number of new units (e.g. acres) to which BMP can be applied

Intervention potential in Maumee Basin, million acres

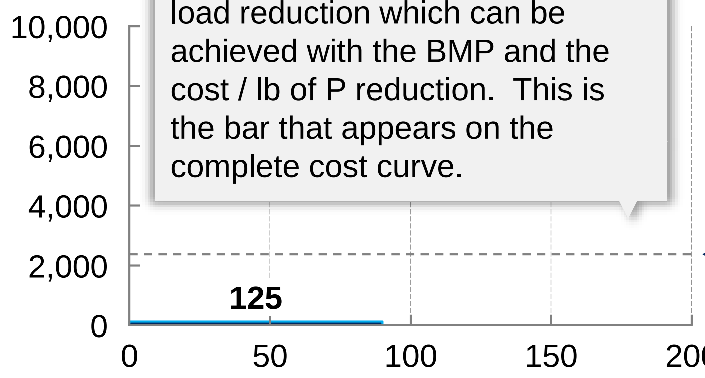


Stacked bar chart shows BMP potential application in Maumee basin as well as on how many units it has already been applied

Cost ÷ (**0.83** lb P/ac [4] × Impact)

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



This chart shows the volume of P load reduction which can be achieved with the BMP and the cost / lb of P reduction. This is the bar that appears on the complete cost curve.

Average cost across all interventions is **~$2,373** / lb P load reduction [3]

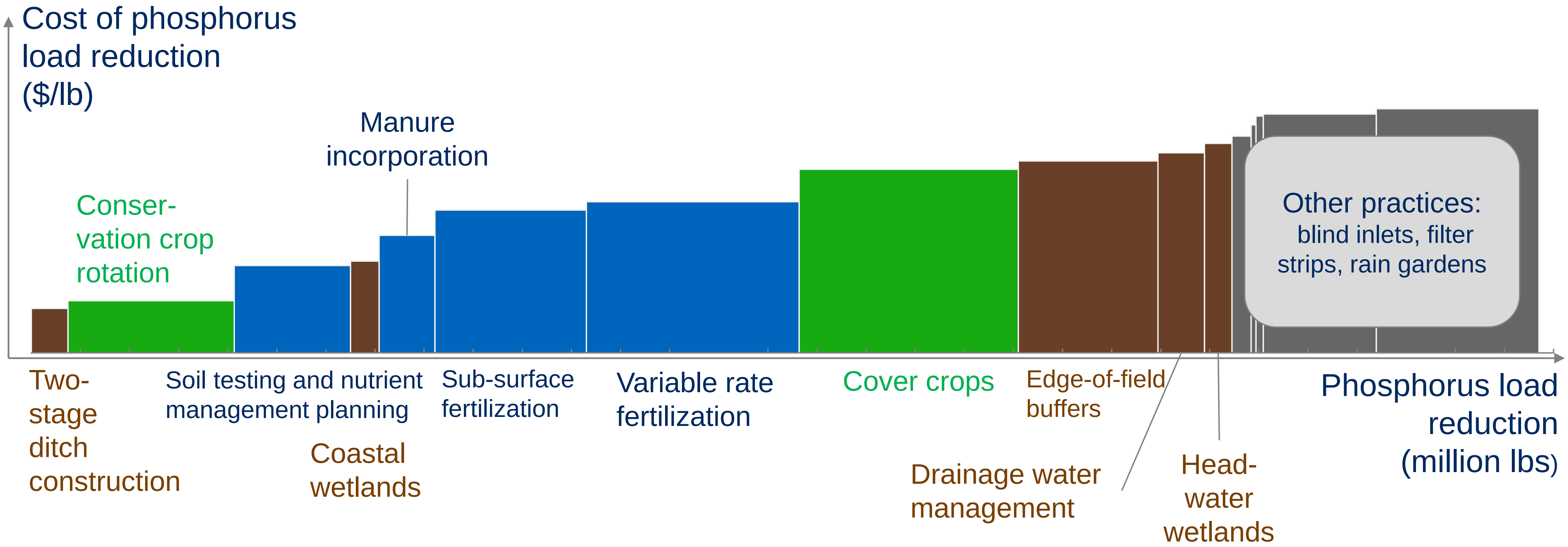
Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

Footnotes contain information about assumptions made as well as sources for the data used

Top-priority practices can be bucketed into three categories

Colors on graph correspond to categories of best management practices



Nutrient Management | **Erosion Management** | **Water Management**

1 **Nutrient management:** Soil testing & nutrient management planning

Develop and verify 'voluntary nutrient management plans' addressing '4Rs' (right source, rate, place, and timing) of P application at field level, based on regular soil testing

Impact

10 – 25% P load reduction / acre

Using data-driven plans and regular soil testing to reduce fertilizer application rates and/or improve fertilizer use efficiency

Cost

$ (10) – 19 / acre

= $/acres

	Cost	Benefit
Recurring	$1 – $13 Soil testing	$(15) - $ 0 Reduced P applied
One-time	$4 – $6 Plan development	

New application

~620K acres

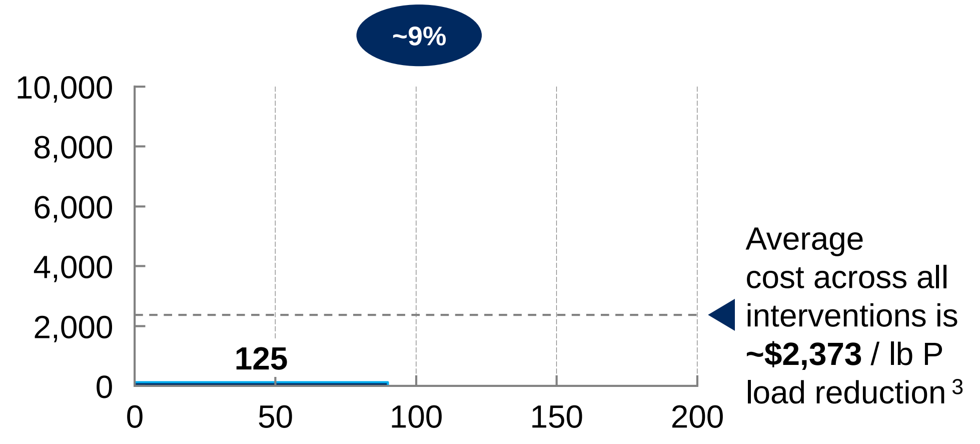
Intervention potential in Maumee Basin, million acres

Already applied	1.7
New application	0.62 0.8
Not available	0.12
Total	2.48

Cost ÷ (0.83 lb P/ac [4] ⊗ Impact)

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from "The Agricultural BMP Handbook for Minnesota" and "Chesapeake Assessment Scenario Tool", OSU "Nutrient Management Plan", refined via ODA internal estimates; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

2 **Nutrient management:** Variable rate fertilization

In-field varied P application via precision agriculture tools

Impact

10 – 30% P load reduction / acre

Utilize custom fertilizer spreaders, GPS, and sensing technologies enabling targeted, site-specific P application to improve in-field use efficiency

Cost

$39 – $109 / acre

= $/acres

	Cost	Benefit
Recurring	$8 – $12 Software, monitors	$(44) - $(28) Less fertilizer
One-time	$75 – $125 Training	

New application

~992K acres

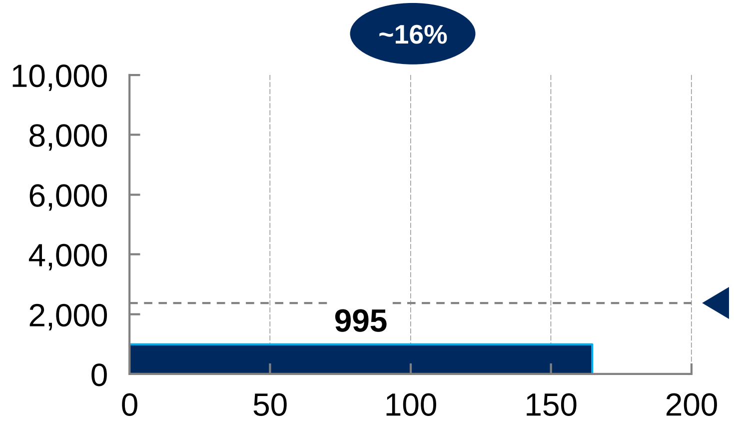
Intervention potential in Maumee Basin, million acres

Already applied	0.74
New application	0.99
Not available	0.74
Total	2.48

Cost ÷ (**0.83** lb P/ac [4] ⊗ Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Likely inclusive, rather than incremental, to 'soil testing & nutrient management planning'

SOURCE: For [Cost] and [Impact] Preliminary estimates from the Chesapeake Bay Program (2019), US EPA STEPL/Region 5 "BMPList", and "Chesapeake Assessment Scenario Tool", refined via ODA internal estimates; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

3 **Nutrient management:** Sub-surface fertilizer placement

P application >1cm below soil surface using specialized equipment (i.e., manual injectors)

Impact

20 – 40% P load reduction / acre

Sub-surface P placement reduces both surface and sub-surface load by limiting exposure of applied P to run-off in high-flow events (i.e., extreme rainfall)

Cost

$15 – $70 / acre

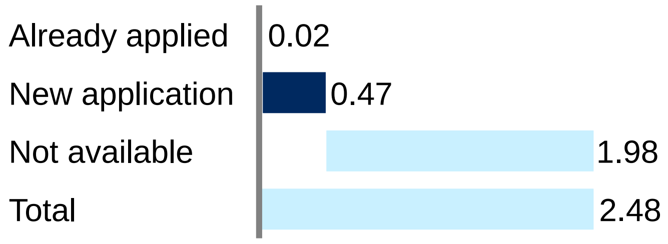
\# $/acres

	Cost	Benefit
Recurring	**$15 – $70** ▪ Equipment (rental), ▪ Labor	
One-time		

New application

~471K acres

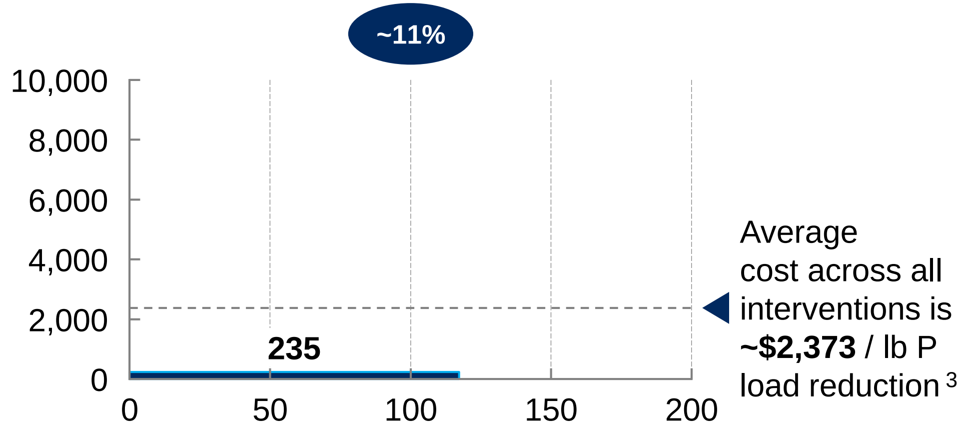
Intervention potential in Maumee Basin, million acres



Cost ÷ [**0.83** lb P/ac [4] ⊗ Impact]

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cash cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from ODA Estimate; Ohio EPA (2019), "Draft - Evaluating Management Options to Reduce Lake Erie Algal Blooms with Models of the Maumee Watershed"; University of Michigan Water Center, "Informing Lake Erie Agriculture Nutrient Management"; "Executive Summary – Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River basin" (2013). [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

4 **Nutrient Management:** Manure incorporation

Incorporation of manure within 3 days, <40% soil disturbance

Impact

10 - 20% P load reduction / acre

Mixing organic sources of P into the soil profile within a specified time period from application limits interaction of nutrients with water during high flow events (e.g. heavy rainfall)

Cost

$10 – $20 / acre

$/acres

	Cost	*Benefit*
Recurring	**$10 – $20** Equipment and labor	
One-time		

New application

~347K acres

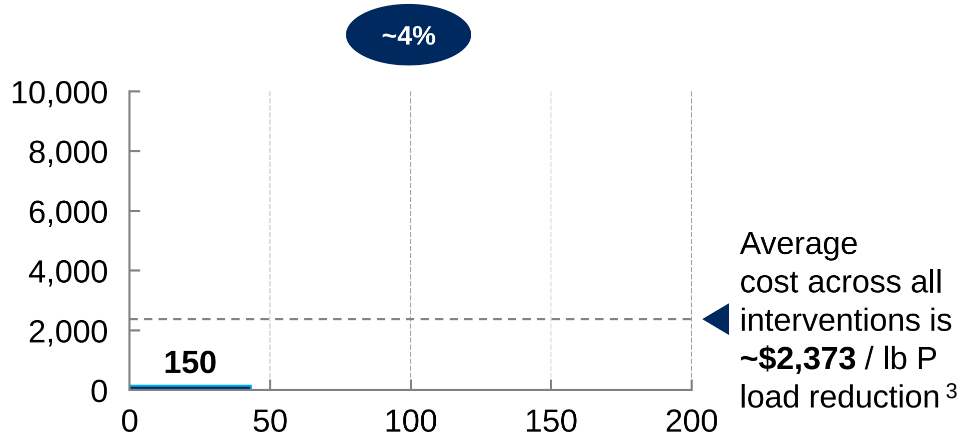
Intervention potential in Maumee Basin, million acres

Already applied	0.14
New application	0.34
Not available	1.98
Total	2.48

Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from Chesapeake Bay Program (2019), "Chesapeake Assessment Scenario Tool"; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

5 Nutrient Management: Phosphorus filters

P removal structure using industrial byproducts to trap P en route to waterways

Impact

20 - 23% P load reduction / acre

Utilization of an underground tank – containing a chemical composite which acts as an 'adhesive tape' - to catch P as water flows to ditch or nearby creek, stream, or lake

Cost

$758 – $1,263 / acre

$/acres

	Cost	Benefit
Recurring	$8 - $13 Material replacement	
One-time	$750 – $1,250 Sorbing media	

New application

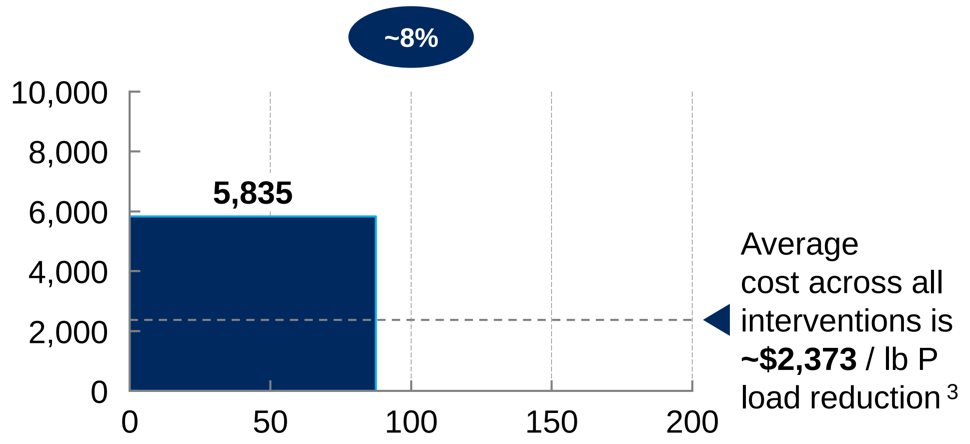
~496K acres

Intervention potential in Maumee Basin, million acres

Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Application of Phosphorus filters on single acre results in treatment of ~20 acres, on average

SOURCE: For [Cost] and [Impact] Preliminary estimates from BalticSea 2020, "Ditch dams and filters to trap phosphorus in agriculture" (article); [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

6 Erosion Management: Conservation crop rotation

Incorporation of 1+ resource-conserving crop in rotation (i.e., alfalfa / hay)

Impact

15 – 35% P load reduction / acre

Choosing crop rotation designed to minimize nutrient and resources losses – i.e., summer-harvested crops enable fertilization outside of highest flow periods; planting of perennials reduces need for P application

Cost

$5 – $10 / acre

$/acres

	Cost	Benefit
Recurring	**$5 – $10** Planting and labor	
One-time		

New application

~620K acres

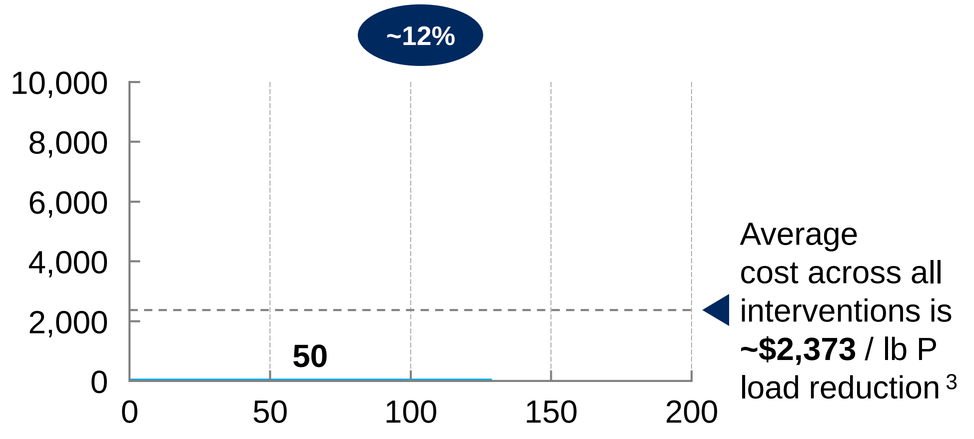
Intervention potential in Maumee Basin, million acres

Already applied	0.12
New application	0.62
Not available	1.73
Total	2.48

Cost ÷ [**0.83** lb P/ac [4] × Impact]

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of ‘cost’ range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of ‘cost’ range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from Iowa State University, "Executive Summary - Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin" (2013); US EPA, STEPL/Region 5 "BMPList"; University of Michigan Water Center; ; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

7 Erosion Management: Cover crops

Planting small grains, legumes, or other crops in-between cash crop production seasons when land would otherwise lay fallow

Impact

15 – 40% P load reduction / acre

Increase water infiltration pushes DRP down into the soil which increase soil organic matter content and reduce P run-off when it rain

Cost

$45 – $100 / acre

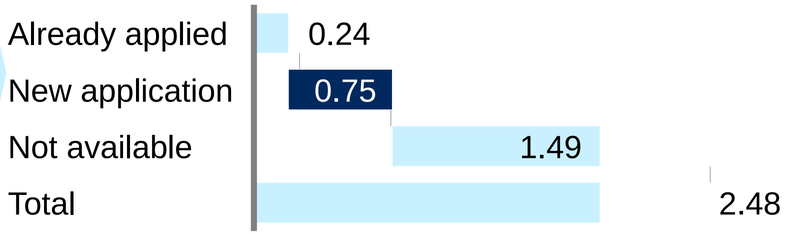
Cost | *Benefit* | # $/acres

	Cost	*Benefit*
Recurring	**$45 – $100** Planting and labor	
One-time		

New application

~744K acres

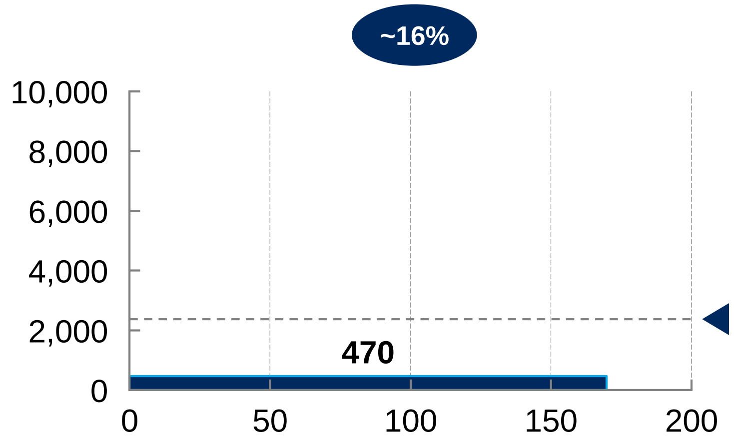
Intervention potential in Maumee Basin, million acres



Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from Iowa State University, "Executive Summary - Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin" (2013); US EPA, STEPL/Region 5 "BMPList"; University of Michigan Water Center, "Informing Lake Erie Agriculture Nutrient; Goldman-Carter, J. & Bryant, L. (2016); [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

8 Erosion Management: Grassed waterways

In-field graded channels seeded to grass or other vegetation

Impact

15 – 25% P load reduction / acre

Use living cover in-field, on existing channels, to resist formation of gullies, which interrupts surface runoff

Cost

$3,100 – $4,200 / acre

$/acres

	Cost	Benefit
Recurring	**$100 – $200** Rented land rate	
One-time	**$3K – $4K** Seeding grass, waterway design	

New application

~10K acres

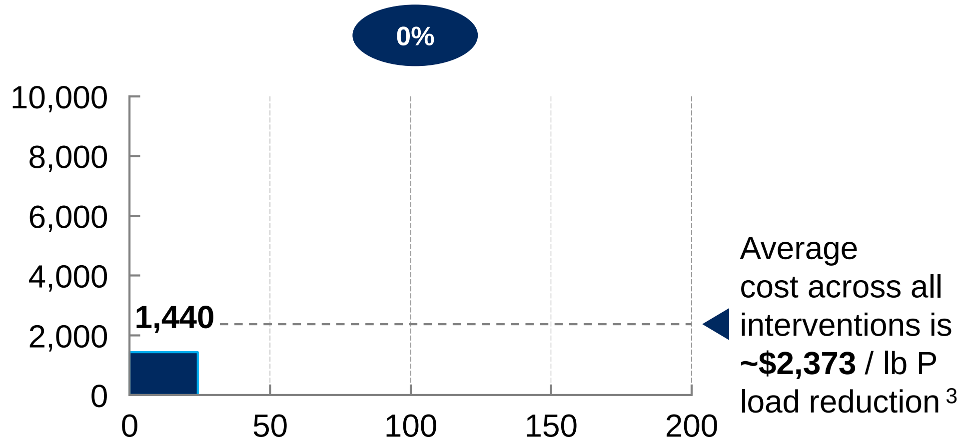
Intervention potential in Maumee Basin, million acres

Already applied	0.01
New application	0.01
Not available	2.46
Total	2.48

Cost ÷ (**0.83** lb P/ac [4] ⊗ Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from The Agricultural BMP Handbook for Minnesota; Rush Creek Headwaters SWA (2018) ; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

9 **Erosion Management:** Cascading waterways

Repaired grassed waterways retrofitted with pond-like areas within

Impact

3 – 8% P load reduction / acre treated[6]

Modification of grassed waterways to enable direct treatment of surface P flows, via inclusion of intermittent ponds to support infiltration

Cost

$305 – $765/ acre treated[5]

Cost | Benefit | # $/acres

	Cost	Benefit
Recurring	**$5 - $15** Monitoring, reinforcing pits	
One-time	**$300 - $750** Excavate waterway, design	

New application

~124K acres

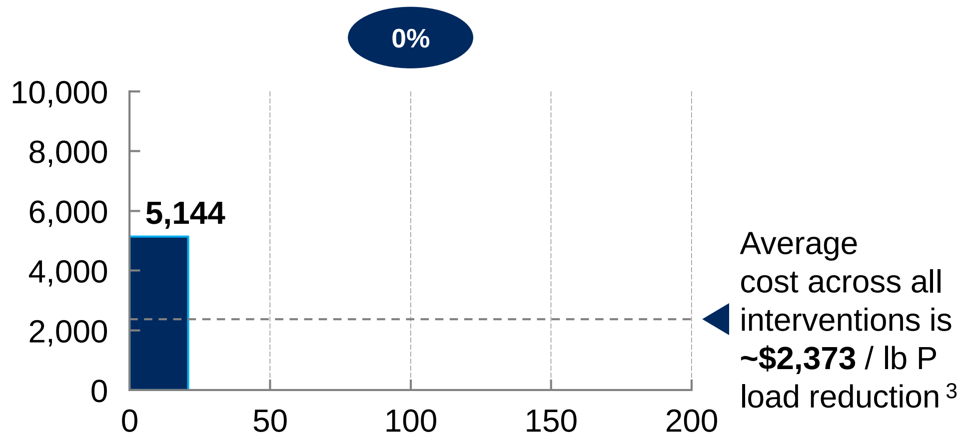
Intervention potential in Maumee Basin, million acres

Already applied	0.00
New application	0.124
Not available	2.35
Total	2.48

Cost ÷ [**0.83** lb P/ac [4] × Impact]

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Application of cascading waterways on single acre results in treatment of ~20 acres, on average; 6 incremental to impact of grassed waterways

SOURCE: For [Cost] and [Impact] Preliminary estimates from ODA estimates; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

10 **Wetlands:** Coastal flow-through wetlands (created)

Construction of 'flow-through' wetlands at mouth of the Maumee basin

Impact

10 - 30% P load reduction / 1% flow treated

Foster anaerobic aquatic plant ecosystems in way of Phosphorus-laden water flows to enable sediment settling and direct uptake of dissolved reactive phosphorus (DRP)

Cost

$2.2M / 1% flow treated

$/acres

	Cost	*Benefit*
Recurring	**$44K** ▪ Upkeep ▪ Maintenance	
One-time	**$2.2M** ▪ Material costs ▪ Labor/Construction	

New application

~4% of Maumee flow

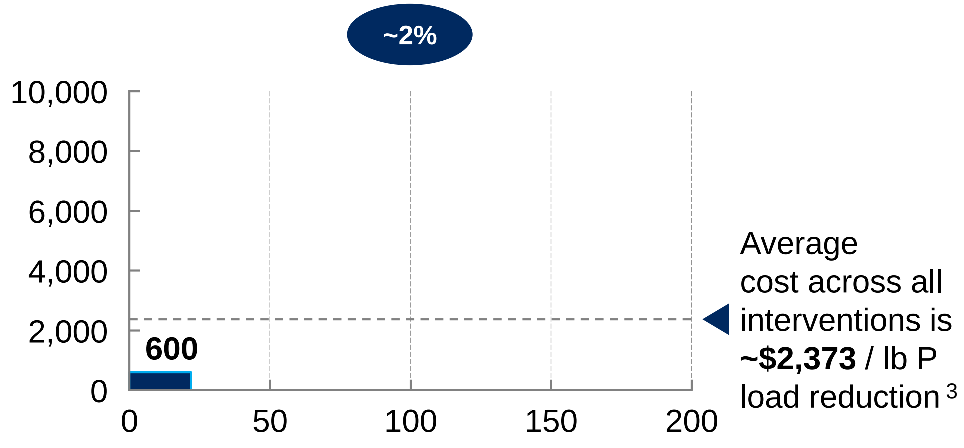
Intervention potential in Maumee Basin, % of flow

Already applied	0
New application	4
Not available	96
Total	100

Cost ÷ (24,904 lbs per 1% of Maumee River flow)[3] × Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (3-year cash cost) [1]



Volume of P load reduction, '000 lbs P [2]

24,904 lbs per 1% of Maumee River flow)[3] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] Preliminary estimates from ODNR, incl. project-specific estimates appraised; Ohio EPA (2019), "Draft - Evaluating Management Options to Reduce Lake Erie Algal Blooms with Models of the Maumee Watershed"; [Incremental implementation] estimates consider budgeted projects from ODNR

11 Wetlands: Wetlands restoration (inland)

Construction of a wetland at a location where wetlands existed historically

Impact

2 – 60% P load reduction / acre treated[6]

Restoring wetlands slows water flow to the lake, allowing increased time for sediments to settle and nutrients to be taken up by plants – usually cheaper than creation of new wetlands

Cost

$42 – $88 / acre treated[5]

$/acres

	Cost	*Benefit*
Recurring	$2 – $8	
One-time	$40 – $80 Installation	

New application

~83K acres

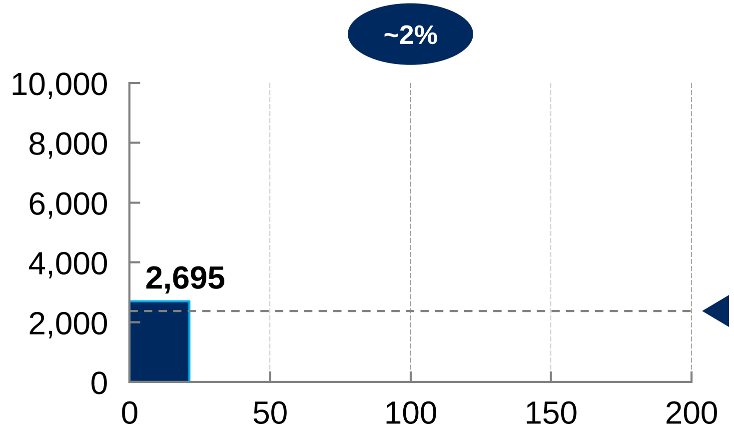
Intervention potential in Maumee Basin, million acres

Already applied	0
New application	0.08
Not available	2.4
Total	2.5

Cost ÷ [**0.83** lb P/ ac [4] ⊗ Impact]

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/t ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Single acre of wetlands estimated to treat ~50 acres, on average; 6 Considered inclusive, rather than incremental, of base load reduction from non-functioning or pre-existing wetlands'

SOURCE: : For [Cost]: Ohio EPA (2019), "Draft - Evaluating Management Options to Reduce Lake Erie Algal Blooms with Models of the Maumee Watershed"; Chesapeake Bay Program (2019), "Chesapeake Assessment Scenario Tool" and [Impact]: US Army Corps of Engineers Review, "Wetlands for Phosphorus Reduction in Great Lakes Watersheds" (2017); "Arkansas BMP Tool" (reproduced from Table 2, Merriman, 2009); Chesapeake Bay Program (2019), "Chesapeake Assessment Scenario Tool"; The Agricultural BMP Handbook for Minnesota; [Incremental implementation] estimates are illustrative and to be refined.

12 Hydraulic Retention / Detention: Drainage water management

Allow adjustment of subsurface outlet elevation via manually-constructed water control structure

Impact

5 – 20% P load reduction / acre treated[5]

Retain sub-surface load at critical times by controlling the amount and timing of water leaving agricultural fields through tile lines

Cost

$107 – $165 / acre treated[5]

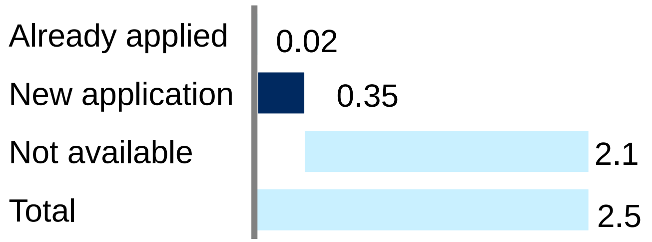
= $/acres

	Cost	Benefit
Recurring	$7 – $15 Labor ops	
One-time	$100 – $150 Water structure development	

New application

~345K acres

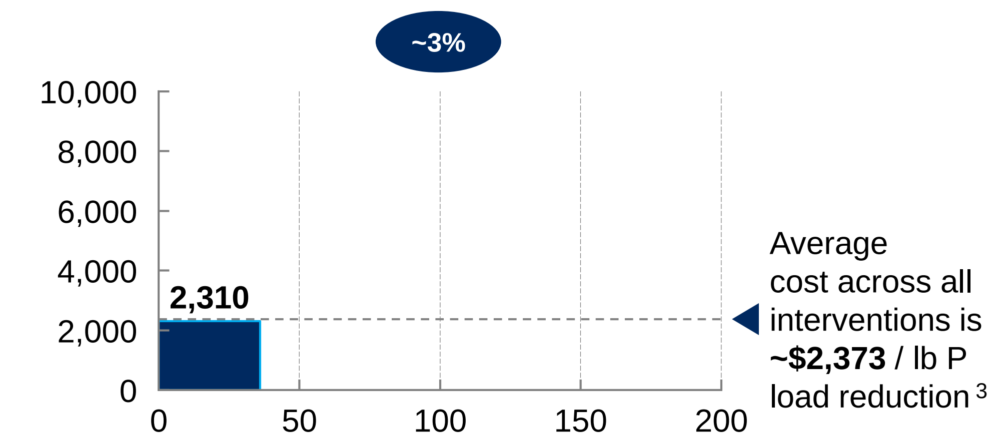
Intervention potential in Maumee Basin, million acres



Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% = Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 For every acre on which drainage water management structures are applied, ~20 acres are treated, on average

SOURCE: For [Cost]: USDA NRCS 'Cost Scenarios'; For [Impact] Rush Creek Headwaters SWA (2018); "Executive Summary - Iowa Science Assessment of Nonpoint Source Practices to Reduce Nitrogen and Phosphorus Transport in the Mississippi River Basin" (2013); Williams, M.R., King, K.W., & Fausey, N.R. (2015); Needelman, B.A., Kleinman, P.J.A., Strock, J.S., & Allen, A.L. (2007); Skaggs, R.W., Breve, M.A., & Gilliam, J.W. (2009);; Refined via ODA and OEPA experts; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

13 Hydraulic Retention / Detention: Blind inlet

Tile riser replacement at farm depression low-point to reduce nutrient flow

Impact

25 – 38% P load reduction / acre treated[4]

Installation of "French drains" in place of tile risers to filter water through soil and rock before entering the tile system; practice reduces surface-laden P flows

Cost

$1k – $3K / acre treated[4]

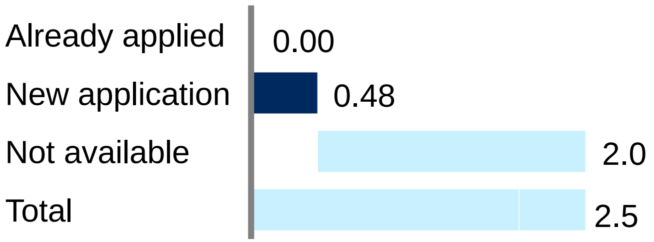
$/acres

	Cost	Benefit
Recurring		
One-time	$1K – $3K Construction, installation	

New application

~484K acres

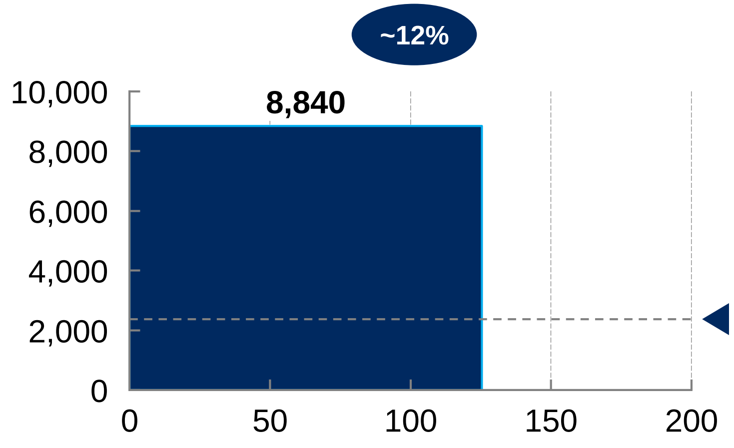
Intervention potential in Maumee Basin, million acres



Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 4 For every acre applied, blind inlets are estimated to treat ~10 acres

SOURCE: For [Cost] and [Impact] Preliminary estimates from Gupta et al (2018), "Evaluating WASCoBs, Vegetative Filter Strips, and Road-side Ditches in a Rural Watershed"; Ohio Phosphorus Task Force (2012), "Significance of Tile Drainage as a Conduit for Phosphorus Transport"; Gupta et al (2018), "Evaluating WASCoBs, Vegetative Filter Strips, and Road-side Ditches in a Rural Watershed"; Significance of Tile Drainage as a Conduit for Phosphorus Transport" >; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

14 Hydraulic Retention / Detention: Water and sediment control basin (WASCOB)

Earth embankment across slope to trap sediment and detain water

Impact

3 – 10% P load reduction / acre treated[5]

A basin constructed to collect water and prevent P-laden sediment from moving downstream

Cost

$755 – $1,265 / acre treated[5]

= $/acres

	Cost	*Benefit*
Recurring	**$4 – $13** Land rental rate	
One-time	**$0.7K – $1.2K** Planting grass on mounted dike	

New application

~99K acres

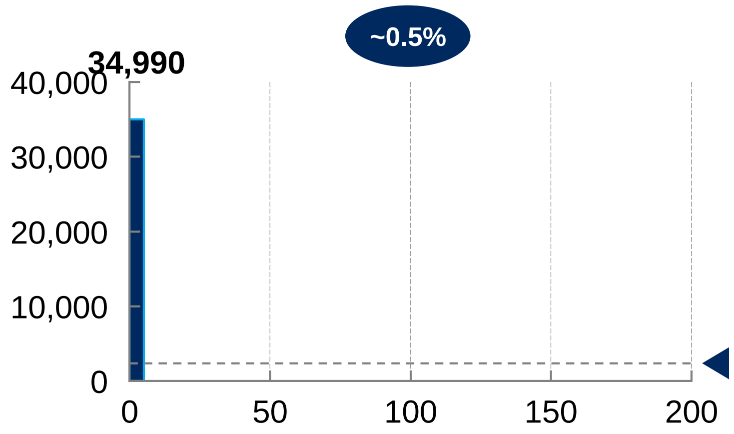
Intervention potential in Maumee Basin, million acres

Already applied	0
New application	0.1
Not available	2.4
Total	2.5

Cost ÷ (**0.83** lb P/ac [4] × Impact)

x% = Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Application of WASCOB on single acre results in treatment of ~20 acres, on average

SOURCE: For [Cost] and [Impact] Stinner et al (2018), "Instrumentation, Measurement, and Findings from the USDA-ARS Edge-of-Field Research Network"; Williams et al (2013), "Drainage water management effects on tile discharge and water quality" refined via ODA and OEPA experts; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

15 Edge-of-field buffers: Riparian forest buffers

Planting of perennial vegetation beside waterways to filter phosphorus from runoff

Impact

30 – 40% P load reduction / acre treated[5]

Using combination of trees, shrubs, and other perennials adjacent to streams, lakes, or wetlands (typically 35-120+ ft corridors) for improved nutrient filtration and runoff interruption to reduce both surface and sub-surface P loads (as well as other co-benefits)

Cost

$520 – $740 / acre treated[5]

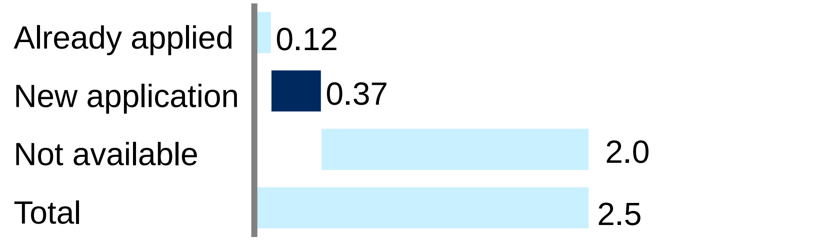
$/acres

	Cost	*Benefit*
Recurring	**$20 – $40** Land rental costs	
One-time	**$500 – $700** Purchase & plant trees / shrubs	

New application

~372K acres

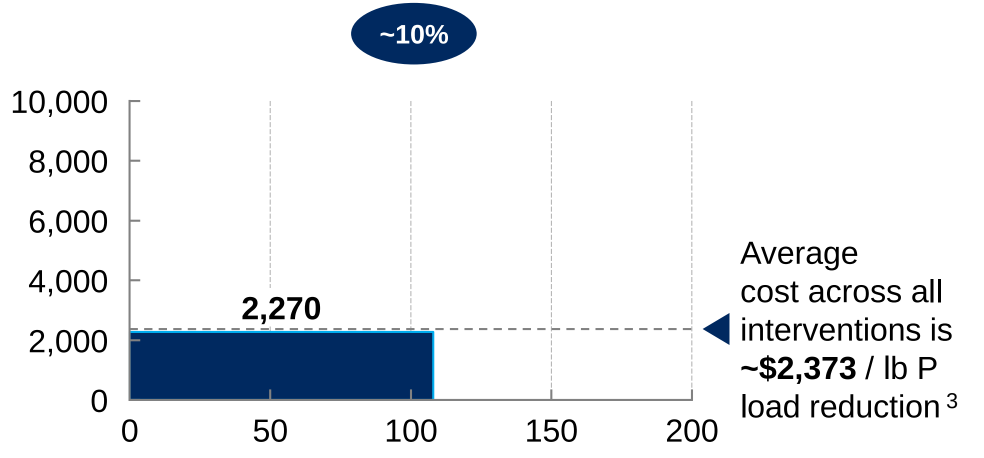
Intervention potential in Maumee Basin, million acres



Cost ÷ (**0.83** lb P/ac [4] ⊗ Impact)

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Application of riparian forest buffer on single acre results in treatment of 2-3 acres, on average

SOURCE: For [Cost] and [Impact] Preliminary estimates come from The Agricultural BMP Handbook for Minnesota; US EPA, STEPL/Region 5 "BMPList"; [Incremental implementation] with refinement driven from ODA estimates and academic literature (OSU)

16 Edge-of-field buffers: Filter areas

Expansion of targeted P-filtration areas at targeted drainage point

Impact

3 – 5% P load reduction / acre treated[5]

Modified version of filter strips, expanding filtration area at critical points of outflow, enabling treatment of larger tracts of land

Cost

$19 – $45 / acre treated[5]

= $/acres

	Cost	*Benefit*
Recurring	**$10 – $15** Mowing, land rental	
One-time	**$9 – $30** Purchase seeds, plant grasses	

New application

~471K acres

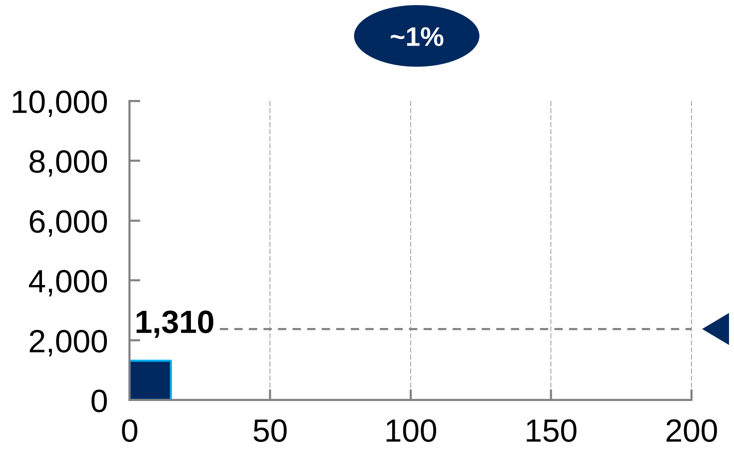
Intervention potential in Maumee Basin, million acres

Already applied	0.02
New application	0.47
Not available	1.98
Total	2.48

Cost ÷ (**0.83** lb P/ac [4] × Impact)

#% = Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 Application of filter areas on single acre results in treatment of ~20 acres, on average (~50 acres per square mile treatment)

SOURCE: For [Cost] and [Impact] Preliminary estimates are from ODA; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

17 **Edge-of-field buffers:** Filter strips

Herbaceous vegetation areas near waterways removing P from overland flow

Impact

30 – 43% P load reduction / acre

Herbaceous coverage – typically grasses, sedges, ferns, legumes, etc. which may tolerate intermittent flooding – reduces sediment and flow into ditches and streams

Cost

$370 – $900 / acre

= $/acres

	Cost	*Benefit*
Recurring	**$200 – $300** Mowing, land not rented	
One-time	**$170 – $600** Purchase seeds, plant grasses	

New application

~18K acres

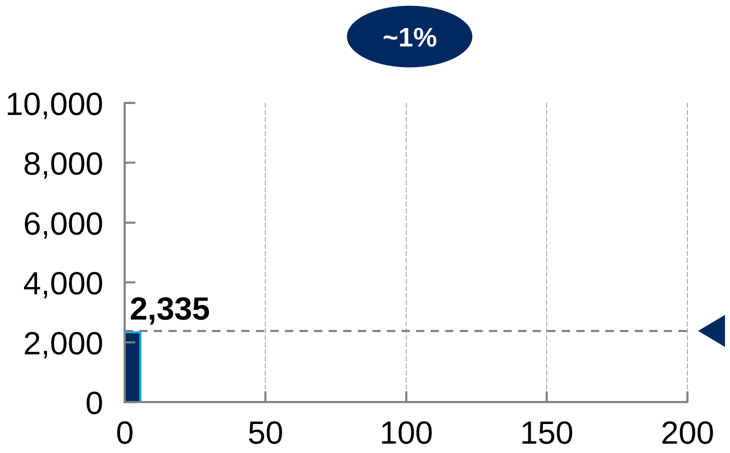
Intervention potential in Maumee Basin, million acres

Already applied	0.03
New application	0.02
Not available	2.43
Total	2.48

Cost ÷ (0.83 lb P/ac [4] × Impact)

#% = Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/ac [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: ODA expert insights; Helmers et al, "Buffers and vegetative filter strips"

18 Stream management: Two-stage ditch construction

Installation of two-stage ditches to restore floodplain access

Impact

5 – 30% P load reduction / Lineal ft

Constructed ditches slow down and spread out water during periods of high flow. This and vegetation placed throughout the channel helps retain a greater proportion of sediments and nutrients.

Cost

$3 - $18/ Lineal ft

	Cost	*Benefit*
Recurring		
One-time	$3 – 18	

New application

~327K Lineal ft

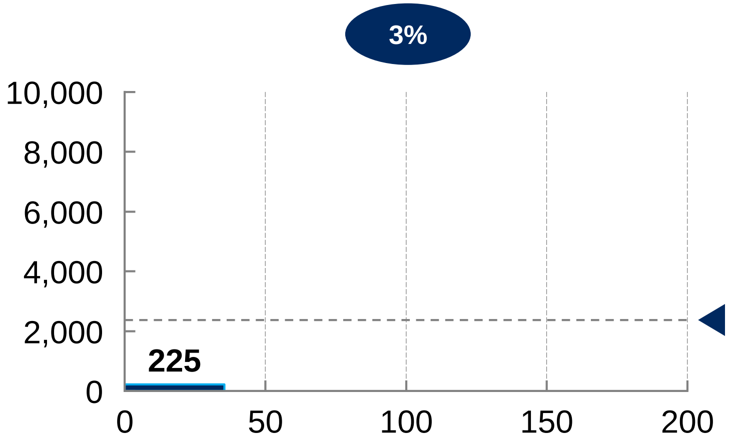
Intervention potential in Maumee Basin, lineal feet

Already applied	0.00
New application	0.13
Not available	3.03
Total	3.27

Cost ÷ (**0.83** lb P/Lineal ft [4] ⊗ Impact)

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.83 lb P/Lineal ft [4] ⊗ Impact ⊗ New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] estimates from Indiana, "Recommended Measures & Estimated Load Reductions" and Clary et al, "Stream Restoration BMP Database"; US EPA, STEPL/Region 5 (bottom-up modeling); [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

19 **Stream management:** Streambank stabilization

Structural protection of streambanks and constructed channels

Impact

50 – 75% P load reduction / Lineal ft

Streambanks are protected from erosion, which in turn limits the amount of particulate phosphorus which reaches waterways

Cost

$5 - $15 / Lineal ft

	Cost	*Benefit*
Recurring		
One-time	$5 – 15	

New application

~132K Lineal ft

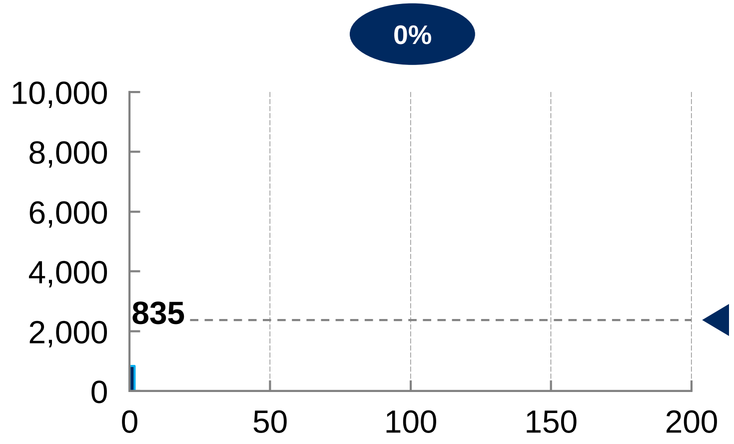
Intervention potential in Maumee Basin, million acres

Already applied	0.00
New application	0.13
Not available	14.65
Total	14.78

Cost ÷ (**0.02** lb P/Lineal ft [4] × Impact)

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost) [1]



Average cost across all interventions is **~$2,373** / lb P load reduction [3]

Volume of P load reduction, '000 lbs P [2]

0.02 lb P/Lineal ft [4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of ‘cost’ range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of ‘cost’ range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land

SOURCE: For [Cost] and [Impact] estimates from Indiana, “Recommended Measures & Estimated Load Reductions”; Clary et al, “Stream Restoration BMP Database”; Open Channel / Two-Stage Ditch (NRCS 582) via USDA; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)

20 **Green infrastructure:** Bio-retention / rain gardens

Shallow planted depression to retain stormwater pre-discharge

Impact

23 – 43% P load reduction / acre treated[5]

Retention of stormwater for longer periods of time allows for increased infiltration into the soil and uptake by plants

Cost

$50K – $750K / acre treated[5]

= $/acres

	Cost	*Benefit*
Recurring		
One-time	$50K – 750K Installation cost	

New application

~100K acres

Intervention potential in Maumee Basin, million acres

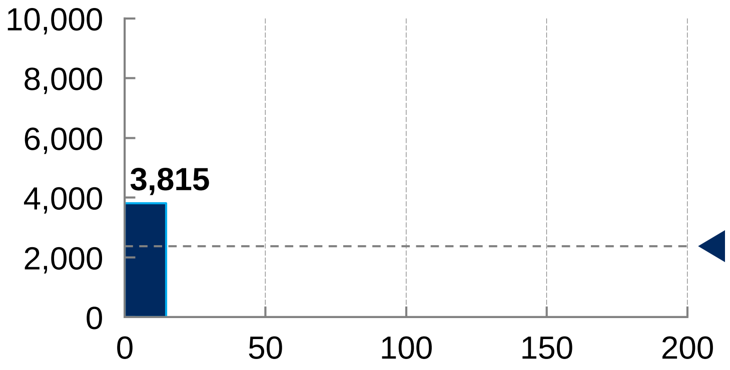
Already applied	0.00
New application	0.10
Not available	0.23
Total	0.33

Cost ÷ [0.45 lb P/ac[4] × Impact]

#% Share of target load reduction

Cost of Phosphorus load reduction $ / lb TP reduced (5-year cost)[1]

~1%



Average cost across all interventions is **~$2,373** / lb P load reduction[3]

Volume of P load reduction, '000 lbs P[2]

0.45 lb P/ac[4] × Impact × New application

1 Simple average of two scenarios, reflecting (i) upper bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs, and (ii) lower bound of 'cost' range and lower bound of 'impact range, where cost includes 'one-time' implementation costs, as well as (5x) annually-recurring costs; 2 Simple average of two scenarios, reflecting (i) lower bound and (ii) upper bound of 'impact' range; 3 Simple average of "Cost of Phosphorus load reduction" for ~20 most cost-efficient practices towards target load reduction; 4 Baseline Spring TP load per acre (5yr trailing average) in Maumee basin on agricultural land; 5 For each acre on which bio-retention / rain gardens are applied, ~20 acres are estimated to be treated, on average

SOURCE: For [Cost] and [Impact] Chesapeake Bay Program (2019), "Chesapeake Assessment Scenario Tool"; US EPA, STEPL/Region 5 "BMPList"; Refined through ODA and OEPA expert insights; [Incremental implementation] estimates driven from ODA estimates and academic literature (OSU)