# Economic Impacts of Implementing Agricultural Best Management Practices to Achieve Goals Outlined in Virginia's Tributary Strategy

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# EXECUTIVE SUMMARY

In 2000, Virginia, along with Chesapeake Bay partner states, committed to reduce pollution sufficiently to remove the Bay and its tidal tributaries from the federal list of "impaired" waters by 2010. To achieve this goal, member states developed Tributary Strategies that identified the priority problem as excess nutrients and proposed a specific course of action to reduce nitrogen and phosphorus levels within the Bay and its tributaries. This study computes the economic impacts of expenditures on agricultural Best Management Practices (BMP) needed to achieve goals outlined in the 2005 *Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Strategy*. The *Strategy* outlined a plan to reach nitrogen, phosphorus, and sediment reductions necessary to achieve Virginia's portion of Chesapeake Bay restoration goals by 2010. Based on implementation costs described in the *Strategy* that have been adjusted for inflation and revised implementation levels, it is estimated that $804 million (in 2010 dollars) would be needed to reach agricultural BMP goals over a five-year period.

Although this study is based on the 2005 *Strategy*, and as such, also assumes a five-year timeframe for BMP implementation, it is important to note that the U.S. Environmental Protection Agency is now in the process of developing a Total Maximum Daily Load (TMDL) for the entire Chesapeake Bay and a new timeline has been established. States will now be required to achieve full implementation of pollution reduction practices by 2025, with 60 percent implementation by 2017. Hence, the results of this study will tend to underestimate expenditures that arise from maintenance of effort that continue beyond the initial five year period until 2025. Correspondingly, economic impacts will be underestimated as well.

State and federal agricultural, soil conservation, and Bay protection programs collectively provide favorable cost shares for implementing and maintaining BMPs, sometimes on the order of 75 to as much as 90 percent of the cost depending on the practice and farm eligibility. This study assumes that typical state and federal cost share program reimbursement rates would be maintained at 75 percent ($603 million in 2010 dollars) of the cost of implementing the BMPs. Farmers will provide the remaining 25 percent ($201 million dollars).

Results indicate that the economic impacts of BMP implementation are substantially positive. If full implementation of agricultural BMPs outlined in the 2005 *Strategy* were achieved over a five-year time frame, $940 million in total industrial output in terms of 2010 dollars would result. Total industrial output is the value of all industry production including sales of intermediate inputs for use in production as well as sales of products to final consumers. In terms of gross domestic product, the most common measure of economic activity, an economic impact of $455 million would be realized. Gross domestic product is a subset of total industrial output. It reflects only sales to final consumers. Furthermore, 11,751 person-years of employment would be created. That is to say, 11,751 jobs, one year each in duration, would be created during the implementation period. Over 80 percent of the economic impacts occur in the Potomac River and James River tributary basins. However, all tributary basin regions experience positive economic impacts. The administrative and waste services sector (which includes the landscape services industry), construction sector, and professional, scientific and technical service sector (which reflects expenditures on BMP technical assistance) experience the largest industry-level economic impacts. However, positive economic impacts occur in other industries as well.

In response to a request from the Chesapeake Bay Foundation, the Center for Economic and Policy Studies, a unit of the Weldon Cooper Center for Public Service at the University of Virginia, undertook an analysis of the economic impacts of expenditures associated with achieving agricultural Best Management Practice (BMP) goals outlined in the 2005 *Commonwealth of Virginia Chesapeake Bay Nutrient and Sediment Reduction Tributary Strategy* (henceforth, referred to as the "*Strategy*").

The idea that Chesapeake Bay restoration activities might generate additional economic activity is not new. Indeed, the *Strategy* acknowledges that expenditures on BMPs can potentially have a net generative effect on the Bay area economy:

> "Purchasing wastewater treatment technologies and BMPs is similar to making other infrastructure investments. Just as a highway project provides economic stimulus for the local economy, cleaning up the Bay will also stimulate Virginia's economy." (p. 47)

This study quantifies some of the total, regional tributary basin and industrial economic impacts that might be expected to result from the process of implementing BMPs described in the *Strategy*. The study uses BMP cost estimates provided in the *Strategy* and assumes that federal and state governments will provide 75 percent of the cost share needed to fund full implementation of the BMPs. The remaining 25 percent will be funded by farmers.

## Methodology

Impact analysis was undertaken using the IMPLAN model. IMPLAN (IMpact analysis for PLANning) is an industry standard input-output model that has been used in many economic impact studies, including studies of the regional economic impacts of agricultural water pollution regulations (Otto 2008; Prato and Hey 2006; Boggess, Johns, and Meline 1997). The model represents the total impact of new spending as consisting of three parts. The "direct effect" consists of the expected injection of new economic activity or expenditure into the region. This direct expenditure then causes a "ripple effect" on the regional economy when money re-circulates through the economy causing "indirect" and "induced" effects. The "indirect effect" is the sum of all impacts associated with inter-industry purchases. The "induced effect" is the sum of all impacts associated with household purchases. The "multiplier" can be obtained by dividing the total by the direct effect.

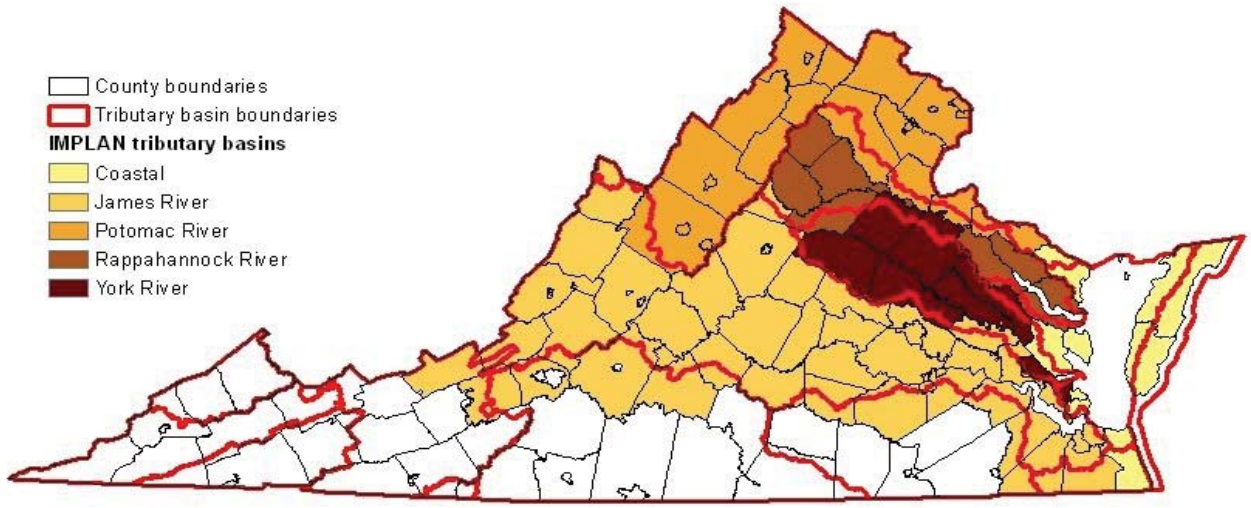
Economic impacts are evaluated within IMPLAN using three different measures: (a) total industrial output, (b) value-added, and (c) employment. Total industry output is the total value of industry production during a period. It measures sales of intermediate inputs for use in production as well as sales of products to final consumers. Value added is a subset of total industrial output. It reflects only sales to final consumers. It is the most commonly used measure of economic activity. Value-added is the concept behind gross domestic product and can be compared to the GDP figure provided by the Bureau of Economic Analysis for states and metropolitan areas. It can also be represented as total factor income plus indirect business taxes. Employment is measured in terms of person-years of employment. A person-year of employment is a job of one year in duration. Employment includes full-time and part-time workers as well as the self-employed and is measured by place of work.

In order to estimate the economic impacts at the tributary basin level, five geographically distinct regional models are constructed for IMPLAN. These five regions were built using county and independent city geographical units. The IMPLAN model creates a "regionalized" input-output model appropriate for assessing the impacts of BMPs for each tributary basin region based on the economic data for the constituent counties.

Distinct regions are created by assigning each county to only one Chesapeake Bay tributary basin drainage region (i.e., Small Coastal Rivers or "Coastal," Potomac-Shenandoah Rivers or "Potomac River," "James River," "Rappahannock River," and "York River" basins). Since some county land areas fall within more than one tributary basin (e.g., parts of Greene County lie within both the Rappahannock and James River tributary basins), counties were uniquely assigned to one tributary basin region when the plurality of its Chesapeake Bay drainage area drained into the tributary (e.g., Greene County was assigned to the James River tributary basin region). The regions defined in this manner roughly approximate the boundaries of the actual tributary basins. **Figure 1** shows the tributary basin region assignments. **Appendix A** lists the county assignments to each tributary basin region and the corresponding percentages of county and independent city land areas falling into the assigned tributary basin region.

In order to estimate the expenditures needed to achieve *Strategy* goals, a data file containing county-level information on 2007 implementation levels for each agricultural best management practice (BMP) identified in the *Strategy* was obtained from the U.S Environmental Protection Agency Chesapeake Bay Program Office. The data file also included information on *Strategy* goals. The gap between the

**Figure 1. Map of IMPLAN Tributary Basin Regions**




goals and 2007 levels by BMP is used to approximate the additional effort needed to achieve the tributary strategy. This gap will overestimate somewhat the actual gap due to the implementation of additional BMPs that occurred in years 2008 and 2009.

Estimates of BMP implementation costs were obtained from the *Strategy*. These estimates are based on five-year implementation costs for attaining Virginia's tributary 2005-2010 goals. However, the recently promulgated Chesapeake Bay Total Maximum Daily Load (TMDL) timeline requires only 60 percent implementation by 2017 with complete implementation by 2025. Therefore, the cost estimates will tend to underestimate costs that arise from maintenance of effort until 2025.

Implementation costs include capital and operations and maintenance. They were computed on a per unit basis. In line with the *Strategy*, technical assistance costs were estimated to be 10 percent of capital costs. **Table 1** shows the unit and total cost estimates broken into capital, operations and maintenance (O&M), and technical assistance components.[1] Descriptions of these BMPs are available elsewhere.[2]

The estimated total cost of implementing the tributary strategies in terms of 2005 dollars is $734.57 million. The costs of implementing by tributary basin region are as follows: Coastal ($33.62 million), James River ($259.72 million), Potomac River ($333.49 million), Rappahannock River ($64.29), and York River ($43.4 million).

Information was not available on the specific types of inputs purchased for each BMP. However, BMP practices were aligned first with NAICS (North American Industrial Classification System) codes and then IMPLAN sectors using general descriptive about information each practice.

1 These figures can be compared to those reported in the *Strategy* in Table C-1 "Total Estimated Costs" (p. 60) based on 2002 implementation levels. However, the exact same conservation tillage category was not available in the data file used and encompasses other tillage practices. Therefore, these cost estimates are somewhat higher than reported in the Strategy.

2 See, for example, the *Chesapeake Bay Program's Best Management Practice (BMP) Basics* http://archive.chesapeakebay.net/pubs/waterqualitycriteria/BMPHandbook1-8f.pdf

The following assignments were made: (a) installation and maintenance of forest buffers, grass buffers, and tree planting were designated as "landscaping services" (NAICS 561730) which is categorized as the "services to buildings and dwellings" sector in IMPLAN (code 458), (b) wetland restoration, off-stream watering installation, and stream stabilization were designated as "all other heavy construction" (NAICS 234990) which is categorized as IMPLAN sector "other new construction" (code 41), (c) expenditures associated with nutrient management plans, enhanced nutrient management, conservation plans, and cover crops were designated as "support activities for crop production" (NAICS 11511) which is categorized as the sector "agriculture and forestry support activities" in IMPLAN (code 18), (d) waste management facility installation and maintenance was categorized as "commercial and institutional building construction" (NAICS 233320) or IMPLAN sector "commercial and institutional buildings" (code 38), (e) poultry litter transport was designated as "truck transportation" IMPLAN sector (code 394), and (f) conservation tillage and continuous no-till expenditures were assigned to "other commercial and industrial machinery and equipment rental and leasing" (NAICS 532490) which was categorized as sector "machinery and equipment rental and leasing" in IMPLAN (code 434). Technical assistance costs associated with the implementation of BMPs were designated as "other scientific and technical consulting services" (NAICS 541690), which is categorized as sector "environmental and other technical services" in IMPLAN (code 445).

Within the model, funds associated with implementation of BMPs are represented as an injection of new expenditures.[3] These expenditures are $735 million in 2005 dollars. Using IMPLAN industry-level deflators derived from the Bureau of Labor Statistics Growth Model, these expenditures are estimated to be $804 million in 2010 dollars. The farm share of implementation will be represented as an offsetting loss of household income to the region.

State and federal agricultural, soil conservation, and Bay protection programs collectively provide favorable cost shares for implementing and maintaining many BMPs,

3 IMPLAN Regional Purchase Coefficients (RPCs) were used to compute regional expenditures for IMPLAN sectors. However, all expenditures on support activities for crop production were assumed to be made in the region.

**Table 1. Tributary Strategy Agricultural BMPs and Implementation Cost Estimates (2005 dollars)**

| Agricultural BMPs | Cost Units | Capital $ Unit | O&M $ Unit | Capital Costs ($) | O&M Costs ($) | Technical Assistance Costs ($) | Total Costs ($) |
|---|---|---|---|---|---|---|---|
| Conservation- Tillage | $/Acre | 287 | 0 | 13,876,333 | 0 | 1,387,633 | 15,263,966 |
| Continuous No-Till | $/Acre | 100 | 0 | 3,023,588 | 0 | 302,359 | 3,325,947 |
| Forest Buffers | $/Acre | 545 | 16 | 101,723,259 | 2,986,371 | 10,172,326 | 114,881,955 |
| Wetland Restoration | $/Acre | 889 | 37 | 77,977,630 | 3,245,413 | 7,797,763 | 89,020,807 |
| Land Retirement[a] | $/Acre | 928 | 0 | 0 | 0 | 0 | 0 |
| Grass Buffers | $/Acre | 175 | 0 | 19,462,112 | 0 | 1,946,211 | 21,408,323 |
| Tree Planting | $/Acre | 1,284 | 16 | 246,077,591 | 3,066,387 | 24,607,759 | 273,751,738 |
| Nutrient Management Plans | $/Acre | 7 | 0 | 3,761,251 | 0 | 376,125 | 4,137,376 |
| Enhanced Nutrient Management | $/Acre | 7 | 0 | 72,870 | 0 | 7,287 | 80,157 |
| 20% Poultry Litter Transport | $/Dry Ton | 0 | 60 | 0 | 8,002,891 | 0 | 8,002,891 |
| Conservation Plans | $/Acre | 7 | 5 | 7,211,178 | 5,150,842 | 721,118 | 13,083,138 |
| Cover Crops | $/Acre | 97 | 0 | 39,774,478 | 0 | 3,977,448 | 43,751,926 |
| Off-Stream Watering w/ Fencing | $/Acre | 284 | 29 | 71,520,376 | 7,303,137 | 7,152,038 | 85,975,551 |
| Off-Stream Watering w/o Fencing | $/Acre | 152 | 21 | 40,308,728 | 5,568,969 | 4,030,873 | 49,908,570 |
| Off-Stream Watering w/ Fencing & RG | $/Acre | 186 | 36 | 20,950 | 4,055 | 2,095 | 27,100 |
| Stream Stabilization | $/LinFt | 12 | 0 | 1,461,000 | 0 | 146,100 | 1,607,100 |
| Animal Waste Management | $/Acre | 32,278 | 3,601 | 8,537,614 | 952,474 | 853,761 | 10,343,849 |
| Totals: | | | | 634,808,959 | 63,480,896 | 36,280,539 | 734,570,394 |

a All tributary strategy goals were met for this BMP

sometimes on the order of 75 to as much as 90 percent of the cost depending on the practice and farm eligibility.[4] However, these programs are sometimes oversubscribed and future funding levels are uncertain. Although additional appropriations have been made, such as clean water and drinking water state revolving funds from the American Recovery and Reinvestment Act of 2009 in addition to the Food, Conservation, and Energy Act of 2008 (the Farm Bill), and more funding is likely as part of redoubled Chesapeake Bay cleanup efforts that stem from Executive Order 13508 (Federal Leadership Commitee for the Chesapeake Bay 2009), it is assumed for the purposes of this analysis that only 75 percent of the costs incurred in meeting the *Strategy* agricultural BMP goals will be funded by federal and state government ($603 million in 2010 dollars). Farmers will fund the remainder ($201 million in 2010 dollars).

These modeling assumptions do not take into account several additional potential sources of economic impact from implementing BMPs. First, no effort was made to model the effect of BMP implementation on farm profitability, future agricultural production choices, or farm closure. There is mixed empirical evidence on the cost effects of implementing BMPs with some studies showing farm profitability or minimal or no effects for some practices or for some reasonable level of public cost share (Valentin, Bernardo, and Kastens 2004; Pease, et al.; Tice and Epplin 1984). Second, attainment of *Strategy* goals would make many farmers eligible to participate in regional nutrient trading markets with point sources of nutrient pollution as part of the Chesapeake Bay Watershed Nutrient Credit Exchange Program. Although there are clear obstacles to water quality trading (Stephenson et al. 2009), some estimates place the potential market value of such credits to farmers in the tens of millions of dollars (World Resources Institute 2009). Farmers meeting baseline levels of nutrient reduction as evidenced by implementation of up to five BMPs (i.e., soil conservation plan, nutrient management plan, cover cropping, livestock stream exclusion, and riparian buffer) might cause additional regional economic impacts from investing in additional BMPs and selling nutrient credits.[5] Third, there is no attempt to estimate economic impacts that arise from successful Bay cleanup that stimulates or preserves commercial fishing, recreation, and other activities depending on Bay environmental health. Many of these activities are curtailed because of poor water quality (Lipton 2008; Lipton 2004). As an indication of the potential importance of these economic impacts, Kirkely (1997) estimates that for every $1 million in expenditures by commercial fishing activities, Virginia's economic output increases by $5.3 million, payroll and profit by $3.7 million, and employment by 123.3 person-years. Lipton and Miller (1995) estimate that every 10.5 new recreational boaters create one job.

## Results

Overall the results suggest that significant economic impacts may be realized by implementation of agricultural BMPs with a sizeable public cost share. These impacts vary significantly by region and industry.

**Table 2** presents the total Chesapeake Bay drainage region impact and impact by tributary basin region for output, employment, and value-added. All dollar denominated values are adjusted to 2010 dollars. The table indicates that the total impact of achieving the Strategy BMPs can be expected to be $940 million in total industrial output, 11,751 person years of employment, and $455 million in value-added. This total includes direct impacts of $594 million in output, 8,544 person-years of employment and $247 million in value-added. The direct impact reflects BMP expenditures made in the region minus farm household income losses. Indirect impacts are $160 million in output, 1,623 person-years of employment, and $96 million in value-added. Induced impacts are $187 million in output, 1,584 person-years of employment, and $112 million in value-added.

The table shows that the bulk of the economic impacts are experienced in the Potomac River and James River tributary basin regions. **Figure 2** indicates that the Potomac tributary region provides the largest percentage of output (46%), employment (42%), and value-added (51%) impacts followed by the James River region. The Coastal region provides the smallest.

**Table 3** provides a breakdown of total economic impacts by 2-digit NAICS industry. It shows that "administrative and waste services" which includes the landscaping services industry experiences the largest impact. Over 90 percent of this impact can be attributed to the direct impact of BMP landscape industry expenditures. The construction industry ranks second, again with over 90 percent of the impact originating from the positive direct construction industry expenditures. The agricultural, forestry, fishing and hunting

4 Details on current cost sharing levels by BMP are available in the Virginia Department of Conservation and Recreation publication, *Program year 2010 Virginia agricultural BMP cost share manual*. http://webdat.dcr.virginia.gov/agbmp-man/toc.pdf

5 Information on this program is provided in the Virginia Department of Environmental Quality publication *Trading nutrient reductions from nonpoint source best management practices in the Chesapeake Bay watershed: guidance for agricultural landowners and your potential trading partners*. http://www.deq.virginia.gov/export/sites/default/vpdes/pdf/VANPSTradingManual_2-5-08.pdf

sector is shown to experience a positive impact, largely as a result of direct expenditures on agriculture. However, another approximately 10 percent of the impact can be attributed to intermediate purchases such as horticultural products for landscaping. The professional, scientific and technical service industry (which includes expenditures on BMP technical assistance) impact reflects the importance of all three economic impact components: direct effects, indirect effects, and induced effects. Many industries such as retail trade, health and social services, accomodation and food services experience negative direct impacts as a result of the withdrawal of household spending from the economy. However, the indirect and induced impacts of spending on BMP implementation cause each industry to realize gains in output, employment, and value-added.

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**Table 2. Virginia Summative and Tributary Basin Impacts (2010 Dollars)**

| | Output (Million $) | Employment | Value-added (Million $) |
|---|---|---|---|
| Total | | | |
| Direct | 593.68 | 8,544 | 246.64 |
| Indirect | 159.79 | 1,623 | 96.01 |
| Induced | 186.59 | 1,584 | 112.13 |
| Total | 940.07 | 11,751 | 454.77 |
| Coastal | | | |
| Direct | 27.27 | 369 | 10.2 |
| Indirect | 7.57 | 79 | 4.25 |
| Induced | 7.24 | 70 | 4.33 |
| Total | 42.08 | 518 | 18.78 |
| James River | | | |
| Direct | 208.22 | 3,170 | 75.07 |
| Indirect | 60.74 | 656 | 36.68 |
| Induced | 66.55 | 585 | 39.01 |
| Total | 335.51 | 4,411 | 150.76 |
| Potomac River | | | |
| Direct | 271.56 | 3,681 | 129.14 |
| Indirect | 70.91 | 646 | 43.48 |
| Induced | 89.26 | 710 | 54.62 |
| Total | 431.73 | 5,037 | 227.23 |
| Rappahannock River | | | |
| Direct | 50.68 | 635 | 14.53 |
| Indirect | 10.46 | 135 | 6.17 |
| Induced | 13.29 | 128 | 7.96 |
| Total | 74.43 | 898 | 28.66 |
| York River | | | |
| Direct | 35.95 | 689 | 17.7 |
| Indirect | 10.11 | 107 | 5.43 |
| Induced | 10.25 | 91 | 6.21 |
| Total | 56.31 | 887 | 29.34 |

**Figure 2. Economic Impact Shares by Region, Output, Employment, and Value-added**

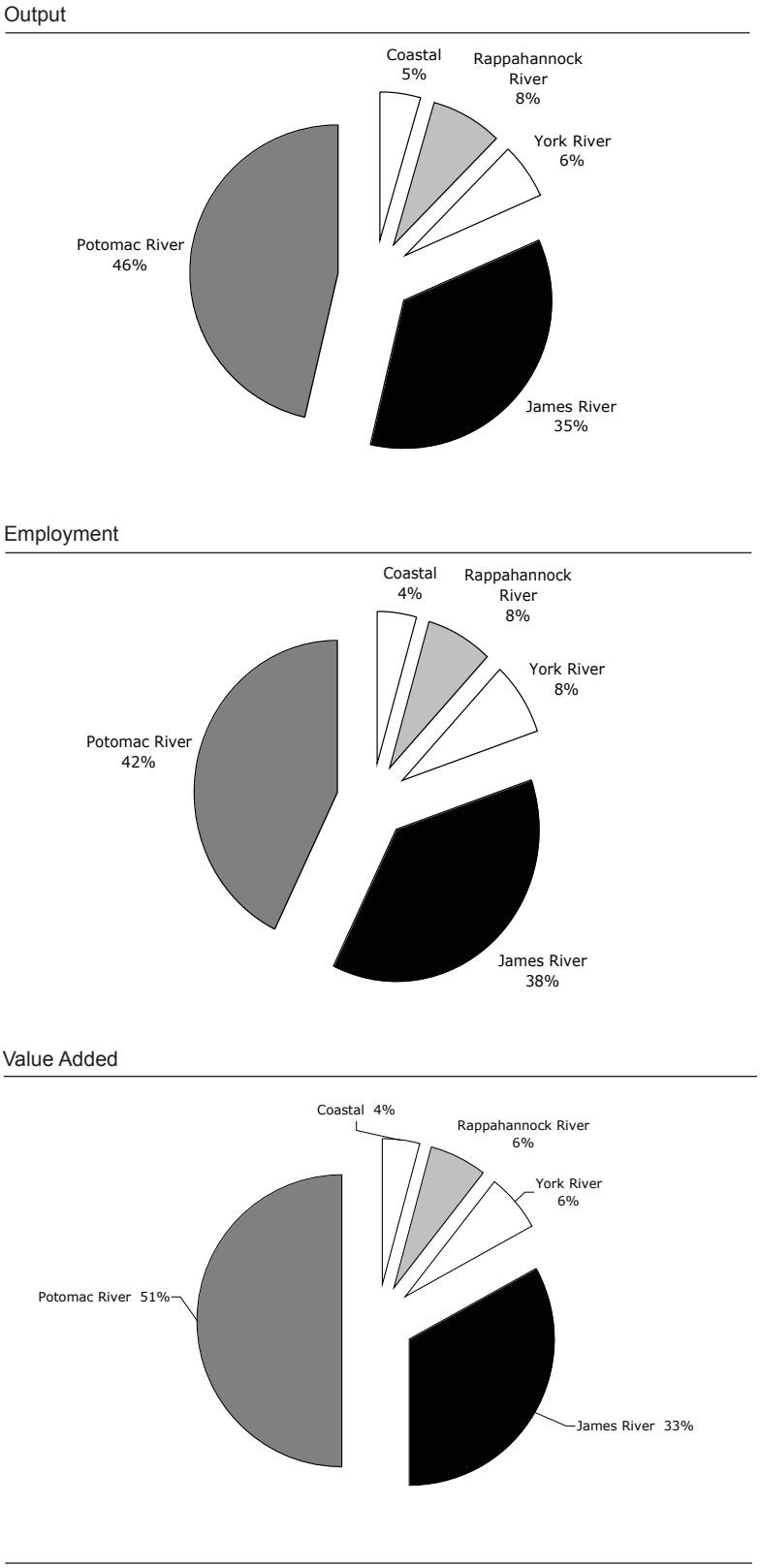

**Table 3. Total Impact of Agricultural BMPs by Major Industry (2010 Dollars)**

| | Output (Million $) | Employment | Value-added (Million $) |
|---|---|---|---|
| Agriculture, forestry, fishing & hunting | 71.76 | 2,089 | 41.38 |
| Mining | 0.32 | 1 | 0.11 |
| Utilities | 3.25 | 3 | 2.08 |
| Construction | 172.08 | 1,565 | 95.72 |
| Manufacturing | 14.01 | 48 | 4.30 |
| Wholesale trade | 10.83 | 53 | 7.41 |
| Transportation & warehousing | 17.60 | 157 | 9.41 |
| Retail trade | 44.68 | 605 | 28.38 |
| Information | 11.23 | 37 | 5.34 |
| Finance & insurance | 14.02 | 59 | 8.64 |
| Real estate and rental | 30.78 | 117 | 17.75 |
| Professional, scientific, & technical services | 83.91 | 509 | 48.60 |
| Management of companies | 6.32 | 25 | 4.06 |
| Administrative & waste services | 320.52 | 6,088 | 161.80 |
| Educational services | 1.23 | 20 | 0.76 |
| Health & social services | 6.53 | 76 | 4.00 |
| Arts, entertainment, & recreation | 1.54 | 38 | 0.86 |
| Accommodation & food services | 7.11 | 119 | 3.71 |
| Other services | 9.56 | 105 | 5.46 |
| Government & other | 112.79 | 36 | 4.99 |
| Total | 940.07 | 11,751 | 454.77 |

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## Appendix A. Tributary Basin Region County and Independent City Assignments

| Tributary Basin | County/ Independent City | % of County Area in Basin |
|---|---|---|
| Coastal | Accomack County | 44.1 |
| | Gloucester County | 61.9 |
| | Hampton City | 72.5 |
| | Mathews County | 100 |
| | Northampton County | 32.3 |
| | Northumberland County | 57.1 |
| | Poquoson City | 100 |
| | Virginia Beach City | 26.2 |
| James River | Albemarle County | 98 |
| | Alleghany County | 100 |
| | Amelia County | 100 |
| | Amherst County | 100 |
| | Appomattox County | 70.6 |
| | Bath County | 100 |
| | Bedford County | 13.9 |
| | Botetourt County | 87.4 |
| | Buckingham County | 100 |
| | Buena Vista City | 100 |
| | Campbell County | 13.7 |
| | Charles City County | 100 |
| | Charlottesville City | 100 |
| | Chesapeake City | 32.1 |
| | Chesterfield County | 100 |
| | Clifton Forge City | 100 |
| | Colonial Heights City | 100 |
| | Covington City | 100 |
| | Craig County | 86.3 |
| | Cumberland County | 100 |
| | Dinwiddie County | 15.6 |
| | Fluvanna County | 99.8 |
| | Giles County | 3.3 |
| | Goochland County | 96.3 |
| | Greene County | 59.2 |
| | Henrico County | 100 |
| | Highland County | 74.1 |
| | Hopewell City | 100 |
| | Isle of Wight County | 50.6 |
| | James City County | 76.3 |
| | Lexington City | 100 |
| | Lynchburg City | 100 |
| | Montgomery County | 5.7 |
| | Nelson County | 100 |

**Appendix A.** Tributary Basin Region County and Independent City Assignments (continued)

| Tributary Basin | County/ Independent City | % of County Area in Basin |
|---|---|---|
| James River (continued) | New Kent County | 52.9 |
| | Newport News City | 89.8 |
| | Norfolk City | 80.8 |
| | Nottoway County | 52.6 |
| | Petersburg City | 66.1 |
| | Portsmouth City | 100 |
| | Powhatan County | 100 |
| | Prince Edward County | 95.5 |
| | Prince George County | 48.6 |
| | Richmond City | 100 |
| | Roanoke County | 10.4 |
| | Rockbridge County | 100 |
| | Suffolk City | 43.7 |
| | Surry County | 41.8 |
| | Williamsburg City | 76.3 |
| Potomac River | Alexandria City | 100 |
| | Arlington County | 100 |
| | Augusta County | 74.6 |
| | Clarke County | 100 |
| | Fairfax City | 100 |
| | Fairfax County | 100 |
| | Falls Church City | 100 |
| | Fauquier County | 56.4 |
| | Frederick County | 100 |
| | Harrisonburg City | 100 |
| | King George County | 61.8 |
| | Loudoun County | 100 |
| | Manassas City | 100 |
| | Manassas Park City | 100 |
| | Page County | 99.9 |
| | Prince William County | 100 |
| | Rockingham County | 100 |
| | Shenandoah County | 100 |
| | Stafford County | 70.5 |
| | Staunton City | 100 |
| | Warren County | 99.8 |
| | Waynesboro City | 100 |
| | Westmoreland County | 73.1 |
| | Winchester City | 100 |

**Appendix A.** Tributary Basin Region County and Independent City Assignments (continued)

| Tributary Basin | County/ Independent City | % of County Area in Basin |
|---|---|---|
| Rappahannock River | Culpeper County | 100 |
| | Essex County | 89.3 |
| | Fredericksburg City | 100 |
| | Lancaster County | 86.6 |
| | Madison County | 100 |
| | Middlesex County | 53.4 |
| | Orange County | 55.9 |
| | Rappahannock County | 99.9 |
| | Richmond County | 99.9 |
| York River | Caroline County | 78 |
| | Hanover County | 84.3 |
| | King and Queen County | 77.8 |
| | King William County | 100 |
| | Louisa County | 96.3 |
| | Spotsylvania County | 77.2 |
| | York County | 59.2 |



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