3 Section 3: Terrestrial Inputs

3.1 Introduction

Terrestrial inputs, mainly in the form of atmospheric deposition, fertilizer, and manure drive much of the spatial distribution of loads throughout the watershed. Referring to Figure 3-1 at right, terrestrial inputs are multiplied by a watershed load sensitivity to inputs, discussed in section 4, to modify spatially averaged loads before further modification by downstream factors related to BMPs and the physical setting. Much of this section is similar to what would be referred to in the Phase 5 watershed model as Scenario Builder. The structure of the Phase 6 watershed model integrates the various calculations into a single analysis system as described in section 1.5: Software Structure.

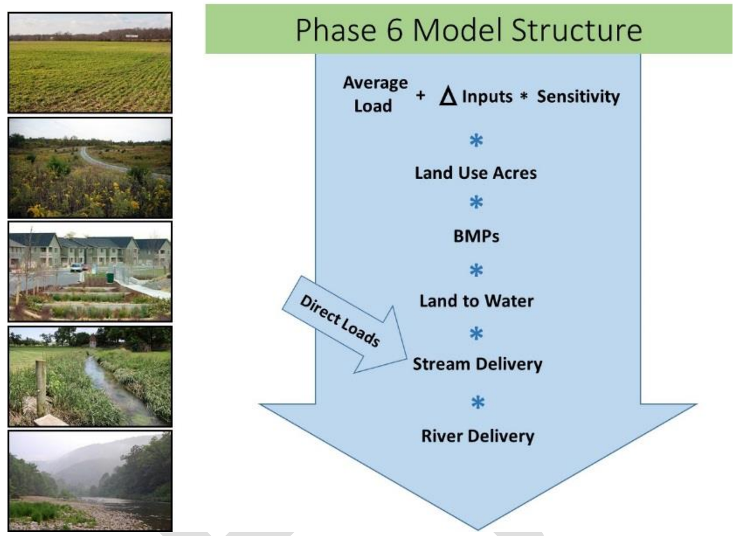


Figure 3-1: Phase 6 Model Structure

3.1.1 Comparison of Chesapeake Basin-Wide Loads

The major sources of nitrogen and phosphorus to the watershed are commercial fertilizer, manure, point sources, and for nitrogen only, atmospheric deposition.

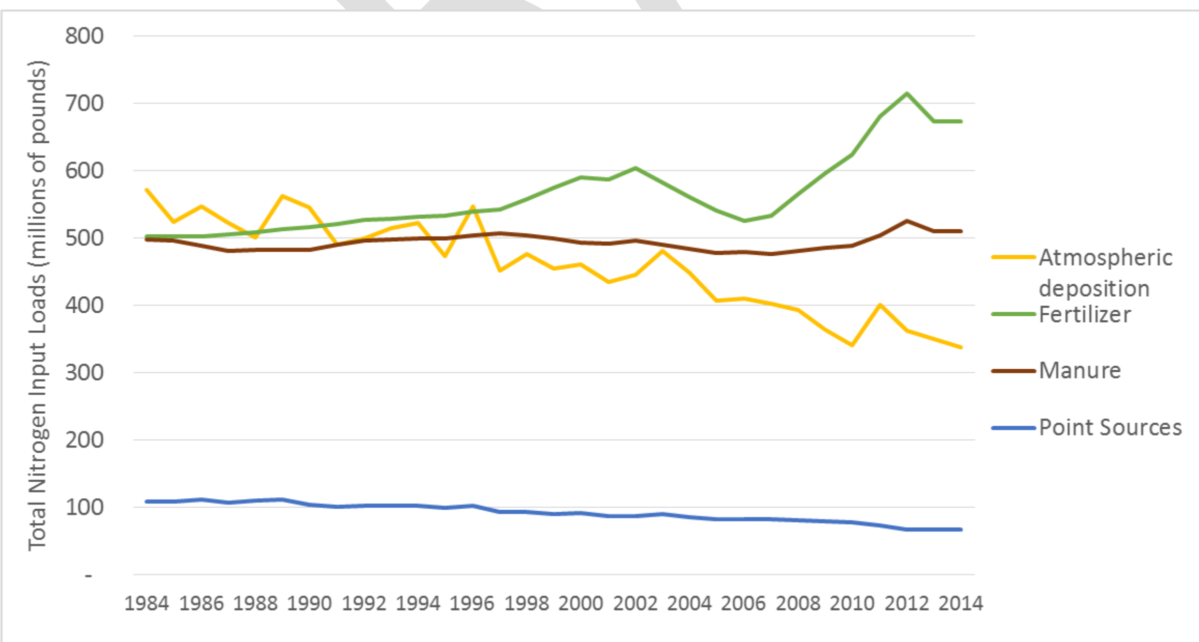


Figure 3-2: Major nitrogen inputs to the Phase 6 Model

Figure 3-2 above shows the nitrogen inputs over time. Atmospheric deposition, commercial fertilizer, and manure are all roughly equivalent sources at the beginning of the simulation in 1985. Point sources are much lower in total pounds. However since point sources are direct loads to streams while all other sources undergo losses in land processing, the delivered load of point sources is similar to any of the land-applied sources. During the simulation period, point sources and atmospheric deposition decrease while manure stays relatively constant and commercial fertilizer increases such that commercial fertilizer applications are roughly double atmospheric deposition by 2014.

Figure 3-2 depicts similar time series of inputs for phosphorus. As with nitrogen point sources are down considerably during the period of simulation and manure is relatively constant, increasing slightly toward the end of the period. Phosphorus in commercial fertilizer goes the opposite direction than for nitrogen, showing a sharp decline in the early 2000s, partially in reaction to a price increase.

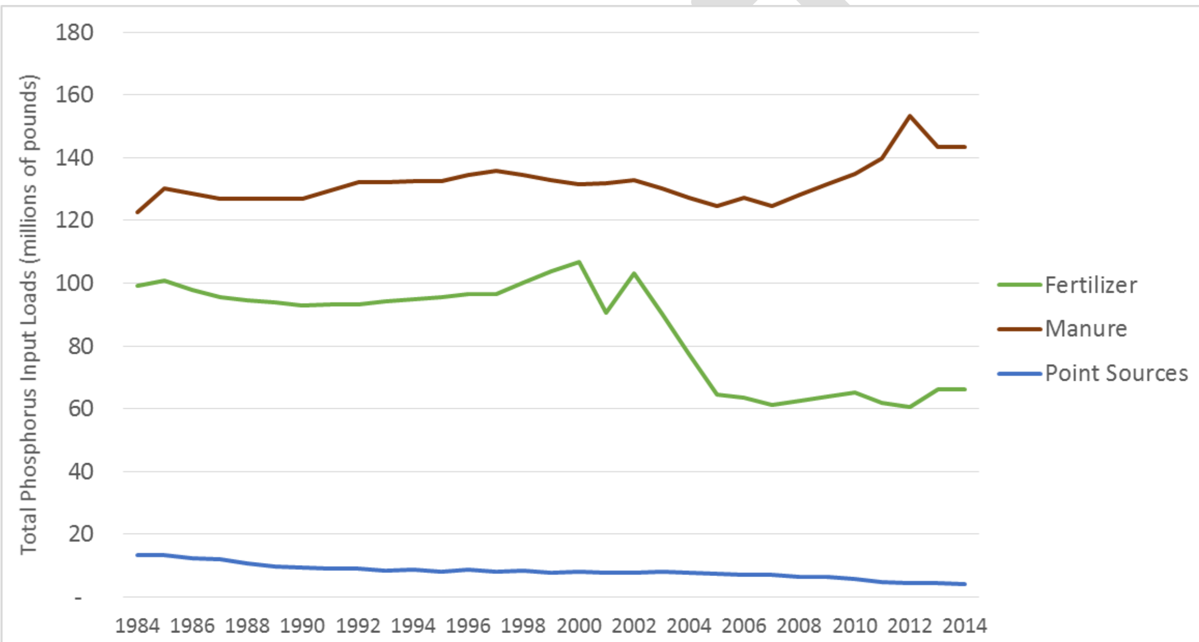


Figure 3-3: Major Phosphorus inputs to the Phase 6 model

3.1.2 Growth Regions for Crops

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. 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.

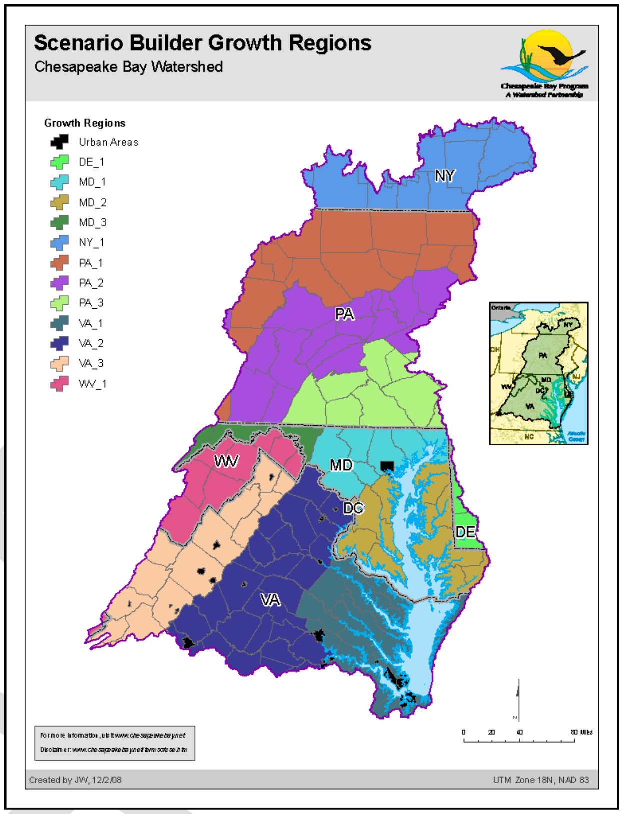


Figure 3-4: Growth Regions for Crops

Resulting growth regions are provided in Figure 3-4**.**

3.2 Manure Nutrient Applications

Manure nutrient applications upon individual crops are estimated 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 3-1 provides an example of this method.

Table 3-1: 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.

3.2.1 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 3-1 describes an example manure nitrogen calculation for beef.

Equation 3-1: 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

Table 3-3 and Table 3-4 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 3-5 provides an overview of these various processes simulated by Scenario Builder.

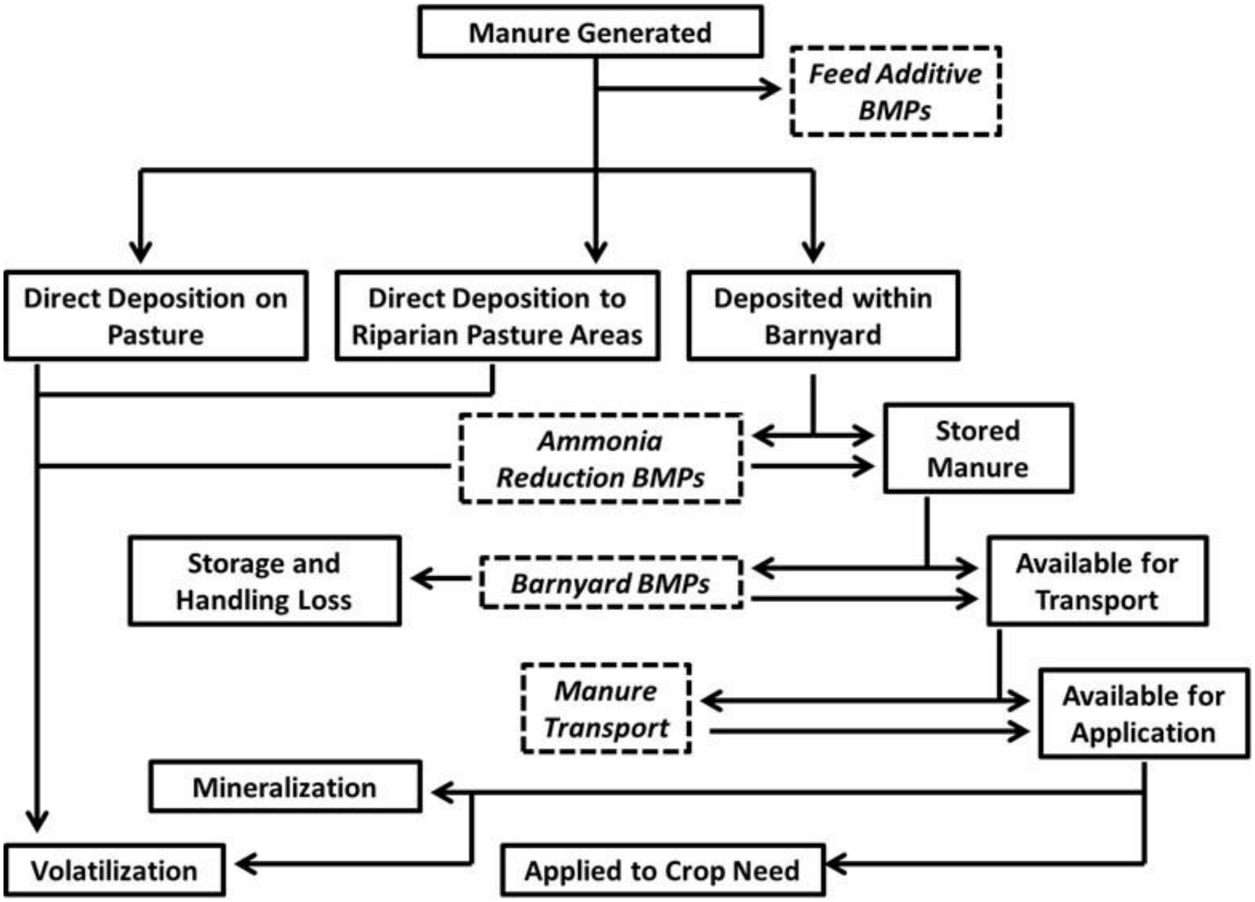


Figure 3-5: Manure Application Processes

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.

3.2.1.1 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 3-2: 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:

Table 3-2: average production cycles per year

Animal Type	Production Cycles per year
Pullets	2.25
Broilers	6
Turkeys	2
Hogs for Slaughter	2

To avoid undercounting animals, Scenario Builder uses Equation 3-2 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 3-2 and the Census of Agriculture. More detailed methods for estimating poultry populations are described in Appendix A.

Table 3-3: 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 3-4: Manure Nutrient Species Concentrations for Livestock per Lb of Dry Manure (2013 example)

Livestock Type	Mineralized Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Ammonia Nitrogen	Mineralized Phosphorus	Organic Phosphorus	Phosphate
beef	0.011398	0	0.010108	0.007282	0.004359	0	0.002108
dairy	0.018451	0	0.016362	0.007408	0.000217	0	0.006547
goats	0.01293	0	0.01293	0.008755	0.005349	0	0.003113
hogs and pigs for breeding	0.017869	0	0.013208	0.039196	0.006469	0	0.012948
hogs for slaughter	0.021195	0	0.015666	0.046473	0.00472	0	0.009447

horses	0.008282	0	0.015381	0.00801	0.00435	0	0.001591
other cattle	0.014786	0	0.013113	0.007605	0.004458	0	0.002158
sheep and lambs	0.014262	0	0.014262	0.009657	0.003955	0	0.003955

Values for poultry vary by year. See Appendix A for details.
Mineralization also varies by year.

3.2.1.2 Nitrate Nitrogen

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

3.2.1.3 Ammonia Nitrogen

The ammonia concentrations listed in Table 3-4 are a combination of the existing Scenario Builder's ammonia concentrations per pound listed in Table 3-5 taken from ASAE, 2003 and the total nitrogen concentrations listed in Table 3-3 – most of which were taken from the updated ASAE, 2005. Equation 3-3 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 3-5: 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 3-3: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

3.2.1.4 Mineralized Nitrogen

Mineralization of organic nutrients in manure transforms previously unavailable nutrients into a form 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 adjusts the amount of mineralized nutrient available from the current year's manure application to take into account previous applications.

Nutrient management plans currently estimate multiple years' worth of mineralization on a field when assessing how much additional manure or fertilizer is needed to grow a crop. However, this estimate of previous applications has changed over time. For example, nutrient management planners may have conservatively assumed no previous application in the 1980s, but three or even more years of previous applications in the 2000s. For this reason, Scenario Builder varies the mineralization rate by decade, using a three-year rate in the 2000s, a single-year rate in the 1980s, and interpolating between the two values for the 1990s. These mineralization values are published in Table 3-6.

Table 3-6: Mineralization of Organic Nitrogen

Animal Type	1985	1990	1995	2000	2005	2010	2013
hogs and pigs for breeding**	0.3	0.3	0.4375	0.575	0.575	0.575	0.575
beef**	0.3	0.3	0.415	0.53	0.53	0.53	0.53
dairy**	0.3	0.3	0.415	0.53	0.53	0.53	0.53
hogs for slaughter**	0.3	0.3	0.4375	0.575	0.575	0.575	0.575
horses*	0.2	0.2	0.275	0.35	0.35	0.35	0.35
other cattle**	0.3	0.3	0.415	0.53	0.53	0.53	0.53
sheep and lambs*	0.3	0.3	0.4	0.5	0.5	0.5	0.5
goats*	0.3	0.3	0.4	0.5	0.5	0.5	0.5
broilers**	0.55	0.55	0.65	0.75	0.75	0.75	0.75
pullets**	0.55	0.55	0.65	0.75	0.75	0.75	0.75
turkeys**	0.55	0.55	0.65	0.75	0.75	0.75	0.75
layers**	0.55	0.55	0.65	0.75	0.75	0.75	0.75

* Source for values is Mid Atlantic Water Program, 2013.
**Source for values is University of Maryland Cooperative Extension, 2011.
Red values are interpolated between 1990 and 2000.

The final mineralized nitrogen values published in Table 3-4 are the product of the non-ammonia nitrogen concentrations and the mineralization factors listed in Table 3-6. See Equation 3-4 for an example calculation.

Equation 3-4: 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 (2013):

0.011398 Lbs Mineralized N/Lb Dry Manure = (0.028788 Lbs Total N/Lb Dry Manure - 0.007282 Lbs Ammonia N/Lb Dry Manure) X 0.53

3.2.1.5 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 3-5 for an example calculation.

Equation 3-5: 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 (2013):

0.010108 Lbs Organic N/Lb Dry Manure = 0.028788 Lbs Total N/Lb Dry Manure - 0.007282 Lbs Ammonia N/Lb Dry Manure – 0.011398 Lbs Mineralized N/Lb Dry Manure

3.2.1.6 Phosphate

Phosphate is considered to be readily available for plant uptake. The phosphate concentrations listed in Table 3-5 are a combination of the existing Scenario Builder's phosphate concentrations per pound listed in Table 3-7 taken from ASAE, 2003 and the total phosphorus concentrations listed in Table 3-4 – most of which were taken from the updated ASAE, 2005. Equation 3-6 shows how new phosphate concentrations were calculated.

Table 3-7: Existing Scenario Builder Phosphate Concentrations Per Lb Phosphate

Animal Type	Lbs Phosphate/Lb Total Phosphorus
Hogs for Breeding	0.666822
Beef	0.325977
Dairy	0.967978
Hogs for Slaughter	0.666822
Horses	0.267767
Other Cattle	0.326154
Sheep and Lambs	0.500000
Goats	0.367872
broiler*	0.306602
layer*	0.306741
pullet*	0.306743
turkey*	0.306702

*Total phosphorus for poultry species can vary by year, but fraction phosphate is assumed to remain the same.

Equation 3-6: 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

3.2.1.7 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 3-7 provides an example calculation of mineralized phosphorus.

Equation 3-7: 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

3.2.1.8 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.

3.2.2 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 3-8.

Table 3-8: Beef Percent Manure Deposited by Area in West Virginia Growth Region 1

Growth Region	Animal Type	Month	Barnyard Percent	Pasture Percent	Access Area Percent
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

3.2.2.1 Direct Deposition on Pasture

Table 3-8 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.

3.2.2.2 Direct Deposition to Riparian Pasture Areas

Table 3-8 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 3B.

3.2.2.3 Manure Deposition to Barnyard Areas

Table 3-8 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. Storages and handling losses contribute to loads to streams as discussed in Section 8: Direct Loads.

3.2.2.4 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 3-9. These fractions have remained unchanged through multiple versions of Scenario Builder and the Watershed Model. Equation 3-8provides an example for calculating ammonia volatilization.

Table 3-9: Fraction of Ammonia Volatilized Within Barnyard Manure

AnimalName	Fraction Volatilized
beef	0.65
dairy	0.65
other cattle	0.65
horses	0.32
hogs and pigs for breeding	0.81
hogs for slaughter	0.5
sheep and lambs	0.65
goats	0.65
Pullets*	0.57
Turkeys*	0.57
Layers*	0.57
Broilers*	0.57

*Poultry litter nutrient concentrations provided in Appendix A are assumed to be post-volatilization, thus ammonia nitrogen concentrations were retroactively increased to account for barnyard volatilization.

Equation 3-8; 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

3.2.2.5 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

3.2.3 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 a non-BMP condition of storage and handling loss, Scenario Builder multiplies the post-volatilized nutrients by 1 minus the fraction of manure recoverable in Table 3-10. An example of the resulting storage and handling loss values are provided in Table 3-11. The recoverable manure values are increased when states report that manure was treated on the farm by an Animal Waste Management System (AWMS).

Table 3-10: NRCS Estimated Recoverability of Manure Nutrients Before and After CNMPs

Animal Type	Fraction of Manure Recoverable Before CNMPs	Fraction of Manure Recoverable after CNMPs
Beef	0.6	0.75
Dairy	0.553	0.6775
Other Cattle	0.5765	0.71375
Horses	0.635	0.825
Hogs for Breeding	0.798	0.9602
Hogs for Slaughter	0.775	0.9483
Sheep and Lambs	0.635	0.825
Angora Goats	0.635	0.825
Pullets*	0.85	0.95
Layers*	0.85	0.95
Turkeys*	0.765	0.932
Broilers*	0.75	0.98

*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 3-11: Calculating Beef Manure Available for Transport (2013)

Calculation Step	Mineralized Nitrogen	Nitrate Nitrogen	Organic Nitrogen	Ammonia Nitrogen	Mineralized Phosphorus	Organic Phosphorus	Phosphate
Original Concentration	0.011398	0	0.010108	0.007282	0.004359	0	0.002108
Ammonia Volatilization Loss	0	0	0	0.004733	0	0	0
Post-Volatilization Concentration	0.011398	0	0.010108	0.002549	0.004359	0	0.002108
Storage and Handling Loss	0.004559	0	0.004043	0.00102	0.001744	0	0.000843
Post-Storage and Handling	0.006839	0	0.006065	0.001529	0.002615	0	0.001265

Loss Concentration	

3.2.3.1 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. Table 3-10 includes a list of the post-BMP manure recoverability. A BMP expert panel is currently considering Investigating other manure recoverability sources, and may opt to change the values in Table 3-10.

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.

3.2.4 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 3-12 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 3-12: 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

3.2.5 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 3-13 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 3-13: 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

3.2.6 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.

3.2.7 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.

3.2.7.1 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 3-9.

Equation 3-9: 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 3-14. Major crops are those with an “Application Goal Yield Unit” not equal to acres. Equation 3-9 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 3-14: 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	acres
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	acres
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

3.2.8 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 3-6. 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 3-15 lists the land uses included in each land use group. The detailed equations for each curve are also included in Table 3-16 through Table 3-19.

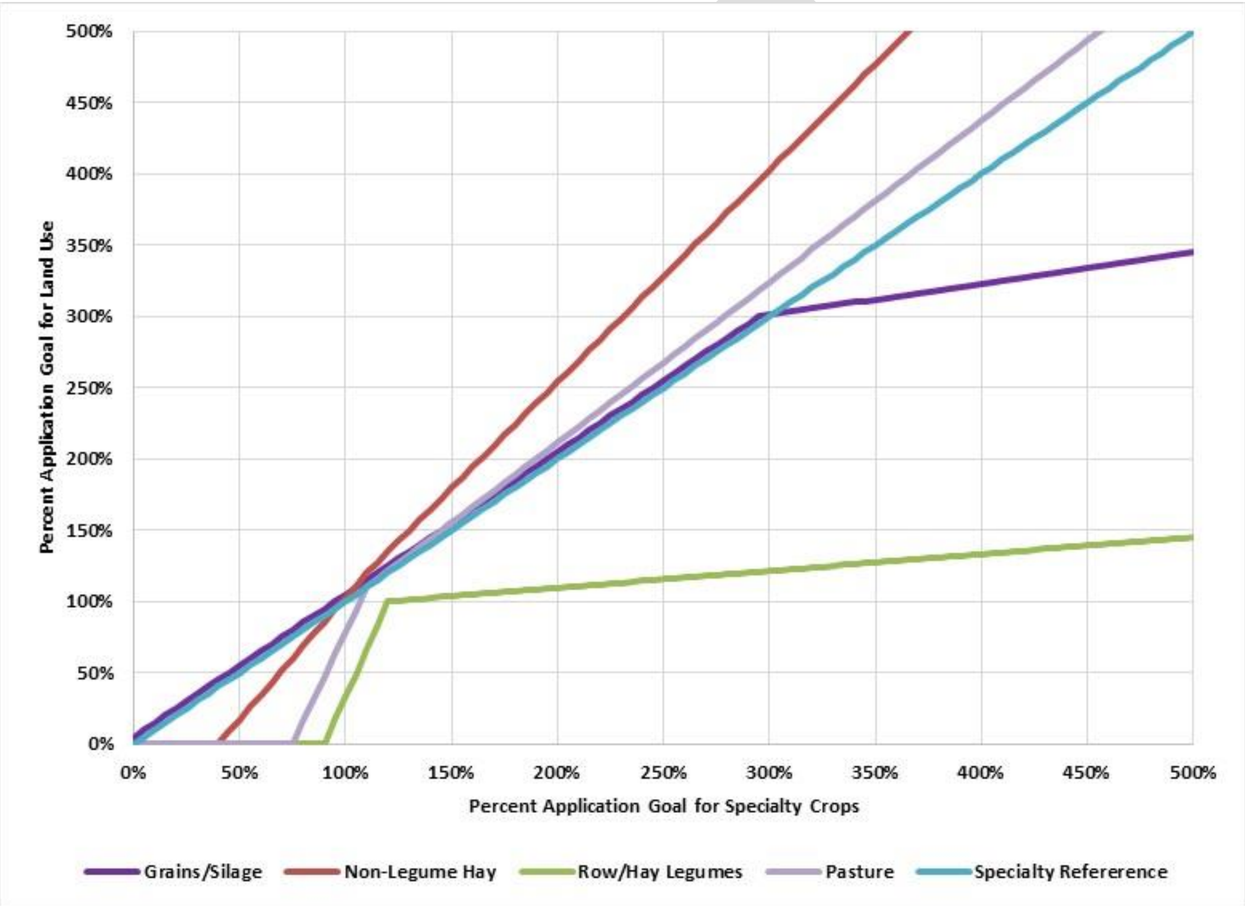


Figure 3-6: Manure Nitrogen Application Curves by Crop Group

Table 3-15: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

Table 3-16: Grains/Silage Manure Curve Inflection Points

Specialty Reference Percent Goal	Grains/Silage Percent Goal	Slope at each point	Intercept for each point
0	0	51	0
0.001	0.051	1	0.05
2.95	3	0.217948749	2.357051191
1000	220.3058		

Table 3-17: Non-Legume Hay Curve Inflection Points

Specialty Reference Percent Goal	Non-Legume Hay Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.4	0	1.714285714	-0.685714286
1.1	1.2	1.487179487	-0.435897436
5	7		

Table 3-18: Row/Hay Legume Curve Inflection Points

Specialty Reference Percent Goal	Row/Hay Legume Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.9	0	3.333333333	-3
1.2	1	0.118421053	0.857894737
5	1.45		

Table 3-19: Pasture Curve Inflection Points

Specialty Reference Percent Goal	Pasture Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.75	0	3.142857143	-2.357142857
1.1	1.1	1.128205128	-0.141025641
5	5.5		

As Figure 3-6 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 ammonium nitrogen from manure. While mineralized nitrogen is tracked separately within Scenario Builder, it is considered by the Watershed Model to be ammonium nitrogen.

3.3 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 relies upon AAPFCO fertilizer sales data.

3.3.1 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.

3.3.1.1 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. Table 3-20 and Table 3-21 include the raw sales by state before individual outliers were removed. Note that 1997 values were not considered in the procedure

Table 3-20: . 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 3-21: Raw Pounds of Phosphorus Fertilizer Sales by State (AAPFCO)

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	7,069,736	32,950,758	68,216,215	47,707,004	58,609,224	11,957,072	226,510,009
1986	5,897,622	28,995,852	57,296,981	41,374,002	47,929,478	8,802,712	190,296,645
1987	5,476,568	31,765,834	57,937,747	48,008,933	46,521,178	9,215,834	198,926,095
1988	5,061,966	32,401,013	52,718,445	47,814,758	48,537,439	11,112,868	197,646,490
1989	5,523,451	21,082,105	53,190,870	45,967,711	48,017,702	11,370,286	185,152,126
1990	-	-	59,571,213	46,037,826	54,826,821	10,501,988	170,937,849
1991	6,521,385	31,047,969	46,988,025	45,247,129	62,848,614	15,133,319	207,786,442
1992	6,846,196	31,427,583	63,311,491	48,197,079	68,899,268	15,757,547	234,439,164
1993	5,908,438	25,968,779	54,105,787	63,754,872	66,363,025	9,103,265	225,204,166
1994	6,055,140	30,571,355	66,952,424	57,991,768	58,477,417	8,369,270	228,417,374
1995	6,064,768	28,813,141	56,832,799	54,708,789	57,494,443	6,134,409	210,048,349
1996	6,275,361	29,242,751	39,514,128	48,084,661	57,424,904	5,244,452	185,786,257
1997	-	-	-	-	-	-	-
1998	6,303,762	26,029,207	41,510,475	49,748,803	54,981,481	8,143,765	186,717,494
1999	8,129,565	20,505,625	43,439,636	42,756,364	59,371,671	5,685,632	179,888,492
2000	5,590,524	36,468,933	33,760,226	52,003,600	56,012,334	5,559,659	189,395,277
2001	4,016,265	22,731,154	36,928,989	36,957,910	49,327,699	4,718,908	154,680,925
2002	4,322,658	23,263,636	38,086,319	47,049,633	56,136,182	4,105,197	172,963,623
2003	3,625,522	13,461,916	27,871,941	27,638,699	47,754,272	2,801,179	123,153,528

2004	2,637,297	18,008,809	34,512,982	32,255,176	47,505,609	3,114,747	138,034,621
2005	3,419,193	14,471,777	28,513,442	29,416,153	41,689,415	1,211,056	118,721,036
2006	2,973,035	10,957,490	28,553,534	32,475,310	41,385,402	3,293,772	119,638,543
2007	3,285,836	16,955,275	28,117,138	29,836,744	38,839,676	3,299,850	120,334,519
2008	3,146,493	13,120,873	26,950,222	33,728,602	30,850,095	1,419,004	109,215,289
2009	2,753,862	7,932,270	18,351,523	26,412,126	25,261,371	815,403	81,526,555
2010	7,799,517	10,144,980	27,330,975	25,566,084	30,058,216	11,493,959	112,393,731
2011	3,141,824	18,137,832	24,707,413	24,643,970	27,870,449	3,968,745	102,470,234
2012	2,643,346	17,214,105	24,704,230	26,257,731	28,822,909	3,080,058	102,722,380

*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. Table 3-22 and Table 3-23 include the revised fertilizer sales data by state following this step.

Table 3-22: . 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 3-23: Revised Pounds of Phosphorus Fertilizer Sales by State

Year	DE	MD	NY	PA	VA	WV	Regional Total
1985	7,069,736	32,950,758	68,216,215	47,707,004	58,609,224	11,957,072	226,510,009
1986	5,897,622	28,995,852	57,296,981	41,374,002	47,929,478	8,802,712	190,296,645
1987	5,476,568	31,765,834	57,937,747	48,008,933	46,521,178	9,215,834	198,926,095
1988	5,061,966	32,401,013	52,718,445	47,814,758	48,537,439	11,112,868	197,646,490
1989	5,523,451	21,082,105	53,190,870	45,967,711	48,017,702	11,370,286	185,152,126
1990	6,022,418	26,065,037	59,571,213	46,037,826	54,826,821	10,501,988	203,025,304
1991	6,521,385	31,047,969	46,988,025	45,247,129	62,848,614	10,501,988	203,155,110
1992	6,846,196	31,427,583	63,311,491	48,197,079	68,899,268	9,802,626	228,484,243
1993	5,908,438	25,968,779	54,105,787	63,754,872	66,363,025	9,103,265	225,204,166
1994	6,055,140	30,571,355	66,952,424	57,991,768	58,477,417	8,369,270	228,417,374
1995	6,064,768	28,813,141	56,832,799	54,708,789	57,494,443	6,134,409	210,048,349
1996	6,275,361	29,242,751	39,514,128	48,084,661	57,424,904	5,244,452	185,786,257
1997	6,289,562	27,635,979	40,512,301	48,916,732	56,203,193	6,694,109	186,251,876
1998	6,303,762	26,029,207	41,510,475	49,748,803	54,981,481	8,143,765	186,717,494
1999	8,129,565	20,505,625	43,439,636	42,756,364	59,371,671	5,685,632	179,888,492
2000	5,590,524	36,468,933	33,760,226	52,003,600	56,012,334	5,559,659	189,395,277
2001	4,016,265	22,731,154	36,928,989	36,957,910	49,327,699	4,718,908	154,680,925

2002	4,322,658	23,263,636	38,086,319	47,049,633	56,136,182	4,105,197	172,963,623
2003	3,625,522	13,461,916	27,871,941	27,638,699	47,754,272	2,801,179	123,153,528
2004	2,637,297	18,008,809	34,512,982	32,255,176	47,505,609	3,114,747	138,034,621
2005	3,419,193	14,471,777	28,513,442	29,416,153	41,689,415	1,211,056	118,721,036
2006	2,973,035	10,957,490	28,553,534	32,475,310	41,385,402	3,293,772	119,638,543
2007	3,285,836	16,955,275	28,117,138	29,836,744	38,839,676	3,299,850	120,334,519
2008	3,146,493	13,120,873	26,950,222	33,728,602	30,850,095	1,419,004	109,215,289
2009	2,753,862	7,932,270	18,351,523	26,412,126	25,261,371	815,403	81,526,555
2010	7,799,517	10,144,980	27,330,975	25,566,084	30,058,216	11,493,959	112,393,731
2011	3,141,824	18,137,832	24,707,413	24,643,970	27,870,449	3,968,745	102,470,234
2012	2,643,346	17,214,105	24,704,230	26,257,731	28,822,909	3,080,058	102,722,380

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 Table 3-22 and Table 3-23. 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 3-24. 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 3-25.

Table 3-24: Regional Rolling Average Fraction of Farm Fertilizer Sales

Year	Raw Fraction for N	Rolling Average Fraction for N	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 3-25: Final Estimated Pounds Regional Fertilizer Sales for Farm Use

Year	Final Regional Farm N	Final Regional Farm P
1985	618,022,483	204,133,724
1986	550,255,025	171,497,776
1987	549,929,054	179,274,747
1988	537,852,478	178,121,550
1989	534,248,448	166,861,470
1990	599,821,208	182,969,006
1991	607,092,275	183,085,990
1992	694,275,922	205,912,929
1993	679,679,481	202,956,881
1994	687,237,913	205,683,286
1995	681,616,681	185,307,491
1996	648,773,210	167,888,130
1997	636,919,424	166,268,434
1998	656,936,953	169,841,622
1999	710,770,017	163,804,253

2000	694,397,158	170,106,871
2001	633,797,554	135,606,686
2002	694,445,284	150,256,636
2003	502,196,245	105,144,393
2004	619,383,842	116,916,117
2005	565,244,123	99,020,077
2006	550,715,019	100,099,138
2007	559,760,850	95,475,455
2008	503,804,695	85,448,000
2009	483,678,191	65,345,319
2010	546,155,129	98,813,162
2011	589,014,829	91,838,211
2012	603,579,944	89,797,313

3.3.1.2 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 3-26 with the resulting, watershed-wide fertilizer sale estimates included in Table 3-27.

Table 3-26: 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 3-27: Final Watershed-Wide Pounds of Fertilizer Use for Farms

Year	Watershed N Farm Use	Watershed P Farm Use
1985	410,394,928	135,554,041
1986	365,394,266	113,882,293
1987	365,177,806	119,046,554
1988	357,158,412	118,280,779
1989	354,765,173	110,803,575
1990	398,308,457	121,499,710
1991	403,136,774	121,577,392
1992	461,030,666	136,735,514
1993	451,337,968	134,772,564
1994	456,357,109	136,583,020
1995	452,624,356	123,052,569
1996	430,814,804	111,485,324
1997	422,943,353	110,409,773
1998	439,120,517	113,528,308
1999	478,196,516	110,205,300
2000	470,173,959	115,178,786
2001	431,848,742	92,397,922
2002	476,110,510	103,015,695
2003	343,128,981	71,840,618
2004	422,033,670	79,663,909
2005	384,272,024	67,317,189
2006	373,684,830	67,921,753
2007	379,211,085	64,680,034
2008	342,399,088	58,072,736
2009	329,601,074	44,529,374

2010	373,020,262	67,488,722
2011	403,076,302	62,846,986
2012	413,741,002	61,554,117

3.3.1.3 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 3-10 includes an example calculation for the inorganic crop application goal fraction.

Equation 3-10: 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)

The inorganic crop application goal is calculated after accounting for manure available to crops. This calculation accounts for volatilization, storage and handling loss, and changes to the landscape and manure pile due to BMPs.

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.

3.3.1.4 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.

Fertilizer use for any given crop in any given county in 2013 is assumed to be related to fertilizer use in 2012. Scenario Builder assumed that farmers continued to apply nutrients (manure, biosolids and inorganic fertilizer) to crops to achieve the same overall application-to-crop-goal percentage as they did in 2012. For example, if total applications to corn met 95 percent of a county's total corn application goal in 2012, then Scenario Builder assumed total applications in 2013 must also have met 95 percent of the county's total corn application goal. If only 85 percent of the goal could be met with manure and biosolids in 2013, then fertilizer was applied to meet the remaining 10 percent. If, however, manure and biosolids applications in 2013 exceeded the 2012 application percent, then no inorganic fertilizer was added.

3.3.2 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.

3.3.3 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.

3.3.4 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 Figure 3-7 and Figure 3-8. Again, these application curves were developed for land use groups within which many crops are included. These land use groups are described in Table 3-28 and Table 3-29. 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. Tables 3-26 through 3-32 contain the inflection points and slopes for each land use group curve.

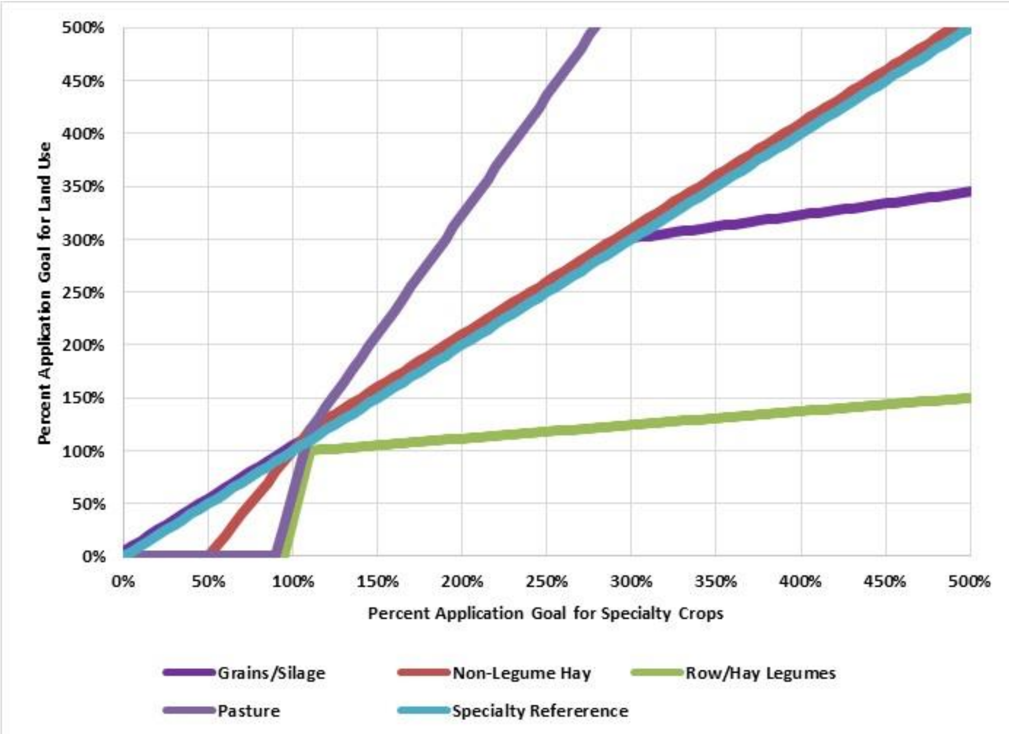


Figure 3-7: Inorganic Nitrogen Application Curves by Crop Group

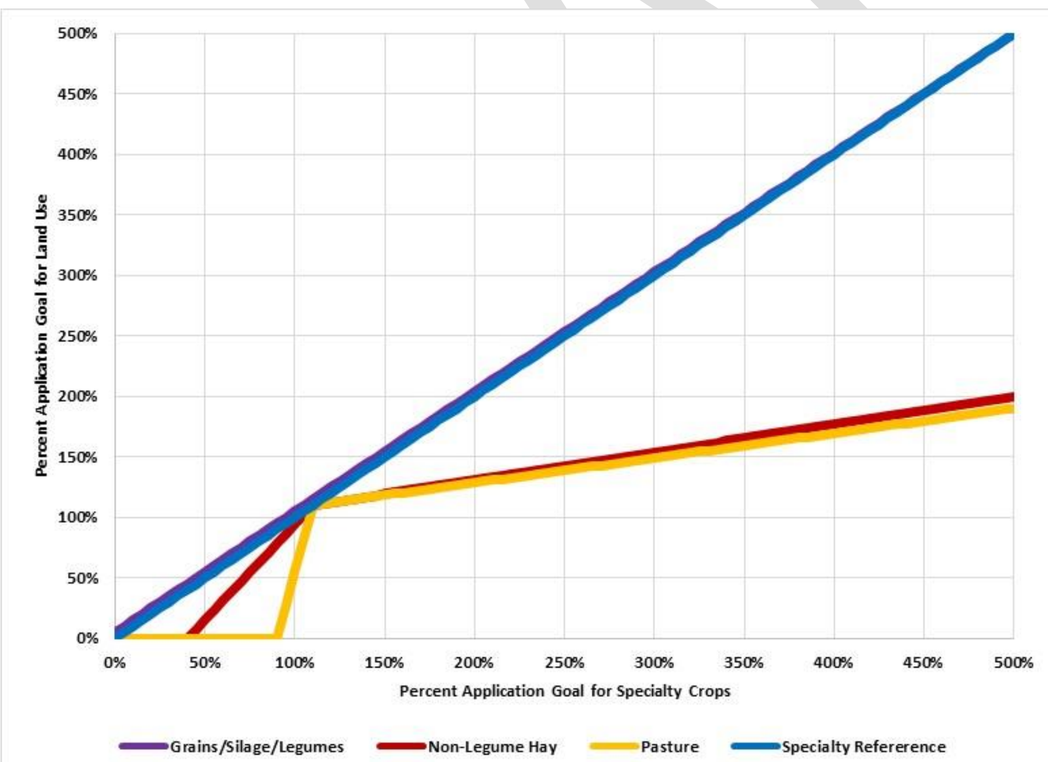


Figure 3-8: Inorganic Phosphorus Application Curves by Crop Group

Table 3-28: 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 3-29: 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

Table 3-30: Grains/Silage Inorganic N Curve Inflection Points

Specialty Reference Percent Goal	Grains/Silage Percent Goal	Slope at each point	Intercept for each point
0	0	51	0
0.001	0.051	1	0.05
2.95	3	0.2179487	2.3570512
1000	220.3058		

Table 3-31: Non-Legume Hay Inorganic N Curve Inflection Points

Specialty Reference Percent Goal	Non-Legume Hay Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.5	0	2	-1
1.1	1.2	1	0.1
5	5.1		

Table 3-32: Row/Hay Legumes Inorganic N Curve Inflection Points

Specialty Reference Percent Goal	Row/Hay Legume Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.95	0	6.6666667	-6.3333333
1.1	1	0.1282051	0.8589744
5	1.5		

Table 3-33: Pasture Inorganic N Curve Inflection Points

Specialty Reference Percent Goal	Pasture Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.9	0	6	-5.4
1.1	1.2	2.2564103	-1.2820513
5	10		

Table 3-34: Grains/Silage/Legumes Inorganic P Curve Inflection Points

Specialty Reference Percent Goal	Grains/Silage/Legumes Percent Goal	Slope at each point	Intercept for each point
0	0	51	0
0.001	0.051	1	0.05
1.1	1.15	0.9871795	0.0641026
5	5		

Table 3-35: Non-Legume Hay Inorganic P Curve Inflection Points

Specialty Reference Percent Goal	Non-Legume Hay Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.4	0	1.5714286	-0.6285714
1.1	1.1	0.2307692	0.8461538
5	2		

Table 3-36: Pasture Inorganic P Curve Inflection Points

Specialty Reference Percent Goal	Pasture Percent Goal	Slope at each point	Intercept for each point
0	0	0	0
0.9	0	5.5	-4.95
1.1	1.1	0.2051282	0.874359
5	1.9		

3.3.5 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.

3.4 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 3-37. 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 3-37: 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 3-11 was carried over from Phase 5 to estimate final nitrogen fixation for each crop after considering applications from manure and fertilizer nitrogen.

Equation 3-11: Estimating Final Nitrogen Fixation

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

If the result of Equation 3-11 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.

3.5 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.

3.5.1 MAJOR CROP TOTAL UPTAKE

Phase 5 (and subsequently, Phase 6) nutrient uptake begins with theoretical uptake values. These values are provided in Table 3-38. For any major crop, total nutrient uptake is calculated using Equation 3-12. Major crops are those listed in Table 3-38 which have an application goal unit other than “acres.”

Equation 3-12: 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 3-38: 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	acres	120.000000	82.6729584	16.36235208
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	acres	100.000000	107.647066	12.200000
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	cwt	acres	500.000000	0.329412	0.049412

Area					
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

3.5.2 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 3-13.

Equation 3-13: 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

3.5.3 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 3-14 shows how heat units are calculated, and Equation 3-15 shows how the monthly fraction is calculated.

Equation 3-14: Calculating Heat Units

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

Equation 3-15: 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.

3.6 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.

3.7 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.

3.8 Atmospheric Deposition

Atmospheric deposition is still Phase 5 data for the Phase 6 Beta 2 model. See section 5 of the Phase 5 documentation for a description of this data set.

The phase 5 atmospheric deposition was based on the phase 5 rainfall data set. The concentrations varied slowly through time with the daily load dependent on the amount of rainfall that day. In updating to the NLDAS2 rainfall data set, it was necessary to revise the atmospheric deposition data set such that the loading was consistent with rainfall. This was accomplished by creating a monthly concentration such that the monthly load in phase 6 matched the monthly load in phase 5.

The phase 6 atmospheric deposition data are being constructed by a new analysis through Penn State. The description of that work will appear in this space when it is available. This is expected for the July, 2016 version of the Phase 6 Beta.

The Penn State data will give daily estimates of load for the period 1985-2015

3.8.1 Trends in deposition for scenarios

To determine a trend, a 3-year centered moving average concentration is calculated for the years 1986-2014 for each land segment. A separate joint-point regression is created for each land segment and species to determine the trend.

3.9 Comparison with other estimates of inputs

The following section is built with data from Sparrow, Phase 5.3.2, and Phase 6 Beta 1. Beta 2 inputs have not been added to the figures due to time constraints. Future versions will update these figures.

Inputs of fertilizer, manure, and atmospheric deposition were compiled for the CBP Phase 5.3.2 watershed model (U.S. EPA 2010a) and for the USGS Sparrow model (Ator and others, 2011). The NHDPlus atmospheric deposition attributes include inorganic nitrogen for the year 2002 compiled for every catchment of NHDPlus (Figure 1), and the atmosphere was assumed to be a negligible source of phosphorus. Both models have similar input rates and spatial distribution (Figure 3-9). The wet atmospheric input load in 2002 by SPARROW and P532 were 195 and 183 millions of pounds, respectively. SPARROW only includes wet atmospheric deposition while P532 includes both wet and dry inputs. The dry atmospheric deposition by P532 in the year 2002 was 276 millions of pounds.

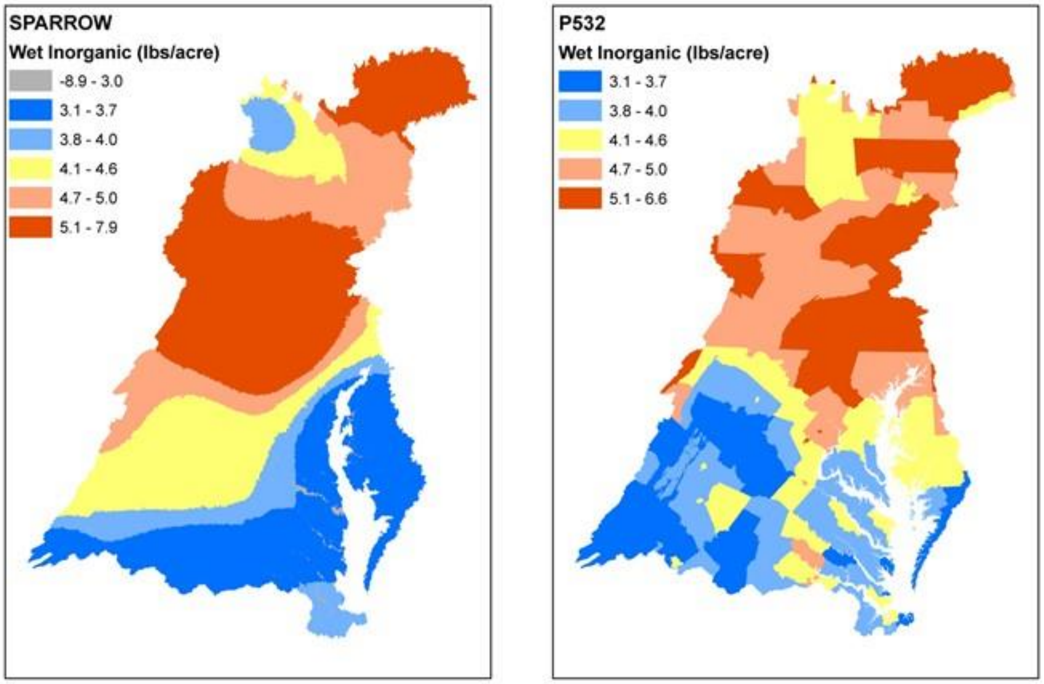


Figure 3-9: P532 and SPARROW atmospheric deposition inputs for the year 2002.

Ruddy et al. (2006) created a data set that represents the estimated amount of nutrient inputs to the land surface, compiled for every catchment of NHDPlus for the conterminous United States. Inorganic fertilizer estimates were calculated from the Association of American Plant Food Control Officials fertilizer sales data, Census of Agriculture fertilizer expenditures, and U.S. Census Bureau county population. P532, on the other hand, used crop uptake and Census of Agriculture yields to determine the inorganic fertilizer application rates. Both models have similar nitrogen input rates; however, they did not show a similar spatial distribution (Figure 3-10).The nitrogen fertilizer input load in 2002 by SPARROW and P532 were 424 and 624 millions of pounds, respectively.

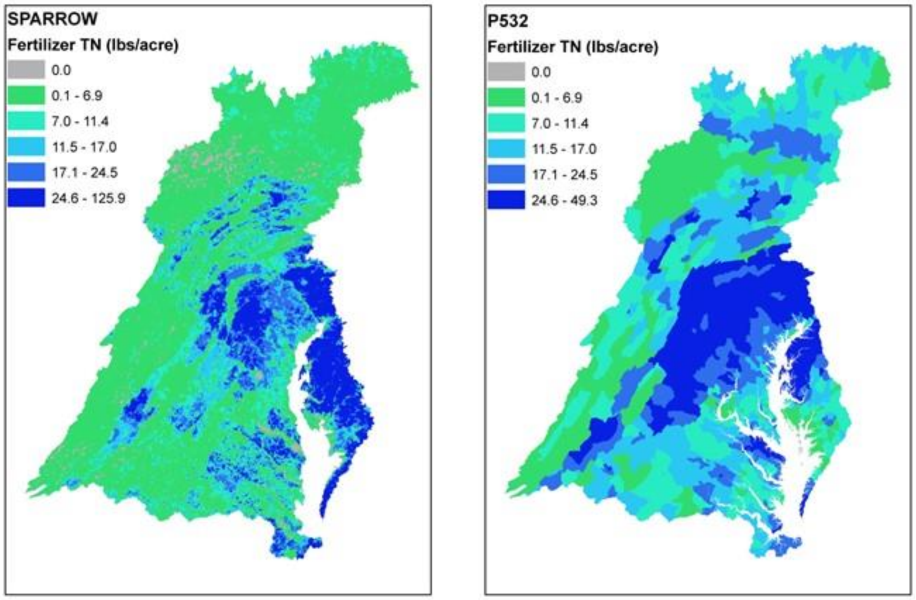
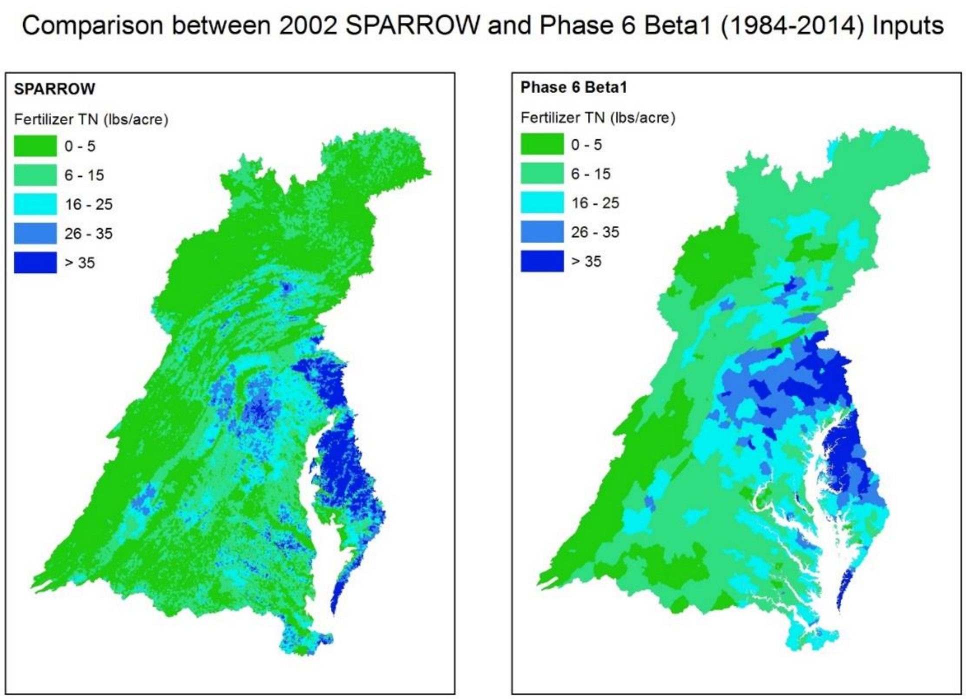


Figure 3-10: P532 and SPARROW total nitrogen fertilizer inputs for the year 2002



Both models have similar phosphorus input rates and similar spatial distribution (Figure 3-11). The phosphorus fertilizer input load in 2002 by SPARROW and P532 were 88 and 82 millions of pounds, respectively.

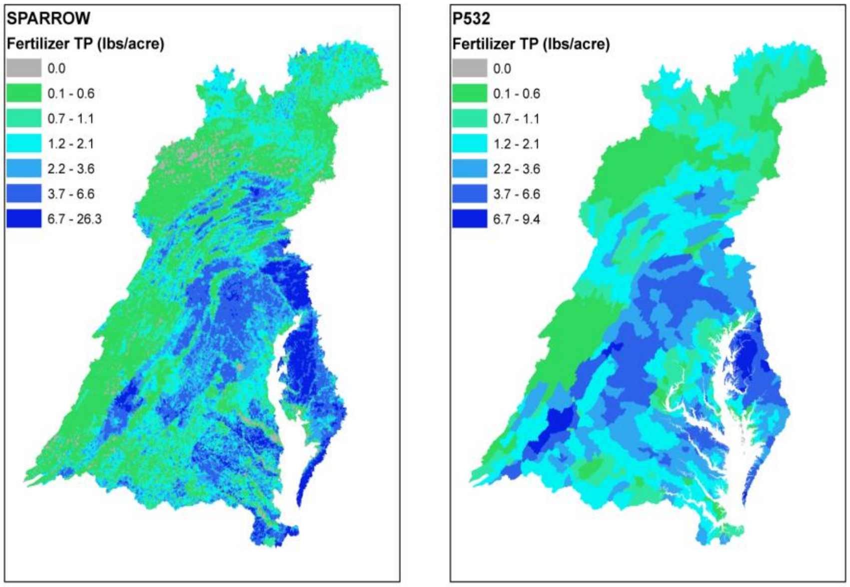
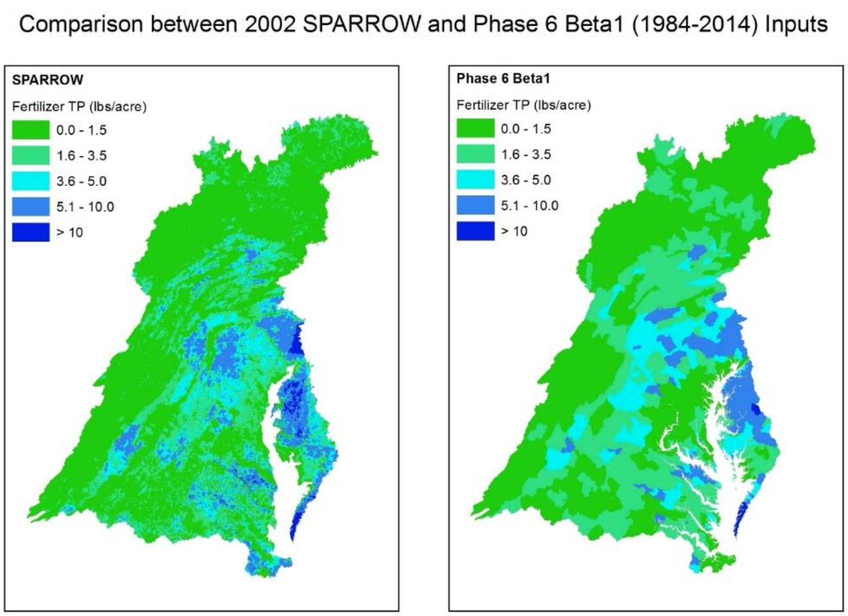


Figure 3-11: P532 and SPARROW total phosphorus fertilizer inputs for the year 2002



The nitrogen and phosphorus content of livestock wastes was estimated using Census of Agriculture. The procedures include: (1) estimating animal populations, (2) calculating nitrogen and phosphorus content of the animal manure, and (3) estimating the component of nitrogen and phosphorus from confined and unconfined livestock. SPARROW estimates of nitrogen input from manure do not account for loss through volatilization. These estimates represent the total nitrogen content in manure as excreted by each livestock group.

Both models have almost the same nitrogen and phosphorus input rates and spatial distribution (Figure 3-12 and Figure 3-13). The nitrogen manure input load in 2002 by SPARROW and P532 were 491 and 478 millions of pounds, respectively. The phosphorus manure input load in 2002 by SPARROW and P532 were 134.14 and 134.12 millions of pounds, respectively.

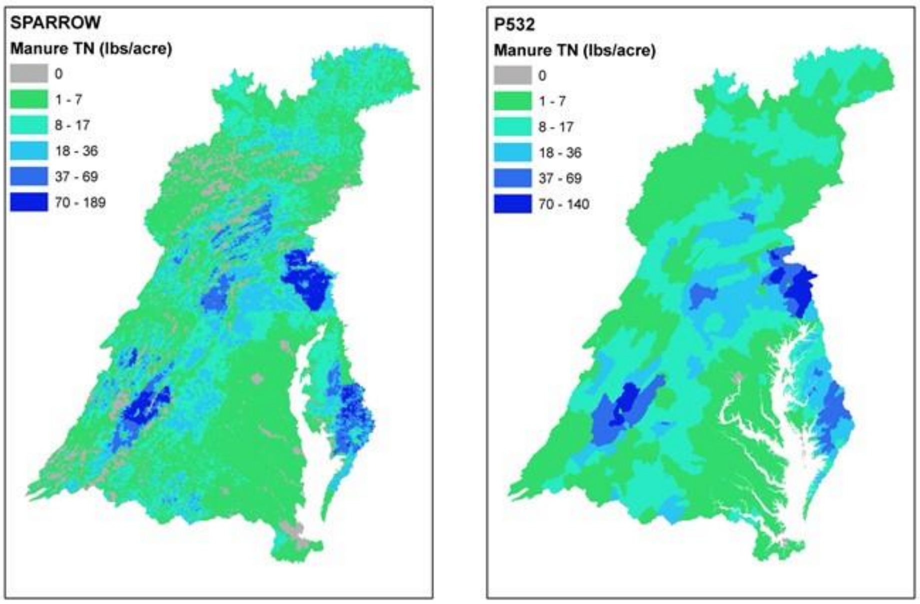
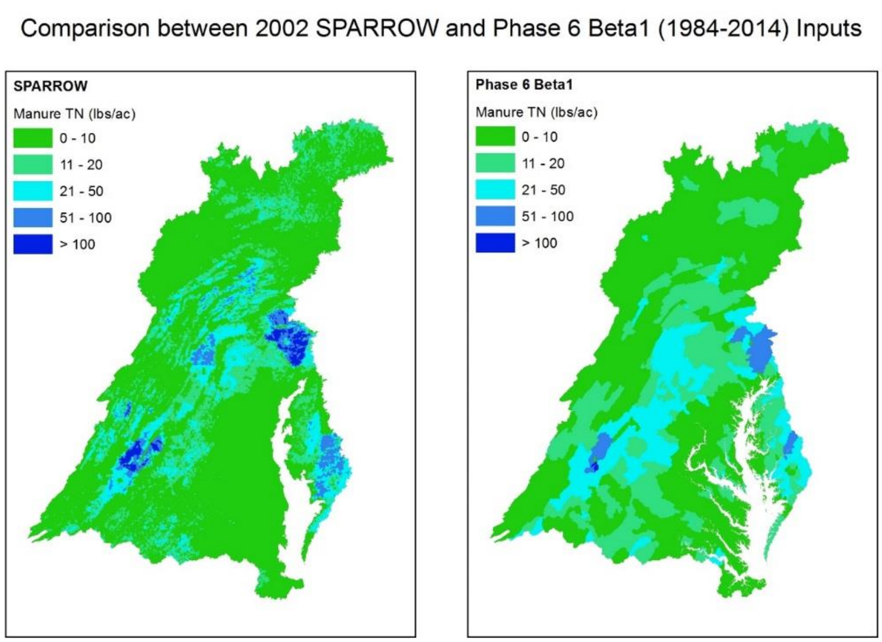


Figure 3-12: P532 and SPARROW total nitrogen manure inputs for the year 2002



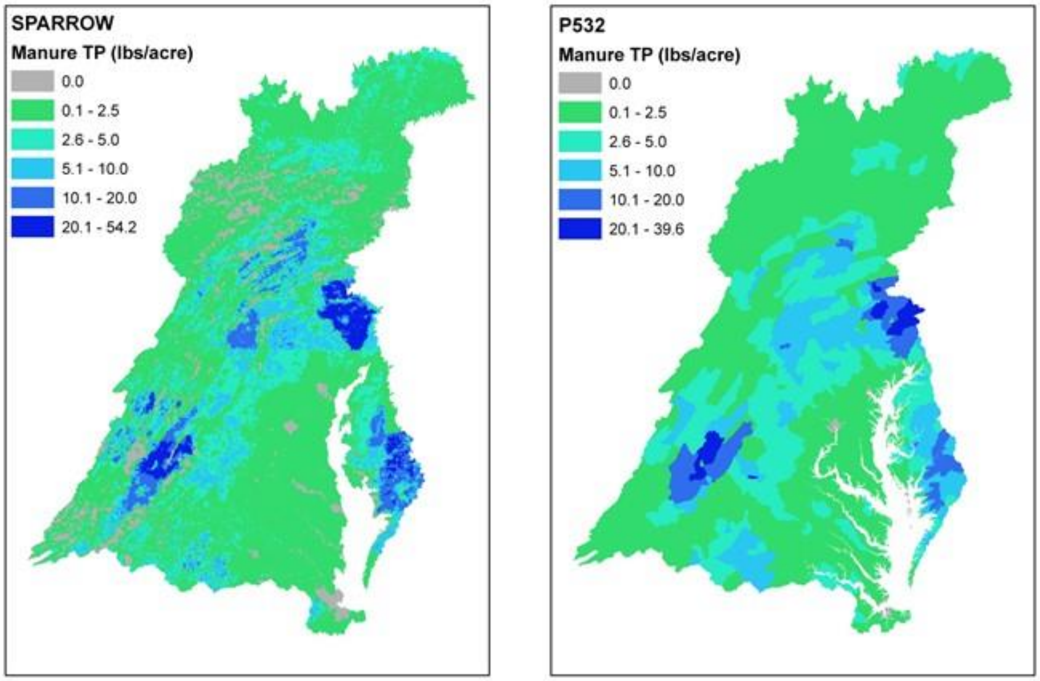
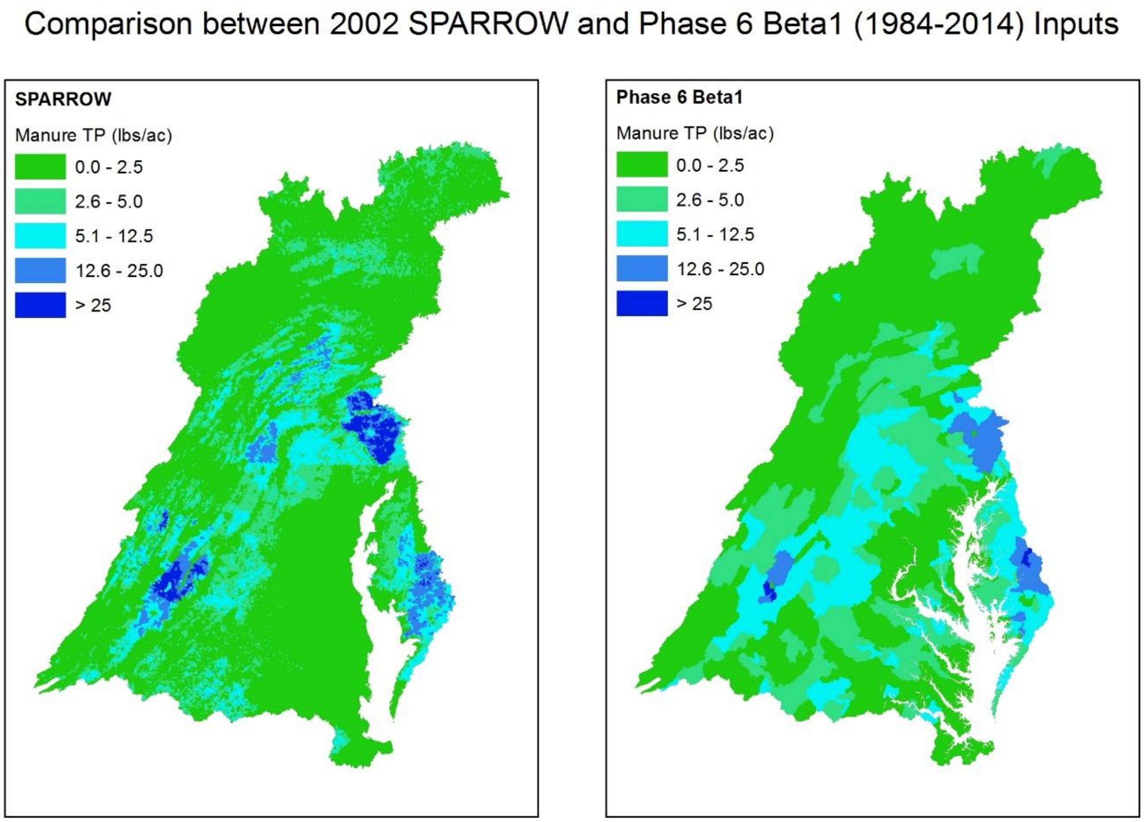


Figure 3-13: P532 and SPARROW total phosphorus manure inputs for the year 2002


Comparison between 2002 SPARROW and Phase 6 Beta1 (1984-2014) Inputs
SPARROW
Manure TP (lbs/ac)
0.0 - 2.5
2.6 - 5.0
5.1 - 12.5
12.6 - 25.0
> 25
Phase 6 Beta1
Manure TP (lbs/ac)
0.0 - 2.5
2.6 - 5.0
5.1 - 12.5
12.6 - 25.0
> 25