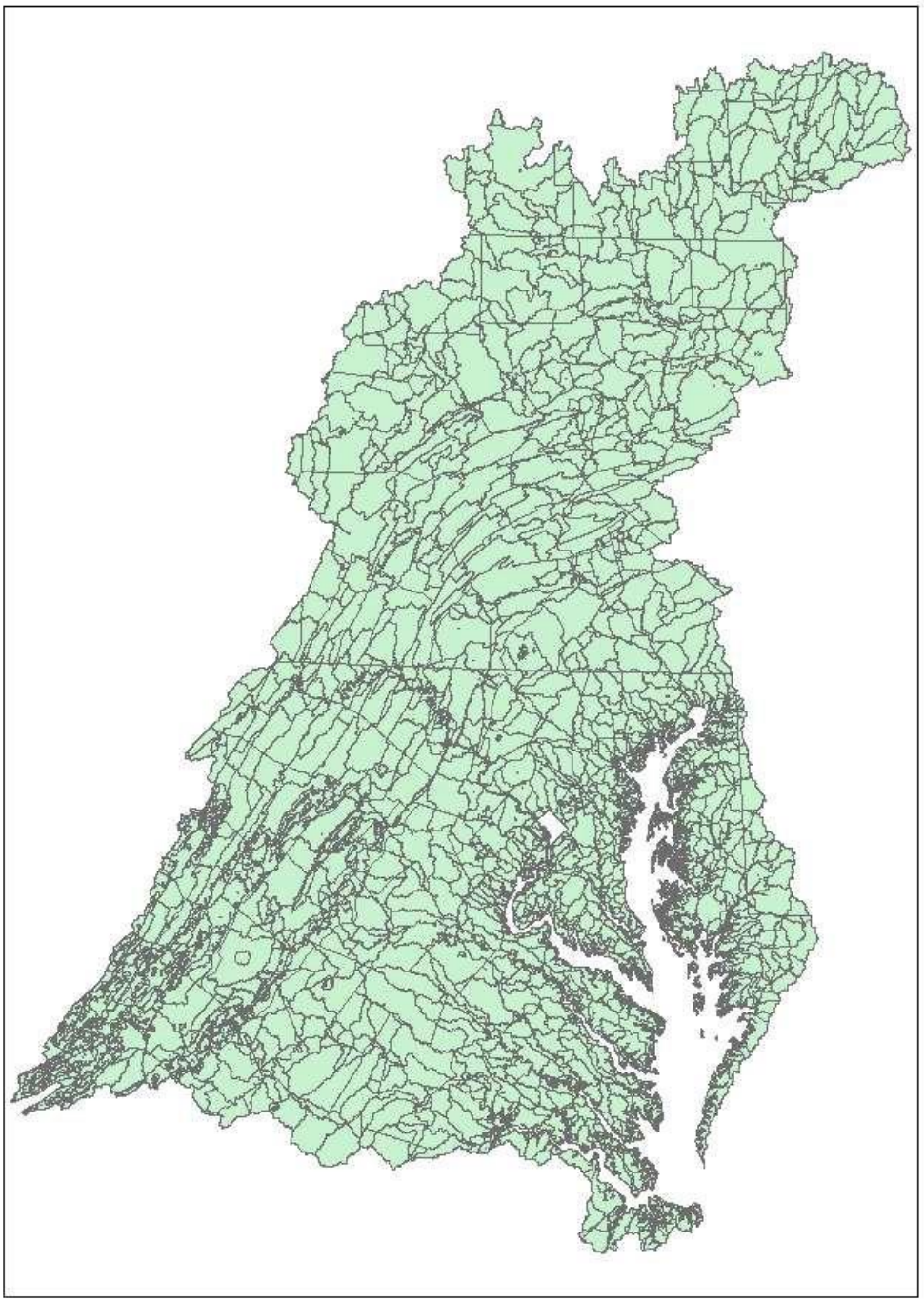
Agricultural Costs of the Chesapeake Bay TMDL

Supporting Information

Figure S1. Phase 5.3.2 Land–River Segments in the Chesapeake Bay Watershed



Source: Produced using GIS data from USEPA (6)

Table S1. BMP Descriptions

BMP	Description
Alternative Watering	Use of permanent or portable livestock water troughs placed away from the stream corridor. The source of water supplied to the facilities can be from any source including pipelines, spring developments, water wells, and ponds. In-stream watering facilities such as stream crossings or access points are not considered in this definition.
Ammonia Emissions Reduction – Alum	Litter amendments like alum suppress the formation of ammonia from ammonium in litter.
Ammonia Emissions Reduction – Biofilters & Lagoon	Biofilters attached to animal enclosure ventilation systems detoxify ammonia. Lagoon covers prevent volatilization from loss due to wind.
AWMS – Livestock	Animal Waste Management Systems (AWMS) designed for proper handling, storage, and utilization of wastes generated from Animal Feeding Operations (AFOs); reduced storage and handling loss is conserved in the manure available for land application.
AWMS – Poultry	
Barnyard Runoff	Control runoff from barnyard areas (e.g., roof runoff control, diversion of clean water from entering the barnyard, and control of runoff from barnyard areas).
Capture & Reuse	Capture and reuse entails the use of lined return ditches or other collections methods to lined holding ponds that retain excess irrigation water runoff and capturing stormwater runoff.
Carbon Sequestration	Conversion of cropland to hay land (warm season grasses). The hay land is managed as a permanent hay land providing a mechanism for sequestering carbon within the soil.
Commodity Cover Crops	May be harvested for grain, hay or silage and they may receive nutrient applications, but only after March 1 of the spring following their establishment.
Conservation Plan	Combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices or a certified private consultant. In all cases the plan must meet technical standards.

BMP	Description
Conservation Tillage	Planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components, (a) a minimum 30% residue coverage at the time of planting and (b) a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface.
Continuous No-Till	Crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. It involves no-till methods on all crops in a multi-crop, multi-year rotation.
Cover Crops	The planting and growing of cereal crops (non-harvested) with minimal disturbance of the surface soil. Different species are accepted as well as, different times of planting (early, late and standard), and fertilizer application restrictions.
Cropland Irrigation Management	Decreases climatic variability and maximizes crop yields. The potential nutrient reduction benefit stems not from the increased average yield (20-25%) of irrigated versus non-irrigated cropland, but from the greater consistency of crop yields over time matched to nutrient applications. This increased consistency in crop yields provides a subsequent increased consistency in plant nutrient uptakes over time matched to applications, resulting in a decrease in potential environmental nutrient losses.
Dairy Precision Feeding	Reduces quantity of phosphorous and nitrogen fed to livestock by formulating diets within 110% of Nutritional Research Council recommended level to minimize the excretion of nutrients without negatively affecting milk production.
Decision Agriculture	Information and technology based management system that is site specific and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment.
Enhanced Nutrient Management	The nutrient management rates of nitrogen application are set 35% higher than crop needs to ensure nitrogen availability under optimal growing conditions. An incentive or crop insurance is used to cover the risk of yield loss.
Forest Buffers	Linear wooded areas along rivers, stream and shorelines. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35 feet minimum width required.

BMP	Description
Grass Buffers	Linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment and other pollutant from runoff. The recommended buffer width for riparian forests buffers (agriculture) is 100 feet, with a 35 feet minimum width required.
Horse Pasture Management	Stabilizing overused small pasture containment areas (animal concentration area) adjacent to animal shelters or farmstead.
Land Retirement	Takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees.
Liquid/Poultry Manure Injection	The subsurface application of liquid manure (from cattle, swine, and poultry) reduces nutrient losses for both surface runoff and ammonia emissions. This practice is indicative of low disturbance soil injection systems and is not appropriate for tillage incorporation or other post surface application incorporation methods.
Loafing Lot Management	Stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures (does not include poultry pad installation).
Manure Transport – Inside CBWS	Manure is transported by truck from the county of origin to either another county in the Chesapeake Bay Watershed (CBWS) or outside of the watershed. Manure transported to another county in the Watershed results in increased manure mass in the receiving county.
Manure Transport – Outside CBWS	
Mortality Composters	A physical structure and process for disposing of dead livestock. Composted material is combined with poultry litter and land applied using nutrient management plan recommendations.
Nutrient Management	Nutrient management plan (NMP) implementation (crop) is a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. A NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates. Plans should be revised every 2 to 3 years.
Poultry Phytase	Phytase is an enzyme added to poultry-feed that helps poultry absorb phosphorus. The addition of phytase to poultry feed allows for more efficient nutrient uptake by poultry, which in turn allows decreased phosphorus levels in feed and less overall phosphorus in poultry waste.

BMP	Description
Swine Phytase	Phytase is an enzyme added to swine-feed that helps swine absorb phosphorus. The addition of phytase to swine feed allows for more efficient nutrient uptake by swine, which in turn allows decreased phosphorus levels in feed and less overall phosphorus in swine waste.
Precision Intensive Rotational Grazing	Practice utilizes more intensive forms of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas of the upland pastures. PIRG can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). This practice requires intensive management of livestock rotation, also known as Managed Intensive Grazing systems (MIG), that have very short rotation schedules.
Prescribed Grazing	Utilizes a range of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas. PG can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank).
Stream Access Control with Fencing	Stream access control with fencing involves excluding a strip of land with fencing along the stream corridor to provide protection from livestock. The fenced areas may be planted with trees or grass, or left to natural plant succession, and can be of various widths. The implementation of stream fencing provides stream access control for livestock but does not necessarily exclude animals from entering the stream by incorporating limited and stabilized in-stream crossing or watering facilities.
Stream Restoration	A collection of site-specific engineering techniques used to stabilize an eroding streambank and channel. These are areas not associated with animal entry.
Tree Planting	Any tree planting, except those used to establish riparian forest buffers, targeting lands that are highly erodible or identified as critical resource areas.
Water Control Structures	Installing and managing boarded gate systems in agricultural land that contains surface drainage ditches.
Wetland Restoration	Activities to re-establish the natural hydraulic condition in a field that existed prior to the installation of subsurface or surface drainage. Projects may include restoration, creation and enhancement acreage.

Source: Abt Associates/USEPA (4)

Table S2. Annual Costs of Cost-Effective BMP Portfolios: Scenario 1—No Land Retirement ($ million)

BMP	Delaware	Maryland	New York	Pennsylvania**	Virginia**	West Virginia	Chesapeake Bay	Percentage of Bay Total
Alternative Watering*	$0	$0	$0	$0	0	$0	$0	0%
Ammonia Emissions Reduction – Alum*	0	0	0	0	0	0	0	0%
Ammonia Emissions Reduction – Biofilters & Lagoon	0	0	6.6	44.7	39.6	0	90.9	13.0%
AWMS – Livestock	0	0	8.3	97.8	108.2	0	214.3	30.6%
AWMS – Poultry	1.0	0	0.1	.3	4.7	0	6.1	.9%
Barnyard Runoff	0.1	0.0	0.1	3.4	2.4	0.2	6.2	.9%
Capture & Reuse	0.2	0.7	1.6	9.5	4.7	0.0	16.7	2.4%
Carbon Sequestration*	0	0	0	0	0	0	0	0%
Commodity Cover Crops*	0	0	0	0	0	0	0	0%
Conservation Plan	0.3	0.6	1.5	3.6	3.7	0.1	9.8	1.4%
Conservation Tillage	0	0	0	0	0	0	0	0%
Continuous No-Till	0	0	0	0	0	0	0	0%
Cover Crops	0	1.3	4.0	28.1	34.3	0.0	67.7	9.7%
Cropland Irrigation Management	0	0	0	0	0	0	0	0%
Dairy Precision Feeding	0	0	0	0	0	0	0	0%
Decision Agriculture*	0	0	0	0	0	0	0	0%
Enhanced Nutrient Management	0	0.0	2.5	3.2	5.3	0.1	11.1	1.6%
Forest Buffers*	0	0	0	0	0	0	0	0%
Grass Buffers*	0	0	0	0	0	0	0	0%
Horse Pasture Management*	0	0	0	0	0	0	0	0%
Land Retirement*	0	0	0	0	0	0	0	0%
Liquid/Poultry Manure Injection*	0	0	0	0	0	0	0	0%
Loafing Lot Management*	0	0	0	0	0	0	0	0%
Manure Transport – Inside CBWS*	0	0	0	0	0	0	0	0%

BMP	Delaware	Maryland	New York	Pennsylvania**	Virginia**	West Virginia	Chesapeake Bay	Percentage of Bay Total
Manure Transport – Outside CBWS*	0	0	0	0	0	0	0	0%
Mortality Composters*	0	0	0	0	0	0	0	0%
Nutrient Management	0	0.0	0.4	0	13.4	0	13.8	2.0%
Poultry Phytase	0	0	0	0	0	0	0	0%
Swine Phytase	0	0	0	0	0	0	0	0%
Precision Intensive Rotational Grazing*	0	0	0	0	0	0	0	0%
Prescribed Grazing	0	0.0	2.2	7.5	26.1	1.0	36.8	5.3%
Stream Access Control with Fencing	0	0	24.5	43.2	121.6	15.4	204.7	29.2%
Stream Restoration*	0	0	0	0	0	0	0	0%
Tree Planting*	0	0	0	0	0	0	0	0%
Water Control Structures	2.3	10.2	0	0	10.1	0	22.6	3.2%
Wetland Restoration*	0	0	0	0	0	0	0	0%
Totals	**$3.9**	**$12.8**	**$51.8**	**$241.3**	**$374.1**	**$16.8**	**$700.7**	**100.0%**

Notes: 1. An * indicates that the BMP was not included in the cost-effectiveness analysis.

2. Due to rounding, the total for each state may not equal the sum across BMPs for that state, and the Chesapeake Bay totals may not equal the sums across states. Because of rounding, the percentages in the final column sum to 100.2% rather than 100%.

3. ** Pennsylvania and Virginia do not meet their TMDL targets in Scenario 1. Pennsylvania met 72% of its N target, 98% of its P target, and 97% of its TSS target in Scenario 1. Virginia met 62% of its P target and 94% of its TSS target in Scenario 1.

Table S3. Annual Costs of Cost-Effective BMP Portfolios: Scenario 2—Land Retirement ($ million)

BMP	Delaware	Maryland	New York	Pennsylvania	Virginia	West Virginia	Chesapeake Bay	Percentage of Bay Total
Alternative Watering*	$0	$0	$0	$0	$0	$0	$0	0%
Ammonia Emissions Reduction – Alum*	0	0	0	0	0	0	0	0%
Ammonia Emissions Reduction – Biofilters & Lagoon	0	0	0	17.6	0	0	17.6	4.9%
AWMS – Livestock	0	0	0	0	68.4	0	68.4	19.1%
AWMS – Poultry	0	0	0	0.0	4.7	0	4.7	1.3%
Barnyard Runoff	0.1	0.0	0.1	2.8	2.4	0.2	5.6	1.6%
Capture & Reuse	0.2	0.6	0.6	8.9	4.7	0	15.0	4.2%
Carbon Sequestration*	0	0	0	0	0	0	0	0%
Commodity Cover Crops*	0	0	0	0	0	0	0	0%
Conservation Plan	0.2	0.3	0.7	2.7	2.8	0.1	6.8	1.9%
Conservation Tillage	0	0	0	0	0	0	0	0%
Continuous No-Till	0	0	0	0	0	0	0	0%
Cover Crops	0	0.3	1.7	21.1	16.2	0.0	39.3	11.0%
Cropland Irrigation Management	0	0	0	0	0	0	0	0%
Dairy Precision Feeding	0	0	0	0	0	0	0	0%
Decision Agriculture*	0	0	0	0	0	0	0	0%
Enhanced Nutrient Management	0	0	0	2.1	0	0	2.1	0.6%
Forest Buffers*	0	0	0	0	0	0	0	0%
Grass Buffers*	0	0	0	0	0	0	0	0%
Horse Pasture Management*	0	0	0	0	0	0	0	0%
Land Retirement	1.1	6.0	6.7	39.7	76.3	3.1	133.0	37.2%
Liquid/Poultry Manure Injection*	0	0	0	0	0	0	0	0%

BMP	Delaware	Maryland	New York	Pennsylvania	Virginia	West Virginia	Chesapeake Bay	Percentage of Bay Total
Loafing Lot Management*	0	0	0	0	0	0	0	0%
Manure Transport – Inside CBWS*	0	0	0	0	0	0	0	0%
Manure Transport – Outside CBWS*	0	0	0	0	0	0	0	0%
Mortality Composters*	0	0	0	0	0	0	0	0%
Nutrient Management	0	0.0	0.2	0	15.6	0	15.8	4.4%
Poultry Phytase	0	0	0	0	0	0	0	0%
Swine Phytase	0	0	0	0	0	0	0	0%
Precision Intensive Rotational Grazing*	0	0	0	0	0	0	0	0%
Prescribed Grazing	0	0	0.0	4.0	19.5	0.7	24.1	6.7%
Stream Access Control with Fencing	0	0	0	2.7	12.5	2.0	17.2	4.8%
Stream Restoration*	0	0	0	0	0	0	0	0%
Tree Planting*	0	0	0	0	0	0	0	0%
Water Control Structures	1.9	5.6	0	0	0.6	0	8.1	2.3%
Wetland Restoration*	0	0	0	0	0	0	0	0%
Totals	**$3.5**	**$12.9**	**$10.1**	**$101.6**	**$223.6**	**$6.0**	**$357.7**	**100.0%**

Notes: 1. An * indicates that the BMP was not included in the cost-effectiveness analysis.

2. Due to rounding, the total for each state may not equal the sum across BMPs for that state, and the Chesapeake Bay totals may not equal the sums across states.