Chesapeake Bay Program Partnership's Phase 6 Scenario Builder Documentation

Draft Document for Partnership Review

January 21, 2016

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1 Introduction

The Chesapeake Bay Program Partnership's Phase 6 Scenario Builder (Scenario Builder) is a data management tool that provides estimates of land use acres, nutrient inputs, cropland attributes, and best management practice (BMP) implementation data to the Chesapeake Bay Program Partnership's Phase 6 Watershed Model (Watershed Model). In this way, Scenario Builder provides information about how the landscape and nutrient inputs have changed over time, or could change under different scenarios in the future. The Watershed Model then combines these inputs with climate, soils and hydrology information to estimate deliver of nutrients and sediments to water bodies throughout the Chesapeake Bay watershed from 1985 through the present, and for different potential future scenarios. A complete list of inputs provided by Scenario Builder can be found in Table 1. The sections that follow describe how Scenario Builder combines disparate data sources to create estimates for each of these input files.

Table 1. Files Provided by Scenario Builder for the Watershed Model

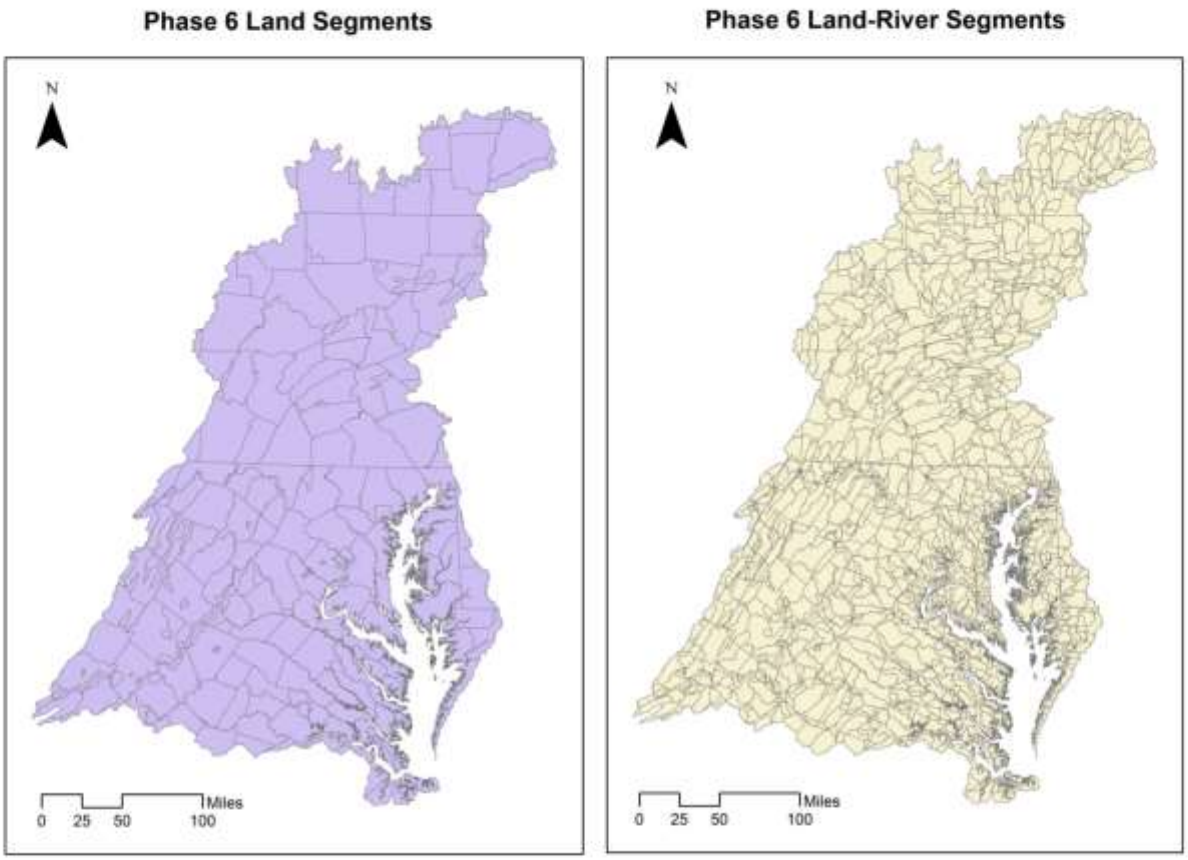
Input	Spatial Scale	Temporal Scale
Septic Nutrient Loads	Land Segment	Daily
Land Use Acres	Land-River-Segment	Yearly
Manure Nutrient Applications	Land Segment/Land Use	Monthly
Inorganic Fertilizer Nutrient Applications	Land Segment/Land Use	Monthly
Legume Nitrogen Fixation	Land Segment/Land Use	Monthly
Nutrient Uptake	Land Segment/Land Use	Yearly
Nutrient Uptake Monthly Fractions	Land Segment/Land Use	Monthly
Crop Soil Cover Fractions	Land Segment/Land Use	Monthly
Detached Soil Pounds	Land Segment/Land Use	Monthly
Riparian Pasture Access Area Nutrient Loads	Land-River-Segment/Land Use	Monthly
Animal Feeding Area Nutrient Loads	Land-River-Segment/Land Use	Yearly
BMP Nutrient "Pass-through" Fractions	Land-River-Segment/Land Use	Yearly
BMP Pounds Reduced	Land-River-Segment/Land Use	Yearly

1.1 Spatial and Temporal Scale of Scenario Builder Data Outputs

Scenario Builder data outputs are provided to the Watershed Model at different spatial and temporal scales as listed in Table 1. Data can be provided on a daily, monthly or yearly time scale depending upon the needs of the Watershed Model. Spatial scales are described below.

Land Segment – Geographic area with similar precipitation patterns within a county.
Land-River-Segment – Geographic area within a land segment with unique hydrologic characteristics draining to a single, simulated river in the Watershed Model.
Land-River Segment/Land Use – Tabular geographic representation of an area within a land-river segment with common nutrient application and transport characteristics (e.g., pasture).

Figure 1. Phase 6 Modeling Segments



1.1.1 Growth Regions for Crops

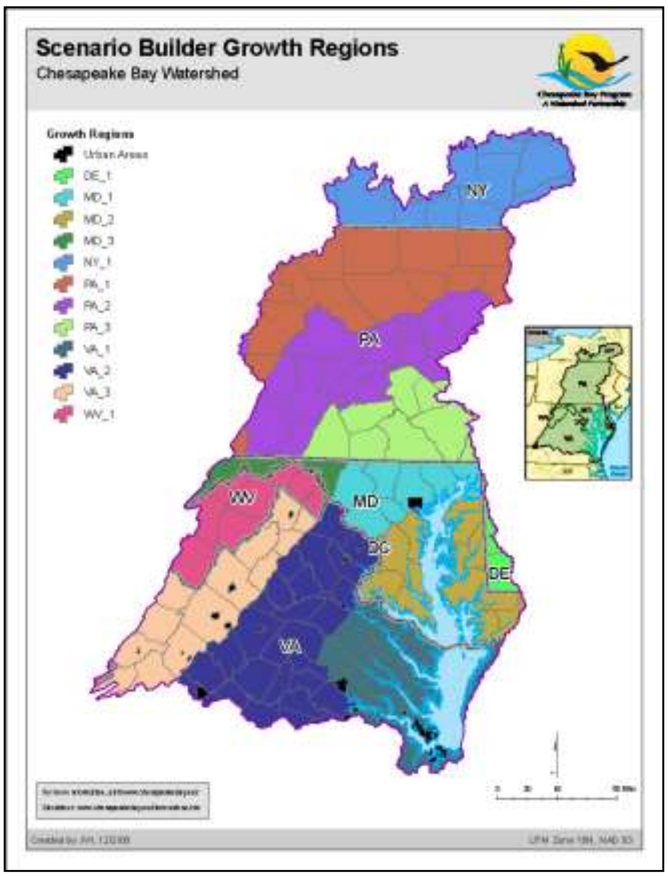
Additionally, much of the crop data used by Scenario Builder can vary at a “growth region” level. For example, the planting and harvesting dates for a crop dictate when applications can be made and uptake occurs, and those dates vary by growth region. There are twelve growth regions in the Chesapeake Bay Watershed. Each state is necessarily its own region, since there are separate crop management and nutrient guidelines for each state. Where the agronomy guide from each state divided the state into different growing regions, then those regions were used. Where the guides did not make a distinction, the 1990 USDA Hardiness Zone delineations were used to see if the state should be divided. The more recent 2003 hardiness zones were not used since it is considered unlikely that farmers changed planting dates and 1990 is closer to the mid-point of the modeled period (1982 – 2005). The USDA Hardiness Zone boundaries are set where there is a 10° Fahrenheit difference in the average annual temperature. The lines were established by comparing multiple maps and determining which counties fell into which regions. Boundary lines were shifted to match county lines. Specifically:

- In New York, the portion of the state that lies in the watershed is primarily the central part, which the Cornell Ag Guide considers one region.
- In Pennsylvania, the Agronomy Guide divides the state into separate growing regions for each crop; however, the lines of the regions are very similar to each other and to the lines of USDA Hardiness Zones. Therefore, it was determined that Pennsylvania would be divided into three regions that follow the boundaries given in the Agronomy Guide: Zone 1, Zone 2 and Zone 3.

- In West Virginia, the portion of the state that lies in the watershed was in a single USDA Zone, so WV has one region.
- Maryland's Nutrient Management Manual does not divide the state; however, there are two USDA Zones. Therefore, MD was divided into USDA Zone 6 and USDA Zone 7. Concern arose that this left an eastern shore county in the same zone as a Western Maryland county and were thus subject to the same conditions. To address this concern, a third zone, "Western MD" was added that includes Garrett, Allegheny and Washington counties.
- Delaware also falls into one USDA Zone, and was therefore left undivided.
- Virginia's Agricultural Guide divides the state into three sections that roughly follow geologic provinces: Eastern, Piedmont and West of Blue Ridge.

Resulting growth regions are provided in Figure 2**.**

Figure 2. Scenario Builder Growth Regions



2 Septic Nutrient Loads

Septic systems are commonly designed so that the waste goes into a tank, where solids sink to the bottom, and liquids flow through to a septic field. While some phosphorus can become soluble, the Partnership assumes that only nitrogen is distributed to the septic field.

To calculate the amount of nitrogen generated from septic systems, the USGS provides Scenario Builder with an estimate of the number of septic systems within each land-river segment and the average number of people contributing waste to each system. More detailed methods for estimating population served by septic and the number of septic systems will be provided by USGS at a later date. From this estimate, Scenario Builder then calculates nitrogen load from the edge of septic drainfields within a land-river segment using equation 1. This equation contains both an average nitrogen load per person per year and an assumption of 60% nitrogen attenuation. Both these values are being reviewed by the Wastewater Workgroup.

Equation 1. Total Septic Nitrogen Loads

Total Persons on Septic X 8.92 Lbs N/Person/Year X 0.4

3 Land Use Acres

Scenario Builder provides the Watershed Model with an estimate of land use acres in each land-river segment based upon data provided by the USGS Chesapeake Bay Land Change Model (CBLCM) and the USDA Census of Agriculture. Table 2 provides a list of land uses provided. Land uses are grouped into agricultural, developed and natural categories. Details about how acres of each land use are generated are included within this section, followed by a description of how the two sets of land use acres are combined to create a final set for each land-river segment.

Table 2. Phase 6 Land Uses

Agriculture	Developed			Natural
	Non-Regulated	MS4	CSS	
Ag Open Space	Non-Regulated Roads	MS4 Roads	CSS Roads	Disturbed Forest
Full Season Soybeans	Non-Regulated Buildings and Other	MS4 Buildings and Other	CSS Buildings and Other	Harvested Forest
Grain with Manure	Non-Regulated Tree Canopy over Impervious	MS4 Tree Canopy over Impervious	CSS Tree Canopy over Impervious	Forest
Grain without Manure	Non-Regulated Tree Canopy over Herbaceous	MS4 Tree Canopy over Scrub Shrub	CSS Tree Canopy over Scrub Shrub	Palustrine Forested Wetland
Legume Hay	Non-Regulated Turf Grass	MS4 Tree Canopy over Herbaceous	CSS Tree Canopy over Herbaceous	Palustrine Scrub-Shrub Wetland
Silage with Manure		MS4 Turf Grass	CSS Turf Grass	Palustrine Emergent Wetland
Silage without Manure		MS4 Construction	CSS Construction	Open Space
Small Grains and Grains				Water
Small Grains and Soybeans				Non-Regulated Tree Canopy over Scrub Shrub
Specialty Crop High				
Specialty Crop Low				
Other Agronomic Crops				
Other Hay				
Pasture				
Farmstead				
Permitted Feeding Space				
Non-Permitted Feeding Space				

3.1 Chesapeake Bay Land Change Model

Fifteen land use classes have been mapped for input to the Phase 6 Beta watershed model. These classes were largely mapped using nationally available data throughout the watershed augmented with local land use and parcel data to differentiate turf grass from cropland and pasture where such data were available. National data informing the land use classes include the National Land Cover Dataset (land cover, tree canopy, and impervious cover), Decennial Census of Population and Housing, NAVTEQ streets and land use, National Wetlands Inventory, National Hydrography Dataset (1:24K), and the NASS

Cropland Data Layer. In Lancaster County, Pennsylvania all classes except for cropland and pasture were derived from locally provided information. For Maryland, MDE and MDP used local data to estimate land use extents in 19 counties for 10 of the 15 land uses.

Each of the fifteen land use classes were mapped as fractional 10m-resolution raster datasets with values ranging from 0 to 100 representing the fraction of each cell composed by each class. Most cells are composed of multiple classes (e.g., 50% turf grass, 10% tree canopy over turf grass, 10% tree canopy over impervious roads, and 30% impervious roads). The land use classes can be viewed at:

http://ec2-52-4-30-207.compute-1.amazonaws.com/chesbay/

3.1.1 Mapped P6 Beta Land Use Classes (listed in production order):

Impervious Roads (IR) – paved and unpaved roads and bridges.

Impervious Non-Roads (INR) – buildings, driveways, sidewalks, parking lots, runways and some private roads.

Forest (FOR) – large (> 1-acre) contiguous patches of trees and shrubs assumed to have an unmanaged understory

Tree Canopy (TCT, TCS, TCIR, TCINR) – small fragments of trees over turf grass, shrubs, impervious roads, and impervious non-roads.

Water (WAT) – all streams, ponds, swimming pools, canals, ditches, wet detention basins, reservoirs, etc. mapped in the National Hydrography Dataset, NWI ponds & lakes, and the National Land Cover Dataset (Open Water). Assumes all single-line streams are 15’ wide.

Wetlands (WTF, WTO, WTT) – National Wetlands Inventory (NWI) non-pond, non-lake wetlands divided into tidal (WTT), floodplain (WTF), and headwater (WTO) subclasses based on NWI attributes and landscape position. Tidal wetlands removed from the watershed model and added to the water quality hydrodynamic model.

Turf Grass (TG) – all herbaceous lands within developed areas including remaining fractions of land within a pixel after accounting for tree canopy, impervious, and water.

Open Space (OSP) – non-fertilized herbaceous and non-forest scrub/shrub that is justifiably not turf or extractive (e.g., beaches, vacant lots, transmission line right-of-ways, junkyards, fairgrounds, gravel roads, railroads).

Cropland (CRP): rural herbaceous lands with a high frequency of crops detection in the annual Cropland Data Layer from 2008 to 2013.

Pasture/Hay (PAS): rural herbaceous lands with a high frequency of pasture/hay detection in the annual Cropland Data Layer from 2008 to 2013.
From these classes, additional information such as MS4 and CSO boundary area polygons were used to separate out classes into individual land uses.

3.2 Estimating Agricultural Acres

Acres of each agricultural land use which includes crops are estimated based upon acres of crops reported by the Census of Agriculture. While many Scenario Builder processes are simulated at the crop-level (such as nutrient applications), the resulting crop-level data is then lumped into land uses with similar crop management routines. Table 3 lists the land uses available for each crop. Note that some crops are also eligible for the double cropped land use, small grains and soybeans. Additionally, some crops have legume fixation estimates as well as manure and inorganic fertilizer application estimates.

Table 3. Census of Agriculture Crops and Associated Land Uses

Crop Name	Land Use(s)	Eligible for Double Crops	Legume
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area	Ag Open Space	N	N
Cropland in cultivated summer fallow Area	Ag Open Space	N	N
Wild hay Harvested Area	Ag Open Space	N	N
Corn for Grain Harvested Area	Grain with Manure/Grain without Manure	Y	N
Sorghum for Grain Harvested Area	Grain with Manure/Grain without Manure	Y	N
Corn for silage or greenchop Harvested Area	Silage with Manure/Silage without Manure	Y	N
Sorghum for silage or greenchop Area	Silage with Manure/Silage without Manure	Y	N
Soybeans for beans Harvested Area	Full Season Soybeans	Y	Y
Alfalfa Hay Harvested Area	Legume Hay	N	Y
Alfalfa seed Harvested Area	Legume Hay	N	Y
Birdsfoot trefoil seed Harvested Area	Legume Hay	N	Y
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	Legume Hay	N	Y
Red clover seed Harvested Area	Legume Hay	N	Y
Vetch seed Harvested Area	Legume Hay	N	Y
Cotton Harvested Area	Other Agronomic Crops	N	N
Dry edible beans, excluding limas Harvested Area	Other Agronomic Crops	N	Y
Peanuts for nuts Harvested Area	Other Agronomic Crops	N	Y
Sod harvested Area	Other Agronomic Crops	N	N
Sod harvested Protected Area	Other Agronomic Crops	N	N
Sweet Corn Harvested Area	Other Agronomic Crops	N	N
tobacco Harvested Area	Other Agronomic Crops	N	N
Bromegrass seed Harvested Area	Other Hay	N	N
Cropland on which all crops failed or were abandoned Area	Other Hay	N	N
Fescue Seed Harvested Area	Other Hay	N	N
Orchardgrass seed Harvested Area	Other Hay	N	N
Other field and grass seed crops Harvested Area	Other Hay	N	N
Other haylage, grass silage, and greenchop Harvested Area	Other Hay	N	N
Other managed hay Harvested Area	Other Hay	N	N
Ryegrass seed Harvested Area	Other Hay	N	N
Small grain hay Harvested Area	Other Hay	N	N
Timothy seed Harvested Area	Other Hay	N	N
Cropland used only for pasture or grazing Area	Pasture	N	N

Pastureland and rangeland other than cropland and woodland pastured Area	Pasture	N	N
Barley for grain Harvested Area	Small Grains and Grains	Y	N
Buckwheat Harvested Area	Small Grains and Grains	Y	N
Canola Harvested Area	Small Grains and Grains	Y	N
Emmer and spelt Harvested Area	Small Grains and Grains	Y	N
Oats for grain Harvested Area	Small Grains and Grains	Y	N
Rye for grain Harvested Area	Small Grains and Grains	Y	N
Triticale Harvested Area	Small Grains and Grains	Y	N
Wheat for Grain Harvested Area	Small Grains and Grains	Y	N
Bedding/garden plants Area	Specialty Crop High	N	N
Bedding/garden plants Protected Area	Specialty Crop High	N	N
Beets Harvested Area	Specialty Crop High	N	N
Broccoli Harvested Area	Specialty Crop High	N	N
Brussels Sprouts Harvested Area	Specialty Crop High	N	N
Bulbs, corms, rhizomes, and tubers – dry Harvested Area	Specialty Crop High	N	N
Bulbs, corms, rhizomes, and tubers – dry Protected Area	Specialty Crop High	N	N
Cantaloupe Harvested Area	Specialty Crop High	N	N
Carrots Harvested Area	Specialty Crop High	N	N
Cauliflower Harvested Area	Specialty Crop High	N	N
Celery Harvested Area	Specialty Crop High	N	N
Chinese Cabbage Harvested Area	Specialty Crop High	N	N
Collards Harvested Area	Specialty Crop High	N	N
Cucumbers and Pickles Harvested Area	Specialty Crop High	N	N
Cut flowers and cut florist greens Area	Specialty Crop High	N	N
Cut flowers and cut florist greens Protected Area	Specialty Crop High	N	N
Dry Onions Harvested Area	Specialty Crop High	N	N
Eggplant Harvested Area	Specialty Crop High	N	N
Escarole and Endive Harvested Area	Specialty Crop High	N	N
Foliage plants Area	Specialty Crop High	N	N
Foliage plants Protected Area	Specialty Crop High	N	N
Garlic Harvested Area	Specialty Crop High	N	N
Green Onions Harvested Area	Specialty Crop High	N	N
Greenhouse vegetables Area	Specialty Crop High	N	N
Head Cabbage Harvested Area	Specialty Crop High	N	N
Herbs, Fresh Cut Harvested Area	Specialty Crop High	N	N
Honeydew Melons Harvested Area	Specialty Crop High	N	N
Kale Harvested Area	Specialty Crop High	N	N
Lettuce, All Harvested Area	Specialty Crop High	N	N
Mushrooms Area	Specialty Crop High	N	N
Mustard Greens Harvested Area	Specialty Crop High	N	N
Okra Area	Specialty Crop High	N	N
Other nursery and greenhouse crops Area	Specialty Crop High	N	N
Parsley Harvested Area	Specialty Crop High	N	N
Peppers, Bell Harvested Area	Specialty Crop High	N	N
Peppers, Chile (all peppers – excluding bell) Harvested Area	Specialty Crop High	N	N
Popcorn Harvested Area	Specialty Crop High	N	N
Potatoes Harvested Area	Specialty Crop High	N	N
Potted flowering plants Area	Specialty Crop High	N	N
Potted flowering plants Protected Area	Specialty Crop High	N	N
Pumpkins Harvested Area	Specialty Crop High	N	N
Radishes Harvested Area	Specialty Crop High	N	N
Rhubarb Harvested Area	Specialty Crop High	N	N
Spinach Harvested Area	Specialty Crop High	N	N

Squash Harvested Area	Specialty Crop High	N	N
Sweet potatoes Harvested Area	Specialty Crop High	N	N
Tomatoes Harvested Area	Specialty Crop High	N	N
Turnip Greens Harvested Area	Specialty Crop High	N	N
Turnips Harvested Area	Specialty Crop High	N	N
Vegetable & flower seeds Area	Specialty Crop High	N	N
Vegetable & flower seeds Protected Area	Specialty Crop High	N	N
Vegetables, Mixed Area	Specialty Crop High	N	N
Vegetables, Other Harvested Area	Specialty Crop High	N	N
Watermelons Harvested Area	Specialty Crop High	N	N
Aquatic plants Area	Specialty Crop Low	N	N
Aquatic plants Protected Area	Specialty Crop Low	N	N
Asparagus Harvested Area	Specialty Crop Low	N	N
Berries- all Harvested Area	Specialty Crop Low	N	N
Cut Christmas Trees Production Area	Specialty Crop Low	N	N
Green Lima Beans Harvested Area	Specialty Crop Low	N	Y
Greenhouse vegetables Protected Area	Specialty Crop Low	N	N
Land in Orchards Area	Specialty Crop Low	N	N
Mushrooms Protected Area	Specialty Crop Low	N	N
Nursery stock Area	Specialty Crop Low	N	N
Nursery stock Protected Area	Specialty Crop Low	N	N
Other nursery and greenhouse crops Protected Area	Specialty Crop Low	N	N
Peas, Chinese (sugar and Snow) Harvested Area	Specialty Crop Low	N	Y
Peas, Green (excluding southern) Harvested Area	Specialty Crop Low	N	Y
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	Specialty Crop Low	N	Y
short-rotation woody crops Harvest Area	Specialty Crop Low	N	N
short-rotation woody crops Production Area	Specialty Crop Low	N	N
Snap Beans Harvested Area	Specialty Crop Low	N	Y
Sunflower seed, non-oil varieties Harvested Area	Specialty Crop Low	N	N
Sunflower seed, oil varieties Harvested Area	Specialty Crop Low	N	N

In years for which acres of crops are provided by the Census of Agriculture (1982, 1987, 1992, 1997, 2002, 2007 and 2012), those acres are used directly in estimating the total land use acres after considering any acres upon which two crops may have been grown. Acres of crops (and thus, land uses) in intervening years are interpolated. For example, if the Census of Agriculture reported 1,000 acres of pasture in a county in 1992 and 500 acres in 1997, then it is assumed that the county lost 100 acres of pasture each year from 1993 through 1997.

3.2.1 Forecasting Agricultural Acres

The Census of Agriculture is only available every five years through 2012. For all years between releases, crop acres are interpolated. Crop acres for any year after 2012 are projected for each county using a double-exponential smoothing projection method approved by the Agriculture Workgroup.

Double-exponential smoothing is a short-term data forecasting method that is most often used when future values are believed to be related to both long-term and short-term trends in historic values. The method allows users to combine predictions of long-term and short-term trends by placing different weights or emphasis on each type of trend. The Agriculture Workgroup was asked to determine the weights of the alpha and beta values. The choices of the alpha and beta weighting factors, of 0.8 and

0.2 respectively, were chosen based upon an analysis of which factors best predicted both poultry and cattle populations reported in the 2007 Census of Agriculture.

A formula, explanation of terms and example projections are provided below.

- At = Actual county value as reported by Census of Agriculture
- Ft = Unadjusted forecast (before trend)
- Tt = Estimated trend
- AFt = Trend-adjusted forecast
- a= Alpha value is the weight placed upon the most recent Census of Agriculture value
- b= Beta value is the weight placed upon the long-term trend in Census of Agriculture values

Ft = a* At-1 + (1- a) * (Ft-1 + Tt-1)

Tt = b* (At-1-Ft-1) + (1- b) * Tt-1 *(note that Tt should be calculated before Ft)*

AFt = Ft + Tt

Table 4. Hypothetical Projection of a County's Legume Hay Acres

Period	Year	At (Reported Acres Value)	Ft	Tt	Aft
1	1982	**2,000**	2,000	0	2,000
2	1987	**1,250**	2,000	0	2,000
3	1992	**1,000**	1,400	-150	1,250
4	1997	**900**	1,050	-200	850
5	2002	**850**	890	-190	700
6	2007	**900**	820	-160	660
7	2012	**800**	852	-112	740
*8	2017		788	-100	**688**
9	2022				**636**

*For periods >= 8, Aft = (Aft-1) + ((Aft-1) – (Aft-2))

Blue text indicates the value – reported or projected – that would be used by Scenario Builder.

In the hypothetical projection above, the long-term trend showed a steep decline in acres from 1982 through 2012. When coupled with a short-term trend showing another sharp decline from 2007 to 2012, the projection methodology predicts a continued loss of acres in 2017 and 2022.

These projections are done for each agricultural land use aside from the farmstead and feeding operation land uses. Once the projections at the land use level are complete, Scenario Builder assumes that the mixture of crops within each land use is the same as reported in the 2012 Census of Agriculture.

In the hypothetical example above, Scenario Builder projected the county would have 688 acres of the land use, "Legume Hay." That land use actually combines acres of six unique crops reported by the Census of Agriculture. Table 5 provides an example of how 2017 projected acres of Legume Hay are converted into acres of each individual crop.

Table 5. Creating 2017 Crop Acres of Legume Hay for a County

Census of Agriculture Crop	Census of Agriculture Acres 2012	Fraction Census of Agriculture Acres 2012	2017 Projected Acres
Alfalfa Hay Harvested Area	150	0.1875	129
Alfalfa seed Harvested Area	150	0.1875	129
Birdsfoot trefoil seed Harvested Area	150	0.1875	129
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	150	0.1875	129
Red clover seed Harvested Area	100	0.125	86
Vetch seed Harvested Area	100	0.125	86
Total	800	1	688

3.2.2 Filling in the D's

The Census of Agriculture withholds data that could identify individual farm operations. These data are reported with a "D." However, values initially reported as D's are aggregated and reported as "all other counties" by the Census of Agriculture. Individual counties may have a "D" value in one year, yet have actual values in other years. In order to estimate acres of crops and numbers of animals, Scenario builder must remove the D's and replace them with values using a procedure described below.

All non-reported values are first replaced by linearly interpolating between actual values reported in other years. This interpolation occurs at both the state and county scale. If this results in the sum of all county values being greater than the reported state values for a particular year or if 30 percent of more of all counties' D's in a state cannot be replaced by linear interpolation, then a second method is used.

If linear interpolation fails or there are no reported values for prior and subsequent years, then the difference between the state total value and the sum of all county values is redistributed proportionally to all counties listed as "D." This proportional redistribution is done by taking the average county fraction out of the state total for each year in which there are data.

Occasionally, a state value may be listed as "D." In order to remove the "D," a linear regression is performed at the state level over all years for which there are data.

3.2.3 Estimating Double-Cropped Acres

The Census of Agriculture reports harvested acres of over 115 individual crops grown throughout the watershed. These harvested acres naturally add up to more than the acres of agricultural land within the watershed because many acres are reported as being harvested for two different crops in a single year.

This is most common within the widely-maintained corn/soybean/wheat crop rotation. To avoid double-counting some agricultural acres, Scenario Builder estimates those acres that have two or more crops harvested from them using the following procedure. The acres resulting from this procedure are assumed to be major field crops and become the acres of the small grains and soybeans land use.

Double-Cropping Procedure using Census of Agriculture Harvested Crop Acreages

1. Determine acres that are double-cropped:
    a. Determine total "Major Field Cropland Harvested Area" by subtracting acres harvested of the following crops from "Harvested Cropland Area." The result of this step should represent the geographic extent of acreage from which two crops could theoretically be harvested.
        i. Alfalfa hay
        ii. Berries – all
        iii. Cut Christmas trees
        iv. Land in orchards
        v. Nursery, greenhouse, floriculture, aquatic plants, mushrooms, flower seeds, vegetable seeds, and sod
        vi. Other managed hay
        vii. Short-rotation woody crops
        viii. Small grain hay
        ix. Vegetables (includes many crops)
        x. Wild hay
        xi. Dry edible beans, excluding limas
        xii. Tobacco
        xiii. Potatoes
        xiv. Field and grass seed crops
        xv. Sunflower seed (all varieties)
        xvi. Cotton
        xvii. Canola
        xviii. Popcorn
    b. Determine the total acres harvested of the "Major Field Crops" listed below. The result of this step is often greater than the geographic extent of "Major Field Cropland Harvested Area," thus representing the acres from which two crops could theoretically be harvested.
        i. Barley
        ii. Buckwheat
        iii. Canola
        iv. Corn for grain
        v. Corn for silage
        vi. Emmer and spelt
        vii. Oats for grain
        viii. Rye for grain
        ix. Sorghum for Grain
        x. Sorghum for Silage
        xi. Soybeans for beans
        xii. Triticale
        xiii. Wheat for grain

c. If “Major Field Cropland Harvested Area” – “Major Field Crops” >= 0, then there are no double-cropped acres in county.

If “Major Field Cropland Harvested Area” – “Major Field Crops” <0, then this amount becomes the double-cropped acres (acres of small grains and soybeans) in county.

3.2.4 Estimating Grains with Manure and Silage with Manure Acres

The Agricultural Modeling Subcommittee wished to separate the most commonly grown crop in the watershed – corn – into land uses that could and could not receive manure. By doing so, a fraction of corn (and sorghum) acres simulated across the watershed receive only inorganic fertilizer applications. This was recommended in order to account for producers who do not have access to manure or other organic nutrient sources.

The Census of Agriculture does not provide a breakout of acres of each crop type that received manure and those that did not in a given year. It does provide an estimate of the total acres that received manure in each county. This value inherently includes acres of pasture and other crops that do not pertain to the Grains with Manure land use, and should be accounted for if the information is used to estimate acres of grains with manure. However, with very little additional information about manure applications to specific crops, the Agricultural Modeling Subcommittee recommended that acres of corn and sorghum available for manure application be determined using equation 3.

Equation 2. Estimating Fraction for Grains with Manure Land Use

Fraction = Census of Agriculture Acres Receiving Manure/ (Census of Agriculture Acres of Harvested Cropland + Census of Agriculture Acres of Pasture – Census of Agriculture Acres of Soybeans)

The Agricultural Modeling Subcommittee was skeptical that this proxy variable could accurately estimate acres of corn and sorghum that received manure. In an attempt to improve the procedure, the group asked the Maryland Department of Agriculture to provide estimates of the amount of manure nitrogen out of the total amount of nutrients applied to corn in 2011, 2012 and 2013, as reported by farmers on the Annual Implementation Reports. These estimates were compared to the fractions calculated by equation 2. The resulting comparisons are provided in Table 6. After comparing the two values, the Subcommittee felt comfortable using Equation 2 to estimate the fraction of corn and sorghum acres that would be eligible for manure in the Grains with Manure land use.

Table 6. Comparing Manure Eligible Crop Percentages

Region	MD AIR Percentage (2011, 2012, 2013 combined)	Census of Agriculture Percentage (2012)
Statewide	17	21
Lower Eastern Shore	28	32
Western	24	20
Central	2	6
Northwestern	14	26
Northern	5	11

Southern	8	7
Upper Eastern Shore	17	20

3.3 Combining Acres

Initial acreage estimates of total agricultural area along with estimates of each developed and natural land use are provided by the CBLCM. However, these initial estimates are then combined with crop acreages from the Census of Agriculture, and adjusted to create a final set of land use acres for every land-river segment. This adjustment must occur because the combination of CBLCM-generated acres (which includes an estimate of agricultural land) and Census of Agriculture acres will naturally exceed the actual acres of land and water in each county. If too many acres exist in a land-river segment, the initial estimates of acres are reduced in the following, stepwise fashion, taking acres down to zero at the end of each step if necessary:

1. CBLCM Open Space (which includes CBLCM estimates of agricultural land)
2. CBLCM Non-Regulated Tree Canopy over Scrub-Shrub
3. CBLCM Disturbed Forest and Forest proportionally
4. CBLCM Non-Regulated Developed and MS4 Developed and Extractive proportionally, includes:
    a. Non-Regulated Roads
    b. Non-Regulated Buildings and Other
    c. Non-Regulated Tree Canopy over Impervious
    d. Non-Regulated Tree Canopy over Herbaceous
    e. Non-Regulated Turf Grass
    f. MS4 Roads
    g. MS4 Buildings and Other
    h. MS4 Tree Canopy over Impervious
    i. MS4 Tree Canopy over Scrub Shrub
    j. MS4 Tree Canopy over Herbaceous
    k. MS4 Turf Grass
    l. Abandoned Extractive Lands
    m. Active Extractive Lands
5. All agricultural land uses derived from Census of Agriculture proportionally, includes:
    a. Ag Open Space
    b. Full Season Soybeans
    c. Grain with Manure
    d. Grain without Manure
    e. Legume Hay
    f. Silage with Manure
    g. Silage without Manure
    h. Small Grains and Grains
    i. Small Grains and Soybeans
    j. Specialty Crop High
    k. Specialty Crop Low
    l. Other Agronomic Crops
    m. Other Hay
    n. Pasture
    o. Farmstead
6. CBLCM wetlands proportionally, includes:

    a. Palustrine Forested Wetland
    b. Palustrine Scrub-Shrub Wetland
    c. Palustrine Emergent Wetland
7. CBLCM combined sewer system lands proportionally, includes:
    a. CSS Roads
    b. CSS Buildings and Other
    c. CSS Tree Canopy over Impervious
    d. CSS Tree Canopy over Scrub-Shrub
    e. CSS Tree Canopy over Herbaceous
    f. CSS Turf Grass
8. CBLCM Harvested Forest, MS4 Construction and CSS Construction, proportionally
9. Census of Agriculture-derived Permitted Feeding Space and Non-Permitted Feeding Space, proportionally
10. CBLCM Water

This process was be revised in the next calibration run of the Phase 6 Model. The stepwise reductions in each land use are likely to be replaced by proportional reductions across all land uses, with each land use being more or less likely to be adjusted. For example, if the Partnership feels that pasture acres reported in the Census of Agriculture have much less uncertainty than hay acres, the revised procedure is likely to reduce hay at a higher relative proportion than pasture. Details will be provided in the documentation once a method is decided upon.

3.4 Acres of Feeding Operations

The Census of Agriculture does not provide an estimate of animal production areas. These areas include barnyards or feedlots and structures such as dairy barns or poultry houses. These production areas can be large sources of nutrient runoff if not properly maintained with BMPs. To estimate these acres, Scenario Builder assumes that each animal raised requires an average area of barnyard and or structure for production purposes. These average areas per animal are provided in Table 7. These are multiplied by the estimated number of animals produced in each county.

Table 7. Estimated Animal Production Area Requirements

Source Name	Open-Air Barnyard (sq feet)			Roofed Structures (sq feet)			All Area (sq feet)	Cycles (NRCS)	Adjusted All Area (sq ft)	All Area (acres/animal)
	MAX	MIN	MED	MAX	MIN	MED	Total	Total	Total	Total
Pullets*						1.0	1.0	2.25	0.44	0.000010
Turkeys				2.0	2.0	2.0	2.0	2.00	1.02	0.000023
Broilers*						0.85	0.85	6.00	0.14	0.000003
Layers				1.7	1.7	1.7	1.7	1.00	1.72	0.000040
Hogs for Slaughter				9.7	9.7	9.7	9.7	2.00	4.84	0.000111
Hogs and Pigs for Breeding				13.6	13.6	13.6	13.6	1.00	13.56	0.000311
Beef (Beef Heifers)	60.3	50.6	55.4	35.5	18.3	26.9	82.3	1.00	82.31	0.001890
Dairy (Dairy heifers)	96.8	96.8	96.8	28.6	28.6	28.6	125.5	1.00	125.46	0.002881

Other Cattle	50.6	39.8	45.2	24.7	11.8	18.3	63.5	1.00	63.48	0.001458
Horses	147.3	147.4	147.4	147.3	147.3	147.3	294.7	1.00	294.66	0.006765
Sheep and Lambs*						25.0	25.0	1.00	25.02	0.000574
Goats*						15.0	15.0	1.00	15.00	0.000344

*Maximum, minimum and median values provided by Maryland Department of Agriculture, 2015.
All other maximum, minimum and median values provided by FASS, 2010.

The values in the table were provided by the Federation of Animal Science Societies (FASS) and by the Maryland Department of Agriculture. The median values for open-air barnyard and roofed structures were combined to create the average square footage required to raise a single animal. However, some farms have multiple animals which share the same space at different times during the year. For example, a broiler may require 0.85 square feet of production area, but a producer may move flocks of broilers in and out of the house six times over a single year. Thus, the 0.85 square feet is used by six broilers. To avoid counting the same area six times, the median values were divided by the average number of cycles (or flocks) of animals produced, as provided by NRCS, 2003 as shown in equation 3.

Equation 3. Countywide Acres of Feeding Operations = All Area (sq ft)/Yearly Cycles of Production X 2.296e-5 (acres/sq ft) X Animals Produced in County

Total acres of feeding operations are then broken further into permitted and non-permitted feeding space land uses based upon the fraction of animals that are permitted and non-permitted in each county. These fractions are provided by each jurisdiction, and can vary by year. Scenario Builder does not treat nutrients deposited on permitted feeding operations differently than those deposited on non-feeding operations.

3.5 Acres of Farmstead

Many farms contain areas which are not actively used in producing crops or animal products. Oftentimes these areas contain turf grass, houses and other small structures, rural roads and small woodlots. Farmsteads share these characteristics with suburban or rural residential areas, making them almost indistinguishable from a satellite view or land cover mapping perspective. To avoid double-counting with rural residential areas, the current Phase 6 Model contains no acres of farmstead. This may be changed in the final version if a formula can be derived to extract farmsteads from satellite, land cover, or other data sources.

4 Manure Nutrient Applications

Scenario Builder estimates manure nutrient applications upon individual crops for each month during the year. These applications are then aggregated and averaged at the land use level for the Watershed Model. For example, Scenario Builder estimates the amount of nitrogen applied to the crop, Corn for Grain for the month of April. Corn for Grain is a constituent crop of the land use, Grain with Manure. Sorghum for Grain is also a constituent crop of this land use. The combined applications to each acre of Grain with Manure in April will be the result of the total applications to both crops averaged over all acres. Table 8 provides an example of this method.

Table 8. Hypothetical Nutrient Application on Grain with Manure in April

Crop	Month	Lbs of Manure N/Acre	Acres	Total Lbs of Manure N Applied
Corn for Grain	April	30	1,000	30,000
Sorghum for Grain	April	10	500	5,000
Total	April	**23.33***	1,500	35,000

*23.33 Lbs of N/Acre = ((30 Lbs of N/Acre X 1,000 Acres) + (10 Lbs of N/Acre X 500 Acres))/ (1,000 Acres + 500 Acres)

There are many calculation steps and assumptions required before Scenario Builder can supply this level of detailed information to the Watershed Model. The tool must first develop estimates of the amount of manure nutrients available in each county taking into account BMPs that impact the amount of manure available in each county. It must then consider the amount of manure each crop needs according to nutrient management recommendations, and then must distribute the manure to each crop based upon an optimization routine which prioritizes applications to higher commodity crops first. Each of these steps will be described in detail in this section.

4.1 Estimating Manure Available in a County

Scenario Builder begins with the assumption that manure generated within a county is available for deposition or application only within that county. Each jurisdiction is responsible for tracking manure transport which can move manure across county lines and even out of the watershed in a scenario. Transport of manure out of the watershed removes the manure entirely from a scenario.

The initial manure available in each county is estimated based upon yearly animal production and the manure characteristics (quantity generated and nutrient concentrations) of each animal type. Equation 4 describes an example manure nitrogen calculation for beef.

Equation 4. Calculating Beef Manure Total Nitrogen Generated

*Lbs Manure Nitrogen from Beef/Year = Beef Produced/Year X Lbs Dry Manure/Year X Lbs of Total Nitrogen/Lb Dry Manure**

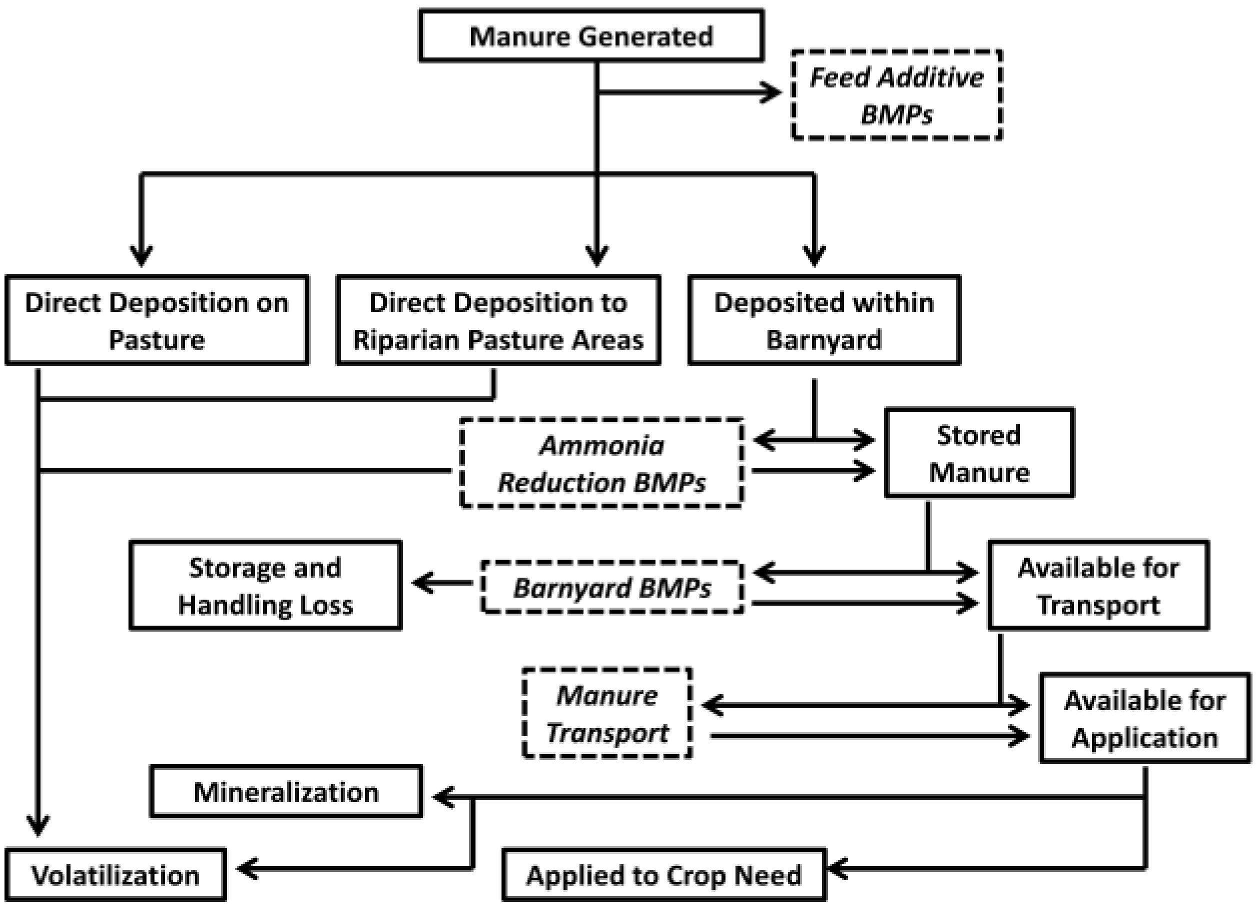
**Scenario Builder actually calculates the individual species of nitrogen (and phosphorus).*

Example Calculation for 1,000 Beef:

157,614.3 Lbs N/Year = 1,000 Beef/Year X 5,475 Lbs Dry Manure/Year X 0.028788 Lbs of N/Lb Dry Manure

Tables 8 and 9 provide the manure characteristics used for livestock. Nutrient concentrations of poultry litter vary by year as described in the Bay Program's Poultry Litter Subcommittee's report included as A. Once this overall total is calculated, the manure is separated into various "piles" by Scenario Builder which are then subject to alterations by BMPs and physical and chemical processes, such as losses to the environment due to improper storage and handling and volatilization of ammonia. Figure 3 provides an overview of these various processes simulated by Scenario Builder.

Figure 3. Manure Application Processes



Arrows indicate direction that nutrients can "travel." Stacked arrows indicate that a BMP can reverse the nutrient "loss," adding nutrients back into the stream. For example, Barnyard BMPs for manure storage can decrease Storage and Handling Loss making more manure available for transport and application.

4.1.1 Animal Numbers

The first step in estimating manure available in a county is to estimate the number of animals raised in the county for the year in question. The number of livestock animals, pullets and layers raised are provided by the Census of Agriculture, and are subject to the D-filling procedure and the interpolation and projection methods described in previous sections.

The values reported by the Census of Agriculture are meant to reflect inventories of all the farms in a county on December 31 of a census year. Inventories do not accurately capture the total production of a county because many producers will cycle multiple flocks or groups of animals through their operation in a given year. For example, a farmer might have 1,000 hogs for slaughter on his or her farm on December 31, but those hogs may be the second group of hogs raised in that year. For those operations that do have multiple groups of animals cycled through during a year, the USDA-NRCS recommends considering both inventory and sales numbers to estimate total animals produced by using the following equation:

Equation 5. Total Animals Produced in a Year
(Census of Agriculture Animal Inventory X 1/Production Cycles) + ((Census of Agriculture Animals Sold/Production Cycles) X (Production Cycles – 1/Production Cycles))

Most animals have a yearly production cycle of one, making the equation unnecessary. However, the USDA-NRCS estimates the following average production cycles per year for select animals:
hogs for slaughter – 2;
pullets – 2.25;
broilers – 6; and
turkeys -2.

To avoid undercounting animals, Scenario Builder uses Equation 5 to estimate production of hogs for slaughter and pullets. Broiler and turkey production are provided yearly by USDA – NASS at a state-level, and Scenario Builder uses those numbers directly rather than relying upon Equation 5 and the Census of Agriculture. More detailed methods for estimating poultry populations are described in Appendix A.

Table 8. Total Nutrient Manure Characteristics for Livestock

Animal Type	Manure Source	Lbs Dry Manure/Animal/Yr	Lbs TN/Lb Dry Manure	LbsTP/Lb Dry Manure
Beef	Use Beef - Cow (confinement) from ASAE 2005 for manure values	5,475.00	0.028788	0.006467
Dairy	Use Lactating Cow, Dry Cow and Heifer from ASAE 2005 for manure values	4,404.33	0.042221	0.006764
Other Cattle	Use average of Beef and Dairy from above to estimate manure values	4,939.67	0.035504	0.006616
Horses	Use average of Horse- Sedentary and Horse - Intense Exercise from ASAE 2005 for manure values	3,102.50	0.031672	0.005941
Hogs for Breeding	Use Gestating Sow and Lactating Sow ASAE 2005 for manure values	657	0.070273	0.019417
Hogs for Slaughter	Use Grow-Finish from ASAE 2005 for manure values	120	0.083333	0.014167
Sheep and Lambs	Use ASAE 2003 for manure values	240.9	0.038182	0.007909
Goats	Use ASAE 2003 for manure values	680.91	0.034615	0.008462

Values for poultry vary by year. See Appendix A for details.

Table 9. Manure Nutrient Species Concentrations for Livestock per Lb of Dry Manure

Livestock Type	Mineralized Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Ammonia Nitrogen	Mineralized Phosphorus	Organic Phosphorus	Phosphate
Beef	0.007527	0.000000	0.013979	0.007282	0.004359	0.000000	0.002108
Dairy	0.012185	0.000000	0.022628	0.007408	0.000217	0.000000	0.006547
Other Cattle	0.009765	0.000000	0.018135	0.007605	0.004458	0.000000	0.002158
Horses	0.011831	0.000000	0.011831	0.008010	0.004350	0.000000	0.001591
Hogs for Breeding	0.015538	0.000000	0.015538	0.039196	0.006469	0.000000	0.012948
Hogs for Slaughter	0.018430	0.000000	0.018430	0.046473	0.004720	0.000000	0.009447
Sheep and Lambs	0.009984	0.000000	0.018541	0.009657	0.003955	0.000000	0.003955
Goats	0.009051	0.000000	0.016809	0.008755	0.005349	0.000000	0.003112

Values for poultry vary by year. See Appendix A for details.

4.1.2 Nitrate Nitrogen

Scenario Builder assumes zero nitrate nitrogen is available in animal manure.

4.1.3 Ammonia Nitrogen

The ammonia concentrations listed in Table 9 are a combination of the existing Scenario Builder's ammonia concentrations per pound listed in Table 10 taken from ASAE, 2003 and the total nitrogen concentrations listed in Table 8 – most of which were taken from the updated ASAE, 2005. Equation 6 shows how ammonia nitrogen was calculated. While ammonia nitrogen is available to crops, it is also subject to volatilization both within the barnyard and within the field, so always less than 100 percent of the ammonia nitrogen generated will be available to plants in any given scenario.

Table 10. Existing Scenario Builder Ammonia Nitrogen Concentrations Per Lb Total Nitrogen

Animal Type	Lbs Ammonia Nitrogen/Lb Total Nitrogen
Beef	0.252942
Dairy	0.175459
Other Cattle*	0.214200*
Horses	0.252889
Hogs for Breeding	0.557768
Hogs for Slaughter	0.557674
Sheep and Lambs	0.252928
Goats	0.252915

*Value for Other Cattle is derived from the average of beef and dairy.

Equation 6: Deriving New Ammonia Nitrogen Concentrations

Lbs Ammonia Nitrogen/Lb Dry Manure = Lbs of Total Nitrogen/Lb Dry Manure X Existing Scenario Builder Concentration of Lbs Ammonia Nitrogen/Lb Nitrogen

Example Calculation for Beef:
0.007282 Lbs Ammonia Nitrogen/Lb Dry Manure = 0.028788 Lbs Total N/Lb Dry Manure X 0.252942 Lbs Ammonia N/Lb Total N

4.1.4 Mineralized Nitrogen

Mineralization of organic nutrients in manure transforms previously unavailable nutrients into a form of that can be used for plant uptake. This process occurs continually within the soil for years after application of manure. Scenario Builder does not directly account for previous years' nutrient applications when calculating current or future year applications to crops. For this reason, the tool uses mineralization factors that are meant to represent only the mineralization that occurred during the year of application. The nitrogen mineralization factors were published by the Mid-Atlantic Water Program in 2006 and are listed in Table 11.

Table 11. Mineralization of Organic Nitrogen

Animal Type	Mineralization Fraction
Beef	0.35
Dairy	0.35
Other Cattle	0.35
Horses	0.5
Hogs for Breeding	0.5
Hogs for Slaughter	0.5
Sheep and Lambs	0.35
Goats	0.35

The final mineralized nitrogen values published in Table 9 are the product of the non-ammonia nitrogen concentrations and the mineralization factors listed in Table 11. See Equation 7 for an example calculation.

Equation 7. Calculating Final Mineralized Nitrogen Concentrations per Lb Dry Manure

Lbs Mineralized N/Lb Dry Manure = (Lbs Total N/Dry Manure – Lbs Ammonia N/ Lb Dry Manure) X Mineralization Fraction

Example Calculation for Beef:

0.007527 Lbs Mineralized N/Lb Dry Manure = (0.028788 Lbs Total N/Lb Dry Manure - 0.007282 Lbs Ammonia N/Lb Dry Manure) X 0.35

4.1.5 Organic Nitrogen

Organic nitrogen is not considered to be available for plant uptake. This portion of the nitrogen from manure is still applied to the land, and thus is available for runoff into nearby water bodies in the Watershed Model. Organic nitrogen concentrations are calculated simply as the difference of non-ammonia total nitrogen minus the previously calculated mineralized nitrogen. See Equation 8 for an example calculation.

Equation 8. Calculating Final Organic Nitrogen Concentrations per Lb Dry Manure

Lbs Organic N/Lb Dry Manure = Lbs Total N/Dry Manure – Lbs Ammonia N/Lb Dry Manure – Lbs Mineralized N/Lb Dry Manure

Example Calculation for Beef:

0.013979 Lbs Organic N/Lb Dry Manure = 0.028788 Lbs Total N/Lb Dry Manure - 0.007282 Lbs Ammonia N/Lb Dry Manure – 0.007527 Lbs Mineralized N/Lb Dry Manure

4.1.6 Phosphate

Phosphate is considered to be readily available for plant uptake. The phosphate concentrations listed in Table 10 are a combination of the existing Scenario Builder's phosphate concentrations per pound listed in Table 12 taken from ASAE, 2003 and the total phosphorus concentrations listed in Table 9 – most of which were taken from the updated ASAE, 2005. Equation 9 shows how new phosphate concentrations were calculated.

Table 12. Existing Scenario Builder Phosphate Concentrations Per Lb Phosphate

Animal Type	Lbs Phosphate/Lb Total Phosphorus
Beef	0.325977
Dairy	0.967978
Other Cattle	0.326154
Horses	0.267767
Hogs for Breeding	0.666822
Hogs for Slaughter	0.666822
Sheep and Lambs	0.500000
Goats	0.367872

Equation 9. Calculating New Phosphate Concentrations

Lbs Phosphate/Lb Dry Manure = Lbs of Total P/Lb Dry Manure X Existing Scenario Builder Lbs of Phosphate/Lb Total P

Example Calculation for Beef:

0.002108 Lbs Phosphate/Lb Dry Manure = 0.006467 Lbs Total P/Lb Dry Manure X 0.325977 Lbs of Phosphate/Lb Total P

4.1.7 Mineralized Phosphorus and Organic Phosphorus

Scenario Builder considers 100 percent of the non-phosphate phosphorus is available for crop need as mineralized phosphorus. Thus, mineralized phosphorus is equal to the difference of the total phosphorus minus the phosphate portion while organic phosphorus equals 0. Equation 10 provides an example calculation of mineralized phosphorus.

Equation 10. Calculating Final Mineralized Phosphorus Concentrations

Lbs Mineralized P/Lb Dry Manure = Lbs Total P/Lb Dry Manure – Lbs Phosphate P/Lb Dry Manure

Example Calculation for Beef:

0.004359 Lbs Mineralized P/Lb Dry Manure = 0.006467 Lbs Total P/Lb Dry Manure – 0.002108 Lbs Phosphate P/Lb Dry Manure

4.1.8 Feed Additive BMPs

A county's initial estimated manure generation can be reduced by the swine phytase BMP or the dairy precision feeding BMP. These two BMPs reflect changes in feeding regimens made by the industry that theoretically reduced the amount of nitrogen in dairy manure and the amount of both phosphorus and nitrogen in dairy manure. Swine phytase is currently an interim BMP, which means it is only available for use in planning scenarios, and was not accounted for in the calibration of the Phase 6 Model. If accounted for, swine phytase would reduce the total phosphorus from hogs and pigs for breeding and hogs and pigs for slaughter by 17 percent. Dairy precision feeding is an approved BMP for all scenarios, including the calibration of the Phase 6 Model. This BMP reduces total nitrogen from dairy by 24 percent and total phosphorus from dairy by 25 percent.

4.2 Separating Manure into Areas of Deposition

The total manure generated after feed additive BMPs are applied is split equally into twelve portions to represent monthly manure generation. This split is made to give jurisdictions the opportunity to distinguish the amount of time an animal spends in each of the following areas each month: pasture; riparian pasture access area; and barnyard. For example, an average dairy cow may spend 25 percent of its day on pasture and riparian pasture areas during the winter months when it is colder, but spend 50 percent (or more) of its day there during warmer summer months. Each jurisdiction was asked to provide percentages for each animal type and month. The percentages could even vary by county or growth region to account for varying climates across a single state. An example of these percentages is included in Table 13.

Table 13. Beef Percent Manure Deposited by Area in West Virginia Growth Region 1

Growth Region	Animal Type	Month	Barnyard Fraction	Pasture Fraction	Access Area Fraction
WV_1	beef	1	6	91	3
WV_1	beef	2	6	91	3
WV_1	beef	3	0	96	4
WV_1	beef	4	0	94	6
WV_1	beef	5	0	94	6

WV_1	beef	6	0	90	10
WV_1	beef	7	0	90	10
WV_1	beef	8	0	90	10
WV_1	beef	9	0	94	6
WV_1	beef	10	0	96	4
WV_1	beef	11	0	96	4
WV_1	beef	12	6	91	3

4.2.1 Direct Deposition on Pasture

Table 13 indicates 91 percent of beef manure is assumed to be deposited on pasture in West Virginia in the month of January. This is manure that will never be available for manure transport or application to meet crop need. The manure is simply applied to the pasture land use and becomes one source of applications to that land use. Additionally, this manure is not assumed to be applied toward crop need. This means that regardless of the amount of direct deposition on pasture, it is always eligible to receive supplemental manure and/or inorganic fertilizer applications later in the scenario simulation.

4.2.2 Direct Deposition to Riparian Pasture Areas

Table 13 indicates 3 percent of beef manure is assumed to be deposited in riparian pasture areas in West Virginia in the month of January. This is also manure that will never be available for manure transport or application to meet crop need. The Phase 6 Scenario Builder makes no estimate of the number of acres of riparian pasture. Instead, this manure becomes a direct application to streams for the Watershed Model. The Watershed Model then simulates nutrient fate and transport for this source.

A more detailed explanation about direct deposition loads to riparian areas is included in Appendix B.

4.2.3 Manure Deposition to Barnyard Areas

Table 13 indicates 6 percent of beef manure is assumed to be deposited in barnyard areas in West Virginia in the month of January. This initial distribution is assumed to be available for manure transport and plant application only after storage and handling losses from the barnyard and volatilization of ammonia from the barnyard are calculated.

4.2.4 Volatilization of Ammonia from Barnyard Manure

The ammonia portion of manure nutrients deposited within the barnyard is subject to volatilization, removing the nutrients from future calculations of storage and handling loss, manure transport and applications to crops. The fractions of ammonia which are volatilized are listed in Table 14. These fractions have remained unchanged through multiple versions of Scenario Builder and the Watershed Model. Equation 11 provides an example for calculating ammonia volatilization.

Table 14. Fraction of Ammonia Volatilized Within Barnyard Manure

Animal Type	Fraction Volatilized

Beef	0.650000
Dairy	0.650000
Other Cattle	0.650000
Horses	0.320000
Hogs for Breeding*	0.482280*
Hogs for Slaughter*	0.478775*
Sheep and Lambs	0.650000
Goats	0.650000

*The existing Scenario Builder estimates of volatilization of ammonia for swine were too high when compared to the overall nitrogen assumed to be retained within swine manure following volatilization and storage and handling loss by NRCS, 2003. The existing volatilization numbers were reduced to more closely resemble the NRCS estimates of retained nitrogen.

Equation 11. Calculating Ammonia Volatilization within the Barnyard

Lbs Ammonia Volatilized/ Lb Dry Manure = Lbs Ammonia/Lb Dry Manure X Fraction Volatilized

Example Calculation for Beef:

0.004733 Lbs Ammonia Volatilized = 0.007282 Lbs Ammonia X 0.65

4.2.5 Ammonia Reduction BMPs

In previous versions of Scenario Builder, jurisdictions could report BMPs which reduce barnyard ammonia losses. These BMPs are often employed to reduce local air deposition of ammonia and resulting smells, making them useful BMPs for air quality while increasing the amount of nutrients available to surface and ground water runoff. The avoided lost nutrients were then added back into the barnyard manure pile and are made available for storage and handling loss, manure transport and application to crops. However, no credit is currently given to these practices in the Phase 6 Scenario Builder because the Phase 6 Watershed Model has yet to include reductions to local air ammonia deposition that result from implementing the BMPs. The previously credited BMPs and associated reductions are listed below.

Biofilters for Poultry Houses – 60% reduction of ammonia volatilization in barnyard
Lagoon Covers for Swine and Cattle – 15% reduction of ammonia volatilization in barnyard
Poultry Litter Amendments (such as Alum) – 50% reduction of ammonia volatilization in barnyard

4.3 Storage and Handling Loss

Barnyard manure left after accounting for volatilization of ammonia and ammonia reduction BMPs is then made available for storage and handling loss within Scenario Builder. Storage and handling loss is a well-documented issue for animal operations. NRCS conducted a survey of animal operations in the 1990s which provided average “recoverability” fractions for animal operations in many regions of the country. One set of factors represented the proportion of total manure that was thought to be “recoverable,” and thus available for plant application prior to implementation of comprehensive nutrient management plans (CNMPs) for animal operations. To calculate storage and handling loss, Scenario Builder multiplies the post-volatilized nutrients by 1 minus the fraction of manure recoverable in Table 14. An example of the resulting storage and handling loss values are provided in Table 15.

NRCS also provided a second set of factors representing the proportions of N and P that were thought to be recoverable within the recoverable manure itself. These are also listed in Table 14. This second set of factors presented a unique problem for Scenario Builder because the nitrogen factors provided by NRCS naturally accounted for all nitrogen losses including volatilization. Thus to provide Scenario Builder with the most accurate estimate of recoverable nitrogen, the volatilization which was already accounted for in a previous step had to be removed from the calculation. This resulted in the loss of more mineralized nitrogen and organic nitrogen in the final step of the process. An example of the resulting losses and final values can be found in Table 15.

Table 14. NRCS Estimated Recoverability of Manure Nutrients Before CNMPs

Animal Type	Fraction of Manure Recoverable	Fraction N Retained in Recovered Manure	Fraction P Retained in Recovered Manure
Beef	0.600000	0.700000	0.850000
Dairy	0.553000	0.670500	0.871000
Other Cattle	0.576500	0.685250	0.860500
Horses	0.635000	0.685000	0.835000
Hogs for Breeding	0.798000	0.731000	0.881000
Hogs for Slaughter	0.775000	0.733000	0.870000
Sheep and Lambs	0.635000	0.685000	0.835000
Angora Goats	0.635000	0.685000	0.835000
Pullets*	0.850000	0.700000	0.900000
Layers*	0.850000	0.737000	0.950000
Turkeys*	0.765000	0.600000	0.930000
Broilers*	0.750000	0.700000	0.950000

*As described in the Poultry Litter Subcommittee report in Appendix A, it is already assumed that poultry litter nutrient concentrations reflect post-recoverable values. Thus, poultry litter nutrients were retroactively increased to calculate nutrients for storage and handling losses.

Table 15. Calculating Beef Manure Available for Transport

Calculation Step	Mineralized Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Ammonia Nitrogen	Mineralized Phosphorus	Organic Phosphorus	Phosphate
Original Concentration	0.007527	0.000000	0.013979	0.007282	0.004359	0.000000	0.002108
Ammonia Volatilization Loss	0.000000	0.000000	0.000000	0.004733	0.000000	0.000000	0.000000
Post-Volatilization Concentration	0.007527	0.000000	0.013979	0.002549	0.004359	0.000000	0.002108
Storage and Handling Loss	0.003011	0.000000	0.005592	0.001019	0.001744	0.000000	0.000843
Post-Storage and Handling Loss Concentration	0.004516	0.000000	0.008387	0.001529	0.002615	0.000000	0.001265
Loss of Non-Ammonia Nutrients	0.000820	0.000000	0.001522	0.000000	0.000392	0.000000	0.000190
Final Manure Available for Transport Concentration	0.003697	0.000000	0.006865	0.001529	0.002223	0.000000	0.001075

4.3.1 Animal Waste Management System BMPs

Scenario Builder has traditionally lowered the storage and handling loss from barnyards when jurisdictions report animal waste management system BMPs. These BMPs provide more adequate storage of manure within barnyards, thus reducing the runoff potential from the production area and keeping more manure in storage for application to crops.

While NRCS provided values for manure and nutrient recoverability post- CNMPs, the Agricultural Modeling Subcommittee chose not to incorporate these values into the new version of Scenario Builder. Instead Scenario Builder continues to reduce storage and handling loss of all nutrients by 75 percent, adding these nutrients back into the pile that will be made available for manure transport and application to crops. A BMP expert panel is currently considering this BMP, and may replace the 75 percent value with NRCS values or other values found in literature.

Following the calculation of AWMS BMPs, Scenario Builder can estimate the total storage and handling loss for the Watershed Model. This resulting estimated loss becomes the application on feeding operation land uses.

4.4 Manure Transport

After AWMS BMPs are accounted for, Scenario Builder has an estimate of the total manure available for manure transport or application to crop lands. Jurisdictions provide manure transport data which allows Scenario Builder to move manure for each animal type across county lines and even out of the watershed.

In Phase 6, Scenario Builder's nutrients are estimated on a dry-weight basis, but the overall pounds of manure that can be transported are estimated on a wet-weight basis to allow states to convert accordingly. This is especially important for manure transport because states typically only track the wet tons of manure. The percent moisture of each ton reported can differ significantly, thus causing under-or-over-estimates of nutrient transport for this BMP is moisture is not standardized. This is an issue that the Partnership has not yet taken up for the Phase 6 Model, but should do so before final calibration occurs. Table 16 lists the assumed moisture content of each type of manure for Phase 6. Broiler moisture fractions were provided by ASAE, 2003 and 2005 with broiler moisture fractions taken from the Poultry Litter Subcommittee report.

Table 16. Moisture Fraction of Animal Manure

Animal Type	Moisture Fraction
beef	0.880000
dairy	0.860000
other cattle	0.870000
horses	0.850000
hogs and pigs for breeding	0.900000
hogs for slaughter	0.900000
sheep and lambs	0.720000
goats	0.670000
pullets	0.740600
turkeys	0.740000
layers	0.742100
broilers	0.286500

4.5 Manure Available to Crops

As discussed previously, Scenario Builder assumes that only a portion of manure nitrogen is available for crops in the first year of application, but assumes that all manure phosphorus is available to crops in the first year of application. Additionally, Scenario Builder assumes that a portion of the ammonia remaining in the manure following manure transport is volatilized within the field, making it not available for crop need. Table 17 lists the fraction of remaining ammonia nitrogen that is assumed to be volatilized within the field for each animal type. The values listed were derived from ammonium conservation coefficients available in the Maryland Nutrient Management Manual and the Penn State Nutrient Management Guide.

Table 17. In-Field Ammonia Volatilization Fractions

Animal Type	Fraction Ammonia Volatilized
beef	0.65
dairy	0.65
other cattle	0.65
horses	0.65
hogs and pigs for breeding	0.55
hogs for slaughter	0.55
sheep and lambs	0.65
goats	0.65
pullets	0.28
turkeys	0.28
layers	0.28
broilers	0.28

4.6 Biosolids

Jurisdictions provided pounds of biosolid nutrients from wastewater treatment plants that were applied to cropland within specific counties and in specific years. Where data were unavailable, the Chesapeake Bay Program estimated biosolid nutrients available for application based upon wastewater treatment plant data contained in ICIS or upon reported values from other years. The resulting dataset shows vast variability of biosolids nutrients between years. The Wastewater Workgroup will review the biosolids dataset and provide revisions in 2016.

Once the total mass of biosolids nutrients are calculated for a county, Scenario Builder lumps these nutrients into the manure available for application bucket and applies the nutrients to crops in the exact same manner as manure is applied. The Wastewater Workgroup will also be reviewing this process and may recommend revisions in 2016.

4.7 CALCULATING CROP MANURE APPLICATION-ELIGIBLE GOALS

Jurisdictions referenced their state nutrient management guidelines in the 1980s, 1990s and 2000s to create tables which included the following information for each crop simulated by Scenario Builder:

- Total N and P application goals per acre or yield unit (varied by decade as nutrient management guidelines changed)
    - Example: 1 lb of N/bushel of corn for grain yield
- Fraction of total application goal which should be met by applications in each month
    - Example: 0.4 of yearly total N on corn for grain should be applied in April
- Indication of which applications are eligible to be met by manure nutrients in each month
    - Example: April applications are eligible to be met by manure nutrients

These values formed the basis of the crop manure application-eligible goals. However, Scenario Builder adjusts the goals yearly to account for changes in yields.

4.7.1 Adjusting Application Goals Based Upon Crop Yields

Nutrient management plan writers across the watershed base application goals on historic crop yield information. If crop yields have increased in recent years, nutrient management planners will adjust the applications upward to match these increases. Likewise, Scenario Builder adjusts yields for major crops up and down according to yearly crop yield data provided by NASS. Finally, the Agricultural Modeling Subcommittee recommended that all yields from NASS be multiplied by 1.1 (110%) to mimic optimistic yield goals developed by producers and nutrient management planners. Crop application goals in Scenario Builder are calculated using Equation 12.

Equation 12. Total Crop Application Goal for Nitrogen

Lbs of N/Year = State-Supplied Lbs of N/Application Goal Yield Unit/Year X Yield/Year X 1.1

Yield data is often sparse or variable for the majority of crops simulated by Scenario Builder, so application goals only differ by year for the major crops listed in Table 17. Major crops are those with an "Application Goal Yield Unit" not equal to acres. Equation 12 is still used to calculate application goals for non-major crops, but the yield unit for all non-major crops becomes acres allowing Scenario Builder to calculate the same per acre application goal across all years and scenarios for these non-major crops. If substantial yield information is located for non-major crops in the future, then the application yield unit could be converted from acres back to the original yield unit to reflect changes in yields over time.

Yields are calculated for each major crop in each county for each year. The step-by-step yield calculation procedure can be found in Appendix C.

Table 17. Crop Original Yield Units and Application Goal Yield Units

Crop Name	Original Yield Unit	Application Goal Yield Unit
Alfalfa Hay Harvested Area	dry tons	dry tons
Alfalfa seed Harvested Area	pounds	acres
Aquatic plants Area	unit	acres
Asparagus Harvested Area	tons	acres

Barley for grain Harvested Area	bushels	bushels
Bedding/garden plants Area	unit	acres
Beets Harvested Area	tons	acres
Berries- all Harvested Area	tons	acres
Birdsfoot trefoil seed Harvested Area	pounds	acres
Broccoli Harvested Area	tons	acres
Bromegrass seed Harvested Area	pounds	acres
Brussels Sprouts Harvested Area	tons	acres
Buckwheat Harvested Area	bushels	bushels
Bulbs, corms, rhizomes, and tubers – dry Harvested Area	cwt	acres
Canola Harvested Area	pounds	acres
Cantaloupe Harvested Area	tons	acres
Carrots Harvested Area	tons	acres
Cauliflower Harvested Area	tons	acres
Celery Harvested Area	cwt	acres
Chinese Cabbage Harvested Area	tons	acres
Collards Harvested Area	tons	acres
Corn for Grain Harvested Area	bushels	bushels
Corn for silage or greenchop Harvested Area	tons	tons
Cotton Harvested Area	bales	acres
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area	unit	acres
Cropland in cultivated summer fallow Area	unit	acres
Cropland on which all crops failed or were abandoned Area	unit	acres
Cropland used only for pasture or grazing Area	tons	acres
Cucumbers and Pickles Harvested Area	tons	acres
Cut Christmas Trees Production Area	unit	acres
Cut flowers and cut florist greens Area	unit	acres
Dry edible beans, excluding limas Harvested Area	cwt	acres
Dry Onions Harvested Area	tons	acres
Eggplant Harvested Area	tons	acres
Emmer and spelt Harvested Area	bushels	bushels
Escarole and Endive Harvested Area	tons	acres
Fescue Seed Harvested Area	pounds	acres
Foliage plants Area	unit	acres
Garlic Harvested Area	tons	acres
Green Lima Beans Harvested Area	tons	acres
Green Onions Harvested Area	tons	acres
Greenhouse vegetables Area	unit	acres
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	green tons	acres
Head Cabbage Harvested Area	tons	acres
Herbs, Fresh Cut Harvested Area	tons	acres
Honeydew Melons Harvested Area	cwt	acres
Kale Harvested Area	cwt	acres
Land in Orchards Area	tons	acres
Lettuce, All Harvested Area	tons	acres
Mushrooms Area	unit	acres

Mustard Greens Harvested Area	cwt	acres
Nursery stock Area	unit	acres
Oats for grain Harvested Area	bushels	bushels
Okra Area	tons	acres
Orchardgrass seed Harvested Area	pounds	acres
Other field and grass seed crops Harvested Area	pounds	acres
Other haylage, grass silage, and greenchop Harvested Area	green tons	acres
Other managed hay Harvested Area	dry tons	acres
Other nursery and greenhouse crops Area	unit	acres
Parsley Harvested Area	cwt	acres
Pastureland and rangeland other than cropland and woodland pastured Area	tons	acres
Peanuts for nuts Harvested Area	pounds	acres
Peas, Chinese (sugar and Snow) Harvested Area	tons	acres
Peas, Green (excluding southern) Harvested Area	tons	acres
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	tons	acres
Peppers, Bell Harvested Area	tons	acres
Peppers, Chile (all peppers – excluding bell) Harvested Area	cwt	acres
Popcorn Harvested Area	pounds	acres
Potatoes Harvested Area	cwt	acres
Potted flowering plants Area	unit	acres
Pumpkins Harvested Area	cwt	acres
Radishes Harvested Area	tons	acres
Red clover seed Harvested Area	pounds	acres
Rhubarb Harvested Area	tons	acres
Rye for grain Harvested Area	bushels	bushels
Ryegrass seed Harvested Area	pounds	acres
short-rotation woody crops Harvest Area	unit	acres
Small grain hay Harvested Area	dry tons	acres
Snap Beans Harvested Area	tons	acres
Sod harvested Area	tons	acres
Sorghum for Grain Harvested Area	bushels	bushels
Sorghum for silage or greenchop Area	tons	tons
Soybeans for beans Harvested Area	bushels	bushels
Spinach Harvested Area	tons	acres
Squash Harvested Area	tons	acres
Sunflower seed, non-oil varieties Harvested Area	pounds	acres
Sunflower seed, oil varieties Harvested Area	pounds	acres
Sweet Corn Harvested Area	pounds	acres
Sweet potatoes Harvested Area	cwt	acres
Timothy seed Harvested Area	pounds	acres
tobacco Harvested Area	pounds	acres
Tomatoes Harvested Area	tons	acres
Triticale Harvested Area	bushels	bushels
Turnip Greens Harvested Area	tons	acres
Turnips Harvested Area	cwt	acres
Vegetable & flower seeds Area	unit	acres

Vegetables, Mixed Area	cwt	acres
Vetch seed Harvested Area	pounds	acres
Watermelons Harvested Area	tons	acres
Wheat for Grain Harvested Area	bushels	bushels
Wild hay Harvested Area	dry tons	acres

4.8 Optimizing Manure Applications to Higher-Commodity Crops

A fundamental assumption within the new Scenario Builder is that all manure estimated to be available to crops in a county must be applied. This means that in counties with high animal populations and little manure transport data, manure may be applied above and beyond the manure application-eligible goal specified for each crop by the jurisdictions. Likewise, applications could be far lower than the manure application-eligible goal in counties with very few animals. Scenario Builder attempts to simulate all potential cases such as these with a single set of application curves which optimize application to higher-commodity crops such as vegetables and corn before applications occur on crops such as pasture, hay and other legumes. The optimization curves are included in Figure 3. Rather than creating over a hundred individual curves, crops were lumped into land use groups, and as discussed previously, each land use contains multiple crops. Table 18 lists the land uses included in each land use group.

Figure 3. Manure Nitrogen Application Curves by Crop Group

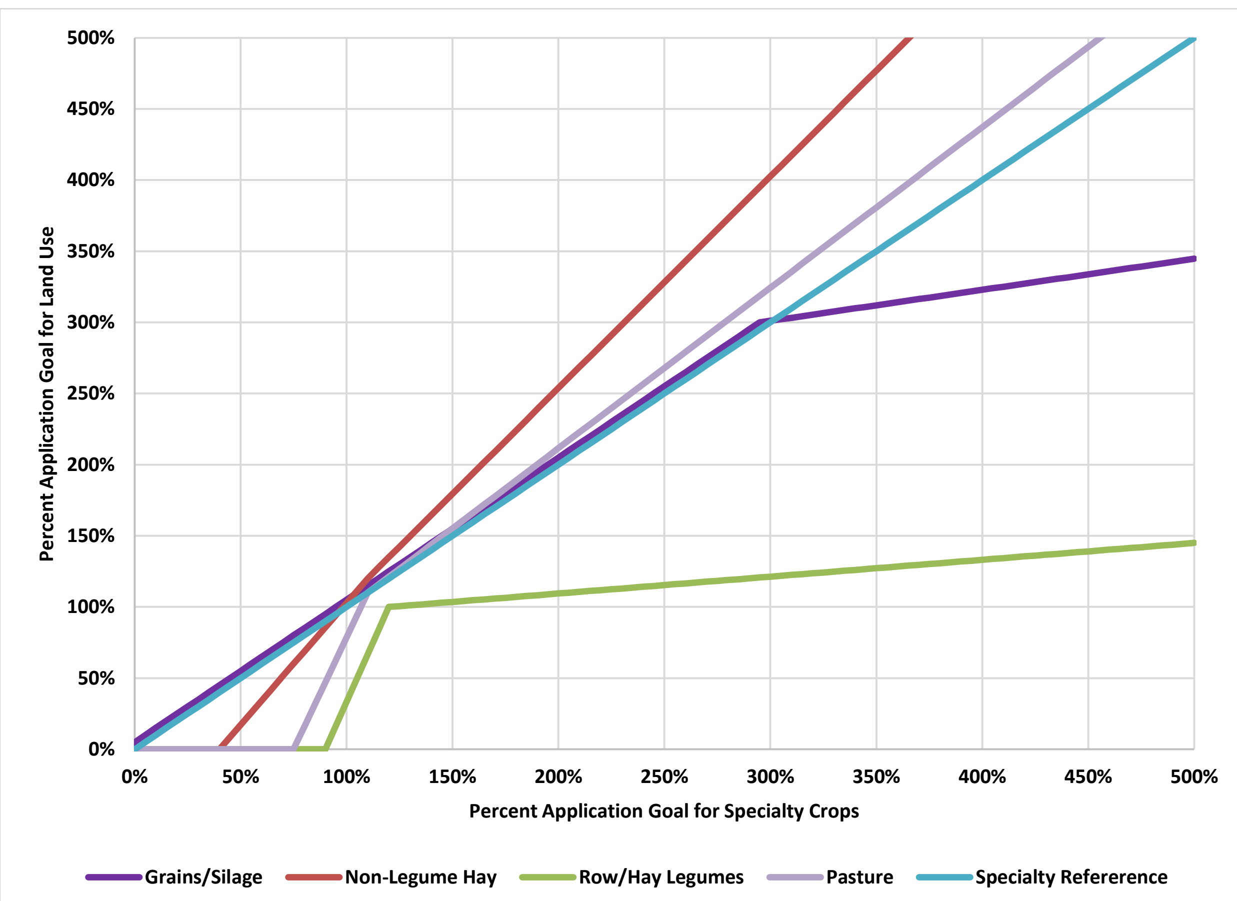


Table 18. Land Use Groups for Manure Application Curves

Land Use Curve Group	Land Use
Grains/Silage	Grain with Manure
Grains/Silage	Silage with Manure
Grains/Silage	Small Grains and Grains
Specialty	Other Agronomic Crops
Specialty	Specialty Crop High
Specialty	Specialty Crop Low
Row/Hay Legumes	Small Grains and Soybeans
Row/Hay Legumes	Full Season Soybeans
Row/Hay Legumes	Legume hay
Pasture	Pasture
Non-Legume Hay	Other Hay

As Figure 3 indicates, Scenario Builder prioritizes applications to specialty crops and grains/silage crops first. For example, if the manure nitrogen available in a county only equals 40 percent of the manure-eligible application goals of all specialty crops and grains/silage crops, then no other crops within the county will receive manure. However, applications to other crop groups quickly begin as more manure nitrogen becomes available in the county. The last crops which will receive manure are leguminous crops including hays and soybeans. Additionally, applications to grains begin to level off in counties with large amounts of manure nitrogen available. As these applications level off, Scenario Builder assumes applications to pasture, non-legume hays and manure-eligible vegetables continue steadily.

Phosphorus manure nutrient applications are tied directly to nitrogen manure applications in Scenario Builder. For example, if the ratio of nitrogen to phosphorus in a county's total manure pile is 3-to-1, than for every three pounds of total nitrogen applied, one pound of phosphorus is applied. The Agricultural Modeling Subcommittee understands that some farmers are now applying manure nutrients to meet phosphorus application goals rather than nitrogen; however, Scenario Builder was designed to simulate applications from 1985 through the present, and it was determined that nitrogen-based manure application more accurately reflected applications on the majority of acres throughout the watershed.

Note that the Watershed Model only sees organic nitrogen and ammonia nitrogen from manure. While mineralized nitrogen is tracked separately within Scenario Builder, it is considered by the Watershed Model to be ammonia nitrogen.

5 Inorganic Fertilizer Nutrient Applications

Crops in Scenario Builder can receive both organic nutrients in the form of manure and biosolids and inorganic fertilizer nutrients to meet nutrient application goals prescribed by states. The Agricultural Modeling Subcommittee determined that no reliable data source exists which provides countywide inorganic fertilizer use adequate for the Phase 6 Scenario Builder. However, both the International Plant Nutrition Institute's Nutrient Use Geographic Information System (NuGIS) and USGS's SPARROW modeling tool provide estimates of countywide inorganic fertilizer use which are based upon fertilizer sales data provided by the Association of American Plant Food Control Officials (AAPFCO). After reviewing both methods, the Agricultural Modeling Subcommittee developed a unique fertilizer use estimation procedure which also heavily relies upon AAPFCO fertilizer sales data.

5.1 Determining Fertilizer Available in County

AAPFCO provides the following fertilizer sales information per year:

- County of fertilizer sale
- Tons of fertilizer sold
- Designated use of fertilizer (farm, non-farm or unknown)
- Concentration of nutrients within fertilizer sold (translated into total nitrogen and total phosphorus)

AAPFCO data cannot be directly used to estimate fertilizer use in a county because the data only reflects the county in which fertilizer was sold. Fertilizer sales may occur around transportation and commerce hubs, such as large cities, rather than in the rural counties where the fertilizer is actually used. Additionally, fertilizers may cross state lines, making it difficult to ascertain the amount of fertilizer used even within a state based solely upon AAPFCO sales data. Finally, the reliability of fertilizer sales data reporting by states to AAPFCO varies over time. For example, a state might report that all fertilizer sold within a county in 1990 was of "unknown" use, but then in 1991, the same state may report that 75 percent of the fertilizer sold in the county was for use on farms. All of these issues inherent with fertilizer sales data had to be addressed in order to estimate fertilizer use in each county. The steps Scenario Builder takes to estimate fertilizer use in each county are addressed briefly below, and more extensively in the following sections.

Step 1. Smooth variability of fertilizer sales across space by aggregating yearly sales to a regional scale across all six states.

Step 2. Smooth variability of fertilizer sales across time by calculating a three-year rolling average fraction of total sales across the region which were designated for farm use.

Step 3. Estimate total watershed-wide fertilizer use by calculating the total dollars spent on fertilizer and soil conditioners (found in the Census of Agriculture) within watershed counties as a fraction of the total dollars spent in counties across all six states.

Step 4. Distribute the resulting watershed-wide fertilizer sales to individual counties based upon:

1) The fraction of each county's inorganic-crop application goal left over after accounting for manure out of the entire watershed's inorganic-crop application goal; and
2) The fraction of dollars spent on fertilizer and soil conditioners by each county out of the total dollars spent across the entire watershed.

5.1.1 Aggregating Fertilizer Sales to Regional Scale

Pounds of total nitrogen and total phosphorus can be ascertained by multiplying the tons of fertilizer sold by the nutrient concentrations provided by AAPFCO. Scenario Builder then aggregates these data for each state within the watershed (including sales for counties both inside and outside the watershed), separating the data by year. Tables 19 and 20 include the raw sales by state before individual outliers were removed. Note that 1997 values were not considered in the procedure

Table 19. Raw Pounds of Nitrogen Fertilizer Sales by State (AAPFCO)

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	41,444,716	112,134,802	194,419,516	137,383,012	198,029,479	25,706,650	709,118,175
1986	33,886,303	98,676,291	176,896,480	114,762,370	159,025,624	19,524,450	602,771,517
1987	33,031,398	102,397,091	169,926,980	149,322,463	156,071,808	20,238,127	630,987,866
1988	31,476,339	104,444,571	152,104,777	147,323,135	156,178,750	25,603,647	617,131,218
1989	34,780,074	97,694,132	153,555,044	141,677,814	158,354,005	26,934,890	612,995,958
1990*	-	-	184,307,431	148,045,008	181,559,182	27,650,998	541,562,619
1991	42,792,192	118,076,477	157,731,977	145,455,746	197,739,464	34,781,014	696,576,869
1992	44,239,436	150,348,101	189,766,607	141,831,862	234,866,164	35,559,100	796,611,270
1993	39,591,974	126,050,961	185,798,322	192,792,795	216,268,364	19,360,917	779,863,333
1994	39,444,256	119,734,506	232,598,340	206,060,959	202,800,760	17,929,914	818,568,734
1995	41,269,782	146,345,257	199,864,693	184,511,703	194,813,200	16,177,250	782,981,885
1996	44,355,021	142,008,878	131,854,972	203,830,918	206,576,580	14,123,004	742,749,372
1997**	-	-	-	-	-	-	-
1998	37,995,676	126,472,170	167,433,714	208,483,600	205,323,088	21,920,063	767,628,313
1999	44,086,204	110,470,922	191,928,900	201,617,740	243,550,980	42,550,316	834,205,062
2000	42,125,399	207,615,434	146,052,721	215,322,704	229,704,509	16,473,409	857,294,175
2001	37,294,300	135,127,059	168,607,460	171,917,882	192,760,703	17,548,599	723,256,001
2002	42,983,855	134,446,805	157,329,402	235,805,657	214,884,861	21,465,524	806,916,105
2003	33,874,050	91,326,561	153,679,136	137,760,896	189,600,236	11,523,040	617,763,919
2004	30,520,293	162,186,060	194,538,736	169,306,844	192,236,091	31,395,060	780,183,083
2005	34,764,568	148,233,088	165,429,881	171,648,508	168,134,916	75,708,134	763,919,094
2006	33,250,192	100,058,576	181,111,309	181,855,345	174,102,984	49,242,074	719,620,479
2007	39,110,557	110,147,192	160,592,593	211,107,399	185,524,912	47,357,757	753,840,410
2008	44,816,762	118,139,285	158,996,237	186,619,695	178,002,531	4,823,692	691,398,202
2009	40,678,401	83,783,873	126,071,437	228,865,028	157,298,984	4,296,655	640,994,378
2010	47,486,702	58,677,608	155,424,698	197,247,992	183,423,406	20,078,088	662,338,494
2011	44,498,304	87,966,135	155,983,311	190,998,888	189,528,340	12,740,116	681,715,094

2012	39,981,186	88,395,490	155,980,123	200,303,240	199,187,416	12,844,511	696,691,966

*DE and MD did not report data to AAPFCO for 1990.
**There was an error in the database for 1997. This is being investigated for future calibration versions.

Table 20. Raw Pounds of Phosphorus Fertilizer Sales by State (AAPFCO)

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	16,200,129	75,505,862	156,315,800	109,319,440	134,301,614	27,399,340	519,042,184
1986	13,514,257	66,443,290	131,294,640	94,807,520	109,829,234	20,171,200	436,060,140
1987	12,549,423	72,790,638	132,762,940	110,011,303	106,602,150	21,117,859	455,834,314
1988	11,599,372	74,246,135	120,803,037	109,566,357	111,222,363	25,464,866	452,902,131
1989	12,656,854	48,309,133	121,885,587	105,333,894	110,031,399	26,054,734	424,271,600
1990*	-	-	136,505,988	105,494,561	125,634,330	24,065,050	391,699,928
1991	14,943,595	71,145,667	107,671,919	103,682,697	144,016,073	34,677,633	476,137,584
1992	15,687,891	72,015,543	145,076,743	110,442,436	157,881,000	36,108,036	537,211,649
1993	13,539,043	59,506,826	123,982,096	146,092,740	152,069,261	20,859,910	516,049,876
1994	13,875,205	70,053,518	153,419,853	132,886,729	133,999,580	19,177,979	523,412,865
1995	13,897,268	66,024,614	130,230,977	125,363,862	131,747,120	14,056,848	481,320,689
1996	14,379,838	67,009,054	90,545,664	110,184,832	131,587,773	12,017,535	425,724,696
1997**	-	-	-	-	-	-	-
1998	14,444,918	59,645,296	95,120,245	113,998,173	125,988,729	18,661,241	427,858,602
1999	18,628,701	46,988,142	99,540,871	97,975,169	136,048,741	13,028,487	412,210,111
2000	12,810,551	83,567,674	77,360,738	119,164,987	128,350,903	12,739,823	433,994,676
2001	9,203,174	52,087,886	84,621,882	84,688,153	113,033,224	10,813,264	354,447,583
2002	9,905,265	53,308,056	87,273,874	107,813,091	128,634,697	9,406,958	396,341,941
2003	8,307,797	30,847,653	63,867,875	63,333,406	109,427,754	6,418,833	282,203,319
2004	6,043,302	41,266,749	79,085,659	73,911,953	108,857,949	7,137,368	316,302,980
2005	7,834,997	33,161,725	65,337,861	67,406,400	95,530,283	2,775,105	272,046,370
2006	6,812,638	25,108,821	65,429,730	74,416,385	94,833,644	7,547,599	274,148,816
2007	7,529,413	38,852,601	64,429,739	68,370,174	89,000,174	7,561,526	275,743,626
2008	7,210,113	30,066,162	61,755,779	77,288,272	70,692,243	3,251,612	250,264,181
2009	6,310,409	18,176,603	42,052,070	60,522,744	57,885,819	1,868,475	186,816,120
2010	17,872,404	23,246,975	62,628,266	58,584,061	68,877,671	26,338,128	257,547,505
2011	7,199,414	41,562,401	56,616,437	56,471,059	63,864,458	9,094,283	234,808,052

2012	6,057,163	39,445,704	56,609,143	60,168,953	66,046,997	7,057,879	235,385,839

*DE and MD did not report data to AAPFCO for 1990.
**There was an error in the database for 1997. This is being investigated for future calibration versions.

These statewide sales data can vary drastically from one year to the next, and it is not known if the variability is real or caused by a lack of reporting or other human error. Scenario Builder reduces some of the variability by replacing any yearly statewide N and P sales totals that fall outside of two standard deviations from the median for the state over all years of data recorded. Outliers are then replaced by taking the average of the two closest years of sales data available. Tables 21 and 22 include the revised fertilizer sales data by state following this step.

Table 21. Revised Pounds of Nitrogen Fertilizer Sales by State

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	41,444,716	112,134,802	194,419,516	137,383,012	198,029,479	25,706,650	709,118,175
1986	33,886,303	98,676,291	176,896,480	143,352,737	159,025,624	19,524,450	631,361,884
1987	33,031,398	102,397,091	169,926,980	149,322,463	156,071,808	20,238,127	630,987,866
1988	31,476,339	104,444,571	152,104,777	147,323,135	156,178,750	25,603,647	617,131,218
1989	34,780,074	97,694,132	153,555,044	141,677,814	158,354,005	26,934,890	612,995,958
1990	38,786,133	107,885,304	184,307,431	148,045,008	181,559,182	27,650,998	688,234,056
1991	42,792,192	118,076,477	157,731,977	145,455,746	197,739,464	34,781,014	696,576,869
1992	44,239,436	150,348,101	189,766,607	141,831,862	234,866,164	35,559,100	796,611,270
1993	39,591,974	126,050,961	185,798,322	192,792,795	216,268,364	19,360,917	779,863,333
1994	39,444,256	119,734,506	192,831,507	206,060,959	202,800,760	17,929,914	778,801,902
1995	41,269,782	146,345,257	199,864,693	184,511,703	194,813,200	16,177,250	782,981,885
1996	44,355,021	142,008,878	131,854,972	203,830,918	206,576,580	14,123,004	742,749,372
1997	41,175,348	134,240,524	149,644,343	206,157,259	205,949,834	18,021,534	755,188,842
1998	37,995,676	126,472,170	167,433,714	208,483,600	205,323,088	21,920,063	767,628,313
1999	44,086,204	110,470,922	191,928,900	201,617,740	217,513,798	42,550,316	808,167,880
2000	42,125,399	122,798,990	146,052,721	215,322,704	229,704,509	16,473,409	772,477,731
2001	37,294,300	135,127,059	168,607,460	171,917,882	192,760,703	17,548,599	723,256,001
2002	42,983,855	134,446,805	157,329,402	235,805,657	214,884,861	21,465,524	806,916,105
2003	33,874,050	91,326,561	153,679,136	137,760,896	189,600,236	11,523,040	617,763,919
2004	30,520,293	162,186,060	194,538,736	169,306,844	192,236,091	31,395,060	780,183,083
2005	34,764,568	148,233,088	165,429,881	171,648,508	168,134,916	40,318,567	728,529,526
2006	33,250,192	100,058,576	181,111,309	181,855,345	174,102,984	49,242,074	719,620,479

2007	39,110,557	110,147,192	160,592,593	211,107,399	185,524,912	47,357,757	753,840,410
2008	44,816,762	118,139,285	158,996,237	186,619,695	178,002,531	4,823,692	691,398,202
2009	40,678,401	83,783,873	126,071,437	228,865,028	157,298,984	4,296,655	640,994,378
2010	47,486,702	58,677,608	155,424,698	197,247,992	183,423,406	20,078,088	662,338,494
2011	44,498,304	87,966,135	155,983,311	190,998,888	189,528,340	12,740,116	681,715,094
2012	39,981,186	88,395,490	155,980,123	200,303,240	199,187,416	12,844,511	696,691,966

Yellow cells indicate values that were replaced during the outlier removal and replacement procedure.

Table 22. Revised Pounds of Phosphorus Fertilizer Sales by State

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	16,200,129	75,505,862	156,315,800	109,319,440	134,301,614	27,399,340	519,042,184
1986	13,514,257	66,443,290	131,294,640	94,807,520	109,829,234	20,171,200	436,060,140
1987	12,549,423	72,790,638	132,762,940	110,011,303	106,602,150	21,117,859	455,834,314
1988	11,599,372	74,246,135	120,803,037	109,566,357	111,222,363	25,464,866	452,902,131
1989	12,656,854	48,309,133	121,885,587	105,333,894	110,031,399	26,054,734	424,271,600
1990	13,800,224	59,727,400	136,505,988	105,494,561	125,634,330	24,065,050	465,227,552
1991	14,943,595	71,145,667	107,671,919	103,682,697	144,016,073	24,065,050	465,525,001
1992	15,687,891	72,015,543	145,076,743	110,442,436	157,881,000	22,462,480	523,566,093
1993	13,539,043	59,506,826	123,982,096	146,092,740	152,069,261	20,859,910	516,049,876
1994	13,875,205	70,053,518	153,419,853	132,886,729	133,999,580	19,177,979	523,412,865
1995	13,897,268	66,024,614	130,230,977	125,363,862	131,747,120	14,056,848	481,320,689
1996	14,379,838	67,009,054	90,545,664	110,184,832	131,587,773	12,017,535	425,724,696
1997	14,412,378	63,327,175	92,832,954	112,091,503	128,788,251	15,339,388	426,791,649
1998	14,444,918	59,645,296	95,120,245	113,998,173	125,988,729	18,661,241	427,858,602
1999	18,628,701	46,988,142	99,540,871	97,975,169	136,048,741	13,028,487	412,210,111
2000	12,810,551	83,567,674	77,360,738	119,164,987	128,350,903	12,739,823	433,994,676
2001	9,203,174	52,087,886	84,621,882	84,688,153	113,033,224	10,813,264	354,447,583
2002	9,905,265	53,308,056	87,273,874	107,813,091	128,634,697	9,406,958	396,341,941
2003	8,307,797	30,847,653	63,867,875	63,333,406	109,427,754	6,418,833	282,203,319
2004	6,043,302	41,266,749	79,085,659	73,911,953	108,857,949	7,137,368	316,302,980
2005	7,834,997	33,161,725	65,337,861	67,406,400	95,530,283	2,775,105	272,046,370
2006	6,812,638	25,108,821	65,429,730	74,416,385	94,833,644	7,547,599	274,148,816
2007							

	7,529,413	38,852,601	64,429,739	68,370,174	89,000,174	7,561,526	275,743,626
2008	7,210,113	30,066,162	61,755,779	77,288,272	70,692,243	3,251,612	250,264,181
2009	6,310,409	18,176,603	42,052,070	60,522,744	57,885,819	1,868,475	186,816,120
2010	17,872,404	23,246,975	62,628,266	58,584,061	68,877,671	26,338,128	257,547,505
2011	7,199,414	41,562,401	56,616,437	56,471,059	63,864,458	9,094,283	234,808,052
2012	6,057,163	39,445,704	56,609,143	60,168,953	66,046,997	7,057,879	235,385,839

Yellow cells indicate values that were replaced during the outlier removal and replacement procedure.

The results are then aggregated across all states to estimate total regional sales of fertilizer for each year, which are shown in the final columns of Tables 21 and 22. The results are aggregated in this way to remove variability that may exist in a single state's fertilizer sales data and to remove any assumptions that fertilizer sales within a county, or even a state reflect fertilizer use in that county or state.

Finally, regional fertilizer sales which were are not separated by designated use at this point, are then broken back out by designated use. Again, variability exists within the reporting of designated use, so Scenario Builder uses the initial designated uses only to calculate a three-year rolling average fraction of fertilizer sales for farm use. This three-year rolling average begins in 1993 using 1991 through 1993 farm use sales because data prior to 1991 was often designated by states as "unknown use." The three-year rolling average fractions are included in Table 23. These rolling averages are then applied to the previously calculated regional sales numbers to estimate regional fertilizer sales for farm use each year. The resulting values are included in Table 24.

Table 23. Regional Rolling Average Fraction of Farm Fertilizer Sales

Year	Raw Fraction for N	Rolling Average Fraction for P	Raw Fraction for P	Rolling Average Fraction for P
1985	0.000000	0.871537	0.000000	0.901213
1986	0.280182	0.871537	0.301093	0.901213
1987	0.437241	0.871537	0.425402	0.901213
1988	0.849291	0.871537	0.880281	0.901213
1989	0.865909	0.871537	0.893873	0.901213
1990	0.719825	0.871537	0.796829	0.901213
1991	0.900965	0.871537	0.927798	0.901213
1992	0.874691	0.871537	0.935436	0.901213
1993	0.838954	0.871537	0.840405	0.901213
1994	0.933644	0.882430	0.925574	0.900471
1995	0.839021	0.870540	0.880662	0.882214
1996	0.847761	0.873475	0.904753	0.903663
1997	NULL	0.843391	NULL	0.892707
1998	0.863840	0.855801	0.914484	0.909618
1999	0.895126	0.879483	0.906692	0.910588
2000	0.937799	0.898922	0.873298	0.898158
2001	0.796009	0.876312	0.850070	0.876687
2002	0.848041	0.860616	0.882786	0.868718

2003	0.794728	0.812926	0.828444	0.853767
2004	0.738918	0.793896	0.829786	0.847006
2005	0.793964	0.775870	0.843939	0.834057
2006	0.762974	0.765285	0.836313	0.836680
2007	0.670699	0.742546	0.699998	0.793417
2008	0.752353	0.728675	0.810832	0.782381
2009	0.840673	0.754575	0.893735	0.801522
2010	0.880733	0.824586	0.932942	0.879170
2011	0.870651	0.864019	0.862052	0.896243
2012	0.847669	0.866351	0.827531	0.874175

Table 24. Final Estimated Pounds Regional Fertilizer Sales for Farm Use

Year	Final Regional Farm N	Final Regional Farm P
1985	618,022,483	467,767,470
1986	550,255,025	392,982,988
1987	549,929,054	410,803,727
1988	537,852,478	408,161,206
1989	534,248,448	382,359,004
1990	599,821,208	419,269,034
1991	607,092,275	419,537,099
1992	694,275,922	471,844,475
1993	679,679,481	465,070,764
1994	687,237,913	471,318,253
1995	681,616,681	424,627,614
1996	648,773,210	384,711,572
1997	636,919,424	381,000,078
1998	656,936,953	389,187,952
1999	710,770,017	375,353,468
2000	694,397,158	389,795,764
2001	633,797,554	310,739,427
2002	694,445,284	344,309,432
2003	502,196,245	240,935,823
2004	619,383,842	267,910,443
2005	565,244,123	226,902,102
2006	550,715,019	229,374,744
2007	559,760,850	218,779,687
2008	503,804,695	195,802,016
2009	483,678,191	149,737,211
2010	546,155,129	226,427,960
2011	589,014,829	210,445,031
2012	603,579,944	205,768,362

5.1.2 Estimating Fertilizer Use Within Chesapeake Bay Watershed

Scenario Builder turns to the Census of Agriculture to help estimate the amount of fertilizer sold within the watershed out of the entire six-state regional sales. The Census of Agriculture provides "dollars spent on fertilizer and soil conditioners" for each county in 1997, 2002, 2007 and 2012. Dollars spent between reported years were interpolated, and 1985 through 1997 dollars spent were assumed to remain constant at 1997 values, while all years past 2012 were assumed to remain constant at 2012 values.

Scenario Builder then sums all dollars spent by counties within the watershed for each year, and compares that value to the total dollars spent by counties across all six states. The resulting fraction becomes the fraction of regional fertilizer sales which occurred within the watershed for each year. These fractions are included in Table 25 with the resulting, watershed-wide fertilizer sale estimates included in Table 26.

Table 25. Fraction of Dollars Spent on Fertilizer and Soil Conditioners within Watershed (Census of Agriculture)

Year	Fraction
1997*	0.664045
1998	0.668436
1999	0.672787
2000	0.677097
2001	0.681367
2002	0.685598
2003	0.683257
2004	0.681377
2005	0.679834
2006	0.678545
2007	0.677452
2008	0.679627
2009	0.681447
2010	0.682993
2011	0.684323
2012	0.685478

*No values were reported prior to 1997, so 1985 through 1996 are assume to be equal to 1997.

Table 26. Final Watershed-Wide Pounds of Fertilizer Use for Farms

Year	Watershed N Farm Use	Watershed P Farm Use
1985	410,394,928	310,618,792
1986	365,394,266	260,958,508
1987	365,177,806	272,792,286
1988	357,158,412	271,037,532
1989	354,765,173	253,903,702

1990	398,308,457	278,413,633
1991	403,136,774	278,591,640
1992	461,030,666	313,326,108
1993	451,337,968	308,828,057
1994	456,357,109	312,976,673
1995	452,624,356	281,971,973
1996	430,814,804	255,465,913
1997	422,943,353	253,001,313
1998	439,120,517	260,147,361
1999	478,196,516	252,532,769
2000	470,173,959	263,929,389
2001	431,848,742	211,727,593
2002	476,110,510	236,057,963
2003	343,128,981	164,621,031
2004	422,033,670	182,547,913
2005	384,272,024	154,255,704
2006	373,684,830	155,641,047
2007	379,211,085	148,212,728
2008	342,399,088	133,072,265
2009	329,601,074	102,037,980
2010	373,020,262	154,648,766
2011	403,076,302	144,012,341
2012	413,741,002	141,049,764

5.1.3 Estimating Fertilizer Use by County

The watershed-wide fertilizer sales values are then distributed down to the county scale to estimate countywide fertilizer use (not sale). This is done by combining two fractions unique to each county in each year. The first is the fraction of dollars spent in fertilizer in that county out of all the dollars spent on fertilizer within the watershed. The second is the fraction of inorganic crop application goal that exists in a county out of the sum of inorganic application goal of all counties. This second fraction is calculated after crop application goals and manure available nutrients are calculated for each county. This ensures that counties with large amounts of manure that are assumed to be applied towards application goal do not also automatically receive large amounts of inorganic fertilizer. Equation 13 includes an example calculation for the inorganic crop application goal fraction.

Equation 13. Calculating Inorganic Crop Application Goal Fraction

Fraction = (Countywide Inorganic-Eligible Crop Application Goal Lbs/Year – Countywide Lbs of Manure Available /Year) / (All Counties' Inorganic-Eligible Crop Application Goal Lbs/Year – All Counties' Countywide Lbs of Manure Available/Year)

Hypothetical Example Calculation for Nitrogen:

0.03 = (30,000,000 Lbs N Application Goal/Year – 15,000,000 Lbs Manure N Available/Year)/ (1,000,000,000 Lbs N Application Goal/Year – 500,000,000 Lbs Manure N Available/Year)

Currently, the inorganic crop application goal is calculated only after accounting for the amount of manure generated within a county. There is currently no consideration of state-reported manure transport or other BMPs that would alter the final estimate of manure available to crops. The Agricultural Modeling Subcommittee may recommend a different calculation method for this second fraction.

Both fractions are then multiplied by 0.5 to ensure that both the dollars spent of fertilizer and soil conditioners reported by the Census of Agriculture and the inorganic crop application goal of each county are taken into account equally when estimating fertilizer use, with no preference to one parameter over the other. The resulting, deflated fractions are added together to create a final inorganic crop application goal fraction by nutrient for each county in each year.

5.1.4 Estimating Future Fertilizer Use by County

Scenario Builder has projections of crop application goals and manure generation for future years, but does not have estimates of fertilizer sales or use in future years. Fertilizer use varies across years based upon many economic factors including, but not limited to: cost of oil; cost of fertilizer; price of crop returns; crop yields; and equipment available for application. Because Scenario Builder does not have access to all of the economic variables at play, it estimates future fertilizer use based upon past fertilizer use.

Estimates of future fertilizer use by county are based upon the following:

- Projected crop application goals
- Projected manure available for application
- Average crop total nutrient application to crop application goal from 1985 through 2012

By including these three variables, Scenario Builder assumes that the county's producers will apply a similar amount of nutrients to crops regardless of how much manure is available as they have in the past. For example, if a hypothetical county has enough manure available for application to meet 50 percent of its crop application goals, but traditionally (from 1985 through 2012) only applied manure and fertilizer to meet 90 percent of its goals, then Scenario Builder assumes the county's producers will use enough fertilizer to bring the total application of manure and fertilizer up to 90 percent of the county's application goals.

There are many alternative ways to estimate future fertilizer use, and the Agricultural Modeling Subcommittee may suggest one such alternative.

5.2 Nutrient Concentrations within Fertilizer

The AAPFCO data was not used directly to determine concentrations of nutrient species. Instead, assumptions from the current Watershed Model were used to break each pound of total nitrogen and total phosphorus into nutrient species. For each pound of nitrogen fertilizer used, 0.75 pounds is assumed to be ammonia nitrogen and 0.25 pounds is assumed to be nitrate nitrogen. Both the ammonia and nitrate portions are assumed to be plant-available. Similarly, 100 percent of each pound of phosphorus fertilizer is assumed to be in the phosphate form and plant-available. These values do not vary between urban and agricultural fertilizer applications.

5.3 Estimating Inorganic Crop Application Goal

The manure crop application section described a process by which Scenario Builder estimates the total manure crop application goal based upon state-submitted application goals and yield information for each crop. This process is repeated for inorganic nutrients. Jurisdictions again provided the fraction of overall crop application that should occur each month from inorganic sources. One assumption that was made was that ALL application goals could be fulfilled with inorganic applications if manure was not available, but all application goals could not be fulfilled with manure applications even if enough manure was available. For example, many jurisdictions stated that regardless of how much manure was available, most producers would still apply inorganic fertilizer to corn near the beginning of the growing season. This means that resulting inorganic crop application goal is equal to the total application goal minus the manure available for application.

5.4 Optimizing Inorganic Applications to Higher Commodity Crops

Just as with manure, Scenario Builder assumes that all inorganic fertilizer available in a county is applied in the county. Also, just as with manure applications, inorganic fertilizer applications are made to higher commodity crops before hay and pasture. Unique application curves were developed for inorganic fertilizer nitrogen and phosphorus applications, and are provided in figures 4 and 5. Again, these application curves were developed for land use groups within which many crops are included. These land use groups are described in Table 27 and Table 28. As you can see, land use groups for inorganic nitrogen applications match the land use groups for manure nitrogen, while the phosphorus land use groups were changed so that all leguminous row crops received a similar application of phosphorus as non-leguminous row crops. Thus legumes do not receive priority in the application process for nitrogen, but do for phosphorus.

Figure 4. Inorganic Nitrogen Application Curves by Crop Group

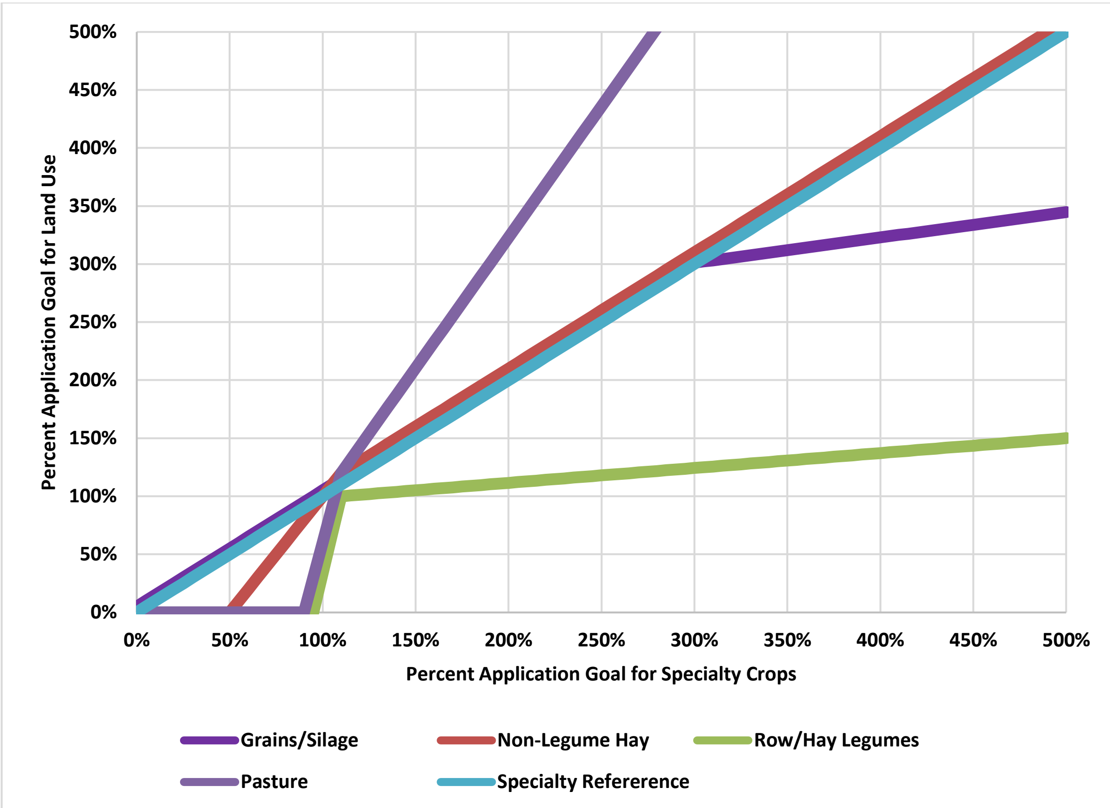


Figure 5. Inorganic Phosphorus Application Curves by Crop Group

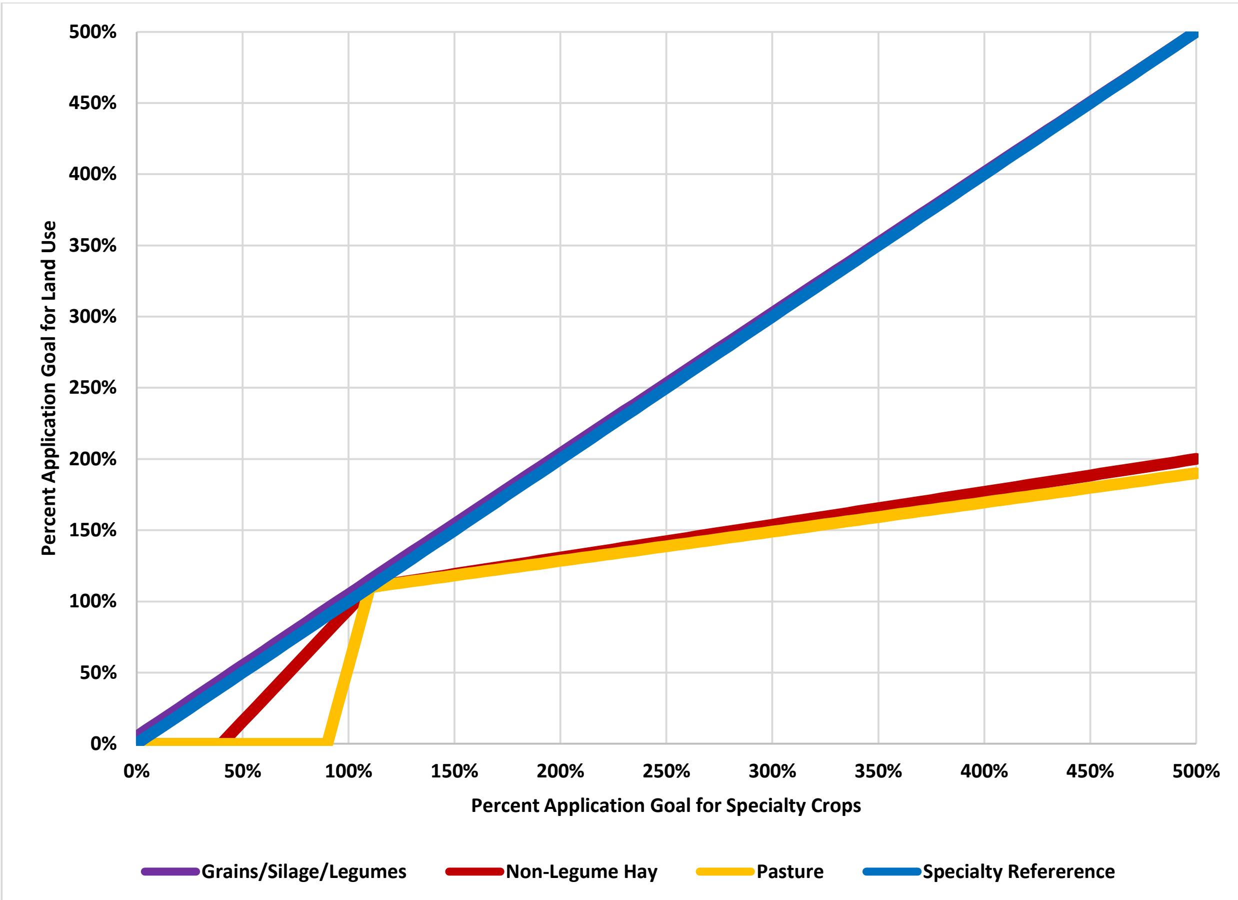


Table 27. Land Use Groups for Inorganic Nitrogen Application Curves

Land Use Curve Group	Land Use
Grains/Silage	Grain with Manure
Grains/Silage	Silage with Manure
Grains/Silage	Small Grains and Grains
Specialty	Other Agronomic Crops
Specialty	Specialty Crop High
Specialty	Specialty Crop Low
Row/Hay Legumes	Small Grains and Soybeans
Row/Hay Legumes	Full Season Soybeans
Row/Hay Legumes	Legume hay
Pasture	Pasture
Non-Legume Hay	Other Hay

Table 28. Land Use Groups for Inorganic Phosphorus Application Curves

Land Use Curve Group	Land Use
Grains/Silage/Legumes	Grain with Manure
Grains/Silage/ Legumes	Silage with Manure
Grains/Silage/Legumes	Small Grains and Grains

Grains/Silage/Legumes	Small Grains and Soybeans
Grains/Silage/Legumes	Full Season Soybeans
Grains/Silage/Legumes	Legume hay
Specialty	Other Agronomic Crops
Specialty	Specialty Crop High
Specialty	Specialty Crop Low
Non-Legume Hay	Other Hay
Pasture	Pasture

5.5 URBAN FERTILIZER APPLICATIONS

The Urban Stormwater Workgroup chose not to base applications of fertilizer to urban land uses (turf grass) directly upon non-farm AAPFCO sales data due to variability in the data. Instead, average application rates from the Phase 5 Watershed Model are used in Phase 6. These rates are 42.8 lbs of nitrogen/acre and 1.3 lbs of phosphorus/acre.

Two data sources were used to estimate the nitrogen rate. By comparing the average of AAPFCO non-farm fertilizer sales for nitrogen between 1985 and 2010 of 130 million lbs/year with 3 million acres of pervious urban area, an estimate of approximately 42 lbs of nitrogen/acre was calculated.

The second data source consulted was application rate information provided by Scotts, TruGreen and other fertilizer producers and lawn care companies. This information yielded an average application rate of 42.8 lbs of nitrogen/acre, which was in-line with the initial estimate calculated from AAPFCO non-farm fertilizer sales.

The phosphorus application rate was simply calculated from the ratio of TN:TP in Scotts 29-2-4 fertilizer products and TruGreen’s 29-2-4 fertilizer products. The average of these two ratios was approximately 33:1, resulting in an average application rate of 1.3 lbs of phosphorus/acre.

6 Legume Fixation

Leguminous plants, such as soybeans, develop bacterial nodules on their roots which transform atmospheric nitrogen gas into ammonia nitrogen. This adds a source of plant-available nitrogen to the soil, and is an important piece of the overall nutrient balance within a watershed. Scenario Builder calculates nitrogen fixation during each month of plant growth for each crop. This fixation is intended to include the portion fixed in the roots and taken up into the plant, and the total amount of fixation can vary by growth region. Leguminous crops simulated by Scenario Builder and their associated nitrogen fixation values are listed in Table 29. These values were provided by jurisdictions prior to the development of the Phase 5 Watershed Model. Two important crops not listed in the table are pasture and urban turf grass. Legume fixation on these two crops was previously calculated only by the Phase 5 Watershed Model, and was not important to Scenario Builder processes. The Agricultural Modeling Subcommittee and Urban Stormwater Workgroup will be asked to provide nitrogen fixation values for each crop for Phase 6, and the former group will also be asked to review the fixation numbers for all crops.

Table 29. Total Nitrogen Pounds Fixated by Leguminous Crops by Growth Region

Crop Name	DE_1	MD_1	MD_2	MD_3	NY_1	PA_1	PA_2	PA_3	VA_1	VA_2	VA_3	WV_1
Alfalfa Hay Harvested Area	180	300	300	300	120	240	240	240	180	180	180	180
Alfalfa seed Harvested Area	180	300	300	300	120	240	240	240	180	180	180	180
Birdsfoot trefoil seed Harvested Area	120	80	80	80	180	180	180	180	160	160	160	160
Dry edible beans, excluding limas Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Green Lima Beans Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	180	300	300	300	120	240	240	240	180	180	180	180
Peanuts for nuts Harvested Area	90	90	90	90	90	90	90	90	90	90	90	90
Peas, Chinese (sugar and Snow) Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Peas, Green (excluding southern) Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Red clover seed Harvested Area	120	80	80	80	180	360	360	360	160	160	160	160
Snap Beans Harvested Area	300	300	300	300	300	300	300	300	300	300	300	300
Soybeans for beans Harvested Area	30	40	40	40	130	130	130	130	40	40	40	40
Vetch seed Harvested Area	300	300	300	300	300	300	300	300	200	200	200	200

Scenario Builder simulates each year independent of all other years, so nutrients fixed from previous years are not considered to accumulate within the soil and are not made available to plants in subsequent years. Additionally, there is no nitrogen fixation in the month of planting. It was assumed that fixation only occurred two-to-four weeks after planting once nodules were established. Fixation is assumed to occur equally within all months of growth thereafter. For example, if soybeans have a fixation of 40 lbs of nitrogen across the entire year, and grows for 3 months, then 20 lbs of fixation is simulated from month 2 through 3.

Scenario Builder also assumes that nitrogen fixation is reduced following applications of manure or fertilizer nitrogen. Equation 14 was carried over from Phase 5 to estimate final nitrogen fixation for each crop after considering applications from manure and fertilizer nitrogen.

Equation 14. Estimating Final Nitrogen Fixation

Lbs Nitrogen Fixed/Acre/Year = Initial Lbs Nitrogen Fixed/Acre/Year – (Lbs Plant-Available Nitrogen from Manure and Fertilizer/Acre/Year X 0.2021)

If the result of equation 14 is less than zero, than zero lbs of nitrogen is fixed for each acre of that crop as Scenario Builder does not consider fixation can go negative.

Legume fixation for each crop is aggregated to the land use level for the Watershed Model.

7 Nutrient Uptake

Scenario Builder provides the Watershed Model with both total pounds of nutrient uptake by land use and fractions of uptake which occur each month on that land use. The total nutrient uptake values and the method for determining monthly fractions were carried over from the Phase 5 version of the tool. The Agricultural Modeling Subcommittee will likely review the values and methods to ensure they are still adequate.

7.1 Major Crop Total Uptake

Phase 5 (and subsequently, Phase 6) nutrient uptake begins with theoretical uptake values. These values are provided in Table 29. For any major crop, total nutrient uptake is calculated using Equation 15. Major crops are those listed in Table 29 which have an application goal unit other than "acres."

Equation 15. Yearly Lbs of Nitrogen Uptake for Major Crops

Lbs of Nitrogen Uptake/Year = Theoretical Lbs Nitrogen Uptake/Yield Unit X Yield/Acre X Acres

Table 29. Theoretical Nutrient Uptake and Maximum Yield in Pounds (Phase 5 Scenario Builder)

Crop	Yield Unit	Application Goal Unit	Maximum Yield	N Uptake (Lbs/Year)	P Uptake (Lbs/Year)
Corn for silage or greenchop Harvested Area	tons	tons	30.000000	10.235290	1.535294
Sorghum for silage or greenchop Area	tons	tons	12.000000	17.364710	2.870588
Alfalfa Hay Harvested Area	dry tons	dry tons	8.599757	59.515570	8.927336
Barley for grain Harvested Area	bushels	bushels	120.000000	1.058824	0.211765
Buckwheat Harvested Area	bushels	bushels	100.000000	1.011765	0.188235
Corn for Grain Harvested Area	bushels	bushels	200.000000	0.976471	0.146471
Emmer and spelt Harvested Area	bushels	bushels	120.000000	1.129412	0.223529
Oats for grain Harvested Area	bushels	bushels	150.000000	0.811765	0.121765
Rye for grain Harvested Area	bushels	bushels	100.000000	1.411765	0.211765
Sorghum for Grain Harvested Area	bushels	bushels	135.000000	1.152941	0.211765
Soybeans for beans Harvested Area	bushels	bushels	60.000000	4.176471	0.423529
Triticale Harvested Area	bushels	bushels	100.000000	1.764706	0.200000
Wheat for Grain Harvested Area	bushels	bushels	133.333300	1.529412	0.229412
Turfgrass	tons	acres	5.000000	64.705880	9.705882
Alfalfa seed Harvested Area	pounds	acres	440.000000	0.510588	0.057647

Aquatic plants Area	unit	acres	1.000000	150.588200	22.588240
Asparagus Harvested Area	tons	acres	4.000000	11.647060	1.747059
Bedding/garden plants Area	unit	acres	1.000000	150.588200	22.588240
Beets Harvested Area	tons	acres	10.000000	7.058824	1.058824
Berries- all Harvested Area	tons	acres	8.000000	9.764706	1.464706
Birdsfoot trefoil seed Harvested Area	pounds	acres	500.000000	0.251177	0.037676
Broccoli Harvested Area	tons	acres	7.900000	16.470590	2.470588
Bromegrass seed Harvested Area	pounds	acres	500.000000	0.387059	0.065882
Brussels Sprouts Harvested Area	tons	acres	8.750000	6.941176	1.041176
Bulbs, corms, rhizomes, and tubers – dry Harvested Area	cwt	acres	181.170000	0.588235	0.088235
Canola Harvested Area	pounds	acres	4000.000000	0.041176	0.007059
Cantaloupe Harvested Area	tons	acres	20.000000	4.000000	0.600000
Carrots Harvested Area	tons	acres	40.000000	4.823529	0.723529
Cauliflower Harvested Area	tons	acres	22.000000	10.588230	1.588235
Celery Harvested Area	cwt	acres	720.000000	0.223529	0.033529
Chinese Cabbage Harvested Area	tons	acres	16.875000	6.941176	1.041176
Collards Harvested Area	tons	acres	9.000000	6.941176	1.041176
Cotton Harvested Area	bales	acres	8.362606	20.329410	3.049412
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area	unit	acres	1.000000	150.588200	22.588240
Cropland in cultivated summer fallow Area	unit	acres	1.000000	150.588200	22.588240
Cropland on which all crops failed or were abandoned Area	unit	acres	1.000000	150.588200	22.588240
Cropland used only for pasture or grazing Area	tons	acres	2.000000	61.176470	9.176471
Cucumbers and Pickles Harvested Area	tons	acres	14.000000	3.411765	0.511765
Cut Christmas Trees Production Area	unit	acres	1.000000	150.588200	22.588240
Cut flowers and cut florist greens Area	unit	acres	1.000000	150.588200	22.588240
Dry edible beans, excluding limas Harvested Area	cwt	acres	20.234720	4.823529	0.723529
Dry Onions Harvested Area	tons	acres	25.000000	5.882353	0.882353
Eggplant Harvested Area	tons	acres	12.000000	30.588240	4.588235

Escarole and Endive Harvested Area	tons	acres	20.000000	5.764706	0.864706
Fescue Seed Harvested Area	pounds	acres	590.000000	0.403529	0.082353
Foliage plants Area	unit	acres	1.000000	150.588200	22.588240
Garlic Harvested Area	tons	acres	8.300000	5.882353	0.882353
Green Lima Beans Harvested Area	tons	acres	5.000000	7.647059	1.147059
Green Onions Harvested Area	tons	acres	9.000000	5.882353	0.882353
Greenhouse vegetables Area	unit	acres	1.000000	150.588200	22.588240
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	green tons	acres	7.200000	23.529410	3.529412
Head Cabbage Harvested Area	tons	acres	24.281670	6.941176	1.041176
Herbs, Fresh Cut Harvested Area	tons	acres	20.000000	11.647060	1.747059
Honeydew Melons Harvested Area	cwt	acres	229.330000	0.158824	0.023824
Kale Harvested Area	cwt	acres	400.000000	0.347059	0.052059
Land in Orchards Area	tons	acres	10.000000	28.235290	4.235294
Lettuce, All Harvested Area	tons	acres	25.000000	5.764706	0.864706
Mushrooms Area	unit	acres	1.000000	150.588200	22.588240
Mustard Greens Harvested Area	cwt	acres	180.000000	0.347059	0.052059
Nursery stock Area	unit	acres	1.000000	150.588200	22.588240
Okra Area	tons	acres	5.000000	72.941180	10.941180
Orchardgrass seed Harvested Area	pounds	acres	500.000000	0.411765	0.041176
Other field and grass seed crops Harvested Area	pounds	acres	500.000000	0.387059	0.065882
Other haylage, grass silage, and greenchop Harvested Area	green tons	acres	13.000000	22.352940	3.352941
Other managed hay Harvested Area	dry tons	acres	3.250000	71.972320	10.795850
Other nursery and greenhouse crops Area	unit	acres	1.000000	150.588200	22.588240
Parsley Harvested Area	cwt	acres	200.000000	0.288235	0.043235
Pastureland and rangeland other than cropland and woodland pastured Area	tons	acres	4.000000	61.176470	9.176471
Peanuts for nuts Harvested Area	pounds	acres	4250.000000	0.047059	0.003529
Peas, Chinese (sugar and Snow) Harvested Area	tons	acres	4.000000	37.647060	5.647059
Peas, Green (excluding southern) Harvested Area	tons	acres	4.000000	37.647060	5.647059

Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	tons	acres	4.000000	37.647060	5.647059
Peppers, Bell Harvested Area	tons	acres	13.000000	5.058824	0.758824
Peppers, Chile (all peppers – excluding bell) Harvested Area	cwt	acres	202.347200	0.252941	0.037941
Popcorn Harvested Area	pounds	acres	4550.000000	0.052311	0.007847
Potatoes Harvested Area	cwt	acres	440.000000	0.588235	0.088235
Potted flowering plants Area	unit	acres	1.000000	150.588200	22.588240
Pumpkins Harvested Area	cwt	acres	500.000000	0.329412	0.049412
Radishes Harvested Area	tons	acres	20.000000	6.941176	1.041176
Red clover seed Harvested Area	pounds	acres	315.000000	0.494118	0.057647
Rhubarb Harvested Area	tons	acres	10.000000	40.470590	6.070588
Ryegrass seed Harvested Area	pounds	acres	788.000000	0.329412	0.065882
short-rotation woody crops Harvest Area	unit	acres	1.000000	150.588200	22.588240
Small grain hay Harvested Area	dry tons	acres	3.250000	37.647060	5.270588
Snap Beans Harvested Area	tons	acres	5.000000	10.588230	1.588235
Sod harvested Area	tons	acres	5.000000	64.705880	9.705882
Spinach Harvested Area	tons	acres	13.290000	11.647060	1.747059
Squash Harvested Area	tons	acres	20.000000	6.588235	0.988235
Sunflower seed, non-oil varieties Harvested Area	pounds	acres	2832.861000	0.076471	0.011471
Sunflower seed, oil varieties Harvested Area	pounds	acres	2832.861000	0.068235	0.010235
Sweet Corn Harvested Area	pounds	acres	20000.000000	0.005647	0.003529
Sweet potatoes Harvested Area	cwt	acres	320.000000	0.588235	0.088235
Timothy seed Harvested Area	pounds	acres	500.000000	0.345882	0.065882
tobacco Harvested Area	pounds	acres	2600.000000	0.038824	0.002353
Tomatoes Harvested Area	tons	acres	39.100000	4.352941	0.652941
Turnip Greens Harvested Area	tons	acres	15.000000	6.941176	1.041176
Turnips Harvested Area	cwt	acres	300.000000	0.347059	0.052059
Vegetable & flower seeds Area	unit	acres	1.000000	150.588200	22.588240
Vegetables, Mixed Area	cwt	acres	284.630000	0.347059	0.052059
Vetch seed Harvested Area	pounds	acres	800.000000	0.345882	0.041176
Watermelons Harvested Area	tons	acres	40.000000	3.176471	0.476471

Wild hay Harvested Area	dry tons	acres	3.250000	25.882350	20.000000

7.2 Non-Major Crop Total Uptake

Uptake for all non-major crops is dealt with in a different way because application rates estimated for non-major crops do not vary by yields as yield data for non-major crops is limited. Instead, each acre of non-major crop receives the same amount of application and uptake each year. To make sure that uptake was reduced from a theoretical value in a similar way that major crop uptake was, Scenario Builder first calculated a ratio between Phase 5's maximum yield for each major crop and the actual yields across all years. This calculation resulted in an average actual major crop yield-to-maximum yield ratio of 0.61. This ratio was applied to the maximum crop yields for non-major crops. That value was then multiplied by the maximum yield value for the crop in an effort to convert the value from a yield-based one to an acre-based one. The resulting values represent an average uptake per acre for each non-major crop, and can simply be multiplied by the acres of each crop to determine the total non-major crop uptake as described in Equation 16.

Equation X. Yearly Lbs of Nitrogen Uptake for Non-Major Crops

Lbs of Nitrogen Uptake/Year = Theoretical Lbs Nitrogen Uptake/Yield Unit X Maximum Yield/Acre X 0.61 X Acres

7.3 Nutrient Uptake Monthly Fractions

Monthly crop uptake is related to the heat units each crop receives on any given day during the growing season. The more heat units on a given day, the greater uptake will be estimated. In the end, the total heat units during the growing season divided across the months to determine the fraction of total uptake that occurs each month. Because temperatures vary across the watershed, this method allows uptake to better reflect meteorological data during the growing season. Equation 17 shows how heat units are calculated, and Equation 18 shows how the monthly fraction is calculated.

Equation 17. Calculating Heat Units

Daily Heat Unit = (Mean Daily Temperature Minimum + Mean Daily Temperature Maximum/ 2) – Crop Basal Temperature

Equation 18. Calculating Monthly Fraction Uptake

Sum of Heat Units for Month / Sum of Heat Units for Growth Season

These monthly values are calculated for each crop, and are then are combined into a weighted average for each land use comprising multiple crops.

8 Crop Soil Cover Fractions

Scenario Builder provides the Watershed Model with an estimate of the amount of soil “covered” by crop canopy or residue for each land use during each month of a scenario year. The Watershed Model then uses the soil cover estimates to simulate erosion from each land use.

The USDA’s (R)evised (U)niversal (S)oil (L)oss (E)quation 2 was used to estimate both canopy and residue cover for each crop type for each month, including months outside of each crop’s growing season. The scenarios were designed using existing Scenario Builder crop data for planting and harvesting dates, and with input from NRCS personnel across the watershed. BMPs, such as conservation tillage, were intentionally left out of the RUSLE2 scenarios to allow these BMPs to be credited with reductions in sediment (and nutrient) losses for future scenarios.

The fraction of cover was defined as the greater fraction of either residue cover or crop cover for each month. For example, the fraction of cover for corn over the winter would be equal to the fraction of residue because no plant canopy exists outside the growing season, while the fraction of cover for corn during the summer would likely be equal to the fraction of canopy cover. These fractions are crop-specific, and are aggregated up to the land use level based upon the relative proportions of crops in each land use. Appendix D provides a detailed explanation of the RUSLE2 scenarios.

9 Detached Soil Fractions

Scenario Builder provides the Watershed Model with an estimate of the pounds of detached sediment that is eroded due to plowing for each land use during each month of a scenario year. The Watershed Model then uses this information to simulate sediment erosion from each land use.

The USDA's RUSLE2 was used to estimate detached sediment by comparing a scenario with plowing and one with no plowing other than planting. The difference between the two scenarios represented the pounds of sediment that could be detached due to regular plowing activities. The scenarios were designed using existing Scenario Builder crop data for planting and harvesting dates, and with input from NRCS personnel across the watershed. BMPs, such as conservation tillage were intentionally left out of these scenarios to allow these BMPs to be credited with reductions in sediment (and nutrient) losses for future scenarios.

Results were provided for each crop and then aggregated up to the land use level based upon the total acres of each crop within that land use. Appendix D provides a detailed explanation of the RUSLE2 scenarios.

10 BMP Pounds and BMP Pass-Through Fractions

Scenario Builder simulates reductions in loads for five types of best management practices. These types are described below.

Effectiveness Value Practices: Many practices reduce pollutants by a percentage. For example, a Dry Extended Detention Pond reduces 20 percent of the nitrogen that would otherwise have been delivered to nearby, simulated streams. This reduction in load is calculated using a simple pass-through value as described in Equation 18. Effectiveness values of practices can vary across hydrogeomorphic region and land use. A complete listing of effectiveness values can be found at: http://casttool.org/Documentation.aspx under the “Source Data” link.

Equation 18. Calculating Nutrient Pass-Through
Pass-Through Value = 1 – BMP Fraction Reduced
Example: Calculating Nutrient Pass-Through for Extended Dry Detention Ponds
0.8 = 1 – 0.2

Stormwater performance standards on urban areas also use effectiveness values and pass-throughs, but they are unique to each and every project or group of projects. The effectiveness of each project or group of projects is determined by the area of impervious acres being treated and the total volume of water being treated. Curves describing these relationships were developed by the Stormwater Performance Standards Expert Panel, and can be found at: http://www.chesapeakebay.net/documents/Final-CBP-Approved-Expert-Panel-Report-on-Stormwater-Performance-Standards-LONG_012015.pdf.

Land Use Change Practices: Land use change practices simply alter a previously projected land use acre to a different land use. For example, Tree Planting can alter an acre of pasture to an acre of forest. By changing from a higher-loading land use to a lower-loading one, nutrients are automatically reduced on that acre of land. Each additional acre of land use change typically results in a lower load for a given geographic area, such as a county, but too much land conversion could actually result in higher loads if manure and fertilizer are piled onto a smaller number of acres.

Land Use Change with Upland Effectiveness Value Practices: Some land use change practices also reduce nutrient loads from upland acres. Because Scenario Builder only works with aggregate, tabular land use acres within each land-river segment, “upland” acres are determined based upon the proportions of land in each segment. For example, one acre of Forest Buffer on Grains with Manure will reduce nitrogen loads from four “upland, agricultural acres.” If the land-river segment is made up of 50 acres of Grains with Manure and 50 acres of Pasture after the land-use change is calculated, then the four acres of “upland” credit will be divided up evenly between two acres of Grains with Manure and two acres of Pasture.

Land Input Load Reduction Practices: Some BMPs directly reduce the amount of nutrients applied to each acre of land within Scenario Builder. For example, the total application of manure to Grains with Manure could be reduced in a county if a jurisdiction indicated that manure was transported out of that county. The reduced application rate is taken into account by the Watershed Model before applying effectiveness BMPs or land output load reduction practices.

Land Output Load Reduction Practices: A few BMPs directly reduce estimated loads delivered to simulated streams in the Watershed Model. For these practices, Scenario Builder provides the Watershed Model with the total pounds of pollutants reduced, and the Model reduces these pounds from simulated loads after taken all other BMPs into account. For example, Stream Restoration is simulated as a load reduction within the stream after all upslope BMPs are calculated.

10.1 Calculating Total Pass-Through Fractions

Just as each acre of land in the real world may be impacted by multiple practices which reduce nutrient runoff, each acre simulated by Scenario Builder can have multiple practices contributing to a final pass-through fraction.

10.1.1 Calculating Group Pass-Through Fractions

To accomplish this, Scenario Builder first breaks BMPs into groups of like BMPs that are mutually exclusive of one another, meaning they cannot be placed on the same acre. For example, Scenario Builder calculates a single, group pass-through factor for all the cover crops. Two cover crop practices cannot receive credit on the same acre, so the group pass-through aggregates the impact of each cover crop practice for a single land use. Equation 19 shows how this is accomplished for each group.

Equation 19. Group Pass-Through Fraction

$$F_g = 1 - \sum_{BMP=1}^{n} \left(\frac{i}{t} * E_{BMP} \right)$$

Where:
F = Pass-Through Fraction
g = BMP group
n = total number of BMPs in the group
BMP = specific BMP
i = Acres of specific BMP implementation
t=Acres of specific land use available for specific BMP implementation
E = BMP effectiveness fraction

Example Group Pass-Through Calculation
0.961 = 1 – ((100 acres/2000 acres X 0.08) + (400 acres/2000 acres X 0.05) + (500 acres/2000 acres X 0.1)

10.1.2 Overall Pass-Through Fractions

The group pass-through fractions must then be combined with pass-through factors from other BMP groups to allow each acre to receive treatment by multiple (overlapping) BMPs. This is simply done by multiplying all the group pass-through values together as shown in Equation 20. This is done for every land use in each land-river segment.

Equation 20. Overall Pass-Through Fraction for Single Land Use

$$F_O = \prod_{g=1}^{G} F_g \leq 1$$

Where:
F = Overall Pass-Through Fraction
g = specific BMP group
G = Total number of BMP groups
Example Overall Pass-Through Fraction with Two BMP Groups
0.91295 = 0.961 X 0.95

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Appendix A. Poultry Litter Subcommittee Report

Recommendations to Estimate Poultry Nutrient Production in the Phase 6 Watershed Model

Report of the Agricultural Modeling Subcommittee to the Poultry Litter Subcommittee and Agriculture Workgroup

March, 2015

Approved by the Agriculture Workgroup March, 2015

Approved by the Water Quality GIT April, 2015

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Introduction

The Poultry Litter Subcommittee (PLS) summarized over a decade of litter sample data collected mainly from broilers and turkeys, with very small amounts of data from pullets and layers. In October, 2014, the Agriculture Workgroup asked the Agricultural Modeling Subcommittee (AMS) to review the PLS records (found in Appendix C) and report (found in Appendix A), and provide recommendations for incorporating the data into poultry nutrient production estimates for the Phase 6 Watershed Model. This report describes processes to estimate poultry litter production by year for each state and type of bird. Many of the recommendations in this report were originally suggested by the PLS. Some other recommendations are based on analysis of the submitted data and other data sources available.

Basic Recommendation

Where possible, the AMS recommends a simple approach to estimating poultry nutrient production. That approach combines bird population estimates with estimates of: 1) mass of litter or manure produced; 2) litter or manure dry solids content; 3) litter or manure nutrient concentrations; 4) recoverability of manure; and 5) nutrients in recoverable manure. The last two parameters account for any losses that are estimated to occur between excretion and application, and are only needed if estimating available nutrients from as-excreted manure. There is no need to include these recoverability factors if estimating available nutrients from litter because litter values are assumed to represent litter that is ready to be field applied after any losses occur. These parameters can be combined using the following basic equations:

Equation 1. Poultry Phosphorus Production Based on Litter (Used for Broilers)

Lbs of P/Year = (Lbs of Litter/Bird Produced) X (Lbs of Dry Matter/Lb of Litter) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Equation 2. Poultry Phosphorus Production Based on As-Excreted Manure (Used for Pullets)

Lbs of Recoverable P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Lbs of Recoverable P/Lb of P) X (Birds Produced/Year)

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Note that the same equations can be used to estimate nitrogen production.

Nutrient Concentration Data Availability

The AMS finds that enough quality data was reported by DE, MD, VA and WV for broilers to calculate each of the parameters in the litter equation. Additionally, VA and WV provided multiple years of concentration data for turkeys and layers. Where data is sufficient to establish state-wide concentrations, the AMS recommends the state-specific values be used. For states and animal types with no data, or limited data, the AMS recommends Bay-wide values be used. Finally, no data was collected for pullets, so the AMS recommends the use of manure nutrient concentration values reported by the American Society of Agricultural and Biological Engineers (ASABE). ASABE last released updated manure production, moisture and nutrient concentration values in a 2005 report (ASABE, 2005). These values represent as-excreted manure rather than litter. Detailed descriptions of how nutrient concentration data is combined with other parameters in the equations for each state and bird type are included in the following sections.

Note about Significant Digits: Values throughout the report will be listed using six significant digits. While the originally collected data was not reported to this level of specificity, the use of equations to estimate changes in the small values, such as nutrient concentrations, requires six significant digits. Any fewer would result in inaccurate assessments of trends in these small values.

Recoverability of As-Excreted Manure

Equations 2 and 3 require the use of “recoverability factors.” Recoverability can be interpreted as the amount of as-excreted manure or nutrients left in litter to be made available to crops after all storage and handling losses and volatilization has occurred. As-excreted manure values cannot be compared to litter values without first applying estimates of recoverability. USDA provided the AMS a list of recoverability estimates based upon survey data from poultry operations (Gollehon, 2014). USDA estimates that recoverability has improved over time due to better manure management through comprehensive nutrient management planning efforts and implementation of better storage systems. The AMS recommends using USDA’s 1985 estimates for manure recoverability as those estimates very closely represent operations with zero or limited implementation of best manure management practices. The AMS acknowledges that BMPs may be recommended by the Partnership that improve the recoverability factors over time, which will ultimately change the estimates for pounds of nutrients available to crops. However, the objective of this report is to represent an estimate of nutrients available to crops without taking BMP implementation into account.

Broilers

The PLS summarized over 9,800 laboratory records describing moisture and nutrient content of poultry litter from DE, MD, VA and WV. These states provided both ranges and mean values for moisture content and nutrient concentration by a given sample type (in-house, uncovered stack, covered stack, roofed storage or other) for each year. These yearly mean values were then combined across sample types to create a single, weighted mean value by state by year.

MD and VA also provided yearly mean values for litter production. It is not known how many samples were taken from manure haulers, planners and farmers, but the PLS recommended using these values to estimate the average litter production per bird in any given year.

The combination of these data allows for the use of Equation 1. This means that collected litter values can be directly estimated and no as-excreted values or recoverability factors from other literature sources are needed to estimate broiler nutrient production.

Equation 1. Poultry Phosphorus Production Based on Litter (Used for Broilers)

Lbs of P/Year = (Lbs of Litter/Bird Produced) X (Lbs of Dry Matter/Lb of Litter) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of Litter Produced

The litter mass production data provided by the PLS indicates a strong relationship between litter production and average bird market weight (also occasionally reported as slaughter weight or produced weight) as shown in Figure 1. It should be pointed out that some of the values reported in Figure 1 were interpolated by states between two years with collected manure hauler information, and some VA data was based upon book values when other information was not available for a year. These sources combined represent the best estimates of manure generation data available in VA and DE. The AMS notes that the relationship between these values and average bird market weight is very similar to a relationship described by the University of Delaware Extension in a 2007 broiler litter estimation tool (Malone, 2007). Due to the similarities, and without additional data, the AMS recommends using the relationship found in the PLS data, and described in Equation 4 to estimate broiler litter production per bird.

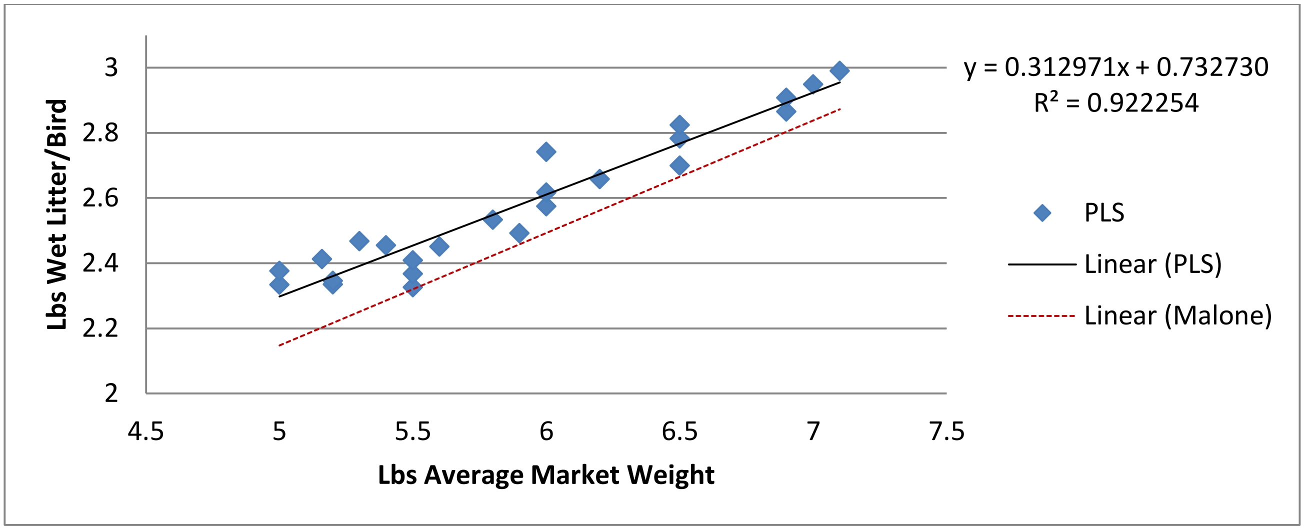
Equation 4. Broiler Litter Production

Lbs of Litter/Bird Produced = 0.312971 X (Average Bird Market Weight) + 0.732730

Source: Average Bird Market Weight can be calculated as Total Pounds Produced from Census of Agriculture/Total Birds Produced from Census of Agriculture

The AMS recommends using this equation to estimate broiler litter production each year from 1985 through the present. For all future years in which slaughter weights are not yet available, the AMS recommends keeping the value constant. For example, if the 2014 estimate is 3 lbs of litter per broiler, then the 2015 estimate should also be 3 lbs of litter per broiler until such time as 2015 values become available.

Figure 1. Broiler Litter Production and Average Market Weight



Moisture Content

The nutrient concentrations submitted are assumed to represent "as-is" litter. This means that moisture content can vary across samples. This variability requires nutrient concentrations be standardized based upon moisture content before they can be compared across sample years. While litter moisture content may vary across houses and across years, the standard deviation of the annual average moisture content across more than 9,800 broiler sample was relatively small (less than 5%). For this reason the AMS elected to use the average moisture content of all the annual average values. This value was 0.286500. The inverse of moisture content is solids content, or for our purposes, Lbs of Dry Matter/Lb of Litter. The inverse of the average moisture content was 0.713500. This value should be used for each year from 1985 through the present (and all future years). This value could be updated by new moisture content data collected in subsequent years.

Nutrient Concentrations

All nutrient concentrations were converted from "as-is" litter nutrient concentrations to dry weight nutrient concentrations. Again, the nutrient concentration values provided by the PLS represent average, annual concentrations. The PLS records indicate a downward trend in phosphorus concentrations from the mid- 1990s through the present. This seems to confirm that changes in feed formulas, genetics and the phytase amendment to feed contributed to reductions in phosphorus concentrations in litter. In fact, the overall decrease in phosphorus concentration across the watershed is estimated to be 16.5% from 1995 through 2013. This is very close to the 16% decrease in phosphorus concentrations credited in the current Phase 5.3.2 Watershed Model to mimic the changes in feed formulas, genetics and the phytase amendment.

However, the majority of these decreases appear to have occurred in the early 2000s, and there is a general increase of P concentrations across the watershed since 2005. Additionally, average market weights and PLS estimates of litter production indicate that producers are growing larger birds in some areas of the watershed, and with them, creating larger quantities of poultry litter. The AMS also acknowledges that changes in nutrient concentrations could be related to changes in management techniques within houses, including decreasing clean-out frequencies and changes to in-house composting techniques (among other contributing factors). Because of these dynamic changes in litter nutrient concentrations, the AMS recommends estimating each year's nutrient concentration value (N or P) by calculating a three-year moving average based upon previous years' data. The moving average results by state and across the watershed are provided in the figures below. The AMS recommends the following rules for applying these three-year moving averages in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values accordingly if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 2: Bay-Wide Lbs P/Lb Dry Litter for Broilers (to be used by NY, PA)

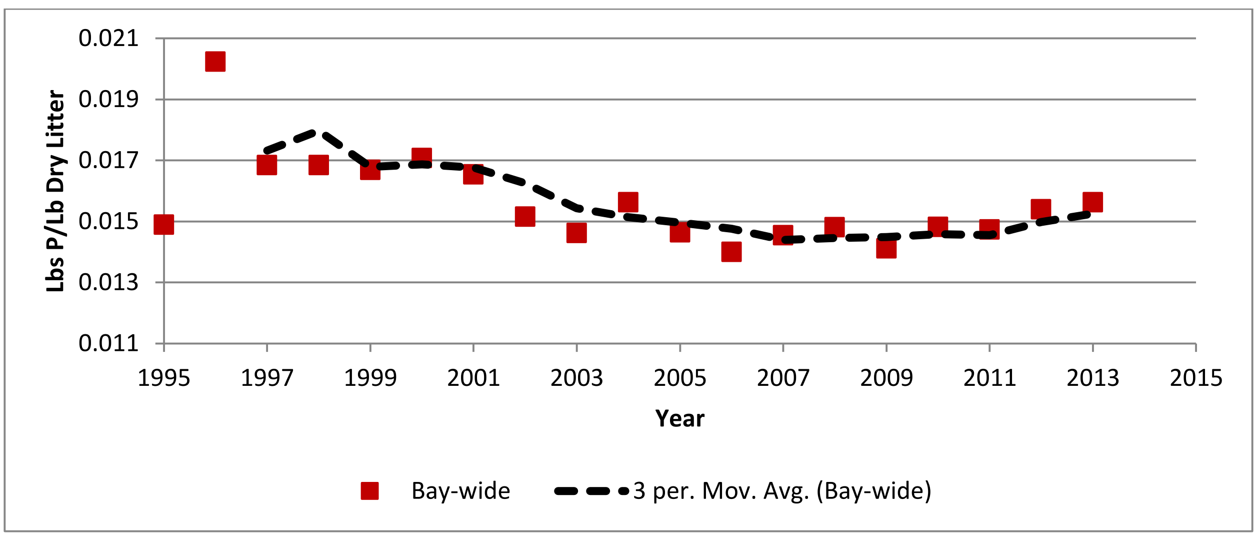


Figure 3: VA Lbs P/Lb Dry Litter for Broilers

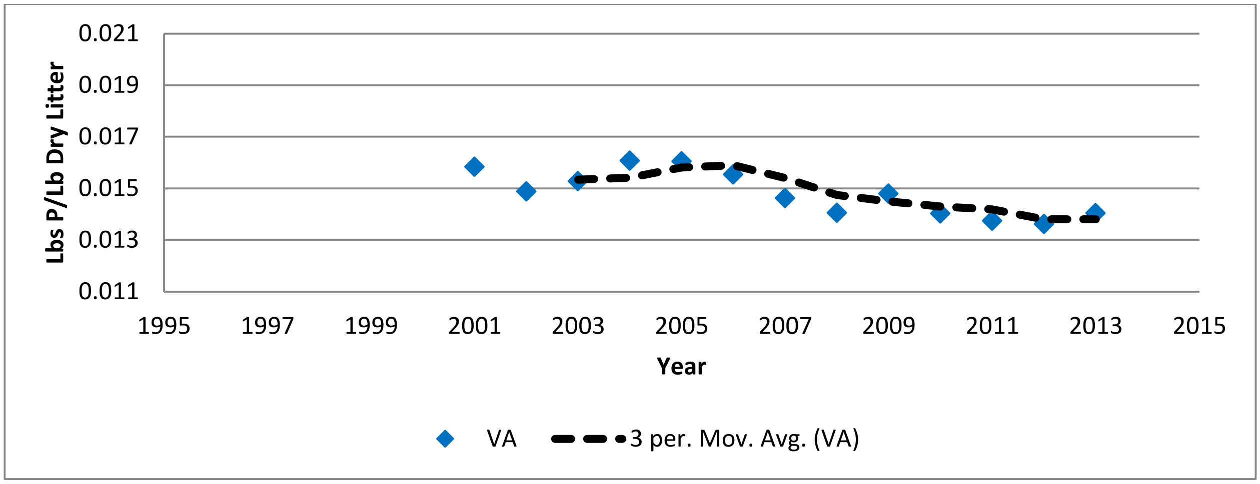


Figure 4: DE/MD Lbs P/Lb Dry Litter for Broilers

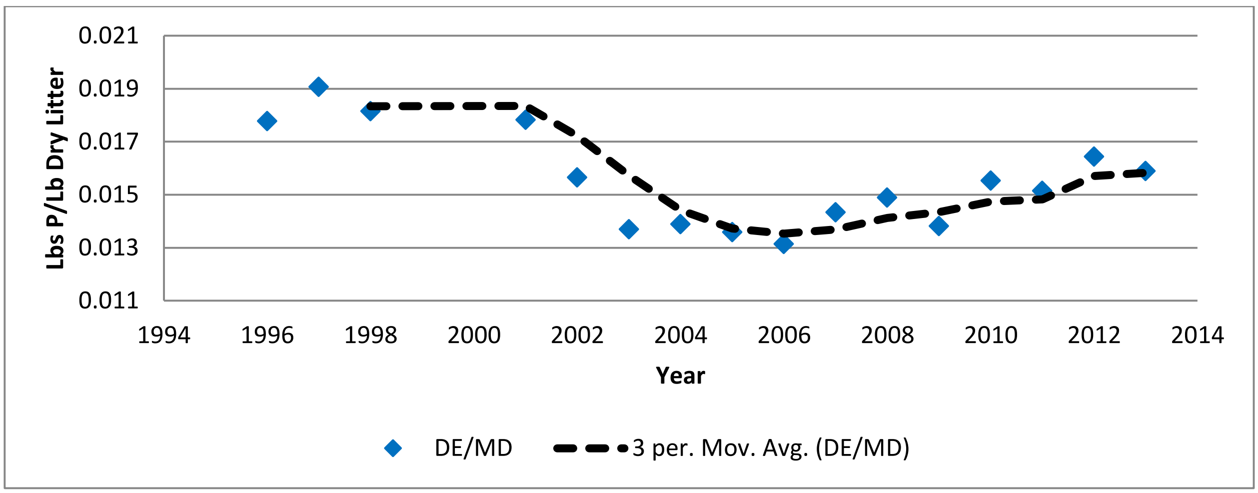


Figure 5: WV Lbs P/Lb Dry Litter for Broilers

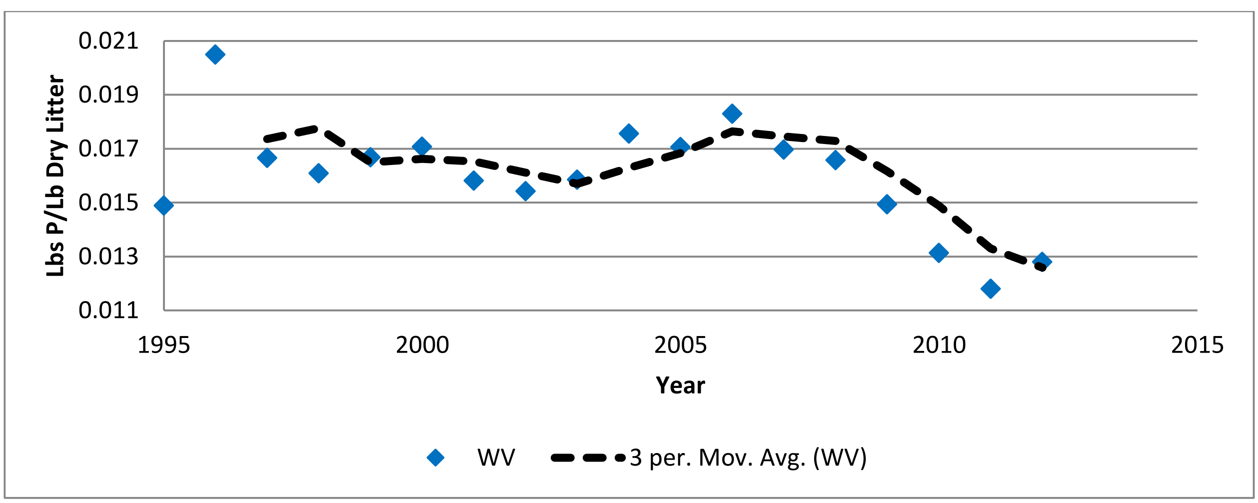


Figure 6: Bay-Wide Lbs N/Lb Dry Litter for Broilers (to be used by NY, PA)

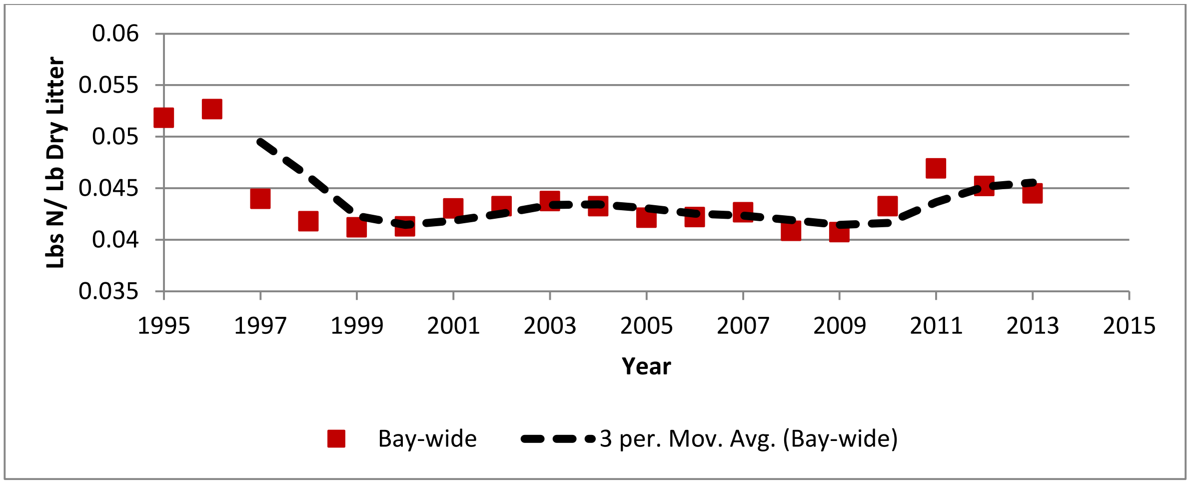


Figure 7: VA Lbs N/Lb Dry Litter for Broilers

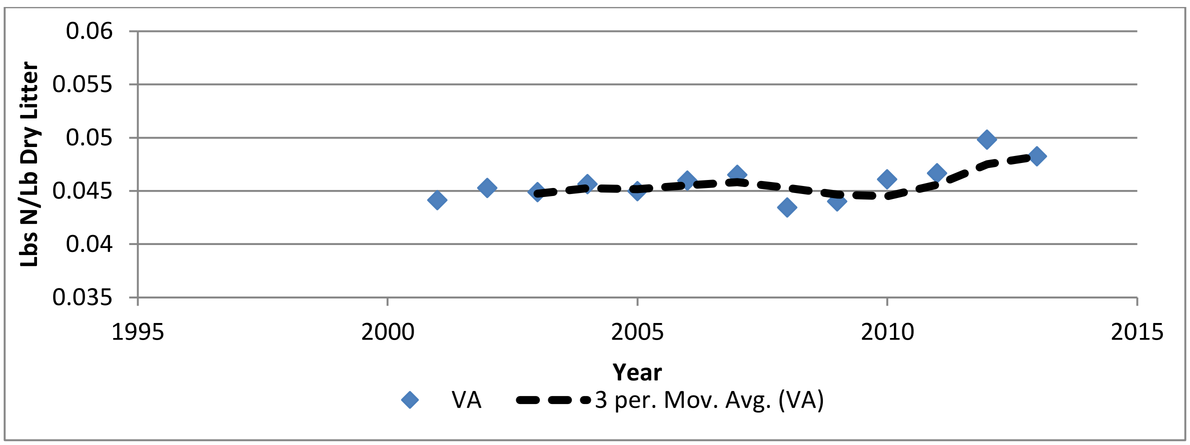


Figure 8: DE/MD Lbs N/Lb Dry Litter for Broilers

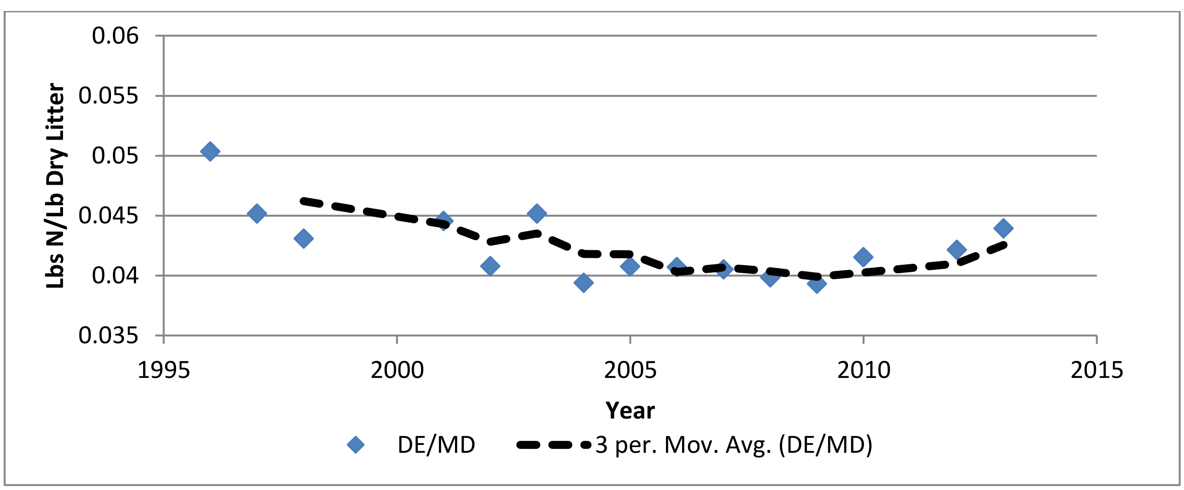
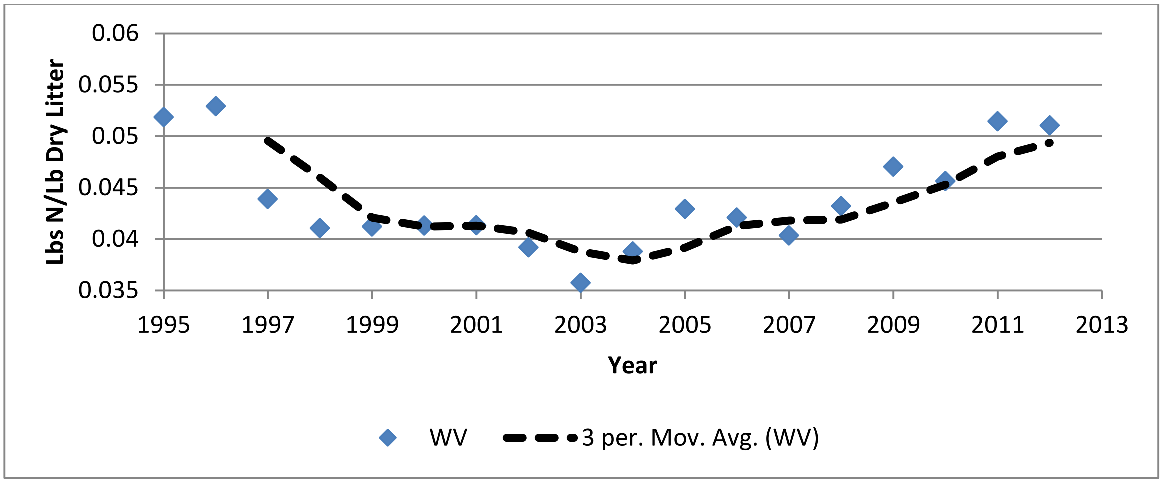


Figure 9: WV Lbs N/Lb Dry Litter for Broilers



Populations

The National Agricultural Statistics Service (NASS) provides statewide annual broiler production numbers at the following website: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1130. The AMS agrees with the PLS recommendation of using these annual production numbers and the annual inventory numbers provided in the Census of Agriculture to estimate countywide broiler production from 1985 through the present. Census of Agriculture inventory numbers are needed to determine the fraction of birds produced in each county because annual production numbers are only released at the statewide level. The two values can be combined using Equation 5 below, and an example of this calculation for DE is provided in Table 1.

Equation 5. Estimating Countywide Populations

Countywide Birds Produced/Year = Statewide Birds Produced/Year X (Countywide Ag Census Inventoried Birds/Ag Census Statewide Birds Produced)

Table 1. Broiler Population Estimates for DE

County	2012 Ag Census Inventory	2012 Ag Census Fraction	2013 NASS Production	Final 2013 Production Estimate
Kent	7,708,825	0.178418	-	37,824,641
New Castle	-	-	-	-
Sussex	35,497,689	0.821582	-	174,175,359
Statewide	43,206,514	-	212,000,000.00	212,000,000

This method should be used for all years for which there are NASS annual bird production data. Production numbers for any future years should be estimated according to the agricultural projection methods approved by the Partnership. These methods estimate future animal populations based upon trends in historic populations.

The resulting pounds of nutrients produced per broiler per year and per state can be found in Appendix C.

Turkeys

Together, VA and WV collected and summarized almost 2,000 samples of turkey litter with nutrient concentrations and moisture content. The concentrations again represented the annual mean concentration of all samples collected within a single year. The AMS recommends using this data to estimate nutrient concentrations in turkey litter across the watershed using the same method described in the broiler section. However, VA acknowledged a lack of confidence in litter mass production data collected from planners, farmers, and manure haulers, and WV did not collect litter mass production data. For this reason, the AMS recommends using ASABE values to estimate the mass of as-excreted manure produced by turkeys. This as-excreted number can then be multiplied by a recoverability factor to account for loss of manure between excretion and hauling to a field, and combined with nutrient concentration information collected by the PLS using Equation 3.

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of As-Excreted Manure

ASABE, 2005 reports that 78 lbs of as-excreted manure are produced per finished turkey tom, while 38 lbs of as-excreted manure are produced per finished turkey hen. Both of these values are reported on a wet basis with 74% moisture content. NASS only reports the number of turkeys sold, but reports no breakdown between turkey toms and turkey hens. For this reason, the AMS recommends averaging these two manure numbers together to represent the average manure production from a turkey until more detailed data on the breakdown between turkey toms and hens becomes available. The average of these two values is 58 lbs of As-Excreted Manure/Turkey Produced. Based upon the reported moisture content, we can assume that there is 0.26 Lbs of Dry Matter/Lb of Manure.

USDA estimates that approximately 72% of manure excreted on turkey operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 72% of as-excreted turkey manure is available for application. This results in approximately 41.76 lbs of Recoverable Manure/Turkey Produced. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 10.8576 lbs of Dry Recoverable Manure/Turkey Produced.

Because the PLS provided dry weight concentrations for turkey litter which are meant to represent concentrations in the litter after any manure has been lost in the production area, there is no need to apply any further loss factors to the turkey manure. We can assume that each remaining pound of manure has a nutrient concentration similar to that of the turkey litter sampled by the PLS.

Nutrient Concentrations

All nutrient concentrations were converted from “as-is” litter nutrient concentrations to dry weight nutrient concentrations. Again, the nutrient concentration values provided by the PLS represent average, annual concentrations. As shown in the figures below, while P has fluctuated over time within turkey litter sampled by VA and WV, the same decrease in P seen in broilers is not shown in the turkey data. However, there appears to be a decrease in P values in both states in recent years. Concentrations of N in turkey litter from both states appear to be steadily increasing through the sample period.

The AMS again recommends the following rules for applying these three-year moving averages of nutrient concentrations in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values according if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 10: Bay-wide P/Lb Dry Litter for Turkeys (to be used by NY, PA, MD, DE)

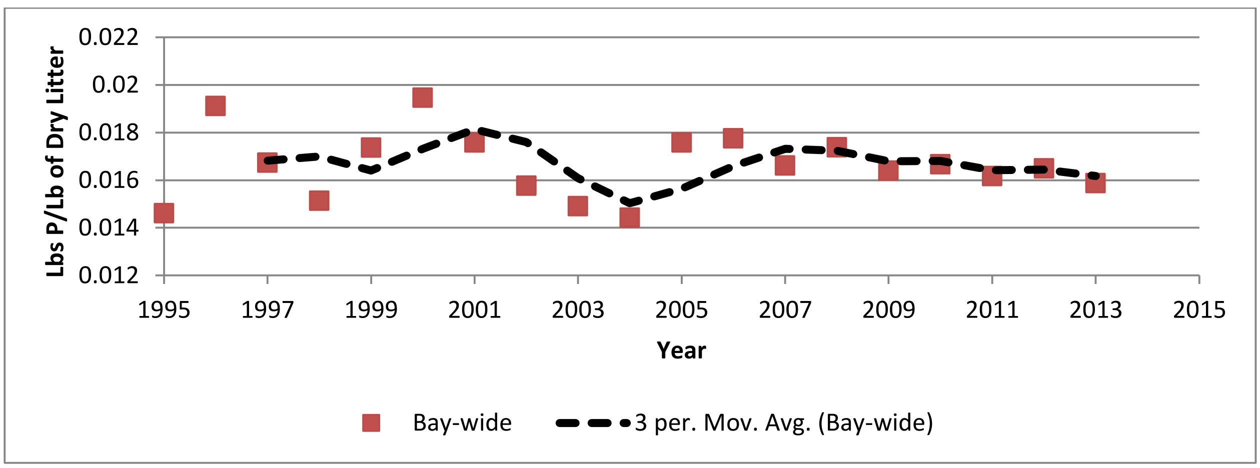


Figure 11: VA P/Lb Dry Litter for Turkeys

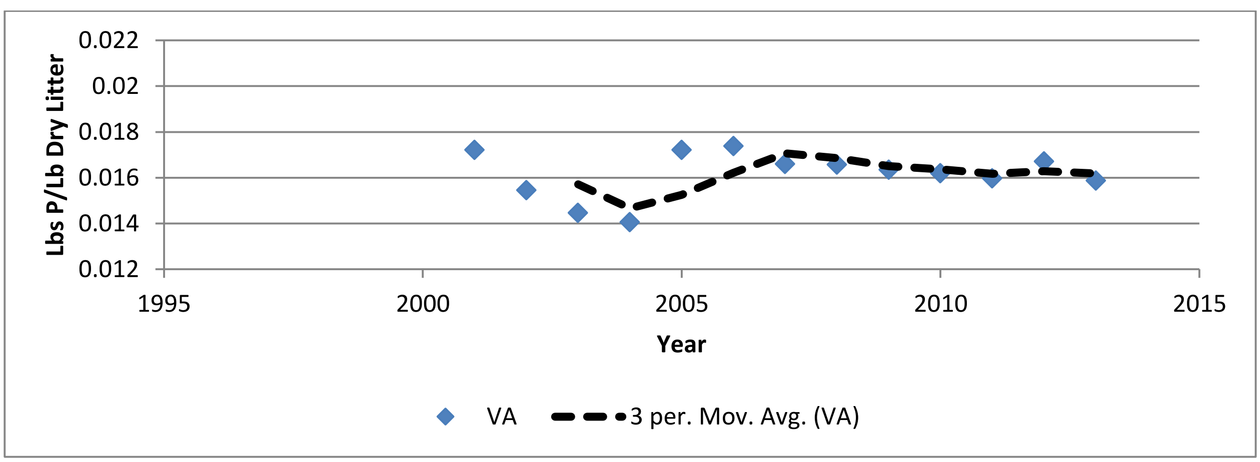


Figure 12: WV P/Lb Dry Litter for Turkeys

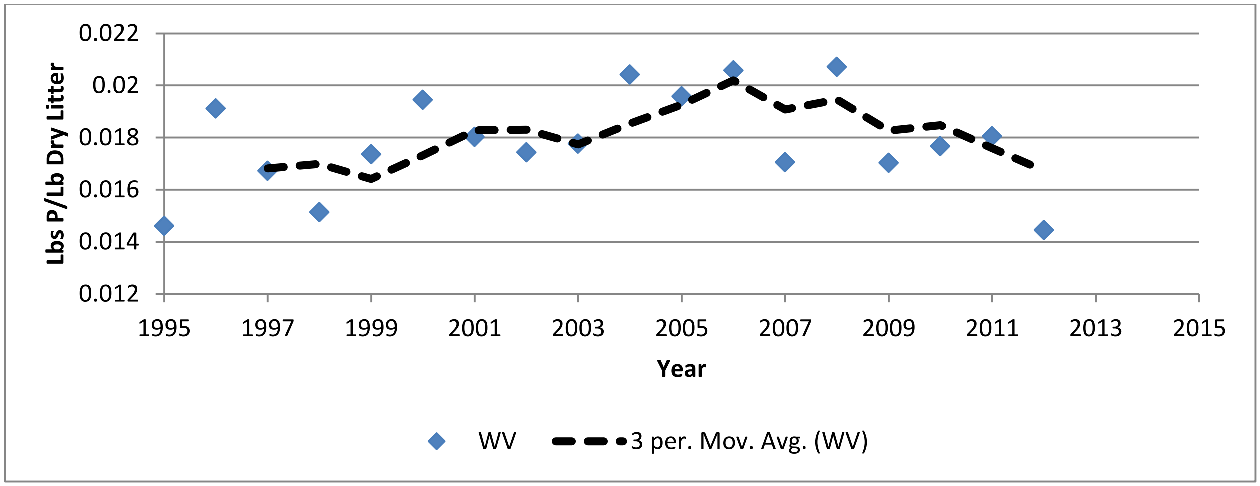


Figure 13: Bay-wide N/Lb Dry Litter for Turkeys (to be used by NY, PA, MD, DE)

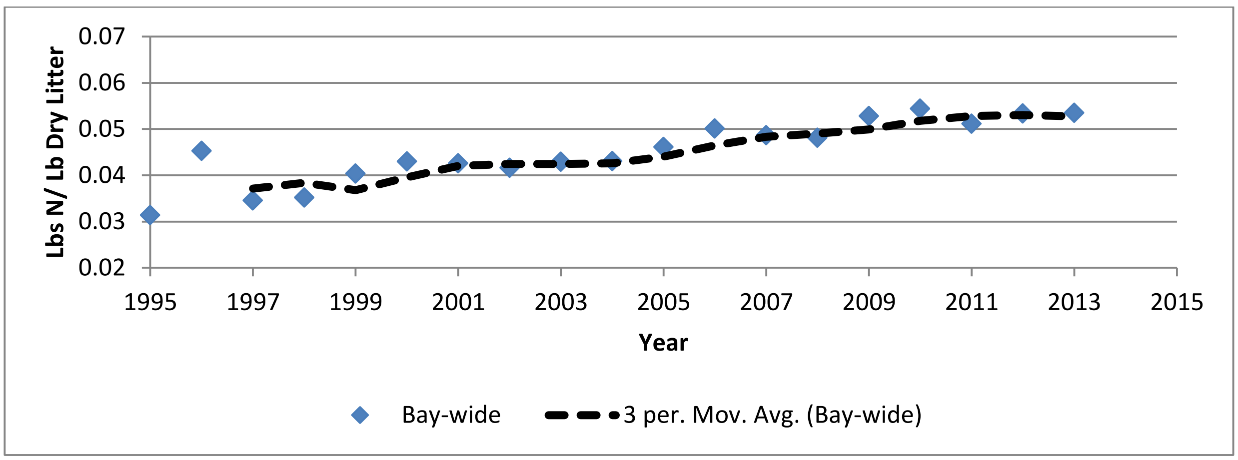


Figure 14: VA N/Lb Dry Litter for Turkeys

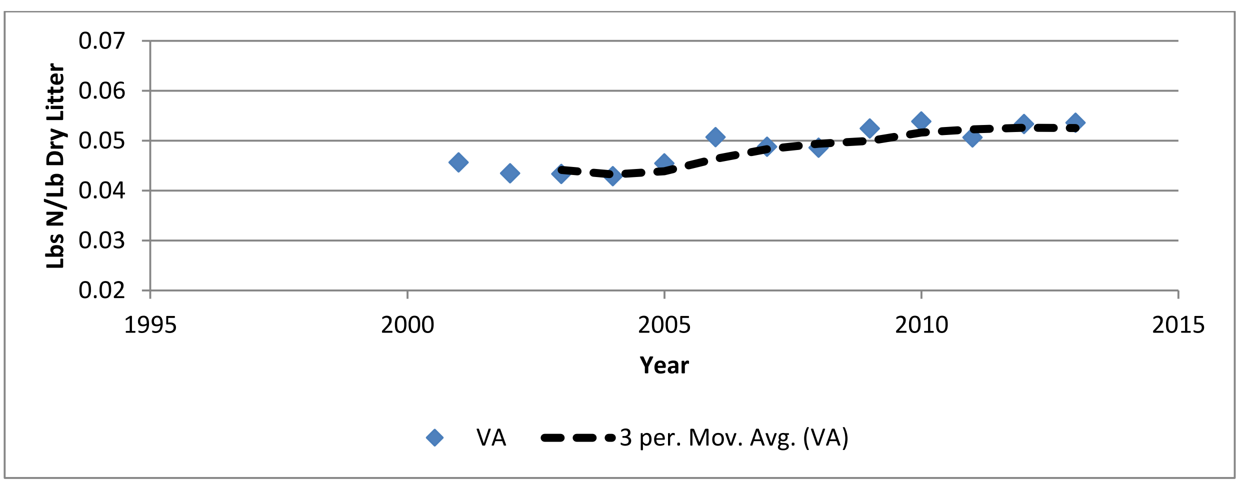
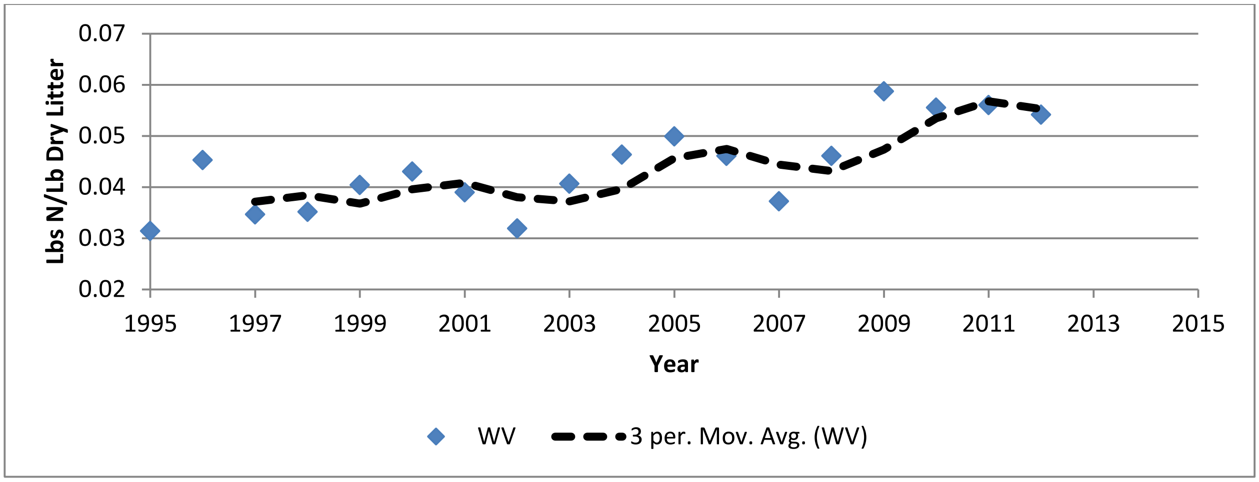


Figure 15: WV N/Lb Dry Litter for Turkeys



Populations

The National Agricultural Statistics Service (NASS) provides annual turkey production numbers by state at the following website: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1130. The AMS agrees with the PLS recommendation of using these annual production numbers and the annual inventory numbers provided in the Census of Agriculture to estimate countywide turkey production from 1985 through the present. This can be done by calculating the fraction of inventoried turkeys within each county as reported by the Census of Agriculture, and multiplying the county fraction by the total statewide NASS production value. An example of this method is shown in Table 1.

The resulting pounds of nutrients produced per turkey per year and per state can be found in Appendix C.

Layers

The Ag Census defines layers as "table-egg type layers, hatching layers for meat-types, hatching layers for table egg types, and reported bantams." With this definition in mind, VA and WV summarized over 1,100 nutrient concentration records for "layer/breeders" with no breakdown between the two bird types. The majority of egg laying hens in the watershed are raised in PA. However, PA provided only a very small number of data points for the most recent years. Given the availability of data, the AMS recommends using the litter concentration data provided by VA and WV until more samples are collected and reported by PA and other states. No states collected data to accurately estimate mass of litter produced. For this reason, the AMS again recommends using ASABE values to estimate the mass of as-excreted manure produced by layers. This as-excreted number can then be multiplied by a recoverability factor to account for loss of manure between excretion and hauling to a field, and combined with nutrient concentration information collected by the PLS using Equation 3.

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of As-Excreted Manure

ASABE, 2005 estimates each layer excretes 69.35 lbs of manure. This manure is assumed to have a 74.21% moisture content, or 0.2579 lbs of dry matter/lb wet manure.

USDA estimates that approximately 82% of manure excreted on layer operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 82% of as-excreted turkey manure is available for application. This results in approximately 56.8670 lbs of Wet Recoverable Manure/Layer. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 14.6667 lbs of Dry Recoverable Manure/Layer Produced.

Because the PLS provided dry weight concentrations for layer litter which are meant to represent concentrations in the litter after any manure has been lost in the production area, there is no need to apply any further loss factors to the turkey manure. We can assume that each remaining pound of manure has a nutrient concentration similar to that of the layer litter sampled by the PLS.

Nutrient Concentrations

The figures below show the concentrations collected by VA and WV, and combined across both states for a Bay-wide average. Concentrations of P within layer litter in these two states appear to be decreasing over the long-term, but increasing slightly in the short-term, particularly in WV. However, WV's P concentration data varies significantly from year-to-year. Concentrations of N appear to remain fairly constant throughout the time period of collection.

The AMS again recommends the following rules for applying these three-year moving averages of nutrient concentrations in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values according if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 16: Bay-wide P/Lb Dry Litter for Layers (to be used for NY, PA, MD, DE)

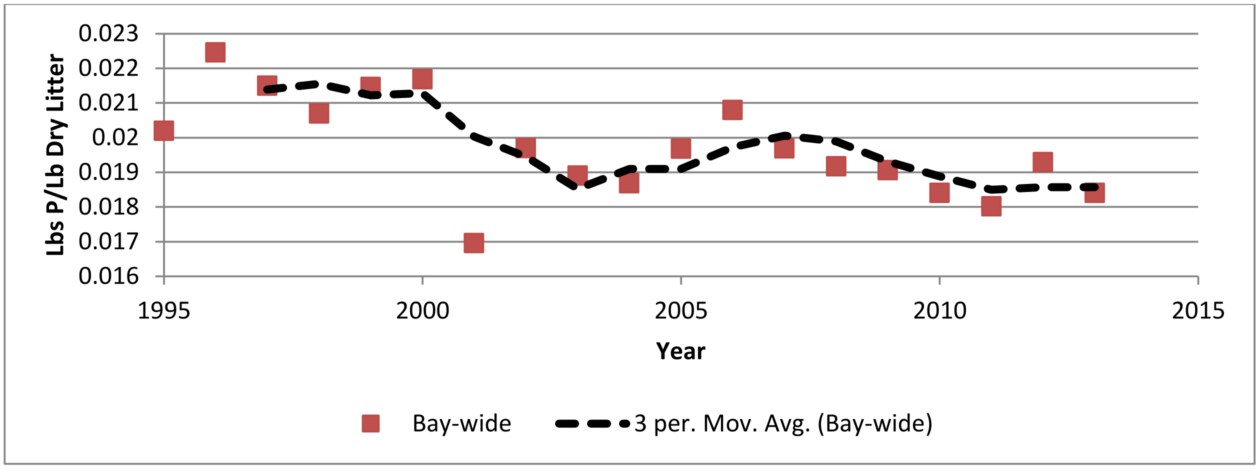


Figure 17: VA P/Lb Dry Litter for Layers

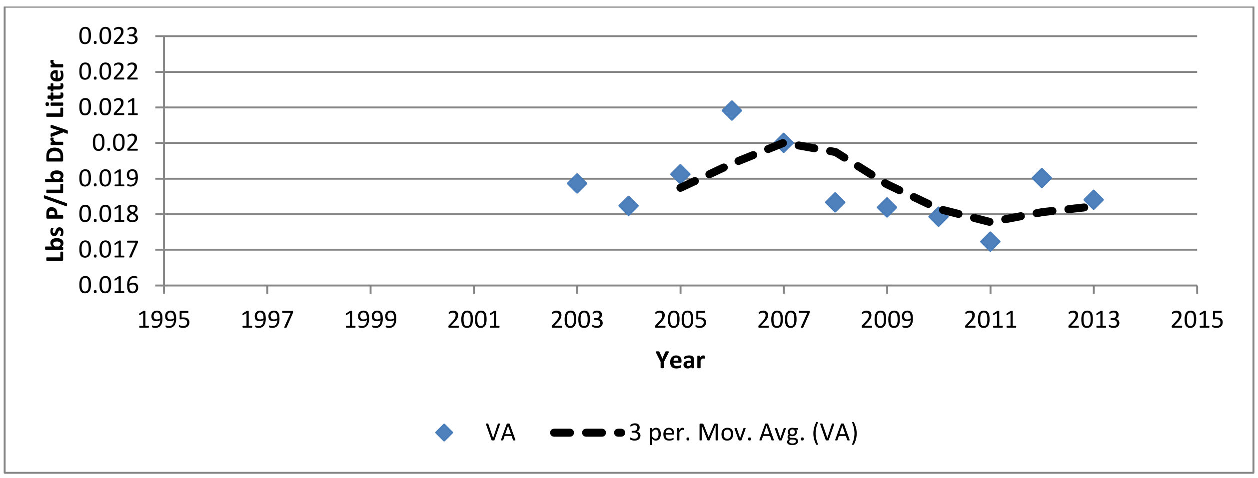


Figure 18: WV P/Lb Dry Litter for Layers

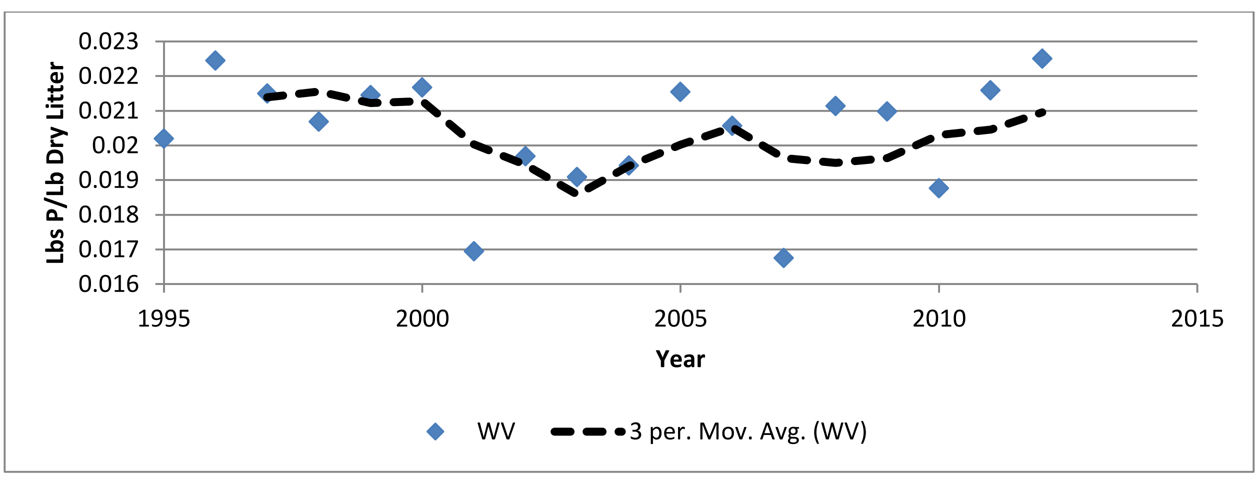


Figure 19: Bay-wide N/Lb Dry Litter for Layers (NY, PA, MD, DE)

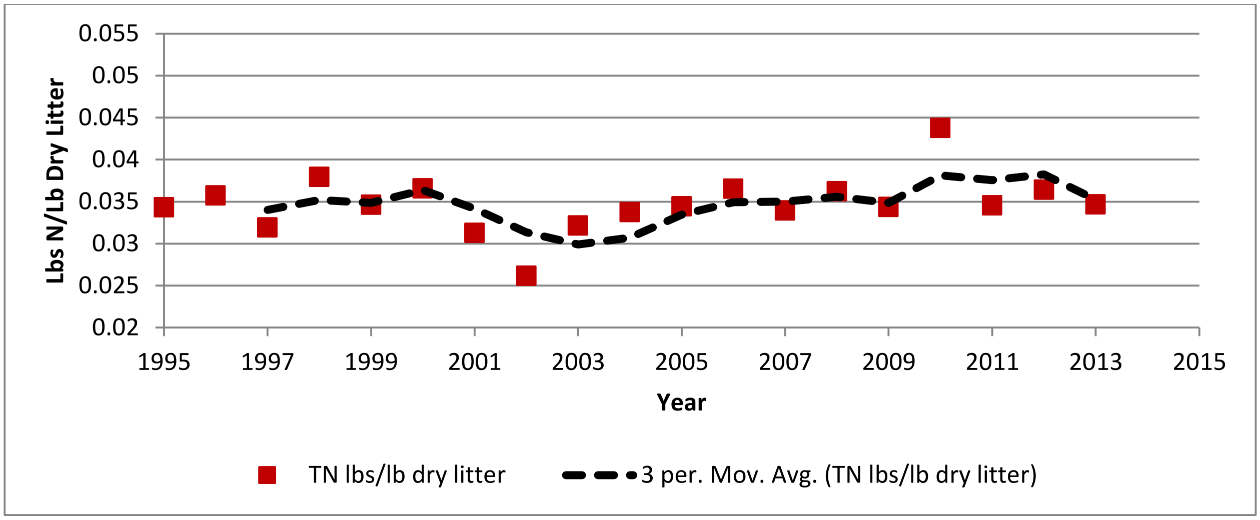


Figure 20: VA N/Lb Dry Litter for Layers

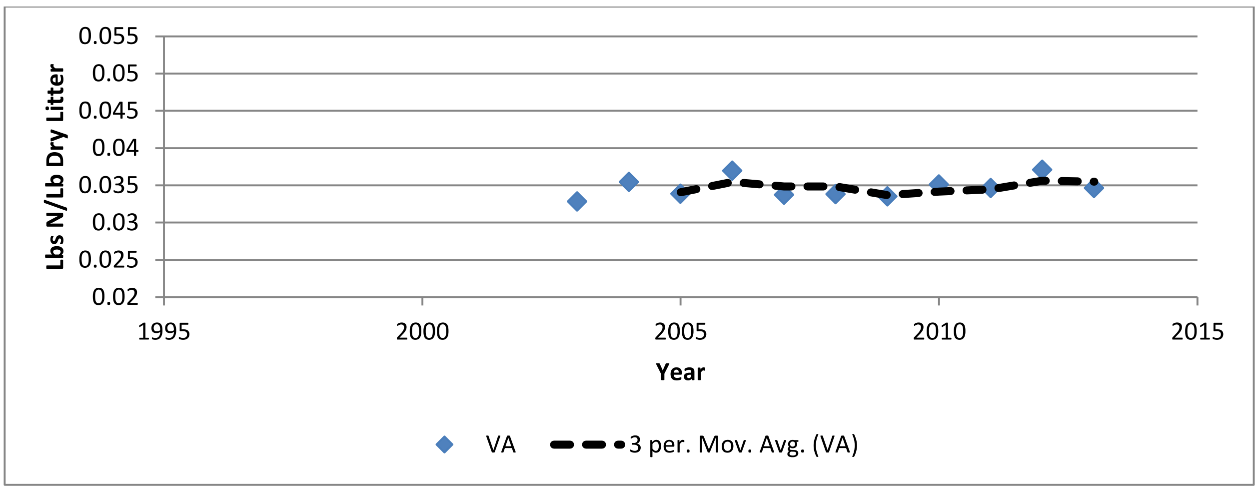
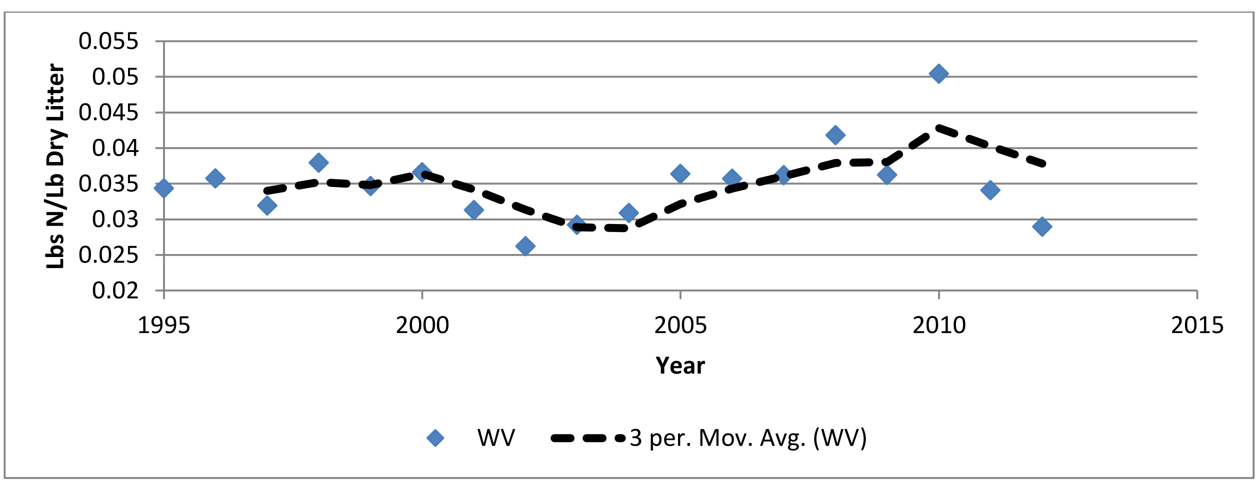


Figure 21: WV N/Lb Dry Litter for Layers



Populations

USDA estimates poultry (and other livestock) populations by combining both year-end inventory[1] and sales data reported in the Census of Agriculture. This is done by deflating both values by the number of typical cycles (flocks) for a bird type in a year. Equation 5 below shows how inventories, sales and cycles are combined to estimate an overall population in the absence of annual production statistics reported for broilers and turkeys.

Equation 5. USDA Bird Production Estimates

Birds Produced/Year = (Year-End Inventoried Birds X 1/Cycles of Birds per Year) + [(Annual Birds Sold/Cycles of Birds per Year) X ((Cycles of Birds per Year-1)/Cycles of Birds per Year)]

The USDA estimates that, on average, layer operations only have one cycle (flock) per year. Because of this, the resulting production estimate from Equation 5 is equivalent to the number of inventoried birds. Inventoried birds should be used to estimate layer production until annual production data is made available.

The resulting pounds of nutrients produced per layer per year and per state can be found in Appendix C.

[1] Census of Agriculture reports a year-end inventory value which represents the number of animals on the operation on December 31, 2012.

Pullets

Unfortunately, very little pullet litter nutrient data is available. Additionally, ASABE has not historically estimated pullet litter nutrients. However, USDA does estimate pullet nutrient production based upon as-excreted manure. The AMS recommends using these estimates in the absence of other data until better data on pullet litter production can be collected. Calculating recoverability of as-excreted nutrients for pullet requires a unique equation because the PLS collected no litter nutrient concentrations as it did for the other bird types. Because it is not known how much N and P that is excreted is lost between excretion and application, we must use a set of recoverability factors to estimate available nutrients for application. These recoverability factors provided by USDA are described in greater detail below.

Equation 2. Poultry Phosphorus Production Based on As-Excreted Manure (Used for Pullets)

Lbs of Recoverable P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Lbs of Recoverable P/Lb of P) X (Birds Produced/Year)

Mass of As-Excreted Manure

USDA estimates each pullet excretes 49.91 lbs of manure. This manure is assumed to have a 74.06% moisture content, or 0.2594 lbs of dry matter/lb wet manure.

USDA estimates that approximately 82% of manure excreted on pullet operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 82% of as-excreted turkey manure is available for application. This results in approximately 40.9262 lbs of Wet Recoverable Manure/Pullet. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 10.6163 lbs of Dry Recoverable Manure/Pullet Produced.

Nutrient Concentrations

USDA estimates that each pound of recoverable, dry pullet manure has 0.0203 lbs P and 0.0524 lbs N. However, only 95 percent of that P is considered recoverable and only 50 percent of that N is considered recoverable due to volatilization losses and other pathways. After applying these recoverability factors, we find that each pound of recoverable, dry pullet manure has 0.019285 lbs of recoverable P and .026200 lbs of recoverable N.

The AMS recommends that these two nutrient values represent typical operations in the year 2002 (USDA estimates these represent typical pullets from 2002 through 2007). After contacting a regional feed manufacturer, the AMS feels that layer and pullet feed are related to such an extent that it would be appropriate to apply the trends in P concentrations seen in layer feed to the pullet data as well. The percent change in P concentrations shown in the Bay-wide layer data from 2002 through 2013 will be applied to estimate trends in pullet P concentrations in all states over this time period. Table 2 below shows this change.

Table 2. Pullet P Concentrations in Recoverable Manure

Year	Original Pullet P Concentration	Percent Change in Bay-wide Layer P	Final Pullet P Concentration
2002	0.019285	NA	0.019285
2003	0.019285	-4.76287%	0.018366
2004	0.019285	3.11706%	0.018939
2005	0.019285	-0.02386%	0.018934

2006	0.019285	3.31276%	0.019562
2007	0.019285	1.69592%	0.019893
2008	0.019285	-0.84711%	0.019725
2009	0.019285	-2.90331%	0.019152
2010	0.019285	-2.22071%	0.018727
2011	0.019285	-2.04213%	0.018345
2012	0.019285	0.41046%	0.018420
2013	0.019285	0.00124%	0.018420

Populations

USDA estimates poultry (and other livestock) populations by combining both year-end inventories[2] and sales data reported in the Census of Agriculture. This is done by deflating both values by the number of typical cycles (flocks) for a bird type in a year. USDA estimates producers grow approximately 2.25 cycles of pullets per year. Equation 5 shows how Census of Agriculture numbers are combined with cycles to produce a yearly production estimate.

Equation 5. USDA Bird Production Estimates

Birds Produced/Year = (Year-End Inventoried Birds X 1/Cycles of Birds per Year) + [(Annual Birds Sold/Cycles of Birds per Year) X ((Cycles of Birds per Year-1)/Cycles of Birds per Year)]

With no other pullet population data available, the AMS recommends using this method to estimate yearly production for each county during years in which the Census of Agriculture was released. Production values for all other years (including future years) should be estimated using the agricultural projection methods already approved by the Partnership.

The resulting pounds of nutrients produced per pullet per year and per state can be found in Appendix C.

[2] Census of Agriculture reports a year-end inventory value which represents the number of animals on the operation on December 31, 2012.

Future Data Collection and Submissions

The PLS established a clear process for collecting and summarizing laboratory analyses of poultry litter and litter production data. This process provided enough information to improve estimates of broiler, turkey and layer nutrient information. However, data gaps still exist, particularly for pullets and layers, and for turkey litter production estimates. The AMS recommends that all states begin regularly reporting laboratory analyses of poultry litter and litter production data on a yearly basis to the Chesapeake Bay Program. On a semi-regular basis (perhaps at the beginning of each Milestone period - 2 years - or more or less frequently), the estimates for poultry litter nutrient production should be updated in the Watershed Model to represent how values have changed since the calibration of the new model. These reported values should be used to update the key parameters in the basic equation: 1) mass of litter produced; 2) litter dry solids content; and 3) litter nutrient concentrations. Absent these values, the Partnership must rely on other widely published values such as those reported in the ASABE, 2005 report. Where possible, future data collection efforts should also focus on the correlation of these key parameters at the farm level, to quantify the effects and extent of various litter management scenarios. A dataset for broilers, for example, might include for each record the volume of litter removed (including total cleanout and removal of crust between flocks) in a cleanout period, the number of flocks and number of birds produced during that cleanout period and their finish weight, and a manure analyses showing the N, P and moisture content of that litter. This would allow the states to determine the amount of N and P produced per bird on a farm level, which can then be aggregated into an average.

The AMS recommends that raw sample data for each parameter be submitted to the Bay Program using standardized templates. This would allow the Partnership to conduct more thorough statistical analyses of the data which in turn would result in better litter estimates for the modeling tools. Ultimately, the Partnership will need to determine both the method and frequency of collecting and updating these values.

Additionally, there is still an opportunity for the Partnership to collect historical data on all bird types prior to final calibration of the Phase 6 Watershed Model. Calibration will occur in October, 2015, so states wishing to provide historic litter production and/or nutrient concentration data should submit the data to the Chesapeake Bay Program by September, 2015. The data can then be analyzed and potentially approved by the Partnership for use in the Phase 6 Watershed Model.

To address the further need for poultry production data, representatives of the commercial poultry industries and land grant universities in the region are currently working cooperatively with the Chesapeake Bay Program partnership to develop and implement a process whereby a more accurate understanding of the annual generation of nutrients by regional commercial poultry production can be realized. USDA National Agricultural Statistics Service (NASS) is recognized by the project partners as the primary source of validated agricultural production data in the region, and representing the optimal path forward to forming the critical data exchange linkage between the regional integrators and the CBP partnership. The PLS has identified the critical data gaps as well as the existing potential options to resolve them. In response to the finding of the PLS, the project partners have identified the implementation of an annual NASS integrator survey as the potential solution to address several existing data limitations. Expectations are for the new NASS survey to be implemented in late 2015, and the resulting data to be made publically available in 2016 for use in the final version of the partnership's Phase 6.0 modeling tools.

Comparing Methods

All nutrient balance analyses require assumptions about nutrient concentrations and manure or litter production. The AMS chose to compare the assumptions described in this document (using Delaware broilers as an example) to assumptions in the current Phase 5.3.2 Watershed Model and assumptions in ASABE's 2005 report. Table 3 shows how differences in population, litter/manure production and nutrient concentrations across these three methods impact final nutrient production estimates. As mentioned previously, both Phase 5.3.2 and ASABE, 2005 estimate as-excreted manure, while the Phase 6 method estimates litter directly. This means that estimates of storage and handling loss and volatilization must be applied to any as-excreted values in both the Phase 5.3.2 and ASABE, 2005 methods. No such estimates are needed in the Phase 6 method because litter values collected by the states are assumed to inherently reflect the losses which occurred after excretion.

This comparison shows that the Phase 5.3.2 method estimates more nutrients available to crops after losses than the other two methods. One main reason for this difference is the assumption that the Census of Agriculture's bird inventory number represents the average population of birds in county on any given day during the year. That assumption does not take into account the number of flocks or cycles of birds grown at a typical house within the county. If for example, the number of days of manure production were reduced from 365 to 300 to account for flock turnover and house cleanout throughout the year, then the Phase 5.3.2 method's estimates of nutrients would be in line with the other two methods. For this reason, the AMS strongly recommends deflating inventory numbers for layers and pullets using the USDA population method described earlier in the report.

The comparison also illustrates that estimates from the ASABE, 2005 method and the Phase 6 method are very similar once estimates of storage and handling loss and volatilization are applied to the ASABE as-excreted values. This comparison provides evidence that the ASABE, 2005 values match closely with estimates collected by the PLS, strengthening the confidence in the use of ASABE, 2005 values for pullets, layers and turkeys. While the AMS does recommend using ASABE, 2005 to estimate nutrient production for pullets and layers (and to a lesser extent for turkeys), the group strongly encourages states to collect sufficient litter data that will allow for direct estimates of litter rather than as-excreted manure for these bird types in the future.

Table 3. Estimates of Nutrients Produced by DE Broilers in 2012

Parameter	Phase 5.3.2 Method	ASABE 2005 Method	Phase 6 Method
Produced Birds	NA	212,000,000	212,000,000
Inventoried Birds	43,206,514	-	-
Days of Manure Production	365	-	-
Lbs of Manure Excreted/Bird/Day (Wet Basis)	0.186813	-	-
Lbs of Manure Excreted/Finished Bird (Wet Basis)	-	11	-
Lbs of Litter/Finished Bird (Wet Basis)	-	-	2.955
Lbs of Dry Matter/Lb of Manure Excreted	0.26	0.26	-
Lbs of Dry Matter/Lbs of Litter	-	-	0.7135
Lbs P/Lb of Manure Excreted (Dry Basis)	*0.011400	0.012500	-
Lbs P/Lb of Litter (Dry Basis)	-	-	0.014397

Lbs N/Lb of Manure Excreted (Dry Basis)	0.049800	0.042857	-
Lbs N/Lb of Litter (Dry Basis)	-	-	0.043065
Total Lbs of Manure Excreted (Wet Basis)	2,946,111,552	2,332,000,000	-
Total Lbs of Litter (Wet Basis)	-	-	626,460,000
Total Lbs of Manure Excreted (Dry Basis)	765,989,004	606,320,000	-
Total Lbs of Litter (Dry Basis)	-	-	446,979,210
Total Tons of Manure Excreted (Wet Basis)	1,473,056	1,166,000	-
Total Tons of Litter (Wet Basis)	-	-	313,230
Total Tons of Manure Excreted (Dry Basis)	382,995	303,160	-
Total Tons of Litter (Dry Basis)	-	-	223,490
Total Lbs of P Excreted	8,732,275	7,579,000	-
Total Lbs of N Excreted	38,146,252	25,985,056	-
Total Lbs of P After Storage and Handling Loss	**7,422,433	**6,442,150	**6,435,160
Total Lbs of N After Storage and Handling Loss and Volatilization	**27,083,839	**18,449,390	**19,249,160

*The Phase 5.3.2 Watershed Model assumes that phytase amendments to feed combined with changes to broiler diets and genetics results in the production of 16% less phosphorus. No such assumption was made for the ASABE 2005 or Phase 6 methods.

**The Phase 5.3.2 Watershed Model assumes that 15% of excreted manure is lost to the nearby environment prior to application on crops. It also estimates that approximately 15% of TN is lost due to volatilization between excretion and application. These same assumptions were applied to the ASABE 2005 Method. However, the Phase 6 Method estimates litter directly, and thus inherently includes any loss of nutrients that may have occurred through storage and handling or volatilization of nitrogen. There has been concern over the Phase 5.3.2 Model’s use of this 15% loss factor. This loss only occurs on operations with no animal waste storage BMPs. This loss factor decreases when animal waste storage systems are applied.

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Appendix B. Pasture Subgroup Recommendations for Direct Deposition in Riparian Pasture Access Area

Agricultural Modeling Subcommittee – Pasture Subgroup

Recommendations on Riparian Pasture and Exclusion Fencing for CBP Phase 6 Watershed Model

Background

Simulation of pastures and livestock loadings and the Best Management Practices (BMPs) used to mitigate these loadings have varied over time by the Chesapeake Bay Program (CBP). Going back to the Tributary Strategies of 2005 and the phase 4.3 watershed model (WSM) simulated livestock exclusion BMP as a percent efficiency reduction applied to 51 upland pasture acres per linear mile of exclusion fencing implemented. The basis for the percent reduction and the extent of pasture impacted were poorly documented and not consistent with current understanding. With the advent of the phase 5.x WSM a land use for the area adjacent to streams with livestock access was developed to represent a degraded riparian pasture situation. Application of exclusion fencing in the phase 5 WSM would result in a land use change from the degraded condition to an unfertilized grass (hay without nutrients) or grassed riparian buffer situation or if trees were planted as forest or a forested riparian buffer. The actual extent of the degraded riparian pasture land use was not discernible via remote sensing of the imagery or other data sets used for land use determinations in phase 5.x. Each partner jurisdiction in consultation with CBP modeling staff analysis of projected Tributary Strategies exclusion made their best estimate of the extent of this degraded riparian pasture land use as a percentage of the total pasture. The relative loadings benefits of exclusion fencing from the phase 4.3 WSM were used to back calculate the estimated unit area loading from the degraded riparian pasture land use. This calculation produced on average across the entire watershed a 9 times (9X) the pasture unit area loading for nutrients and sediment delivered to the edge of stream. Since this was based on the phase 4.3 estimated exclusion benefit there is little documented scientific basis for this loading or benefit of exclusion fencing as simulated in the phase 5 WSM. And since the extent was based on educated guesses some jurisdictions either estimated too little or too much of this land use. Too little degraded riparian pasture land use area resulted in BMP cut-off in subsequent annual progress run scenarios and too much area estimated resulted in loadings that are not real or misattributed in the model calibration and could never be treated by real world implementation of exclusion fencing. These issues related to the extent, justification, and impact on loadings of the degraded riparian pasture land use have resulted in the Agricultural Modeling Subcommittee (AMS) to propose the elimination of this land use for the phase 6 WSM.

Because of this proposed change in land uses between phase 5 and phase 6 WSM the AMS established a Pasture Subgroup (PSG) to propose a solution to estimate loadings from livestock to the simulated streams and crediting exclusion fencing in phase 6 WSM. The membership of the PSG consisted of William Keeling VADEQ (PSG lead), Curtis Dell USDA ARS (AMS Chair), Les Vough UMD retired, Jim Cropper Northeast Pasture Consortium, Gary Shenk EPA, Matt Johnston UMD-CBP, Chris Brosch VT/VADCR, Dave Montali WVDEP, Mark Dubin Coordinator AGWG, Emma Giese CRC.

Evaluation of Simulation Options

The PSG had its initial meeting on September 4, 2014. At this meeting the potential options for simulating loadings from livestock access to streams and how exclusion BMP could be simulated were explored. The three options were: reverting to a pasture efficiency as in phase 4.3, keeping a land use change as in phase 5, or simulating direct deposition. The first option considered was reverting back to the phase 4.3 WSM methods of a percent reduction efficiency applied to the pasture Unit Annual Loading (UAL) per some extent of exclusion fencing implemented. As stated above the documentation in the scientific literature to justify this method of simulation is lacking and to establish a scientifically defensible efficiency for phase 6 WSM exclusion fencing would require a BMP panel to be established. With the extent of pasture in the watershed, numerous assumptions needed, and the limited time available for model development the PSG's consensus opinion was to explore other options for phase 6. Another option was to retain the land use change benefit to exclusion fencing as is currently done in the phase 5 WSM. This option also requires assumptions to be made primarily regarding the extent of the acreage of the degraded riparian pasture land use as well as UAL for this land use. Neither method actually represents one of the main impacts livestock with unrestricted access to streams have that being direct fecal depositions. Without a definitive way to estimate the degraded riparian pasture land use extent, justification for the current UAL, or a mechanistic way of simulating all aspects of livestock loadings a third option was put forward.

The third option is to simulate the direct deposition of fecal matter by livestock to the streams similarly to how point sources are simulated in CBP WSM. This option requires an estimate of the time spent in the riparian area of pastures by animal type and how much of the daily fecal matter is deposited directly into or adjacent to the stream as well as how many of each animal type are excluded per unit of exclusion fencing applied.

Virginia has developed hundreds of bacteria TMDLs for local scale watershed throughout the Commonwealth as well as studies in the Upper Susquehanna detailing livestock access to streams in that portion of the Bay Watershed. It was proposed to evaluate primarily rural TMDLs developed in Virginia and the Susquehanna to see if the needed factors for direct deposition loadings and fencing could be estimated. Additionally the PSG consulted key individuals from the Virginia Tech Department of Biological Engineering due to their extensive experience developing local scale TMDLs for fecal bacteria and their extensive knowledge of watershed modeling and the available literature. This consultation was to seek potential additional methods of simulation and any insights to the 3 options the PSG discussed. Dr. Brian Benham, Dr. Gene Yagow, and Erin Ling were contacted to discuss the various options for simulating livestock loadings and BMPs. They agreed that the three options discussed by the PSG were ways to simulate loadings and BMP benefits in a watershed model and did they not offer any additional potential methodology. Each option has plusses and minuses and that there was no single correct way. Each option requires assumptions to be made and documented. The percent reduction efficiency would be the simplest method of simulation but as detailed above would require extensive evaluation of the available literature and likely to include considerable best professional judgment of any panel of assembled experts. This method also does not represent the actual loading and remediation pathways of to real world situations. The land use change option requires an accurate determination of the extent of the land use and UAL and also does not simulate the actual loading processes. These modeling experts were not sure that the available literature would produce exactly what is needed for either option though there is literature on the benefits of riparian buffers. They did offer suggestions on possible data sets to use such as NHD-Plus, NLCD land use data sets, and NASS Crop Data Layer as possible data sets to be evaluated using GIS for the land use change option if that is the PSG's ultimate preferred recommended method. Though there is data in Virginia and parts of the Upper Susquehanna on potential direct fecal deposition loadings it likely does not exist across the entire Bay Watershed and would require assumptions being made for those areas based on the data available in the portions of the watershed that data does exist. That being said the third option represents the actual loading mechanism of direct fecal deposition and, in conjunction with riparian buffer simulation, could be a mechanistic way to represent the actual loading pathways and BMP applications over the efficiency or land use change options.

Analyses Conducted by PSG

In an effort to see if GIS analysis could provide better estimates of the extent of riparian pasture an analysis was conducted using the NHD-Plus stream network data layer and the 2011 NLCD to estimate the potential extent of pasture and stream intersections across the watershed. Table 1 illustrates the results of that analysis and comparison to existing phase 5 WSM acreage of pasture and degraded riparian pasture land uses. Based on this analysis the overall acreage determined is similar to that currently used in the phase 5 WSM. It is therefore likely that choosing option 2, simulation as a land use change, would retain the characteristics of the phase 5 model.

Table 1 Pasture, Degraded Riparian Pasture, and GIS Statistics

2010 No-Action	Phase 5 Pasture	Phase 5 Pasture	Degraded Riparian Pasture (DRP)	DRP	DRP	GIS
Jurisdiction	Acres	Percent in CB watershed	Acres	Percent in CB watershed	Percent of Pasture	Acres
DC	0	0.00%	0	0.00%	0.00%	NA
DE	5,837	0.25%	0	0.00%	0.00%	NA
MD	202,375	8.74%	806	0.70%	0.40%	NA
NY	180,302	7.78%	12,624	10.95%	7.00%	NA
PA	517,173	22.33%	16,617	14.41%	3.21%	NA
VA	1,162,126	50.17%	61,165	53.03%	5.26%	NA
WV	248,504	10.73%	24,124	20.92%	9.71%	NA
All	2,316,317	100.00%	115,336	100.00%	4.98%	122,743

An evaluation of several dozen local scale bacteria TMDLs from Virginia resulted in the selection of 7 TMDL areas where direct deposition from both beef and dairy cattle was characterized. The key factors common between these TMDL studies necessary for the PSG's effort are time spent by animal type in the stream access area, pasture, and confinement or loafing areas. The stream access area was uniformly considered to be pasture acreage adjacent to the stream. These times varied by month with less time spent in the access area during winter months and more during summer months. Dairy cattle were estimated to be primarily in confinement (loafing, feeding, milking areas) with relatively minor time spent in the access areas or pastures as compared to beef cattle. There were differences between TMDL developers on the percentage of fecal deposits directly deposited to the stream per time spent in the access area. For example some assumed that for the time spent in the access area that 100 percent of that fraction of the daily fecal production was directly deposited in the stream. For example if a beef cow spent 1 hour per day in the access area it was assumed that $1/24^{th}$ of the daily fecal production was deposited in that zone. Other developers assumed a smaller percentage. The basis for this particular assumption was not documented in the TMDL reports and may have been used as a calibration parameter by the modelers.

Based on the Virginia TMDL analysis a spreadsheet was developed using the Virginia specific factors for time in the access area, pasture or confinement, and percentage of daily production directly deposited to the streams (90%) by animal type and each county across the Bay watershed. The 2012 NASS Census of Agriculture was used to derive the county specific animal numbers. This analysis was conducted to gauge the relative loadings differences the proposed direct deposition method would produce as compared to the phase 5 WSM modeled degraded riparian pasture loadings. From the 2012 Census data beef, horses, sheep and lambs, other cattle, and angora goats had the Virginia factors for beef cattle applied with dairy cattle and milk goats getting the Virginia dairy factors applied. These factors by animal type were applied to every county across all states in the watershed. For this comparison the 2010 no-action loadings scenario was used so that the impact of other BMPs would be eliminated. This analysis was presented to the PSG for comment in late January 2015. Comments from the PSG membership on this analysis resulted in modifications to eliminate direct deposited loadings from sheep and lambs, angora goats, and milk goats and recommended these animal types load only to pasture acres and not directly to streams. The experts on the PSG knowledgeable on livestock behavior by animal type made this recommendation since these animals rarely spend time in the stream and spend the vast preponderance of time pastured. It was also determined to collect Pennsylvania and New York (if available) specific factors since grass species and management of livestock including confinement schedules for the northern portion of the watershed are significantly different than in Virginia. Since it was thought the key factors needed for this effort were not available from the remaining Bay jurisdictions it was decided that the Virginia factors would be applied to the Coastal Plain of Maryland and to Delaware. And the Pennsylvania specific factors would be applied to the remaining hydrogeomorphic regions of Maryland, and all of West Virginia's Bay draining areas and if New York data could not be found to New York as well. Table 2 provides the Virginia and Pennsylvania specific factors used for the estimate on magnitude of loadings. Note that for the 2010 no-action scenario phase 5.3.2 Virginia and Pennsylvania constitute approximately 73% of all pasture acres in the modeling domain.

Insert Table 2 here:

Table 3 illustrates the results of this analysis as compared to the phase 5 WSM 2010 no-action scenario. This analysis indicates the same order of magnitude of loadings for TN and TP by simulating direct deposition verses the degraded riparian pasture loadings.

Table 3: VA Factors only revise with PA

Direct Deposition			2010 No-Action DRP		
TN	TP	TSED	TN	TP	TSED

Jurisdiction	lbs/year	lbs/year	tons/year	lbs/year	lbs/year	tons/year
DC	0	0	0	0	0	0
DE	204,997	48,722	0	0	0	0
MD	1,391,376	330,375	0	103,581	10,360	1,825
NY	3,107,746	702,585	0	843,536	123,981	16,755
PA	7,286,163	1,672,429	0	3,102,909	250,898	32,988
VA	4,733,619	1,211,210	0	6,028,494	869,766	374,307
WV	681,188	178,077	0	2,764,962	315,512	113,581
All	17,405,090	4,143,398	0	12,843,482	1,570,517	539,456

Pasture Subgroup Recommendations

It is the opinion of the Pasture Subgroup that **the preferred method to simulate livestock loadings and the benefit of exclusion fencing is to simulate the direct deposition of fecal matter and associated nutrients to the stream network in the phase 6 WSM**. This eliminates the need to estimate an extent of degraded riparian pasture or to estimate the loadings from that land use neither of which can be readily determined or justified. This should eliminate or significantly reduce the currently experienced cut-off of progress implementation reported since exclusion fencing would be applied against the available pasture acres and animals in the segment exclusion fencing implementation is reported. It provides a more realistic simulation of the actual loadings mechanisms that exist from pasture and livestock with unrestricted access to streams. The loadings and benefits of exclusion are tied directly to the numbers and types of animals excluded including reductions associated with buffer establishment. It can be readily implemented in the phase 6 WSM with all needed assumptions clearly documented. It will result in a different attribution of loadings in the phase 6 WSM as compared to the phase 5 WSM. However, it is the Pasture Subgroups opinion that this is an improvement in the simulation because the animal numbers by county are considered more reliable than estimates of a land use that cannot be derived via remote sensing efforts or land use loadings that cannot be justified by the available literature.

NEIEN Reporting using Direct Livestock Loadings

To report and receive credit in the phase 6 WSM for livestock exclusion fencing states will have two options: direct reporting of excluded livestock or reporting of fenced length combined with a default livestock per unit of fencing. Currently both Pennsylvania and Virginia collect the numbers and animals types excluded for each installation of exclusion fencing. Since 2010 Virginia has collected the length of streambank protected, average buffer width, primary, secondary, and tertiary animal type, animal numbers, and animal units excluded. The NEIEN schema would need to be modified to allow reporting of the selected data elements. If a jurisdiction does not collect this specific type of information it is proposed that an average animal unit of livestock excluded per unit of fencing or streambank protected be derived from the Pennsylvania and Virginia data and applied to the reported linear feet of exclusion fencing reported. This method would also be applied to the historic data used for calibration since the pertinent data was not collected throughout the calibration period for phase 6 WSM.

Crediting Exclusion Fencing in Phase 6

If the reporting jurisdiction provides the animal type and numbers excluded along with the length of streambank protected or fencing installed. The corresponding loadings as calculated per animal would be eliminated from being directly input to the simulated stream network and those loadings would be applied as input to the upland pasture acres left after accounting for any buffer created by the exclusion fencing. This loading to pasture would be subject to reduction through watershed processes in accordance with the phase 6 simulation methods. The benefits of buffers are documented in the Agricultural Buffer Expert Panel report recently approved by the WQGIT. Consistent with that report, areported buffer width of 35 feet or greater would generate a land use change converting the impacted pasture acres to unfertilized grass or a riparian grass or herbaceous buffer. A riparian forested buffer established via the planting of trees between the fence and stream would receive the benefit of the riparian forested buffer BMP. If a partner jurisdiction were not able to document a minimum of 35 setback it would be credited assuming a 10 foot setback and the impacted acreage would only get the land use change of pasture to unfertilized grass for that area (10’ times length of streambank protected). The upland benefit applied to buffers would not be eligible in this particular situation. As stated above the number and type of livestock excluded would be reported or approximated and the direct loadings reductions would be identical to installations of exclusion fencing that do create a riparian buffer.

Appendix C. Establishing Yield Goals for Major Crops

Establishing Yield Goals by Crop, County and Year

Raw Datasets:

1) “Yearly NASS” yields for major crops
2) “Ag Census” yields
3) Scenario Builder “Max Yields”

Rule 1: Remove Outliers

1) Calculate Watershed-wide MEDIAN for crop for year for “Yearly NASS” data.
2) Calculate ABSOLUTE DEVIATION FROM MEDIAN as: Yearly County Crop Yield – Watershed-wide MEDIAN.
3) Calculate MEDIAN OF ABSOLUTE DEVIATIONS as: median of results from step 2.
4) Multiply result of step 3 by “4” to determine the MEDIAN OF ABSOLUTE DEVIATION OUTLIER CONSTANT
5) Add result of step 4 to result of step 1 to establish UPPER LIMIT.
6) Subtract result of step 4 from result of step 1 to establish LOWER LIMIT.
7) Remove all yields that do not fall within the range of UPPER LIMIT and LOWER LIMIT, making them NULL. Result becomes “Yearly NASS Revised.”
8) Repeat process for “Ag Census” data. Result becomes “Ag Census Revised.”

Rule 2: Populate with Yearly NASS yields

1) For each county, crop and year, calculate the average of the highest 3 out of the previous 5 values from “Yearly NASS Revised.”
2) If NULL, make equal to most recent non-null value. For example, 1985 is NULL because there are not 3 previous values. Make 1985 equal 1988 where a non-NULL value exists.
3) If NULL, make equal to the average yearly yield across Scenario Builder Growth Region. For example, 1990 is NULL for Somerset County, MD. Make 1990 equal average 1990 yield for Scenario Builder Growth Region MD_2.
4) If NULL, make equal to the average yield over all records for all years for the Scenario Builder Growth Region. For example, 1990 is NULL for ALL counties in Scenario Builder Growth Region MD_2, and no other data exists for Somerset County, so steps 1, 2 and 3 will not provide results. However, data exists for other counties within the Growth Region for other years. Make 1990 for Somerset County equal the average yield for all counties in the Growth Region over all years.
5) Result of above steps becomes “Yearly NASS Final.”

Rule 3: Populate with Ag Census Yields

1) Repeat steps from Rule 2 above for “Ag Census Revised.”
2) If NULL, make equal to the average of all available yields from “Ag Census Revised.”
3) Result of steps becomes “Ag Census Final.”

Rule 4: Combine Yearly NASS Final with Ag Census Final

1) If value exists in “Yearly NASS Final,” use value.
2) If NULL, use existing values from “Ag Census Final.”
3) Result of above steps becomes “USDA Combined Yields.”

Rule 5: Calculate Ratio of USDA Combined Yields to Max Yields

1) For each county, crop and year, calculate the MAX YIELD RATIO from “USDA Combined Yields” to the value from “Max Yield.”
2) Calculate a single COUNTY AVERAGE MAX YIELD RATIO over all crops for a single county from the results of step 1.
3) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to most recent non-null value.
4) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for that year.
5) If NULL, make equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for all years.
6) If NULL, make equal to 1.
7) Result of steps becomes MAX YIELD RATIO.

Rule 6: Calculate Revised Max Yields

1) Multiply Max Yield values by MAX YIELD RATIO for each county, crop and year.
2) Result of steps becomes “Revised Max Yields.

Rule 7: Combine Revised Max Yields with USDA Combined Yields

1) If value exists in “USDA Combined Yields,” use value.
2) If NULL, use values from “Revised Max Yields.”
3) Result becomes “Combined Yields.”

Rule 8: Remove and Replace Outliers

1) Repeat steps from Rule 1 using “Combined Yields.”
2) If NULL, make equal to non-null value from “Combined Yields.”
3) If NULL, make equal to the average of yields for all counties within Scenario Builder Growth Region for that year.
4) If NULL, make equal to average of yields across all counties within Scenario Builder Growth Region for all years.
5) Result becomes “Final Yield Goals.”

1984 a = 1985

Appendix D. Crop Cover and Detached Soil Detailed Methods

Documentation of Scenario Builder Crop Cover and Detached Sediment Storage

10/12/2015

This documentation describes the data and calculation process used to generate the crop cover and detached sediment storage (DETS) files generated by Scenario Builder.

Development of Cover and DETS files

Scenario Builder outputs include crop cover and detached sediment storage (DETS). Crop cover is the area of land available to be eroded. This area is the fraction of residue or canopy cover, whichever is greatest. DETS is the difference in sediment eroded due to plowing. The difference in tons of sediment eroded with and without plowing was determined by subtracting the difference between RUSLE2 scenarios that included plowing and those that did not include any plowing other than plowing associated with planting. DETS is calculated for row crops, not pasture or hay.

Where there were missing data for a particular crop in a particular growing region, values from the nearest growing region or most similar crop were used. The fruit and vegetable cover data was generalized among similar plants according to viney or bushy plant character. Turf grass (urban lawns) did not have a cover value generated from RUSLE2 and 0.95 was used for the entire year. For cultivated summer fallow cropland and idle cropland, a consistent value of 0.05 was used. Failed crops were assigned a consistent value of 0.2. The crop cover data are bound by zero and 95%.

The residue and canopy cover fractions were generated using USDA's Revised Universal Soil Loss Equation, Version 2 (RUSLE2, Renard 1997). RUSLE2 and Scenario Builder are not linked. Rather the RUSLE2 data are in look up tables and Scenario Builder uses these data to create crop cover and DETS based on the acres of each crop. The crop cover and DETS files are generated with values for a monthly time scale, county geographic scale, and by crops. The data are generalized to land use prior to input to the Watershed Model.

Plant/harvest dates and other farming decisions such as double cropping, rotations or continuous planting, as well as representative field conditions such as erodibility, climate regime, and field slopes and lengths were all incorporated. These parameters were determined through existing data from Scenario Builder and discussions with the NRCS conservation staff in each state. The NRCS Chesapeake Bay Coordinator, Timothy Garcia, facilitated contacts with each state to answer questions on typical farming practices that were used as inputs to RUSLE2. The RUSLE2 data were generated with no BMPs, since BMPs are represented separately in Scenario Builder. Tetra Tech performed nearly 250 scenarios in the RUSLE2 program to support this effort. These RUSLE2 inputs are discussed in the following sections.

Development of RUSLE2 Input Selections

RUSLE2 scenarios were developed for ten different "Crop Types" (including pasture/grazing land uses) within each of the 7 Crop Management Zones (CMZ) of the CBWS (Figure 1). To ensure that major crop types were represented, the acres of crop types most prevalent in the CBWS were evaluated. Nine of the top 27 crop types (ranked by % of all agriculture in CBWS) were selected for subsequent RUSLE2 scenarios:

Pasture / Range (15.3% of agriculture in CBWS)

"Corn for Grain Harvested Area" (10.2%)

“Other managed hay Harvested Area” (9.4%)

“Soybeans for beans Harvested Area” (8.1%)

“Corn for silage or greenchop Harvested Area” (3.7%)

“Alfalfa Hay Harvested Area” (3.1%)

Wheat for Grain Harvested Area” (2.2%)

“Cotton/Potato Harvested Area” (0.2/0.1%, respectively

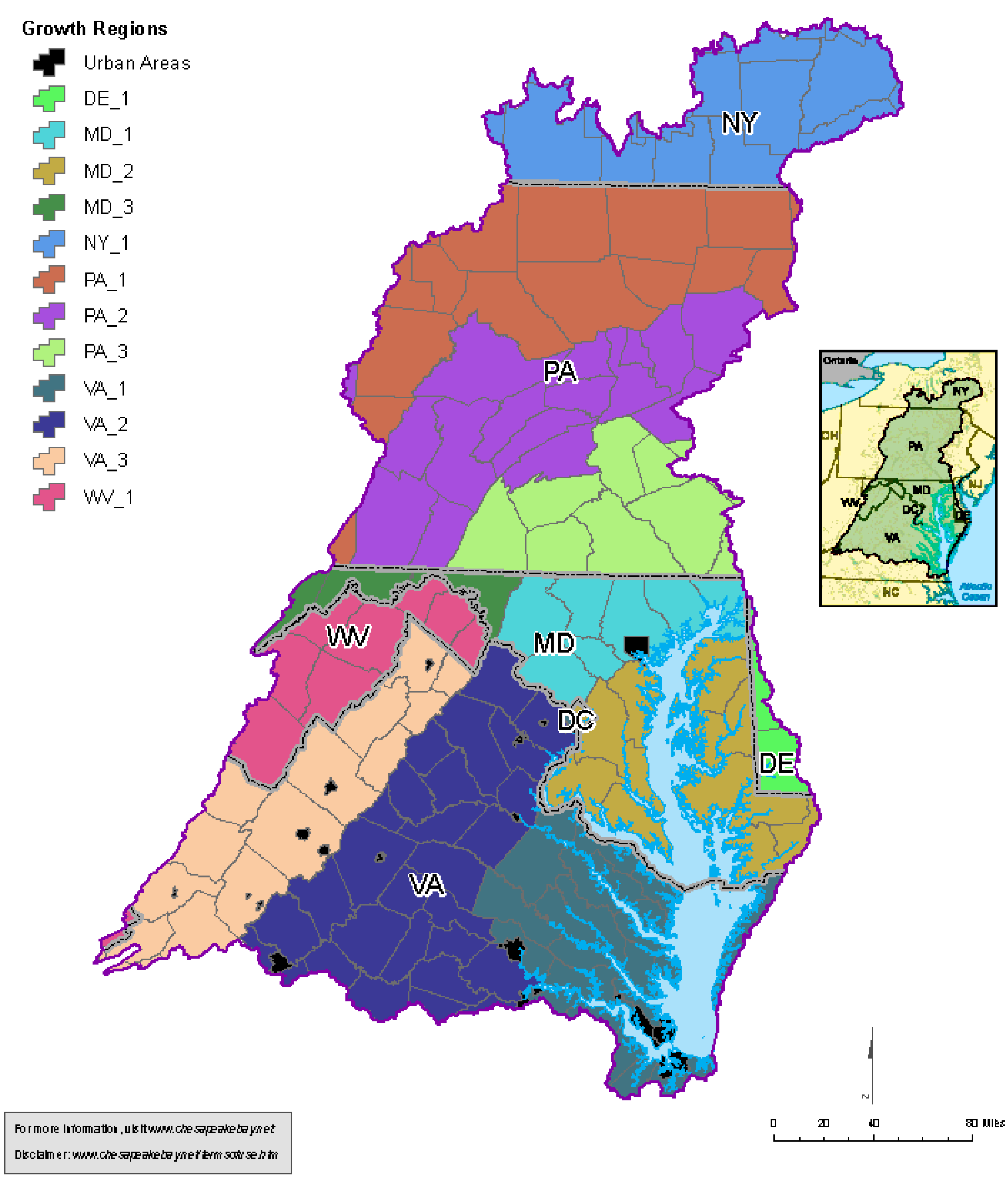
“Snap Beans Harvested Area” (0.1%)

These crops were modeled for a representative county in each CMZ. The CMZ was mapped to the counties in the Chesapeake Bay Watershed. Groups of counties are classified by growth regions. Scenario Builder Growth Region MD 2 was divided into two areas—one east of the Bay and one west of the Bay. Kent and Queen Anne’s County in Maryland use the same data as MD 1. CMZ 4.1 was used to generate the data for NY 1 and PA 1; CMZ 65.0 for Pa 2 and MD 3; CMZ 66.0 for MD 2 West and VA 2; CMZ 65.0 for MD 1 and PA 3; CMZ 62.0 for WV 1; CMZ 59.0 for MD 2 east and DE 1; CMZ 67.0 for VA 1; and CMZ 64.0 for VA 3.

Scenario Builder Growth Regions

Chesapeake Bay Watershed

Chesapeake Bay Program
A Watershed Partnership



Created by JW, 12/2/08 UTM Zone 18N, NAD 83

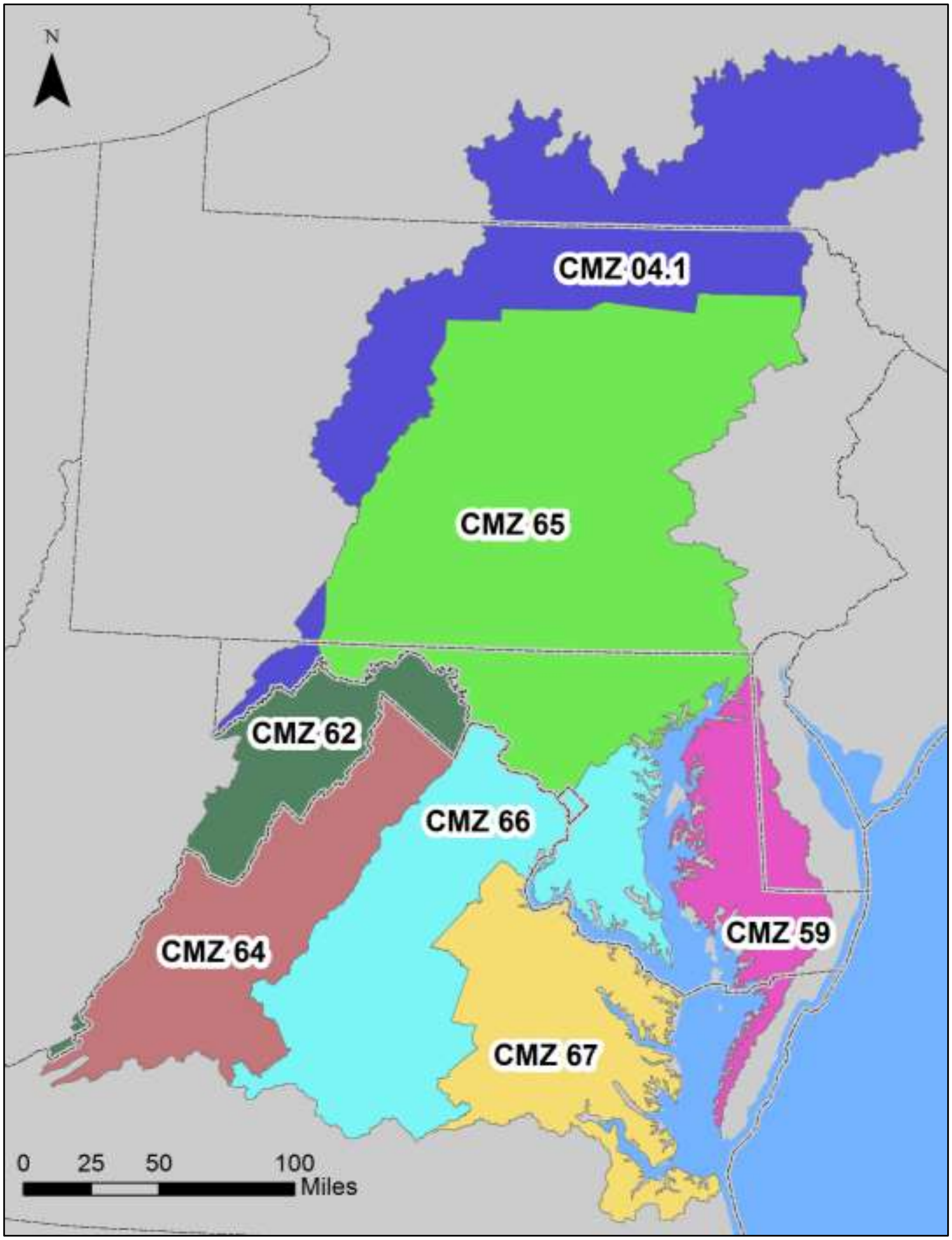


Figure 1. Scenario Builder Growth Regions (first map) Crop Management Zones in CBWS (second map)

All nine selected major crop types listed above were used to develop RUSLE2 scenarios as continuous, “non-double cropped” systems. Because some of these crop types (Corn, Soybean, Wheat) are often under double-cropping systems (DC) a tenth RUSLE2 scenario type was run in select CMZs and states. A comprehensive list of every crop type modeled with RUSLE2 can be found in Table 1.

The following sections discuss the different inputs required for successful RUSLE2 modeling scenarios as well as the specific input values selected through consultation with the Chesapeake Bay Program (CBP) and state NRCS conservation staff. The NRCS staff consulted included:

Chesapeake Bay Timothy Garcia, Chesapeake Bay Watershd Coordinator

Delaware Jayme Arthurs and Phillip King

Maryland Christy Brown

West Virginia Isaac Wolford

Pennsylvania Mark Goodson and Joe Kraft

New York Dale Gates

Virginia Chris Lawrence

Table 1. List of All Crop Cover Types by State/CMZ Combinations Modeled in RUSLE2

	State/CMZ Combination											
	4.1			59		62	64	65		66		67
Crop Cover Type	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	x	x	x	x	x	x	x	x	x	x	x	x
Broccoli, spring						x						
Cabbage		x										
Corn & Wheat			x		x		x	x	x	x	x	x
Corn for Grain	x	x	x	x	x	x	x	x	x	x	x	x
Corn for Silage	x	x	x	x	x	x	x	x	x	x	x	x
Cucumber	x		x	x	x			x	x	x		
Other managed hay Harvested Area	x	x	x	x	x	x	x	x	x	x	x	x
Pasture / Range	x	x	x	x	x	x	x	x	x	x	x	x
Potato	x	x		x	x	x	x	x		x	x	x
Snap Beans				x								
Soybean		x	x	x	x	x	x	x	x	x	x	x
Soybean & Wheat				x	x	x	x	x	x	x	x	x
Tomato							x				x	x
Watermelon	x		x		x			x	x	x		
Wheat for Grain		x	x	x	x	x	x	x	x	x	x	x
Soybean Wheat - Relay			x									

RUSLE2 Factor Selection

There are 6 major factors used in RUSLE2 (R, K, L, S, C, and P). RUSLE2 also has many subfactors under some of these major factors (e.g., C factor is composed of PLU, CC, SC, SR, and SM subfactors). Many of these subfactors are predetermined at daily time steps when selecting RUSLE2 inputs. For example, by selecting a particular county and state, an R factor is calculated on a daily time step for that specific location in the CBWS. The remainder of this section explains the RUSLE2 factors and how certain parameters were selected.

R Factor

The rainfall and runoff factor (R) is based on the erosivity of local rainfall. Erosivity is estimated from the multiplication of two factors for each time step: 1) expected total storm energy (E), and 2) the maximum 30-minute intensity (I_{30}). RUSLE2 has numerous databases from which it accesses this information for each county selected by the user. One representative county for each crop type, for each CMZ was modeled. The counties selected based on communication with state NRCS personnel is shown in Figure 2.

Figure 2. Counties in CBWS Selected for RUSLE2 R-factor Parameter Inputs

C Factor

As previously mentioned, the C (cover) factor is composed of several subfactors. For the purposes of this task the following information was solicited from state NRCS personnel for each of the selected crop types for each CMZ:

Specific Crop Type

Start Date of Planting/Grazing

Planting Technique (when applicable)

Start Date of Harvesting (or, End Date of Grazing)

Harvesting/Grazing Technique

Information for Items 1, 2 and 3 from above can be found in Table 2, where in most cases the day is the 1st of the month. For those Start and End (i.e., Planting and Grazing/Harvesting) dates that did not fall on the first of the month the closest "first of the month" was selected for simpler display purposes in Table 2. For multi-year scenarios (e.g., Alfalfa Hay) that have varying harvest dates the median harvest month is provided in Table 2. Finally, the start date of a winter cover of wheat (e.g., Corn & Wheat) is the essentially the same day of the summer cover crop harvest, and the winter cover's end date is the start date of the summer cover crop's date range.

Table 2. Start and End (Plant and Harvest/Graze) Dates - All Modeled Crop Cover Types

Crop Cover Type	State/CMZ combination										
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Oct - Aug	Apr - Oct	Apr - Sep	Apr - Oct	Oct - Aug	Oct - Aug
Broccoli, Spring[3]						Apr - Jul						
Cabbage1		May - Nov										
Corn & Wheat1			May - Oct		May - Oct		May - Oct	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct
Corn for Grain1	May - Oct	May - Oct	May - Oct	May - Oct	Apr - Oct	Apr - Oct	May - Oct	Apr - Oct	May - Oct	Apr - Oct	May - Oct	May - Oct
Corn for Silage1	May - Oct	May - Sep	May - Sep	May - Sep	Apr - Sep	Apr - Aug	May - Sep	Apr - Sep	May - Sep	Apr - Sep	May - Sep	May - Sep
Cucumber1	May - Nov		May - Nov	Apr - Aug	Apr - Aug			Apr - Aug	May - Nov	Apr - Aug		

[3] RUSLE2 model scenarios represent the same crop types(s) and practice(s) year after year.

Crop Cover Type	State/CMZ combination											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Other Managed Hay Harvested Area	May - Sep	May - Oct	May - Oct	Apr - Oct	Apr - Oct	Apr - Aug	May - Sep**	Apr - Oct	Apr - Oct	Apr - Oct	May - Sep**	May - Sep**
Pasture / Range	May - Sep	May - Oct	May - Oct	Apr - Oct	Apr - Oct	Apr - Aug	Mar - Nov**	Apr - Oct	Apr - Oct	Apr - Oct	Mar - Nov**	Mar - Nov**
Potato1	Apr - Sep	Apr - Sep		Mar - Jun	Mar - Jun	May - Sep	Mar - Jul	Mar - Jun		Mar - Jun	Mar - Jul	Mar - Jul
Snap Beans1				Apr - Aug								
Soybean1		Jun - Oct	Jun - Oct	May - Oct	May - Oct	Jul - Oct	Jun - Nov	May - Oct	May - Oct	May - Oct	Jun – Nov	Jun - Nov
Soybean & Wheat1				May - Oct	May - Oct	May - Sep	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct
Tomato1							May - Aug				May - Aug	May - Aug
Watermelon1	May - Aug		May - Aug		Apr - Nov			Apr - Nov	May - Aug	Apr - Nov		
Wheat for Grain1		Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jun	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jun	Oct - Jun
Soybean Wheat - Relay1			Jun - Oct									

** no direct seeding/planting occurs; start date is for grazing initiation.

K Factor

The K factor indexes soil erodibility. State NRCS personnel were asked to provide a soil series that would best represent the soil types on which agricultural and pastoral land uses are found within in each CMZ and state combination. RUSLE2 allows the user to select the soil series from publicly-available state level databases. These databases were obtained and accessed during RUSLE2 scenario development and employed along with the information found in Table 3.

Table 3. Soil Series Recommended by State NRCS Personnel

CMZ	State	Representative Soil Series/Type

CMZ	State	Representative Soil Series/Type
4.1	MD	Calvin-Gilpin-Ungers channery loams, 10 to 20 percent slopes, moderately eroded\Gilpin Channery loam 30%
4.1	NY	Mardin channery silt loam, 9 to 15 percent slopes, moderately deep\Mardin Channery silt loam moderately deep 75%
4.1	PA	Alvira silt loam, 8 to 15 percent slopes\Alvira Silt loam 80%
59	DE	Mullica mucky sandy loam, 0 to 2 percent slopes\Mullica Mucky sandy loam drained 50%
59	MD	Hambrook sandy loam, 0 to 2 percent slopes\Hambrook Sandy loam 80%
62	WV	Monongahela Silt Loam, 3 to 8 percent slopes\Monongahela silt loam 100%
64	VA	Craigsville cobbly sandy loam\Craigsville Cobbly sandy loam 85%
65	MD	Hagerstown loam, 3 to 8 percent slopes\Hagerstown Loam 85%
65	PA	Alvira silt loam, 8 to 15 percent slopes\Alvira Silt loam 80%
66	MD	Collington-Wist complex, 0 to 2 percent slopes\Collington Fine sandy loam 60%
66	VA	Appling fine sandy loam, 2 to 7 percent slopes\Appling Fine sandy loam 90%
67	VA	Emporia sandy loam, 2 to 6 percent slopes\Emporia Sandy loam 90%

P Factor

The P (practice) factor is used to account for potential management actions that can be taken to reduce or minimize soil erosion from wind and rain-induced detachment. It is often associated with different types and levels of tillage; however, there are many other actions that can be taken.

Start Date of High Till action, where multiple dates were provided for double-cropping scenarios

Type of High Till management action

These data were taken from the plant and harvest date used in Scenario Builder except in Virginia and West Virginia where state NRCS personnel provided RUSLE2 databases. The number of unique dates and times of the different tillage practices involved with the various RUSLE2 scenarios is not reproduced here but is accessible via a RUSLE2 database provided along with the final RUSLE2 outputs.

P Factor – "No Plow" Scenario for developing DETS

A second round of RUSLE2 scenarios was modeled for all those crop scenarios that had plowing, disking, or harrowing as a separate management event from the planting/seeding management event. The majority of modeled cover crops were run under this "no plow" scenario where all separate management practices involving plowing, disking, or harrowing were removed from the management file. The differences between this "no plow" scenario and the High Till scenario for each crop is used to estimate 'detached sediment storage' on the landscape under different management scenarios. This was done for all crop types except for the following (as there was no separate management practice of such types):

"Other Managed Hay Harvested Area" in DE-CMZ59 and VA – all CMZs (64, 66, and 67)

"Soybean & Wheat" in DE-CMZ59 and MD-CMZ66

"Alfalfa Hay Harvested Area" in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

"Alfalfa Hay Harvested Area" in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

"Pasture / Range" in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

L and S Factors

The field slope length (L factor, expressed as meters) and field slope (S factor, expressed as a percent) are used to represent landscape characteristics. One value for each of these two factors is required for each crop type within each CMZ/State combination for RUSLE2 model execution (Table 4). Values were provided by all states with the exception of Pennsylvania (PA). For PA, percent slope numbers in neighboring states and CMZ's, and a relationship between percent slope and slope length provided by PA NRCS (see Appendix A) were used as a proxy for Crop Cover types within PA (

Table 5).

Table 4. Recommended Slope Length (L factor) and Slope (S factor) Inputs to RUSLE2

CMZ	State	Representative Slope Length (L factor, meters)	Representative Slope (S factor, percent)
4.1	MD	150	3
	NY	100 (Alfalfa, Hay, Pasture); 150 (Cabbage, Potato); 200 (Corn, Soybeans, Wheat)	10 (Alfalfa, Hay, Pasture); 5.5 (Cabbage, Potato, Corn, Soybeans, Wheat)
	PA[4]	120 (Alfalfa, Hay, Pasture); 160 (Corn, Soybeans, Wheat); 190 (Cucumber, Watermelon)	10 (Alfalfa, Hay, Pasture); 5.5 (Corn, Soybeans, Wheat); 3.5 (Cucumber, Watermelon)
59	DE	150	1
	MD	150	2.5
62	WV	150	6
64	VA	130	8
65	MD	150	4
	PA2	140 (Alfalfa, Hay, Pasture); 160 (Corn, Soybeans, Wheat); 190 (Cucumber, Watermelon)	7 (Alfalfa, Hay, Pasture); 5.5 (Corn, Soybeans, Wheat); 3.5 (Cucumber, Watermelon)
66	MD	150	1
	VA	160	4
67	VA	200	2

Table 5. Values Recommended by Tetra Tech for L and S Factor Inputs to RUSLE2 for PA

	CMZ 4.1			CMZ 65	
Cover Crop Type	MD	NY	PA (recommended)	MD	PA (recommended)
Alfalfa Hay Harvested Area	3	10	10	4	7
Corn & Wheat	-	-	5.5	4	5.5
Corn for Grain	3	5.5	5.5	4	5.5

[44] See next table for how L and S factor inputs were determined for PA.

Corn for Silage	3	5.5	5.5	4	5.5
Cucumber	3	-	3.5	4	3.5
Other managed hay Harvested Area	3	10	10	4	7
Pasture / Range	3	10	10	4	7
Soybean	-	5.5	5.5	4	5.5
Soybean & Wheat	-	-	-	4	5.5
Watermelon	3	-	3.5	4	3.5
Wheat for Grain	-	5.5	5.5	4	5.5

RUSLE2 Outputs

Outputs from each RUSLE2 scenario were extracted into Microsoft Excel for post-processing. Daily outputs were summarized (averaged) to monthly-scale outputs for subsequent work in Scenario Builder. The following parameters were extracted and summarized:

From RUSLE2's "Erosion by day" tab, "Slope daily erosion values" table:

detach t/ac/yr

slope sed del rate t/ac/yr

slope soil loss rate t/ac/yr

slope soil loss for cons plan t/ac/yr

From RUSLE2's "C subfactor by day" tab and table:

PLU, fraction

Res. surf. cover, fraction

Live surf. cover, %

Rock cover, %

Net surf. cover, fraction

SC, fraction

SC top, fraction

SC bottom, fraction

CC, fraction

Roughness, mm

SR, fraction

SM, fraction

C factor, fraction

C factor top, fraction

C factor bottom, fraction

EI, %

(SEG_SIM_DAY_SURF_COVER_EFF_BOTTOM) slope soil loss for cons plan t/ac/yr

From RUSLE2's "Extra C, L, crit. Length values" tab and table:

Net Canopy cover %

Tables 6 through14 provide annual summary statistics of the "No Plow" scenario monthly outputs provided for the subsequent work. The full data set of all RUSLE2 monthly outputs post-processed in Excel was used to develop the crop cover and DETS data used by Scenario Builder.

Table 6. Annual Average Erosion Rate (lbs/ac/year) – State/CMZ Combinations

	State											
	4.1			59		62	64	65		66		67
Crop Cover Type	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	536	612	2,156	282	3,636	1,931	168	2,528	4,868	78	255	214
Broccoli, spring						2,491						
Cabbage		3,330										
Corn & Wheat			2,313		1,323		5,400	3,078	2,320	275	1,343	955
Corn for Grain	457	352	1,006	1,638	4,970	707	508	748	1,031	223	687	637
Corn for Silage	3,541	4,570	11,103	844	11,397	7,562	6,467	5,275	10,496	1,063	6,574	4,499
Cucumber	8,745		6,777	2,676	17,975			18,595	7,538	459		
Other managed hay Harvested Area	10	1,595	397	367	3,101	1,931	45	162	363	613	49	47
Pasture / Range	158	333	939	551	16	1,204	104	8	76	3	125	104
Potato	20,337	16,222		3,085	20,603	24,111	15,161	41,907		6,743	15,097	18,392
Snap Beans				3,127								

	State											
	4.1			59		62	64	65		66		67
Crop Cover Type	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Soybean		5,339	9,168	638	3,696	6,096	1,533	2,219	3,394	532	1,763	1,474
Soybean & Wheat				206	2,513	1,951	1,230	2,085	3,452	1,051	1,732	1,312
Tomato							11,942				11,238	13,755
Watermelon	1,614		9,797		7,181			6,425	9,797	1,214		
Wheat for Grain		7,064	13,064	301	2,423	2,103	153	2,186	3,615	483	235	223
Soybean Wheat - Relay			2,061									

Table 7. Annual Average Erosion Rate (lbs/ac/year) – State Scale

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	282	1,694	612	3,512	212	1,931
Broccoli, spring						2,491
Cabbage			3,330			
Corn & Wheat		1,559		2,316	2,566	
Corn for Grain	1,638	1,600	352	1,019	611	707
Corn for Silage	844	5,319	4,570	10,800	5,847	7,562
Cucumber	2,676	11,444		7,158		
Other managed hay Harvested Area	367	972	1,595	380	47	1,931
Pasture / Range	551	46	333	507	111	1,204

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Potato	3,085	22,397	16,222		16,217	24,111
Snap Beans	3,127					
Soybean	638	2,149	5,339	6,281	1,590	6,096
Soybean & Wheat	206	1,883		3,452	1,424	1,951
Tomato					12,312	
Watermelon		4,109		9,797		
Wheat for Grain	301	1,697	7,064	8,340	204	2,103
Soybean Wheat - Relay				2,061		

Table 8. Annual Average Erosion Rate (lbs/ac/year) – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	1,101	1,959	1,931	168	3,698	166	214
Broccoli, spring			2,491				
Cabbage	3,330						
Corn & Wheat	2,313	1,323		5,400	2,699	809	955
Corn for Grain	605	3,304	707	508	890	455	637
Corn for Silage	6,405	6,120	7,562	6,467	7,886	3,818	4,499
Cucumber	7,761	10,325			13,067	459	
Other managed hay Harvested Area	899	1,734	1,931	45	262	331	47
Pasture / Range							

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
	477	284	1,204	104	42	64	104
Potato	18,280	11,844	24,111	15,161	41,907	10,920	18,392
Snap Beans		3,127					
Soybean	7,254	2,167	6,096	1,533	2,806	1,147	1,474
Soybean & Wheat		1,359	1,951	1,230	2,768	1,391	1,312
Tomato				11,942		11,238	13,755
Watermelon	5,706	7,181			8,111	1,214	
Wheat for Grain	10,064	1,362	2,103	153	2,901	359	223
Soybean Wheat - Relay	2,061						

Table 9. Annual Average Canopy Cover Percentages – State/CMZ Combinations

Crop Cover Type	State											
	4.1			59		62	64	65		66		67
	MD	**NY**	**PA**	**DE**	**MD**	**WV**	**VA**	**MD**	**PA**	**MD**	**VA**	**VA**
Alfalfa Hay Harvested Area	55.9	56.5	56.6	53.7	38.7	41.4	40.8	35.8	36.4	38.1	38.2	38.7
Broccoli, spring						7.68						
Cabbage		35.1										
Corn & Wheat			48.6		48.9		12	21.5	48.9	48.1	48.2	48.1
Corn for Grain	28.3	28.3	28.1	28.9	34.7	32.2	25.6	34.1	28.1	34.1	30.2	29.3
Corn for Silage	27.2	19.8	19.6	44.1	27.3	22.8	14.4	27.3	19.8	27.3	16.2	15.3
Cucumber	30		62.8	19.4	19.4			19.4	32	63.3		

Crop Cover Type	State											
	4.1			59		62	64	65		66		67
Other managed hay Harvested Area	81.1	51.8	87.3	37.4	38.1	41.4	80	87.1	87.2	38.2	79	79.5
Pasture / Range	69.4	60.9	90.8	38.2	79	42.2	81.2	74.6	83.8	74.3	81.2	81.2
Potato	20.7	20.7		9.9	9.47	15	12.9	7.67		8.06	12.9	12.9
Snap Beans				12.3								
Soybean		39.7	37	38.6	38.1	41.1	34.3	38.5	39.7	37.6	35	33.5
Soybean & Wheat				47.2	51.6	51.2	44	52.2	52.8	48.6	44	44.1
Tomato							8.42				8.54	8.42
Watermelon	85.2		49.1		49.3			49.3	49.1	49.3		
Wheat for Grain		36.2	36.2	39	38.4	35.2	44.1	36.2	39	39	38.6	33.9
Soybean Wheat - Relay			58.9									

Table 10. Annual Average Canopy Cover Percentages – State Scale

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	53.7	42.1	56.5	46.5	39.3	41.4
Broccoli, spring						7.68
Cabbage			35.1			
Corn & Wheat		39.5		48.7	36.1	
Corn for Grain	28.9	32.8	28.3	28.1	28.4	32.2
Corn for Silage	44.1	27.3	19.8	19.7	15.3	22.8
Cucumber	19.4	33		47.4		
Other managed hay Harvested Area	37.4	61.2	51.8	87.2	79.5	41.4
Pasture / Range	38.2	74.3	60.9	87.3	81.2	42.2
Potato	9.9	11.5	20.7		12.9	15

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Snap Beans	12.3					
Soybean	38.6	38.1	39.7	38.4	34.3	41.1
Soybean & Wheat	47.2	50.8		52.8	44	51.2
Tomato					8.46	
Watermelon		58.3		49.1		
Wheat for Grain	39	37.9	36.2	37.6	38.8	35.2
Soybean Wheat - Relay				58.9		

Table 11. Annual Average Canopy Cover Percentages – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	56.3	46.2	41.4	40.8	36.1	38.1	38.7
Broccoli, spring			7.68				
Cabbage	35.1						
Corn & Wheat	48.6	48.9		12	35.2	48.2	48.1
Corn for Grain	28.2	31.8	32.2	25.6	31.1	32.1	29.3
Corn for Silage	22.2	35.7	22.8	14.4	23.6	21.8	15.3
Cucumber	46.4	19.4			25.7	63.3	
Other managed hay Harvested Area	68	37.8	41.4	80	87.2	58.6	79.5
Pasture / Range	73.7	58.6	42.2	81.2	79.2	77.7	81.2
Potato	20.7	9.69	15	12.9	7.67	10.5	12.9
Snap Beans		12.3					
Soybean	38.4	38.4	41.1	34.3	39.1	36.3	33.5
Soybean & Wheat		49.4	51.2	44	52.5	46.3	44.1
Tomato				8.42		8.54	8.42
Watermelon	67.1	49.3			49.2	49.3	
Wheat for Grain	36.2	38.7	35.2	44.1	37.6	38.8	33.9
Soybean Wheat - Relay	58.9						

Table 12. Annual Average Crop Residue Percentages – State/CMZ Combinations

Crop Cover Type	State/CMZ combination

	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	57.3	47.4	53.8	43.8	25.8	47.2	46.3	37.5	40.9	48.4	44.7	43.5
Broccoli, spring						36.3						
Cabbage		14.7										
Corn & Wheat			81.2		87.7		50	59.3	81.2	87.9	83.3	84.3
Corn for Grain	75.8	78.6	71.6	54.1	50.9	69.2	67.6	67.8	71.2	64	61.2	59.7
Corn for Silage	28.4	30	26	32.8	19.6	25.5	22.7	24.4	25.8	23	19.6	17.8
Cucumber	13.2		43.6	14.4	13.6			4.39	21.4	41.3		
Other managed hay Harvested Area	77.8	57.5	45.5	30.1	26.1	47.2	59.8	45.9	46.8	27.5	59.6	56.8
Pasture / Range	47.4	49.6	8.33	26.9	46.9	72.3	29.9	56.7	38.1	54.7	27.5	26.8
Potato	5.83	6.15		14.6	14.5	7.17	15.6	1.35		1.4	13.7	13.1
Snap Beans				14.4								
Soybean		59.9	53	34	33.3	35.4	59.1	45.8	49.4	42.2	53.4	50
Soybean & Wheat				80.8	76.3	65.1	72.3	81	82.8	30.5	64.3	63
Tomato							25.4				24.1	21.5
Watermelon	28.1		33.7		27.6			30.6	33.7	28.7		
Wheat for Grain		28.3	28.7	80.3	52.4	79.8	89	53.9	55.3	53.1	84.5	82.7
Soybean Wheat - Relay			89.8									

Table 13. Annual Average Crop Residue Percentages – State Scale

Crop Cover Type	State

	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	43.8	42.2	47.4	47.4	44.9	47.2
Broccoli, spring						36.3
Cabbage			14.7			
Corn & Wheat		78.3		81.2	72.5	
Corn for Grain	54.1	64.7	78.6	71.4	62.8	69.2
Corn for Silage	32.8	23.9	30	25.9	20	25.5
Cucumber	14.4	18.1		32.5		
Other managed hay Harvested Area	30.1	44.3	57.5	46.2	58.8	47.2
Pasture / Range	26.9	51.4	49.6	23.2	28.1	72.3
Potato	14.6	5.76	6.15		14.1	7.17
Snap Beans	14.4					
Soybean	34	40.4	59.9	51.2	54.2	35.4
Soybean & Wheat	80.8	62.6		82.8	66.5	65.1
Tomato					23.7	
Watermelon		28.7		33.7		
Wheat for Grain	80.3	53.1	28.3	42	85.4	79.8
Soybean Wheat - Relay				89.8		

Table 14. Annual Average Crop Residue Percentages – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	52.8	34.8	47.2	46.3	39.2	46.5	43.5
Broccoli, spring			36.3				
Cabbage	14.7						
Corn & Wheat	81.2	87.7		50	70.3	85.6	84.3
Corn for Grain	75.3	52.5	69.2	67.6	69.5	62.6	59.7
Corn for Silage	28.1	26.2	25.5	22.7	25.1	21.3	17.8
Cucumber	28.4	14			12.9	41.3	
Other managed hay Harvested Area	59.6	28.1	47.2	59.8	46.4	43.6	56.8
Pasture / Range	35.1	36.9	72.3	29.9	47.4	41.1	26.8
Potato	5.99	14.5	7.17	15.6	1.35	7.57	13.1
Snap Beans		14.4					

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Soybean	56.5	33.6	35.4	59.1	47.6	47.8	50
Soybean & Wheat		78.5	65.1	72.3	81.9	47.4	63
Tomato				25.4		24.1	21.5
Watermelon	30.9	27.6			32.1	28.7	
Wheat for Grain	28.5	66.4	79.8	89	54.6	68.8	82.7
Soybean Wheat - Relay	89.8						

Pennsylvania (PA) Slope and Length Relationship Guidance

The following information was provided by Pennsylvania NRCS personnel to assist with determination of the L and S factor inputs for RUSLE2. It was provided exactly as follows in a Microsoft Word document.

Default Slope Length for each Increment of Slope Steepness

For use in all areas of the US except the "Palouse"

Slope	Length
0.5	100
	200
	300
	200
	180
	160
	150
	140
	130
	125
	120
	110
	100
	90
	80
	70
	60

60

50

50

50

50

50

50

50

Slope steepness is the average of the map unit slope range

By Lightle and Weesies 10/1/96

The following slope lengths for the “Palouse” (MLRA B 9) area were determined by Tom Gohlke in consultation with Don McCool, ARS and Harry Riehle. Tom says, “Keep in mind that many real LS’s in the field are complex slopes and consist of combinations of these slopes. For instance, it is common to find an “L” beginning on a 2%-5% slope and extending onto and ending on a 21%-25% slope. The total “L” may be less than the sum of the values for these two segments as shown in the following table.”

Default Slope ranges for Use in the “Palouse”

slope range	length
2-5%	350 ft.
6-10%	275 ft.
11-15%	225 ft.
16-20%	175 ft
21-25%	150 ft
26-35%	125 ft
36 45%	100 ft