CBP/TRS-330-21

Estimates of Nutrient Loads from Animal Mortalities and Reductions Associated with Mortality Disposal Methods and Best Management Practices (BMPs) in the Chesapeake Bay Watershed

Approved by WQGIT: July 24, 2023

Chesapeake Bay Program
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Prepared for

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Executive Summary

This Expert Panel (panel) was charged with defining and configuring the Animal Mortality Management Best Management Practice (BMP) for use in the Phase 6.0 Chesapeake Bay Watershed Model (model). Specifically, the panel was charged with defining the load reduction efficiencies for Nitrogen (N) and Phosphorus (P) for selected mortality management methods and determining how the practice can be represented in the model.

The panel chose to approach this charge by breaking the problem into two parts:

I. Determine the mass of mortalities, N, and P per Animal Unit (AU, 1 AU = 1,000 pounds liveweight) per year produced by the most important animal agricultural practices in the Chesapeake Bay Watershed.

II. Determine the N and P reduction efficiencies of selected mortality disposal methods, and categorize the fractional masses of carcass nutrients removed from agricultural systems, recycled by producers in a Nutrient Management Plan (NMP), volatilized to the atmosphere, and leaving the practice by all other pathways (leaching, overland flow, etc.).

This division of investigation is reflected in the two parts of the Expert Panel Report: Part I: Routine Mortality Production, and Part II: Disposal Methods.

In addition to the charge given by the Ag Working Group, the panel also investigated ancillary benefits of mortality disposal methods, specifically biosecurity and reduction of nuisance conditions.

Part I: Routine Mortality Production

The panel focused on the routine day-to-day losses encountered in agricultural systems. It did not focus on mass mortalities due to natural disasters, Foreign Animal Disease (FAD), or other catastrophic events. Agricultural systems considered were poultry (broilers, layers, turkeys), cattle (dairy, beef cow-calf, cattle on feed), swine (hogs and pigs for breeding, hogs for slaughter), and Equidae (horses, donkeys, mules). Annual mass of N and P contained in mortalities estimated by the panel for all animal groups are given in Table ES.1.

Procedures Used to Estimate Annual Mass of Nutrients Produced

In a departure from previous methods of determining mortality losses, which have focused on average death loss times average animal size to determine mass of mortalities produced, the panel examined the production and housing systems used in the watershed in depth in order to estimate the mass of mortalities produced per AU in the production unit.

In the case of broilers, the panel estimated the mass of N and P contained in mortalities during the grow-out of 1,000 birds by combining the effect of several non-linear phenomena: the death loss pattern through the length of broiler grow-out, the liveweight of birds at each point in the growth pattern of broilers, and the nutrient concentration of carcasses throughout the bird’s life. The mass of nutrients contained in carcasses was then normalized by dividing by live mass of birds at the end of the grow-out period.

Table ES.1. Estimated weight of mortality nutrients produced by farms on a per AU (1,000 pounds liveweight) basis.

Type of Farm	Characteristic Animal(s)	Weight of Mortality Nutrients Produced per Farm (Lbs. AU^{-1} $year^{-1}$)	
		TN	TP
Poultry			
Broiler	6 lb. Market Birds	1.8	0.25
Layer	Laying Hens	2.2	0.40
Tom Turkey	48 lb. Market Toms	2.5	0.33
Hen Turkey	25 lb. Market Hens	2.5	0.32
Swine	270 lb. Market Hog	1.5	0.34
Cattle			
Cow-Calf Herd	Mother Cow	0.65	0.19
Cattle Feedlot	Heifer and Steer Capacity	0.47	0.14
Dairy	Mature Cows (Milking and Dry)	1.9	0.57
Equidae	1,150 lb. Horse	0.34	0.12

Mortality of some animal groups, such as horses, is less predictable on a per-farm basis. Horse owners are more likely to experience the unexpected loss of a single animal than a predictable percentage of animals in a herd. In these cases, the panel considered a large population of animals housed on more than one farm and potentially more than one state. Mortality losses for a 1,000 head herd were then calculated using published data of animal populations, body weights, and average death rates within age groups of various breeds of horses, donkeys, and mules. Mortality nutrient masses within a jurisdiction can be estimated by multiplying the estimated mortality production per AU by Equine AUs housed in the jurisdiction.

Comparison of the Panel's Results to Previous Attempts to Estimate Mortality Masses

Table ES.2 compares the per AU values determined by this panel to those estimated in the Simpson Weammert Report (Felton et al., 2009). In the case of broilers, the approach taken by the panel determined a lower production of mortality nutrients than the estimates of Felton et al. (2009) which used an average death rate times average body mass approach. The method used by this panel estimated a much lower mass of mortalities produced per five-pound market weight broiler than Felton et al. (2009); however, the nutrient composition used in both estimations was very similar. Results for other types of poultry were similar to Felton et al. (2009).

Importance of Mortality Nutrients to the Model

Another finding of the panel is the nutrients contained in mortalities produced on a farm are somewhat insignificant when compared to the manure nutrients produced on the same farm (Table ES.3). This conclusion should be considered when determining how routine mortalities are incorporated in future phases of the model.

Table ES.2. Comparison of estimated production of mortalities and the nutrients contained in mortalities for different types of poultry operations based on the method of this report and the methods used in the Simpson Weammert Report (Felton et al., 2009).

	The Method of This Report			The Method of Felton et al. (2009)		
	Mortalities (lbs.)	Total N (lbs.)	Total P (lbs.)	Mortalities (lbs.)	Total N (lbs.)	Total P (lbs)
Broilers 5 lb. market weight, 1,000 bird grow-out	51	1.3	0.2	175	5.1	0.8
Tom Turkeys 48 lb. market weight, 1,000 bird grow-out	1,700	50	6.5	1,500	n.d.[1]	n.d. [1]
Layers 1,000 birds, annual mass produced	210	8.3	1.5	250	6.9	1.2

[1]Felton et al. (2009) did not estimate the nutrient composition of turkeys.

Table ES.3. Percentage of manure and mortality nitrogen and phosphorus contributed by mortalities for typical animal operations in the Chesapeake Bay Watershed.

Type of Farm	**Percentage of Farm Nutrients (Manure and Mortalities) Originating with Mortalities**	
	TN	**TP**
Poultry		
Broiler	1.3 - 2.4	0.65 – 1.2
Layer	0.70	0.40
Turkey	4.0	2.0
Swine	3.2	3.8
Cattle		
Cow-Calf Herd	0.45	0.58
Cattle Feedlot	0.26 – 0.32	0.45 – 0.75
Dairy	0.55 – 0.65	0.93 – 1.2
Equidae	0.30 - 0.52	0.51 – 1.5

Part II: Disposal Methods

The panel looked in depth at five mortality disposal methods: burial, composting, incineration, landfilling, and rendering. The panel conducted an extensive literature review of the environmental impact of each method. Although the literature of nutrient movement during disposal of animal mortalities is limited, the panel was able to estimate the fraction of nutrients leaving each method along the pathways shown in Figure ES.1. The estimated mass of nutrients leaving by each pathway are given in Table ES.3.

The panel did not attempt to judge the benefits of one disposal method over another. Furthermore, reduction in nutrient load may not be the best criteria by which to judge the benefits of a disposal method. Biosecurity considerations, reduction in nuisance conditions, ease of operation, and implementation cost may be the greatest factors determining the choice of a method to an individual producer.

As shown in Table ES.3, composting and incineration showed the greatest potential to recycle nutrients within a farm nutrient management plan; however, these methods also had the greatest potential of those studied to release nitrogen into the atmosphere. When implemented properly, incineration showed the greatest potential to remove pathogens from mortalities. Burial is also a good method to reduce nuisance conditions and slow the movement of disease vectors off farm, but the greatest setback to a producer using burial as a disposal method is loss of productive land tied up in the practice. Burial also had the greatest potential to leach nutrients into the surrounding soil.

Movement of nutrients to the on-farm environment using landfilling and rendering is essentially zero in terms of the model. This is due to the fact that these methods result in carcasses being removed from the agricultural system. Although not specifically studied by the panel, use of refrigerated storage units are an essential component for the success of multiple-farm landfilling and rendering systems – particularly for small animals such as poultry and swine piglets.

Future Research Needs

The panel universally found a deficit of whole carcass nutrient content data. Although the panel is confident in the data produced for this report, some values were produced through limited published data on mortalities, unpublished industry estimations of death losses, information provided by breeders, and/or personal communication with top researchers in the field. Research should be undertaken to determine the actual mass of mortalities produced on farms under the cultural practices used in the watershed.

Reference

Felton, G., Timmons, J., & Ogejo, J.A. (2009). Mortality composting, definition and nutrient and sediment reduction effectiveness estimates, pp 393-412, In Simpson, T. and J. Weammert. *Final Report, Developing Best Management Practices and Definitions and Effectiveness Estimates for Nitrogen, Phosphorus, and Sediment in the Chesapeake Bay Watershed*. College Park, MD: Univ. of MD Mid Atlantic Water Program.

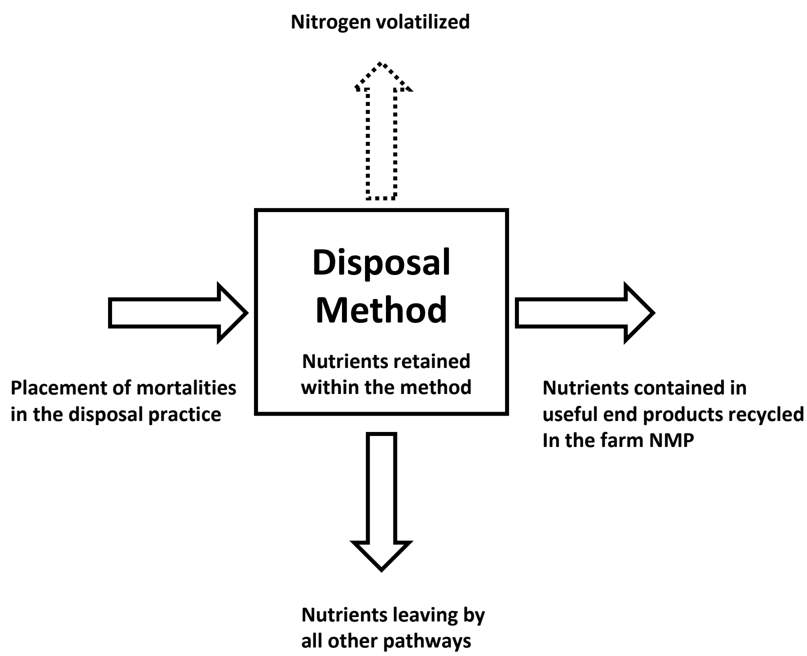

Figure ES.1. Potential movement of nutrients during the implementation of a disposal method.

Table ES.3. Potential movement of nutrients during implementation of a disposal method, fallback values.

	Mass Percentage of Carcass Nutrients Exiting the Method (%)				
	Nutrients recycled with end products in the farm nutrient management plan		Nutrients emitted to the atmosphere	Nutrients leaving the method by all other pathways	
	TN	TP	TN	TN	TP
Burial	0	0	0	15	5
Composting	80	100	10	10	0
Incineration	25	100	75	0	0
Landfilling	0	0	0	0	0
Rendering	0	0	0	0	0

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Appendices

Background

1. Expert panel process

Expert panels formed to evaluate nonpoint best management practices (BMPs) by the Chesapeake Bay Program's Water Quality Goal Implementation Team (WQGIT) or its workgroups follow the expectations and process laid out in the *Protocol for the Development, Review, and Approval of Loading and Effectiveness estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed*, aka the "BMP Protocol."

1.1 Panel history and panel membership

In 2017 the Chesapeake Bay Program's Agriculture Workgroup (AgWG) formed an expert panel establishment group (EPEG) to:

- Determine the necessity for a Phase 6.0 Animal Mortality Management Expert Panel (EP).
- Identify priority tasks for the Phase 6.0 Animal Mortality Management EP,
- Recommend areas of expertise that should be included on the Animal Mortality Management EP, and
- Draft the Animal Mortality Management EP's charge for the review process.

The EPEG met from November 2017 through January 2018, and recommended that the AgWG form an expert panel that would be coordinated through Virginia Tech's cooperative agreement with the EPA-CBPO. The EPEG's memo, which was approved by the AgWG in March 2018, is provided as Appendix A of this report.

Virginia Tech issued a request for proposals and selected the proposal submitted by Doug Hamilton from Oklahoma State University. As per the WQGIT BMP Review Protocol, partnership feedback was solicited on the draft scope of work and proposed panel membership. Following partnership feedback, the panel membership was amended to include an additional regional expert (Bud Malone). The AgWG subsequently approved the panel membership (Table 1) on August 16, 2018.

The panel convened for its first call in November 2018 and held its required public stakeholder session on November 25, 2018 near Baltimore, MD. The panel met face-to-face twice, in November 2018 and June 2019, plus another 14 times by conference call through its duration. Summaries of the meetings and discussions are included as Appendix D to this report. The panel was convened to deliver its recommendations as laid out in the WQGIT's BMP Review Protocol, with their specific charge summarized in the next section.

Table B.1.1 – Expert Panel membership and support

Name	Role	Affiliation
Douglas W. Hamilton, PhD, P.E.	Panel Chair	Oklahoma State University
Thomas M. Bass	Member	Montana State University
Amanda Gumbert, PhD	Member	University of Kentucky
Ernest Hovingh, PhD	Member	Pennsylvania State University
Mark Hutchinson	Member	University of Maine
Teng Teeh Lim, PhD, P.E.	Member	University of Missouri
Sandra Means, P.E.	Member	USDA NRCS, East National Technology Support Center
George "Bud" Malone	Member	Malone Poultry Consulting; University of Delaware (retired)
Panel support		
Jeremy Hanson	Panel Coordinator	Virginia Tech, CBPO
Brian Benham, PhD	VT Project Lead	Virginia Tech
Jeff Sweeney	WTWG & CBPO Modeling Team rep	EPA, CBPO
Mark Zolandz	Regulatory contact	EPA Region III
Loretta Collins	AgWG Coordinator	University of Maryland, CBPO
Mark Dubin	Senior Ag Advisor	University of Maryland, CBPO

1.2 Panel charge

The general scope of work for the Animal Mortality Management Expert Panel (EP) will be to define and configure the Animal Mortality Management BMPs in the Phase 6 model. Specifically, the Animal Mortality Management EPEG recommends the following charge with associated tasks for the Phase 6.0 Livestock and Poultry Mortality Management EP, supplemented by Figure B.1.1 and Table B.1.2 below:

1. Determine scope of the EP based on available data and impact on water quality
    - Animal groups and/or group components to be addressed
        - Definitions available on CBP's Chesapeake Assessment Scenario Tool (CAST)
    - Mortality management practices to be addressed (Table B.1.2)
2. Define load reduction efficiencies for N and P of selected practices for agricultural feeding space areas.
    - Consider fate of N and P across selected practices
        - Decomposition and mineralization
        - Leachate
        - Volatilization
        - Field application
        - Removal from agricultural system

Potential Credit Mechanisms:

Option 1: If an EP finds a water quality benefit, that benefit could be added as a % reduction to feed space loads in a future milestone period.

Option 2: Ag Workgroup could request a change to the manure calculations from the Water Quality GIT and Modeling Workgroup in a future milestone period if an EP defines:

- % mortality
- nutrients available in carcasses
- water quality benefit

Figure B.1.1. Potential mechanisms to simulate estimated contribution of mortality management

Table B.1.2. Initial framework suggested by EPEG for articulating mortality contributions and possible load source for BMP application

General Animal Group (defined by EPEG)	BMP Animal Groups	% N per Carcass	% P per Carcass	Mortality %	Avg. Dead weight?	Mortality Management Baseline (1984)	Mortality Management Today**	
Primary Animal Group	Poultry	?	?	?	?	Burial	Burial	Yes
							Freezer	Yes
							Compost	Yes
							Incineration	Yes
	Swine	?	?	?	?	Burial	Burial	Yes
							Freezer	Yes[#]
							Compost	Yes
							Incineration	Yes
Secondary Animal Group	Cattle	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No
	Equine*	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No
	Other? (e.g. Sheep, Goats)	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No

*Direct-to-rendering also practiced
** Current mortality management in the Bay watershed, as understood by EPEG members
[#]Piglets (nursery) only

3. Determine how the selected mortality management practices can be represented in the model.
    - Consider the information necessary to address Options 1 and 2 (Figure B.1.1)
        - Option 1: applicable to 2020-2021 milestone planning
        - Option 2: applicable to post-Phase 6.0 Watershed Model

The charge from the EPEG also outlined the elements of an EP report as stipulated in the BMP Review Protocol. Those report elements are not re-stated here, but are listed in the appendices of this report. The sections of this report are structured to convey the necessary information requested in the panel charge. As the panel deliberated their work, they agreed that the logical organizing theme for this report would follow from Table B.1.2 above, specifically (a) the animal type(s), their mortality rate estimates and carcass nutrient content, and; (b) disposal methods for the mortalities, and the effect of those methods on the nutrients from animal mortalities.

2. Overview of the Phase 6 Watershed Model animal input and waste simulation processes

The Chesapeake Bay Program has a suite of models that work together to estimate changes to tidal water quality in the Chesapeake Bay. Best management practices are simulated as part of the Watershed Model, which estimates the amount of nitrogen, phosphorus and sediment that reaches the Chesapeake Bay from its tributaries and watershed. The Watershed Model is currently in its “Phase 6” version, which is updated every two years according to rules established by the Chesapeake Bay Program partnership through collaboration of the WQGIT, Modeling Workgroup, Bay Program modelers and other partners.

The Watershed Model combines a wide range of inputs, including the outputs from the CBP’s Airshed Model and Land Use Change Model. Animal mortality management occurs in the agricultural sector and its role in the Watershed Model relates most closely to the Model’s existing livestock and poultry inputs. As previously noted, the current Watershed Model does not include explicit estimates of nutrients contributed by dead animal carcasses. Nutrient inputs in the modeling tools from livestock and poultry are represented by animal manure. This section includes a brief summary of how manure nutrients are simulated within the model, especially since routine animal mortalities and animal manure are sometimes managed concurrently as part of an operation’s waste. There are differences between manure management and mortality management, and this report attempts to parse the issues to the best of panel’s ability. However, since the panel’s recommendations are expected to contribute to the Watershed Model’s overall process and assumptions for the management of animal waste nutrients on agricultural operations, it is best to understand and to frame the estimates of mortality nutrients in relation to manure nutrients, at least until a future version of the Model can build on this panel’s work and include an individual load source for mortalities, if desired.

The overall processes for manure generation, dispersal and subsequent loss or application are illustrated in Figure B.2.1 below. First, the amount of manure is estimated at a county level based on the livestock and poultry populations within that county. The manure generated per animal is based on either as-excreted values from the American Society of Agricultural and Biosystems Engineers (ASABE), or other national or regional datasets, as documented in Chapter 3 of the Model Documentation.

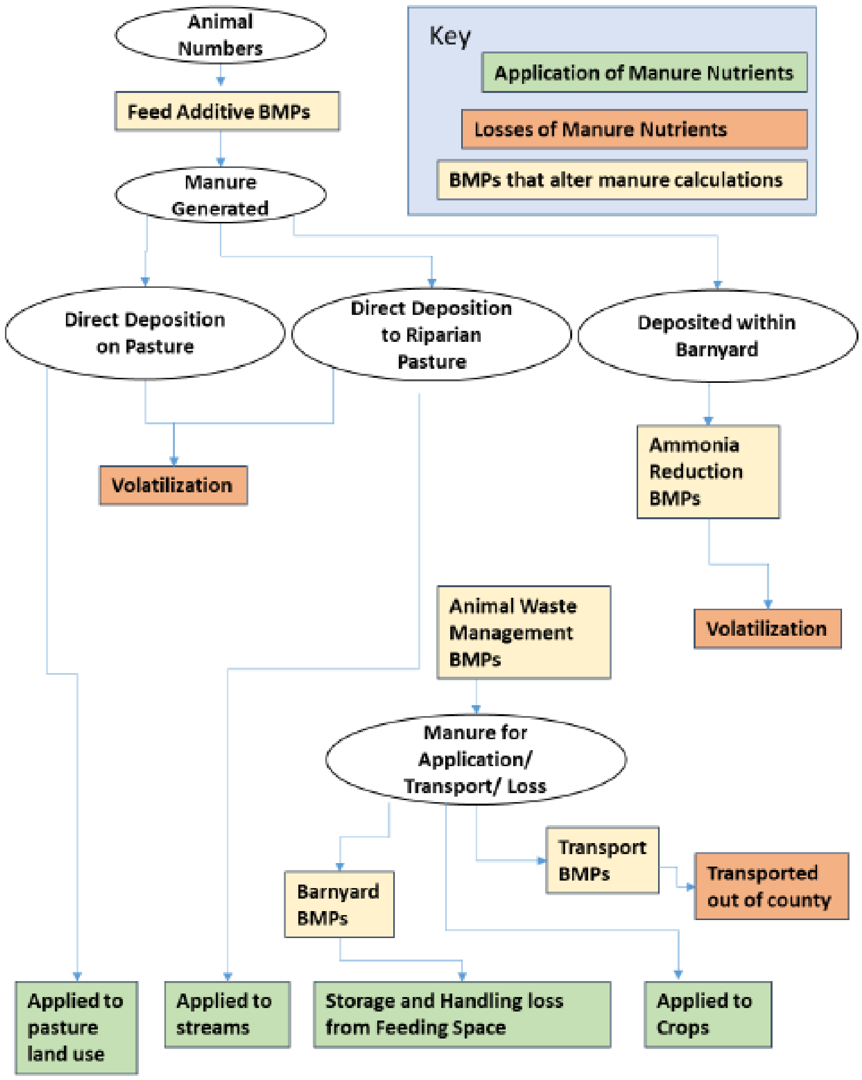

Figure B.2.1. Manure application processes in the Watershed Model (Source: copied from Figure 3-6 in Watershed Model Documentation)

Note: All documentation for the Watershed Model is available on CAST at https://cast.chesapeakebay.net/Documentation/ModelDocumentation

Note: Detailed manure source data, including manure nutrients per animal, is available at https://cast.chesapeakebay.net/Home/SourceData

Once there is a county level estimate of total manure nutrients, from there the manure is placed in three conceptual areas that determine the subsequent fate and transport of the manure. For the purposes of the mortality management EP, the focus is on the “barnyard deposition,” which in turn defines the amount of manure nutrients available for land application or transport.

Figure B.2.1 reiterates the point made by the EPEG that the Watershed Model does not explicitly represent the amount of nutrients from animal mortalities within the agriculture sector. Overall, nutrient inputs in the agriculture sector also include biosolids and inorganic fertilizer, which are irrelevant to this panel's work and thus not discussed here. The only currently simulated source of animal nutrients is from their manure. The panel's recommendations may allow the CBP to simulate an explicit source of nutrients from routine animal mortalities, though the overall amount of those nutrients is expected to be dwarfed by other agriculture sector nutrient sources. Note: For this report it is important to understand that "barnyard" represents all non-pasture portions of livestock or poultry lifecycles for model purposes.

When a best management practice is applied in the Watershed Model, it can reduce loads in a number of general ways, which are described in full within the Model Documentation (Chapter 6), and also summarized in the *Quick Reference Guide for BMPs*, starting on page 17 (https://www.chesapeakebay.net/documents/BMP-Guide_Full.pdf). This section will not describe how each type of BMP is simulated in the Model, but it is important to note that Animal BMPs can have ripple effects on subsequent model processes, such as the load available for land application to crop need. This panel is not tasked with investigating or recommending changes to any of those processes, though the panel's recommendations will likely interact with them. Furthermore, it is understood that adding a new load source for mortalities would violate the calibration rules and would need to wait for a future version of the model (i.e., "Phase 7"), which means that aspects of this report will not apply within Phase 6.

2.1 Summary of watershed animal populations over time

Nutrients from manure generation or animal carcasses from routine mortality are based on the overall animal population. Animal populations vary over time, and the AgWG is often discussing how to improve its animal population data. Currently animal data is primarily based on Census of Agriculture data, as well as annual NASS survey data and state data. The data source varies by animal type, but the focus of this report is not on animal population data, so the data currently within CAST offers a sufficient snapshot for readers of this report. The following two graphs, Figures B.2.2 and B.2.3, split the total animal populations into Livestock and Poultry categories from 1985 to 2019. The respective animal types within each category are seen in the legend for each chart. The graphs are in animal units, which gives a better sense of the relative scale between livestock and poultry categories. Note: The figures below include animal totals from both "permitted" and "non-permitted" load sources in CAST.

The charts below represent animal populations at the 64,000-mile watershed scale. Animal populations and manure is simulated at a county scale and there is wide variation in animal populations amongst the 188 counties that are partially or wholly within the watershed. The greatest animal populations are found in the Shenandoah Valley (including Rockingham County) in Virginia, southeastern Pennsylvania (including Lancaster County), and the Delmarva Peninsula.

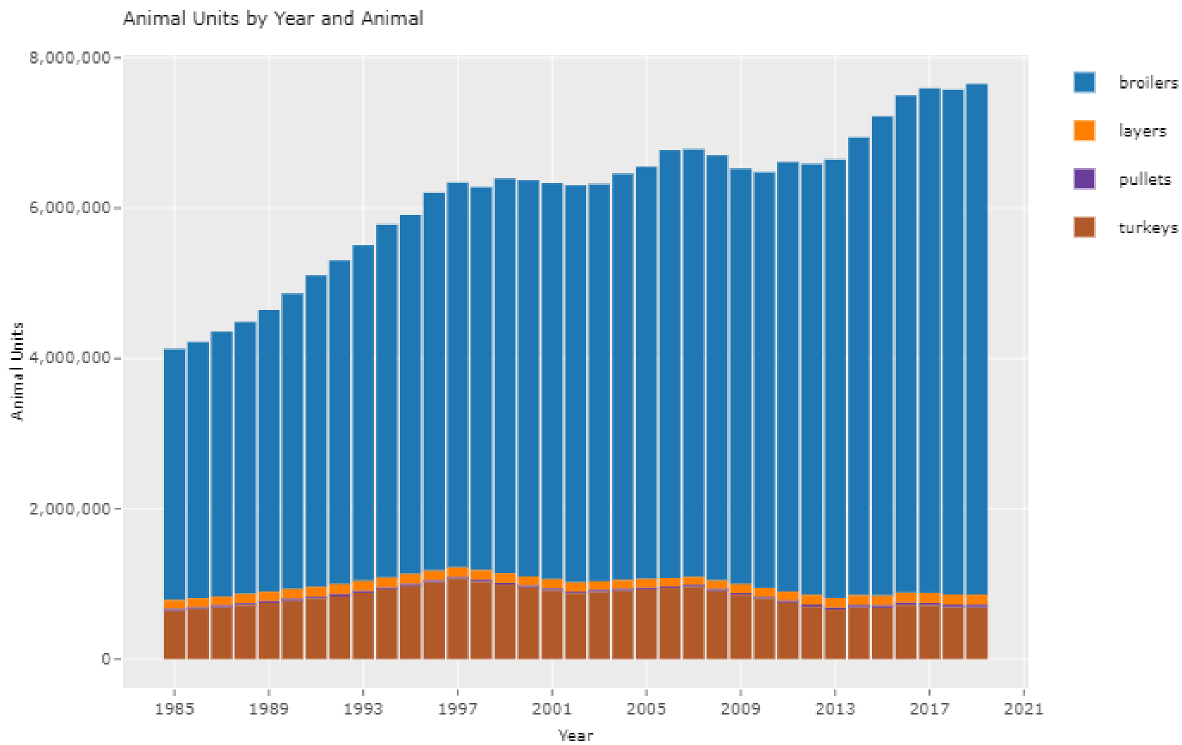

Figure B.2.2 Poultry total annual production (AU), Chesapeake Bay watershed, 1985-2019. Source: CAST trends over time, https://cast.chesapeakebay.net/TrendsOverTime/AnimalUnits

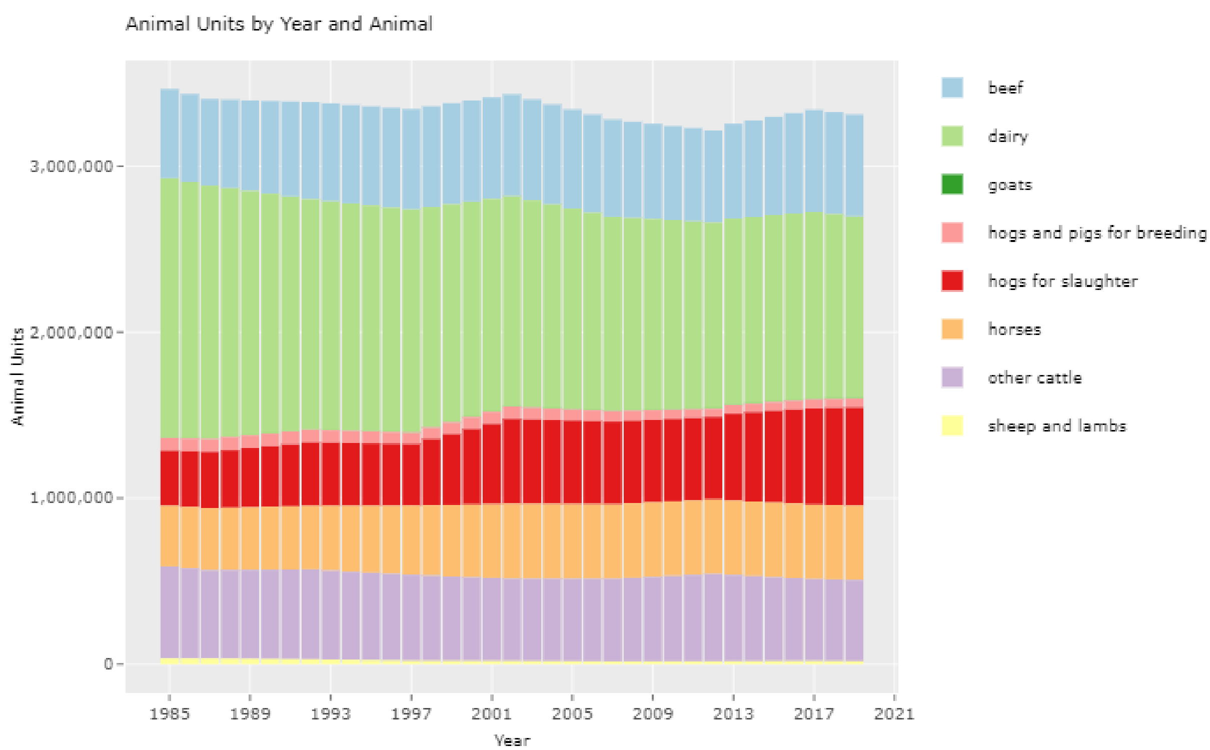

Figure B.2.3 Livestock total annual population (AU), Chesapeake Bay watershed, 1985-2019. Source: CAST, trends over time, https://cast.chesapeakebay.net/TrendsOverTime/AnimalUnits

Part I

Routine Mortality Production

1. Introduction

Unplanned death of livestock and poultry is a fact of life in animal agriculture. The loss of income and production capacity as well as the cost of carcass disposal can place a heavy burden on farmers. Mortalities are both a biosecurity and an environmental hazard. While this report focuses on the nutrient enrichment aspect of environmental pollution, the greatest hazard with mortalities may be the spread of disease by vectors and by direct contact with carcasses. Nuisance conditions associated with the disposal of mortalities also pose one of the greatest societal challenges of animal production.

1.1 Routine versus Catastrophic Mortalities

There are two types of mortalities in modern animal production: routine and catastrophic. Routine mortalities take place during the day-to-day operation of farms. Not all chicks, poults, pigs, calves and foals live to reach maturity, and mature animals die unexpectedly. Catastrophic death occurs because of one-time events such as fires, disease outbreaks, and weather-related incidents. Catastrophic losses might also occur as the result of purposeful depopulation of animals to contain the outbreak of disease. This report concentrates on routine mortalities of livestock and poultry. The first half of this report provides a method to quantify the routine mortalities experienced by animal operations and gives estimated numbers of moralities in typical agricultural production systems in the Chesapeake Bay Watershed. Many of the disposal methods covered in the second half of this report may be used on both routine and catastrophic mortalities.

1.2 Quantification of Routine Mortalities

A summary of the findings of this expert panel is given in Table I.1.1, reported on an animal unit (AU) basis. Estimating the number and weight of routine mortalities has been a vexing problem for farmers, and uncertainty in rate of mortalities produced has stifled the development of mortality disposal methods. In the past, estimates have generally taken the form of “estimated death rate of animals times the average weight of animals equals the rate of mortality production on a weight basis”. The problem with this technique is it is an over-simplification of actual production systems. The death rate of animals is rarely constant. Death rate depends greatly on the age, size, and environmental conditions of the animals. Furthermore, most meat production systems involve young and juvenile animals that are constantly growing. Average death rate rarely occurs when animals are at their average weight. Death more commonly occurs when animals are very young or approaching maturity.

Table I.1.1. Summary of expert panel findings, estimated weight of mortality nutrients produced by farm on an AU (1,000 liveweight) basis.

Type of Farm	Characteristic Animal(s)	Weight of Mortality Nutrients Produced per Farm (lbs AU^{-1} $year^{-1}$)	
		TN	TP
Poultry			
Broiler	6 lb. Market Birds	1.8	0.25
Layer	Laying Hens	2.2	0.40
Tom Turkey	48 lb. Market Toms	2.5	0.33
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Cattle			
Cow-Calf Herd	Mother Cow	0.65	0.19
Cattle Feedlot	Heifer and Steer Capacity	0.47	0.14
Dairy	Mature Cows (Milking and Dry)	1.9	0.57
Equidae	1,150 lb. Horse	0.34	0.12

The approach taken by this expert panel was to look at death at animal production systems for poultry (broilers, layers, and turkeys), swine, cattle (dairy and beef), and equidae (horses, donkeys and mules) as reported in the scientific and industry literature. Death was taken as an episodic event, and the weight of a given animal taken at the time of death was used as the weight of carcasses. Individual carcass weights were accumulated over a growing period (as in the case of broiler production), or over a multi-year cycle (as in the cases of laying hens), or a combination of the average annual death rates of breeding stock and the growth cycle of young stock (as in beef cow-calf herds). Values were then annualized by multiplying by the average number of growth cycles per year (6.1 flocks per year for 6-pound broilers for instance) or dividing by years in a multi-year production cycle (80 week laying period for hens). Weight of nutrients contained in mortalities was estimated by multiplying weight of mortalities by carcass composition. In some cases, such as broilers where it is known that the nutrient composition of flesh and feathers changes with age, the changing nutrient composition was taken into account during the accumulation of mortalities. Production of mortality nutrients was normalized for different production systems by dividing the average annual carcass nutrient weights by a characteristic animal for the system. These characteristic animals were chosen so that mortalities may be calculated using numbers provided by the USDA-NASS census of agriculture (mother cows for beef cow-calf operations), values used by the Chesapeake Bay Program (hogs for slaughter for swine), and populations reported by various trade organizations (horse population data). Data is provided on both a per-head and per-liveweight (AU) basis. Fall back numbers (values to be used in the absence of more identifying information for a farm or jurisdiction) for the general animal groups investigated by the expert panel are given in the summary table (Table I.1.1). More detailed information for individual production systems can be found in the chapters within Part I of this report.

1.3 Relative Mass of Nutrients from Routine Mortalities

The nutrients contained in mortalities are a minor component of the water pollution potential of animal production. The percentage of nitrogen and phosphorus contributed by mortalities to the combined mass of manure and mortality nutrients for the animal groups investigated by this expert panel is given in Table I.1.2. Greater detail is provided in the chapters within Part I of this report. Although the relative amount of waterborne nutrients contributed by mortalities to the Chesapeake Bay watershed may be small, this is not to say that mortality nutrients may not play a greater role in local water pollution. Also, the biosecurity hazard posed by inappropriately disposed carcasses may outweigh that of manure by several orders of magnitude.

Table I.1.2. Percentage of manure and mortality nitrogen and phosphorus contributed by mortalities for typical animal operations in the Chesapeake Bay Watershed.

Type of Farm	**Percentage of Farm Nutrients (Manure plus Mortalities) Originating with Mortalities**	
	TN	**TP**
Poultry		
Broiler	1.3 - 2.4	0.65 – 1.2
Layer	0.70	0.40
Turkey	4.0	2.0
Swine	3.2	3.8
Cattle		
Cow-Calf Herd	0.45	0.58
Cattle Feedlot	0.26 – 0.32	0.45 – 0.75
Dairy	0.55 – 0.65	0.93 – 1.2
Equidae	0.30 - 0.52	0.51 – 1.5

2. Poultry

2.1 Definitions

Broiler: A meat chicken of either sex bred and grown to market weights of 2 to 10 pounds. Broilers weighing more than 6 pounds are often referred to as **Roasters.**

Chick: A meat-type chicken of either sex from day old to the end of brooding.

DELMARVA: The peninsula of land where Delaware (3 counties), Maryland (9 counties), and Virginia (2 counties) converge. This area is situated between the Atlantic Ocean and the Chesapeake Bay, which is also referred to as the "Eastern Shore."

Layer: A female chicken (hen) kept solely for egg production for human consumption.

Mortality: On-farm death losses.

Poult: A meat-type turkey of either sex from day old to the end of brooding.

Pullet: A female chicken that has not yet started to lay eggs for human consumption.

Turkey: A meat-type turkey grown for human consumption. **Hen turkeys** are females grown to 12-16 pounds market weight. **Heavy hens** are females grown to 18 to 25 pounds market weight. **Tom turkeys** are males grown to 42-48 pounds market weight.

2.2 Broilers

2.2.a Broilers in the Watershed

The annual production of broilers in the six states making up the Chesapeake Bay watershed is nearly seven billion pounds (USDA-NASS, 2018). Table I.2.1 lists the total annual production of broilers, the average weight at finishing, and the average grow-out period of broilers in the states comprising the Chesapeake Bay Region. The numbers in Table I.2.1 represent the total of all production in the state listed, not only the portion of the state within the watershed. Production of broilers in the part of New York within the watershed is miniscule (Hawkins et al, 2016). The areas of highest broiler production are the Delmarva Peninsula, the Shenandoah Valley of Virginia, and Lancaster County, Pennsylvania.

Table I.2.1. Broiler production in the Chesapeake Bay Region (from USDA-NASS, 2018).

	Annual Production (Million Pounds)	Number of Birds Raised (Millions)	Average Market Weight (lbs)	Average Length of Grow-out[1] (days)
Delaware	1,900	260	7.2	47
Maryland	1,800	310	6.0	41
Pennsylvania	1,000	185	5.6	39
Virginia	1,600	280	5.8	40
West Virginia	340	86	3.9	31
Total of 5 States	**6,700**	**1,121**	**6.0**[2]	**41**[2]

[1]Based on growth rate of common genetic lines (Aviagen 2019, Cobb-Vantress, 2018).
[2]Weighted average based production capacity in each state.

Almost all broiler production in the watershed is through vertical integration, with large companies (the integrator) suppling chicks to contract growers who raise birds to market weight. Birds are then picked up by the integrator for slaughter. Market weights range from four to eight pounds; however, contract growers generally refer to pick-up times (for instance: five-, six-, and seven-week birds) rather than market weights.

Nearly all broilers within the watershed are raised in confinement. The newest confinement buildings are tunnel ventilated with between 25,000 and 50,000 birds raised under roof (Figures I.2.1, I.2.2 and I.2.3). On the Eastern Shore of Maryland and Delaware, farms have manure storage sheds capable of holding up to 180 days' worth of litter and cake production. Most of these sheds store cake (the wet crusted manure caked under feeders and waterers). Total litter removal occurs every three to four years on average, the bulk of which is transported off the farm of origin. The predominant mortality disposal method is on-farm composting, with freezer storage and transport to rendering facilities becoming more common on the Eastern Shore.

2.2.b Nutrients Contained in Broiler Mortalities

Growth Rate of Broilers

Three recent sources were found of typical growth pattern of broilers. Two sources were from common genetic lines of broiler chickens: Cobb 500 (Cobb-Vantress, 2018) and Ross 308 (Aviagen, 2019). The third was a refereed journal article describing the mortality and composition of male broilers (Caldas et al., 2019). The average growth pattern based on these three sources is shown in Figure I.2.4. The three sources are in very close agreement up to six weeks (42 days) of growth or approximately 6.4 pounds live weight. There is more uncertainty in live weight of birds after six weeks of age as indicated by the confidence interval shown in Figure I.2.4. The major source of uncertainty was the slower growth of the male broilers described in Caldas et al (2019) after five weeks of age. The average growth curve shown in Figure I.2.4 was used in all further calculations.

It should be noted that modern broilers grow much quicker than in previous years. In the 1980s, broilers reached four pounds in seven weeks (MWPS, 1980). Today's birds grow to eight pounds in seven weeks (Figure I.2.4).

Figure I.2.1. Typical layout of a broiler farm in the Chesapeake Bay Watershed (Chip West).

Figure I.2.2. Tunnel Ventilated Broiler Houses (Bud Malone).

Figure I.2.3. Interior of Broiler House – Birds near Market Weight (Poultryventilation.com).

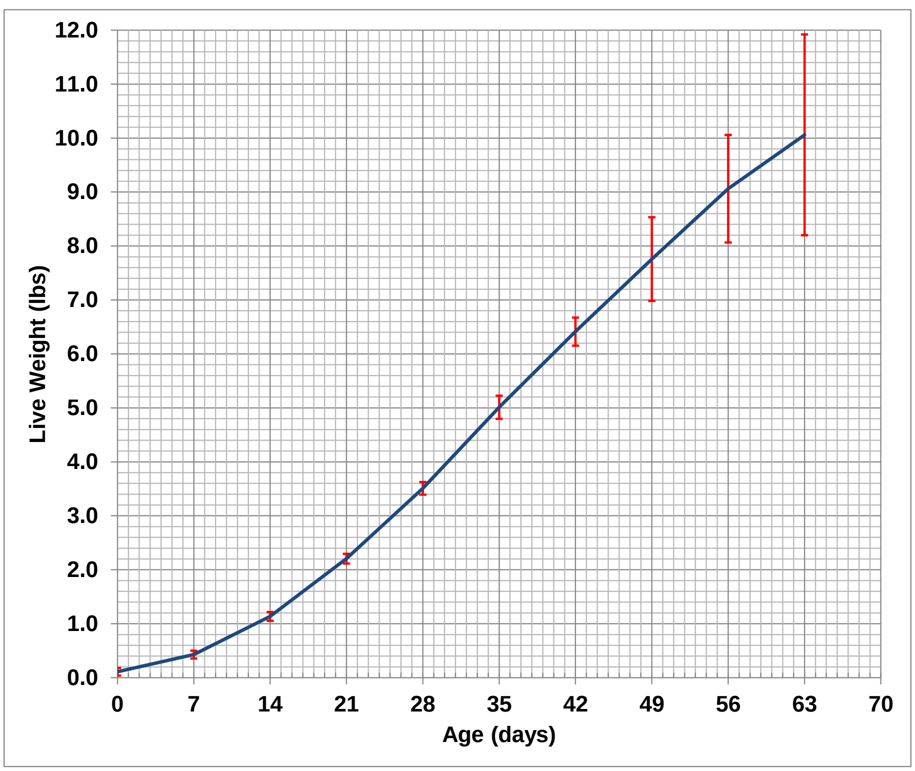

Figure I.2.4. Growth pattern of modern broilers based on average of Cobb 500 (Cobb-Vantress, 2018), Ross 308 (Aviagen, 2019), Caldas et al. (2019); error bars indicate 95% confidence interval.

Mortalities

Broilers do not die all at the same time nor at a constant rate. Weekly mortalities collected from a flock of 1,000 birds are shown in Figure I.2.5. The values labelled "NRCS Delaware" are based on statistical values used to size refrigerators for carcass storage. Those labelled "industry" were provided by industry sources in the Delmarva region (G.W. Malone, personal communication, 2019). Mortality is greatest during the first week that chicks are placed in buildings. The chief cause of mortality is the combined effects of stresses from hatching, transport, placement, house environmental conditions, and the rapid transition from using yolk nutrients to in-house feed and water sources. Uncertainty in chick mortality is indicated by the range of data between the two sources. Mortality decreases as the birds grow, reaching a minimum in both quantity and uncertainty at 28 to 42 days of age. Death rates increase after 42 days as the larger birds suffer greater stresses associated with increased bird density, lower air quality and litter conditions.

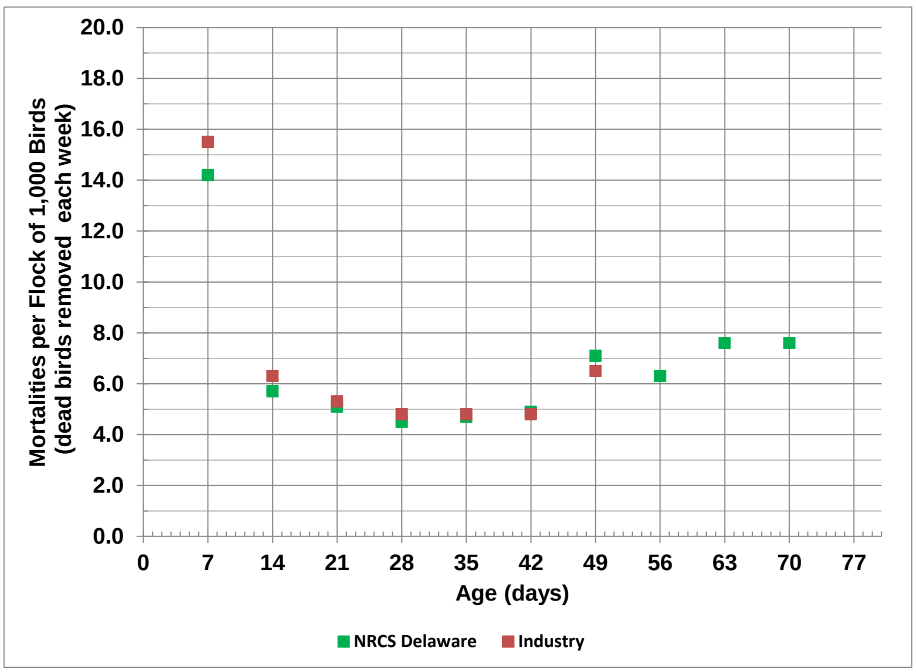

Figure I.2.5. Average weekly death loss of broilers (Malone, personal communication 2019).

Mass of dead birds collected per week was calculated by multiplying number of birds collected per week (Figure I.2.5) times live weight of birds (Figure I.2.4). Pounds of dead birds collected each week versus age for a flock of 1,000 birds is given in Figure I.2.6. Mass of mortalities calculated in this manner fits an exponential function with high correlation (Figure I.2.6).

Carcass Composition

Data on nitrogen composition of live broilers was found in four sources as shown in Table I.2.2. Average whole-body nitrogen content averaged over all four sources was 2.8% on an "as is" basis. Only two journal articles providing phosphorus composition of broiler carcasses were found. Average phosphorus composition of whole broilers based on these two sources was 0.375%.

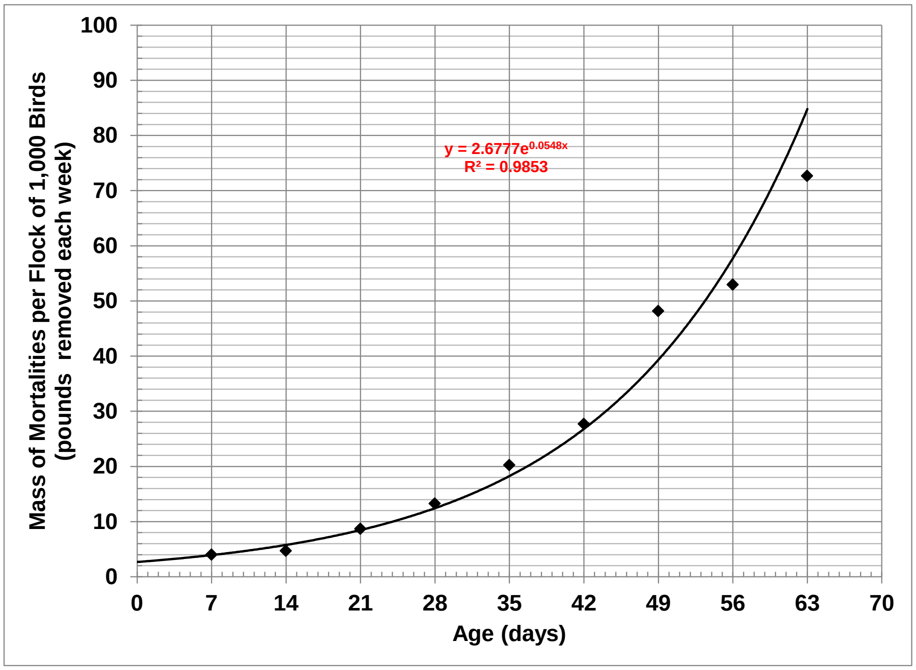

Figure I.2.6. Calculated mass of broiler mortalities collected each week.

Table I.2.2. Total nitrogen and phosphorus composition of broiler carcasses on an “as is” basis.

Literature Source	Elemental Composition (% wet weight)	
	N	P
Caldas et al., 2019	2.83	0.37
Fekete et al., 2019	2.66	
Lomax et al., 1991	2.84	0.38
Vandepopuliere, 1990	2.96	
Average	**2.82**	**0.375**

Caldas et al. (2019) found that nitrogen and phosphorus composition was not constant throughout the life of a male broiler but varied with age (Figure I.2.7). Phosphorus composition remains fairly constant once the basic skeletal structure of the bird is set. The increase in percent nitrogen composition after 20 days of age is attributed primarily to the growth of feathers. Nitrogen content of female birds may be higher than the values shown in Figure I.2.7; because females are likely to have a higher percentage of feathers by mass.

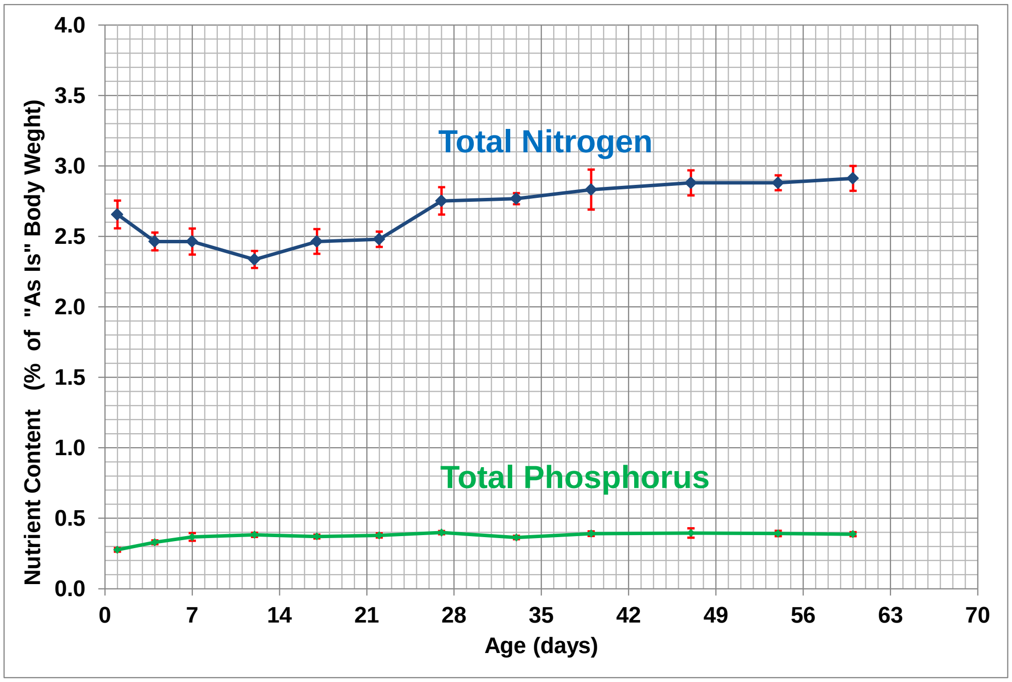

Figure I.2.7. Total nitrogen and phosphorus composition of male broiler carcasses versus age of birds (from Caldas et al., 2019). Error bars indicate 95% confidence interval.

Mass of N and P Available from Broiler Mortalities

Combining the data of Figures I.2.6 and I.2.7 gives the mass of nitrogen and phosphorus available for collection each week for a flock of 1,000 birds. This data is presented in Figure I.2.8. Adding the mass collected in the current week to that collected in previous weeks gives the cumulative mass of nutrients collected up to a certain age of birds (Figure I.2.9.). Since the growth pattern of birds is known (Figure I.2.4), we can also plot cumulative mass of nutrients against the market weight of birds (Figure I.2.10). Mass of mortalities collected and the nutrients contained in carcasses collected over the grow-out of a flock of 1,000 birds is tabulated for market weights of four, six, and eight pounds in Table I.2.3.

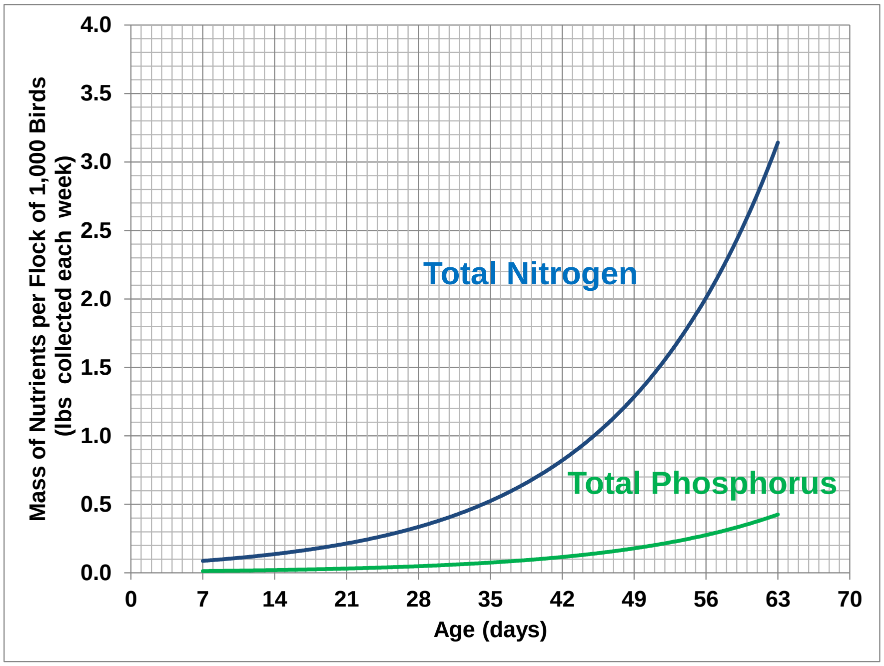

Figure I.2.8. Mass of total nitrogen and phosphorus contained in broiler mortalities collected each week from a flock of 1,000 birds versus age of birds.

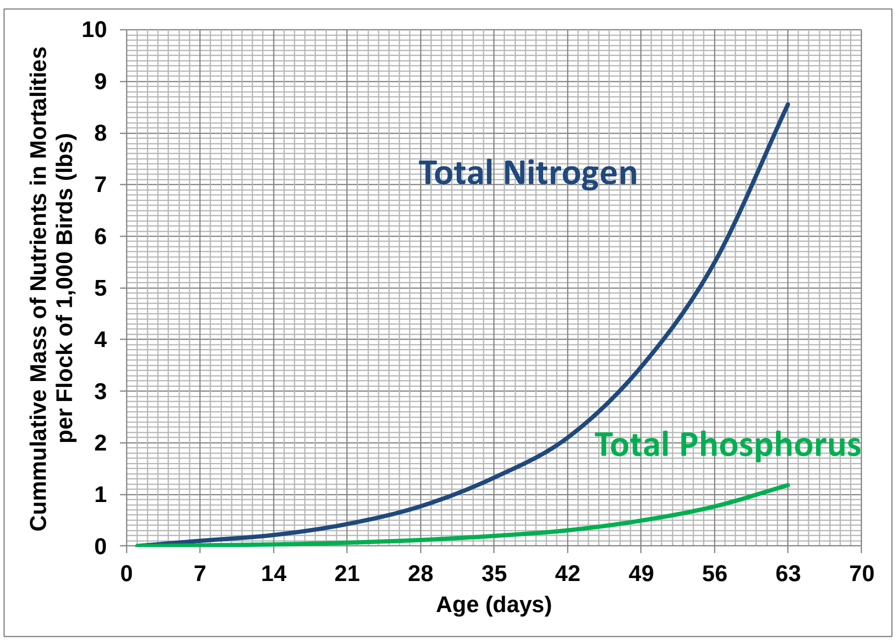

Figure I.2.9. Cumulative mass of total nitrogen and phosphorus collected with broiler mortalities from a flock of 1,000 broilers versus age of birds.

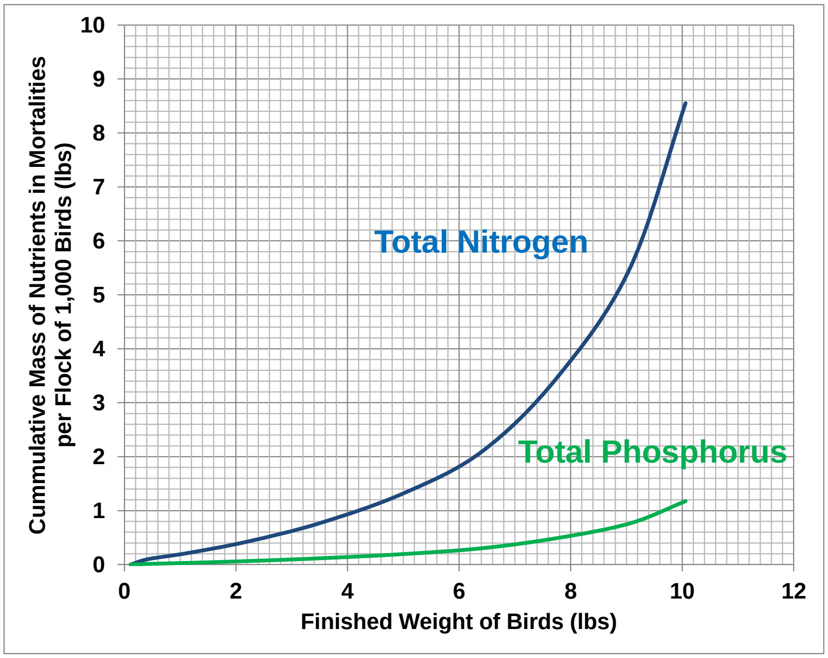

Figure I.2.10. Cumulative mass of nitrogen and phosphorus contained in broiler carcasses produced during the grow-out of a flock of 1,000 birds to various market weights.

Table I.2.3. Mass of broiler mortalities and nutrients contained in carcasses produced during the grow-out of a 1,000 bird flock.

Finished Weight (lb)	Mass of Mortalities and Nutrients collected (lbs)		
	Mortalities	Total N	Total P
4	37	1.0	0.15
6	70	1.8	0.25
8	135	3.8	0.55

2.2.c Annual Mass of Nutrients Contained in Broiler Mortalities

Assuming a broiler will grow to four pounds in 32 days, and given an average 18-day turnaround between flocks, 7.3 flocks of four-pound birds can be grown in a broiler house in one year. Likewise, 6.1 flocks of six-pound birds, and 5.2 flocks of eight-pound birds can be raised each year. Table I.2.4 shows the total mass of mortalities collected each year, and the mass of nutrients contained in those mortalities for a flock of 1,000 birds. Also, mass collected per Animal Unit (1,000 pounds liveweight = 1 AU) based on the estimated flocks per year at each market weight is given in Table I.2.4. The value used to calculate animal unit is mass of birds at the end of the grow-out cycle (i.e. the market weight of birds removed from the house).

Table I.2.4. Expected annual mass of mortalities and nutrients contained in carcasses from a 1,000 bird and one AU (1,000 lbs. liveweight) flock of broilers at various market weights.

		Per 1,000 Birds (lbs year^{-1})			Per 1 AU (lbs year^{-1})		
Market Weight (lb)	Flocks per year	Mortalities	Total N	Total P	Mortalities	Total N	Total P
4	7.3	270	7.3	1.1	68	1.8	0.28
6	6.1	430	11	1.5	72	1.8	0.25
8	5.2	700	20	2.9	88	2.5	0.36

2.2.d Comparison of Results to the Simpson-Weammert Report

Felton et al. (2009) reported on the estimated mass of mortality nutrients in the Chesapeake Bay Watershed as part of the more comprehensive Simpson-Wemmmert report defining nitrogen, phosphorus and sediment delivery by best management practices. Felton et al. (2009) calculated the mass of mortalities and nutrients from broilers based on an average market weight of five pounds. They assumed a 5% death loss of broilers, with all deaths occurring when broilers were in the 70% percentile of body weight (3.5 pounds). They also assumed a body composition of 2.9% nitrogen and 0.46% phosphorus at the time of death. The mass of mortalities and nutrients estimated in this report are compared to estimates of Felton et al. (2009) for a flock of 1,000 broilers at a five-pound market weight in Table I.2.5. **The estimates of Felton et al. (2009) overestimate the mass of mortalities and nutrients calculated by the methods used in this report by a factor of 3 to 4.** The discrepancy with the Simpson-Weammert values lies in the way in which Felton et al. (2009) estimated weight of birds at time of death. On-farm mortality data (Figure I.2.5) shows that not only did Felton et al. (2009) overestimate overall flock mortality in the first 35 days of broiler growth (5% versus 3.4%), but the majority of deaths occurred when birds were substantially lighter than 3.5 lbs.

Table I.2.5. Estimated mass of broiler mortalities and nutrients contained in carcasses during the grow-out of a 1,000 bird flock to five-pound market weight.

	Mass of Mortalities and Nutrients Collected (lbs)		
	Mortalities	Total N	Total P
This report	51	1.3	0.20
Felton et al. (2009)	175	5.1	0.80

2.2.e Comparison of Broiler Mortality Nutrients to Excreted Manure Nutrients

Comparison of nutrients contained in carcasses to nutrient excreted by birds is a true “apples to apples” comparison. Excreted nutrients are the nutrients leaving the birds, before bedding, ammonia volatilization, loss of litter in handling, and a multitude of other factors reduce nutrient concentration in collected manure. Likewise, the nutrients contained in carcasses calculated by the method outlined in this report are nutrients contained in the bird’s body right as it died, before losses from decay, storage, and treatment diminish its mass. Estimates using current formulas for excreted nutrients, which are based on nutrient intake, are highly dependent on assumptions of diet and cultural practices, and should be thought of as rough averages with a high degree of variability - just as this report has highlighted the variability of estimating the mass of carcass nutrients.

A comparison of the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients in excreted manure during the grow-out of the same flock of 1,000 birds at various market weights is provided in Table I.2.6. The American Society of Agricultural and Biological Engineers Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) and the USDA-NRCS *Agricultural Waste Management Field Handbook* (USDA-NRCS, 2008) were used to calculate excreted manure values. Table I.2.6 shows that if carcass nutrients are combined with excreted nutrients, depending on the finished weight of broilers, **between 1.3 and 2.4% of the nitrogen produced on broiler farms originates with mortalities**. Likewise, **between 0.65 and 1.2% of the phosphorus produced on broiler farms comes from mortalities.** The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted during the growth of poultry raised for meat. These values are based on a mass balance of food intake, nutrients accumulated in the body, nutrients respired, and nutrients excreted. Total nitrogen excreted is 0.12 pounds of TN per finished bird. Total phosphorus excreted is 0.035 pounds of TP per finished bird. The *USDA NRCS Agricultural Waste Management Field Handbook* (USDA-NRCS, 2008) assumes finished weight of broilers in the ASABE standard is 6.0 pounds, and provides a proportional method of calculating nutrients excreted at other finishing weights. Furthermore, all birds in a flock of 1,000 do not live to harvest date. From Figure I.2.5, the cumulative death loss of a flock of 4-pound broilers (raised for 32 days) is 30 birds. Therefore, the mass of excreted nitrogen estimated from a nominal flock of 1,000 birds raised to 4 pounds is: 970 finished birds X (4 lbs./6 lbs.) X 0.12 pounds TN per finished bird = 78 pounds TN. Similarly, the mass of phosphorus excreted by a nominal flock of 1,000 4-pound broilers is 23 pounds.

Table I.2.6. Comparison of mass of nutrients contained in mortalities from a flock of 1,000 broilers to the estimated mass of nutrients contained in excreted manure (ASABE, 2005; USDA-NRCS, 2008) by the same flock raised to various market weights.

Market Weight (lb.)	Nutrients Contained in Mortalities (lbs. per 1,000 birds)		Nutrients Contained in Excreted Manure (lbs. per 1,000 birds)	
	TN	TP	TN	TP
4	1.0	0.15	78	23
6	1.8	0.25	120	34
8	3.8	0.55	152	44

2.3 Layers

2.3.a Layers in the Watershed

Total egg production in the Chesapeake Bay Watershed was nearly 10 billion eggs per year in 2017 (USDA-NASS, 2018). Table I.2.7 lists egg production and estimated number of hens by state. It should be noted that the values given in Table I.2.7 are for the entire state, not just the portion of the state within the Chesapeake Bay Watershed. Egg production in Delaware was too small to be listed individually by USDA-NASS (2018). Egg production in New York state was relatively large (1.8 billion eggs per year), but egg production in New York is located entirely outside of the Watershed (Hawkins et al., 2016); whereas, most of the egg production in Pennsylvania, Maryland, Virginia, and West Virginia is located within the watershed. Lancaster County, Pennsylvania has the highest egg production in the watershed, with 61% of all Pennsylvania production taking place in Lancaster County (Hawkins et al., 2016).

Table I.2.7. Egg production and laying hens housed within the Chesapeake Bay Watershed in 2017 (USDA-NASS, 2018).

	Egg Production (Million eggs yr^{-1})	Estimated[1] Number of Hens (Millions)
Maryland	830	2.7
Pennsylvania	8,200	27.0
Virginia	690	2.3
West Virginia	270	0.89
Total of 4 States	**9,990**	**33.0**

[1]Based on 303 eggs hen^{-1} yr^{-1} (Hyline International, 2019)

Almost all layers raised in the Watershed are housed in large confinement buildings (Figure I.2.11), most commonly in cages (although in recent years cage-free housing is becoming dominant). The most common manure handling system for layers is a two-level, high-rise house. Caged birds are housed in the upper level of the high-rise house (Figure I.2.12). Manure is dried and stored in the lower level (Hawkins et al., 2016). Most of the newer, cage-free facilities use belt-dried manure handling systems.

Figure I.2.11. Laying hen farm in Pennsylvania (Phil Clauer, Pennsylvania State University).

Figure I.2.12. Caged layer production (Phil Clauer, Pennsylvania State University)

Young hens (pullets) are placed in the layer houses at about 18 weeks of age. They are housed on the farm for 80 to 100 weeks of age, giving between one and one-and-a-half years of egg production. At the end of their productive life, the entire house of hens is removed for slaughter and replaced with a new batch of pullets.

2.3.b Nutrients Contained in Layer Mortalities

Live Weight of Hens

At 18 weeks, a pullet is sexually mature and able to produce eggs; however, she does not reach full weight until approximately 44 weeks of age. To estimate the growth pattern of laying hens, three popular lines of birds were randomly selected: W36, W80, and Hyline Brown (Hyline International, 2019). These lines include two white egg birds (W36, W80) and one brown egg bird (Hyline Brown), and are representative of the hens found in Lancaster County, PA (Paul Patterson, personal communication, 2019). The growth pattern of the three lines is shown in Figure I.2.13. As can be seen , birds continue to grow throughout their life, but most growth occurs within the first seven weeks after they are placed in the house. Figure I.2.13 also shows that brown egg hens (Hyline Brown) are generally larger than the white egg hens (W36, W80). This difference appears to hold for all genetic lines (Hyline International, 2019). The ratio of two white egg to one brown egg genetic lines was chosen to represent the average of the population of laying hens across the watershed.

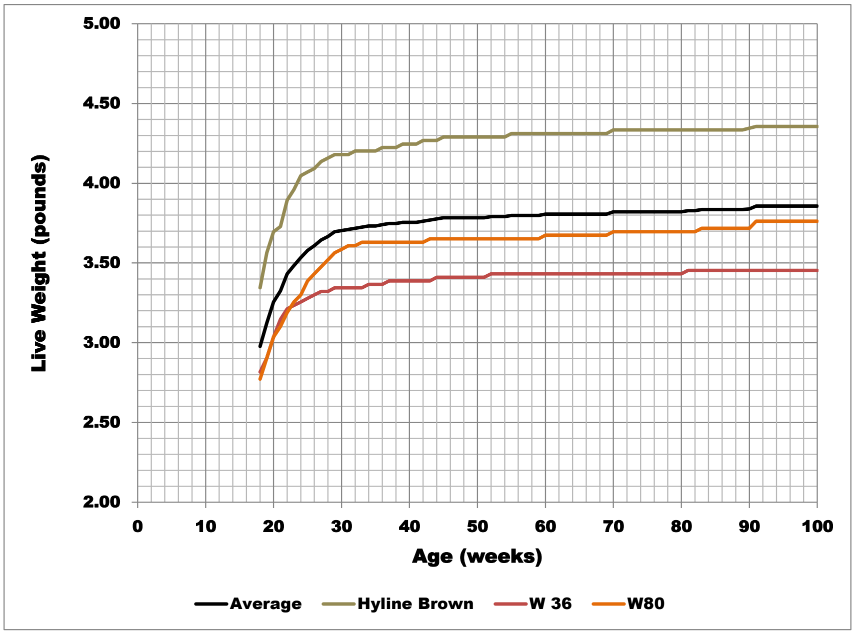

Figure I.2.13. Growth pattern of three common layer genetic lines (Hyline International, 2019).

Hen Mortalities

Figure I.2.14 shows the cumulative mortality of hens taken from the same genetic lines plotted in Figure I.2.13. Cumulative mortality is the number of dead birds removed from a house up to the day of record. All three genetic lines show different patterns of cumulative mortality; however, there does not appear to be a great difference between brown and white egg hens based on the three lines chosen. On average, mortality rate is one dead hen per week from of a flock of 1,000 birds throughout the egg laying period.

The cumulative mass of mortalities collected over the egg laying period is shown in Figure I.2.15. This pattern was calculated by multiplying average bird liveweight shown in Figure I.2.13 by the cumulative mortalities shown in Figure I.2.14. A linear interpolation of the curve gives an average death loss of 4.1 pounds per week, or slightly more than one hen per flock of 1,000 each week. The expected mass of mortalities collected from a flock of 1,000 hens over a 72-day laying period (week 90) is approximately 295 pounds. Averaging this over a 52-week year gives an annual mass of 210 pounds.

Carcass Composition

Only one replicated study giving mass of nutrients contained in laying hen carcasses was found. Haque et al. (1991) determined the nutrient content of whole ground hens to be 3.97% TN and 0.70% TP on an "as is" (wet liveweight) basis. These values are higher than those for the male broilers measured by Caldas et al. (2019)(2.9% TN and 0.40% TP), but this is consistent with the fact that laying hens have a higher percentage of bones and feathers per body weight than broilers (G.W. Malone, personal communication, 2019).

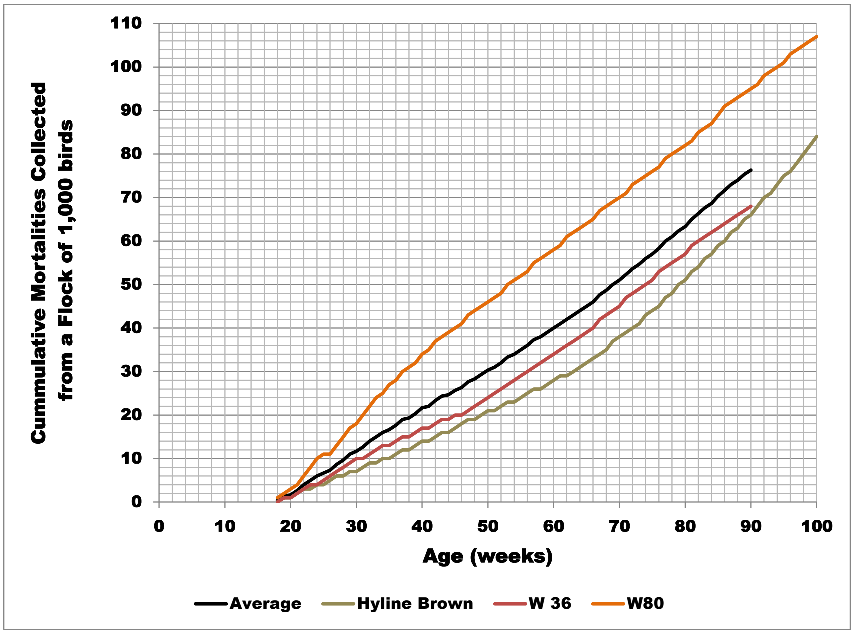

Figure I.2.14. Mortality patterns of three common layer genetic lines (Hyline International, 2019).

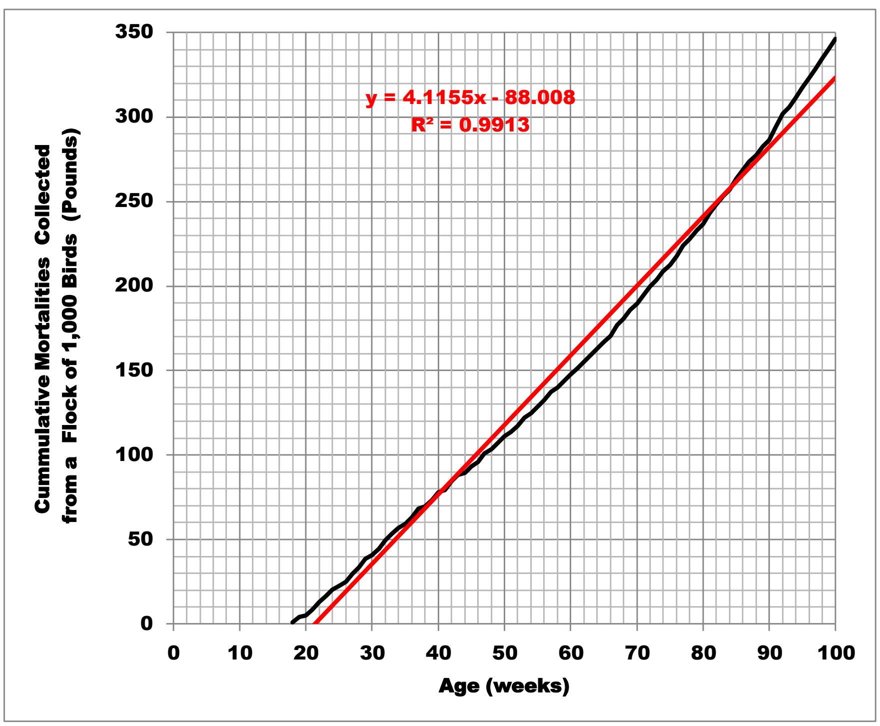

Figure I.2.15. Cumulative mass of mortalities collected during the egg laying period for a flock of 1,000 hens.

2.3.c Annual Mass of Nutrients Contained in Laying Hen Mortalities

Annual mass of nitrogen and phosphorus contained in the mortalities for a flock of 1,000 laying hens and per 1,000 pound animal units is given in Table I.2.8. Given an annual production of mortalities of 210 pounds per 1,000 birds, and a whole body nutrient composition of 3.97% TN and 0.70% TP, the expected mass of nutrients contained in the carcasses from a laying hen flock of 1,000 birds is 8.3 pounds of nitrogen and 1.5 pounds of phosphorus per year. Since the average weight of a hen at 44 weeks is 3.8 pounds, the annual mass of mortality nutrient production per 1,000 pounds liveweight (animal unit (AU) of laying hens is 2.2 pounds TN and 0.40 pounds TP.

Table I.2.8. Expected annual mass of mortalities produced and nutrients contained in carcasses for a 1,000 bird flock and one AU (1,000 lbs liveweight) of laying hens.

Per 1,000 Bird Flock (lbs year^{-1})			Per 1 AU (lbs year^{-1})		
Mortalities	**Total N**	**Total P**	**Mortalities**	**Total N**	**Total P**
210	8.3	1.5	55	2.2	0.40

2.3.d Comparison of Results to the Simpson-Weammert Report

Felton et al. (2009) calculated the mass of mortalities and nutrients from layers in the Chesapeake Bay watershed based on an average live weight of five pounds. They assumed a 5% death loss of birds during a 72-week placement in houses; this results in an annualized death loss of 3.6%. All deaths were assumed to occur when the birds were in the 70% percentile of body weight (3.5 pounds). They also assumed a body composition of 2.9% nitrogen and 0.46% phosphorus at time of death. The mass of mortalities and nutrients estimated in this report are compared to estimates of Felton et al. (2009) for a flock of 1,000 layers in Table I.2.9. **The estimates of Felton et al. (2009) slightly overestimate the mass of mortalities and underestimate the nutrients contained in mortalities compared to the methods used in this report.** The discrepancy in mortality mass occurs because Felton et al. (2009) used a single body mass at time of death (3.5 lbs); whereas, in this report body mass at time of death ranged from 3.0 to 3.85 pounds. Estimated mass of nutrients contained in mortalities are lower in the Felton et al. (2009) estimation, because they assumed a lower carcass nutrient concentration (2.9% N and 0.46% P, versus 3.97% N and 0.70% P).

Table I.2.9. Annual mass of mortalities and nutrients contained in carcasses by a 1,000 bird flock of layers.

	Mass of Carcasses and Nutrients collected (lbs)		
	Mortalities	**Total N**	**Total P**
This report	210	8.3	1.5
Felton et al. (2009)	250	6.9	1.2

2.3.e Comparison of Layer Mortality Nutrients to Excreted Manure Nutrients

Table I.2.10 gives a comparison of the mass of nutrients contained in mortalities produced from a flock of 1,000 laying hens in one year to the mass of nutrients excreted by the same flock in a year. The American Society of Agricultural and Biological Engineers Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) and the USDA-NRCS *Agricultural Waste Management Field Handbook* (USDA-NRCS, 2008) were used to calculate excreted manure values. Based on the data contained in Table I.2.10, if carcass nutrients are compared with excreted nutrients, **less than 0.70% of the nitrogen**

and less than 0.40% of the phosphorus produced on laying hen farms originates from mortalities. ASABE standards (2005) and USDA-NRCS guidelines (2008) estimate 0.0035 pounds of total nitrogen and 0.0011 pounds of total phosphorus are excreted by a laying hen each day, regardless of the weight of the hen. Assuming the cumulative mortalities for a flock of 1,000 birds over a 90-week laying period is 70 birds (Figure I.2.14), then the average number of birds housed over any 52-week period is 965. Mass of nitrogen excreted per year of a nominal flock of 1,000 hens is 965 hens X 0.0035 lbs. TN per hen per day X 365 days per year = 1,233 lbs TN. Likewise, the mass of phosphorus excreted by a flock of 1,000 is 387 lbs. TP per year (Table I.2.10).

Table I.2.10. Comparison of mass of nutrients contained in mortalities from a flock of 1,000 laying hens to the estimated mass of nutrients contained in manure excreted (ASABE, 2005; USDA-NRCS, 2008) by the same flock.

Nutrients Contained in Mortalities (lbs per 1,000 birds per year)		Nutrients Contained in Excreted Manure (lbs per 1,000 birds per year)	
TN	TP	TN	TP
8.3	1.5	1,200	390

2.4 Turkeys

2.4.a Turkeys in the Watershed

Total weight of turkeys raised for meat in the Chesapeake Bay Watershed was 875 million pounds in 2017 (USDA-NASS, 2018). This is considerably less than the 6.7 billion pounds of broilers raised during the same time period (Table I.2.1); however, turkey farms are concentrated in a few key areas. Production of turkeys is confined to three states – Pennsylvania, Virginia, and West Virginia (Table I.2.11), and production in those states is entirely within the Chesapeake Bay Watershed (Hawkins et al, 2016). Hawkins et al. (2016) indicated that half of the turkeys raised in the watershed are located in the Shenandoah Valley of Virginia.

Table I.2.11. Turkey production and number of turkeys raised in key states of the Chesapeake Bay Watershed in 2017 (USDA-NASS 2018).

	Annual Production (Million pounds yr^{-1})	Number of Birds Raised (Million yr^{-1})
Pennsylvania	205	7.5
Virginia	560	17
West Virginia	110	3.7
Total of 3 States	**875**	**28.2**

Turkey production is similar to broiler production in that young birds (poults) are supplied by integrators to contract growers who raise the birds to market weight. A difference with broilers, however, is turkeys are segregated by sex. Females (hens) are smaller and raised to a market size of 18 to 25 pounds in 12 to 16 weeks (Figure I.2.16); whereas, males (toms) are raised to a market weight of 42 to 48 pounds in 20 to 22 weeks (G.W. Malone, personal communication, 2019).

Figure I.2.16. Meat type turkeys (Deposit Photos).

Turkey housing (Figure I.2.17) is similar to broiler houses. Hatched birds are generally kept at a hatchery for the first days of life and are then transported in paper lined cages to brooder houses (Gatton et al., 2006). Ogejo et al. (2016) described three distinct types of turkey grow-out systems: one-stage houses, two-stage houses, and all-in-all-out houses.

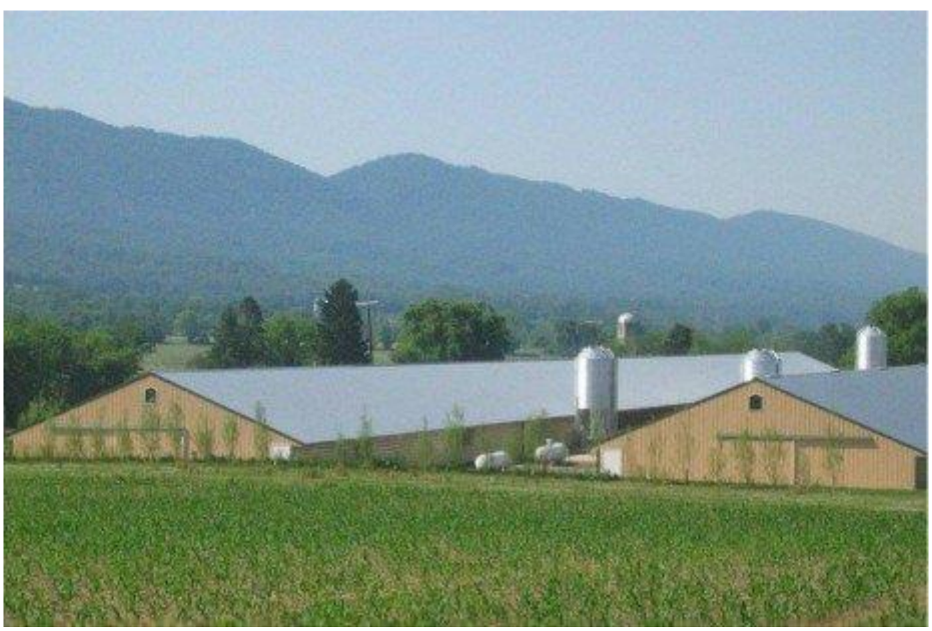

Figure I.2.17. A Pennsylvania turkey farm (Phil Clauer, Pennsylvania State University).

One-stage turkey houses are either brooder or grow-out houses. **Brooder houses** receive poults from the hatchery and grow those birds for 6 to 8 weeks. Birds are then moved to a **grow-out house** for another 6 to 14 weeks depending on gender and desired market weight. Brooder and grow-out houses may be located on the same farm, or birds may move from farm to farm. All litter is cleaned out of brooder houses after each flock and replaced with new bedding. Litter management of grow-out houses may be either partial reuse or multiuse.

With **partial litter reuse**, some crusted litter is removed from the house between flocks, and a total clean-out occurs after raising several flocks on the litter. Five to seven flocks are raised on litter before topping off with fresh bedding; litter is never completely cleaned out of a house under multiuse litter management.

In **two-stage turkey houses**, brooding and grow-out take place in the same house. Poults are started in the brood end of the house for 6 to 8 weeks, then moved to the other end of the house to be grown to market weight. Once a batch of brooders are moved, the brood area is cleaned and prepared to receive another starter flock. This results in two flocks of turkeys of different ages occupying opposite ends of the house. Litter removed from the brooding area is spread on the grower section of the house. Fresh bedding is spread in the brooder end, and litter is typically managed in the grow-out end using partial reuse.

Single flocks of turkeys are raised in the same **all-in-all-out turkey house** from brooding to harvest. Poults are started in a small section of the house. Flock space is expanded as the birds grow until the flock occupies the entire house. All-in-all-out houses use either partial reuse or multi-use litter handling.

For the remainder of this section, we will discuss mortalities occurring with a flock of turkeys from poult to market weight; i.e., mortalities encountered with a two-stage or an all-in-all-out house. Bear in mind that the amount of mortalities experienced by a particular farm may be vastly different than those on another. For instance, mortalities from a one-stage brooding house may be easily disposed of in a small composter, whereas a much larger unit is required to handle mortalities from a one-stage grow-out building. Viewing mortalities through the life cycle of the bird provides an accurate estimate of mortalities produced, and the nutrients contained in carcasses, relative to the total number of turkeys produced in a jurisdiction.

2.4.b Nutrients Contained in Turkey Mortalities

Growth Rate of Turkeys

Three sources were used to determine the average growth rate of turkeys. The Nicholas Select (Aviagen Turkeys, 2020) and Hybrid Converter (Hybrid Turkeys, 2020) represent whole frozen turkey genetic lines. The Hybrid XL (Hybrid Turkeys, 2020) is a line bred for the further processing market. The average liveweight of these three lines versus bird age is plotted in Figure I.2.18. Figure I.2.18 shows the marked difference in growth patterns of male and female turkeys.

Turkey Mortalities

There is also a difference in death rate between sexes in turkeys. Based on numbers provided by an industry source who chose not to be identified (G.W. Malone, personal communication, 2019), overall death loss in toms is approximately 15%, and death loss in hens ranges between 5 and 7% depending on market weight (Table I.2.12). Using the growth curves in Figure I.2.18 and the mortality patterns suggested in Table I.2.12, average mass of mortalities collected each week for a flock of 1,000 toms is plotted in Figure I.2.19. Average weekly mass of mortalities for a flock of 1,000 hens is shown in Figure

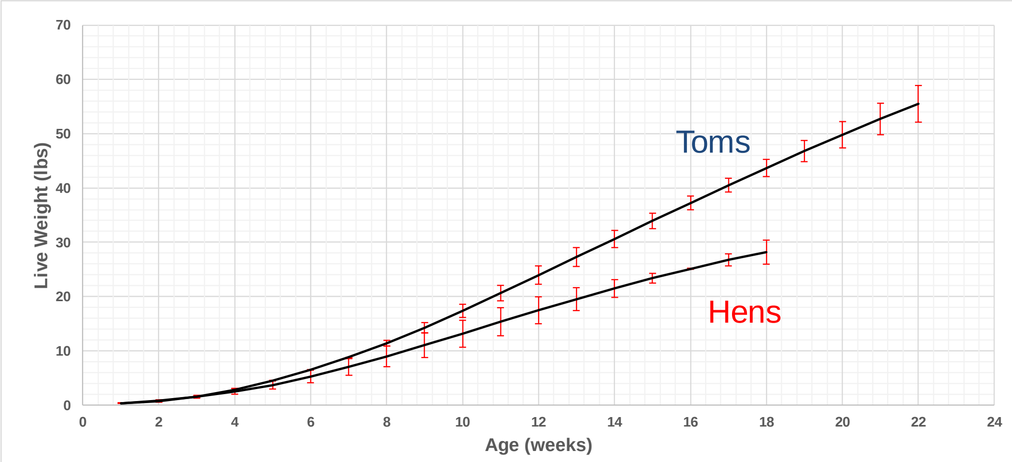

Figure I.2.18. Growth pattern of male (toms) and female (hens) turkeys based on average performance goals of Hybrid Converter, Hybrid XL (Hybrid Turkeys, 2020) and Nicholas Select (Aviagen Turkeys, 2020) genetic lines; error bars indicate 95% confidence interval.

Table I.2.12. Industry provided growth and mortality numbers for turkeys.

	Males (Toms)	Females (Hens)	
Market Weight (lbs)	42 - 48	18	25
Time to Reach Market Weight (weeks)	20 - 22	12	16
Mortality in First 7 to 10 Days (%)	2 - 3	1	1
Mortality in Last 2 to 3 Weeks (%)	1 - 2	0.5	0.5
Overall Mortality (%)	15	5	7

I.2.20. Cumulative mass of death losses is given for toms in Figure I.2.21 and for hens in Figure I.2.22. Cumulative mass of dead birds based on market weight of turkey toms and hens is given in Figure I.2.23.

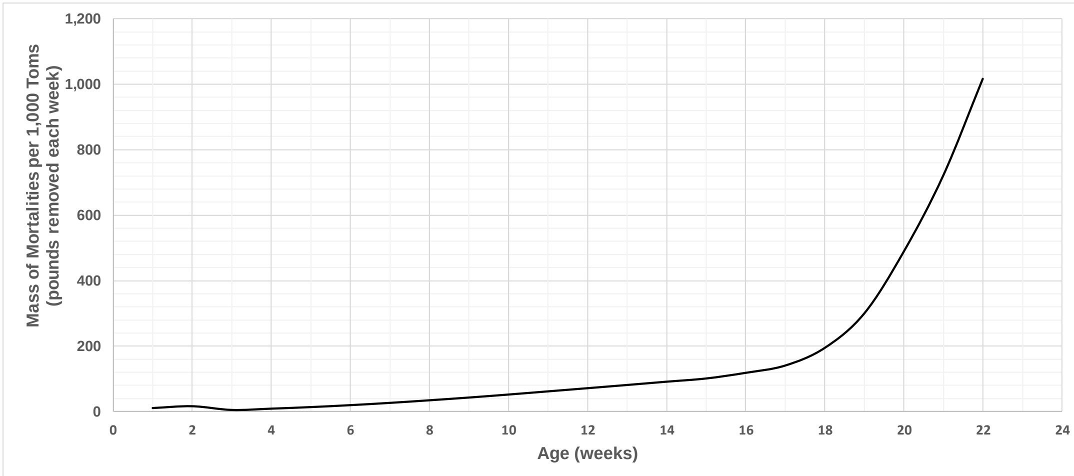

Figure I.2.19. Mass of dead birds collected each week from a flock of 1,000 tom turkeys based on the mortality pattern shown in Table I.2.12, multiplied by the average growth pattern shown in Figure I.2.18.

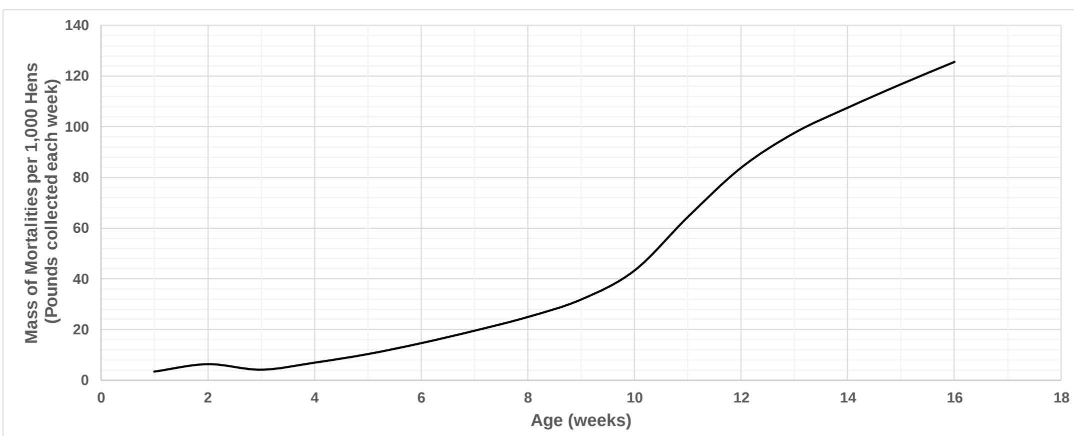

Figure I.2.20. Mass of dead birds collected each week from a flock of 1,000 turkey hens based on the mortality pattern shown in Table I.2.12, multiplied by the average growth pattern shown in Figure I.2.18.

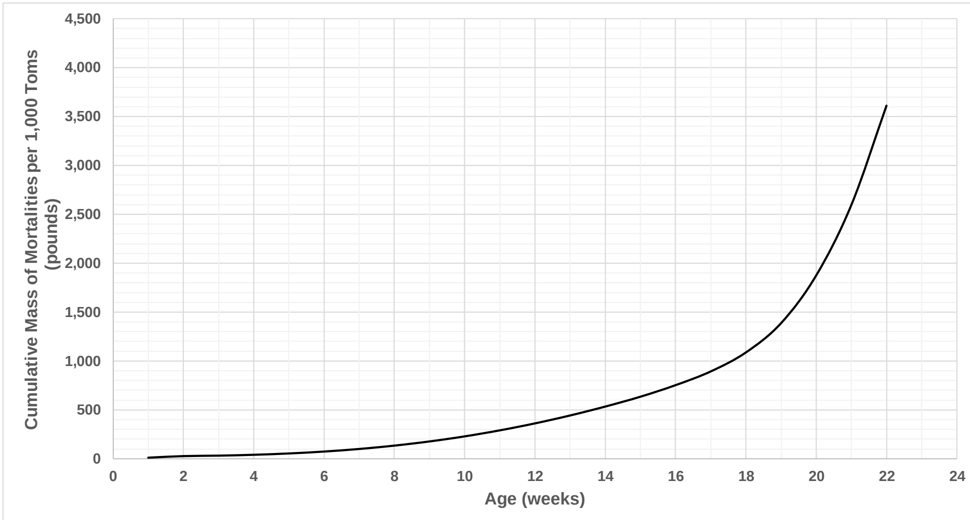

Figure I.2.21. Cumulative mass of dead birds collected from a flock of 1,000 tom turkeys (Based on data of Figure I.2.19).

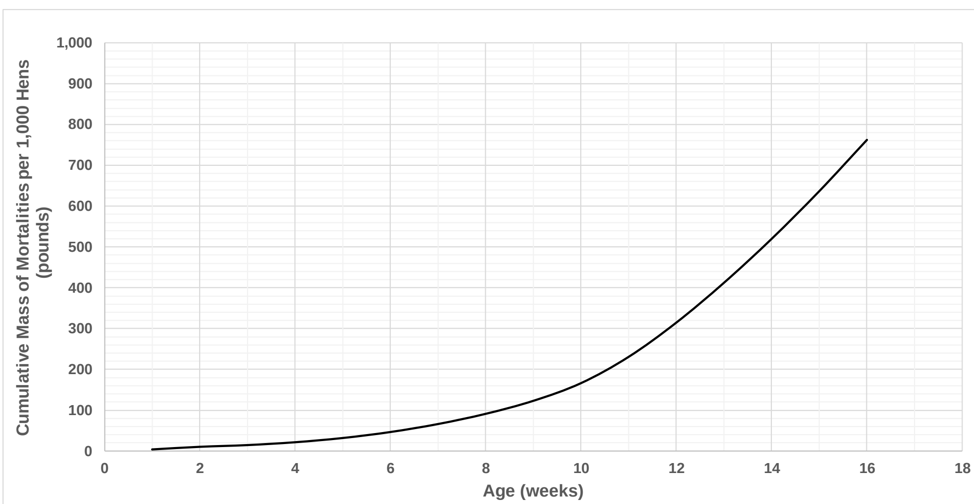

Figure I.2.22. Cumulative mass of dead birds collected from a flock of 1,000 turkey hens (based on data of Figure I.2.20).

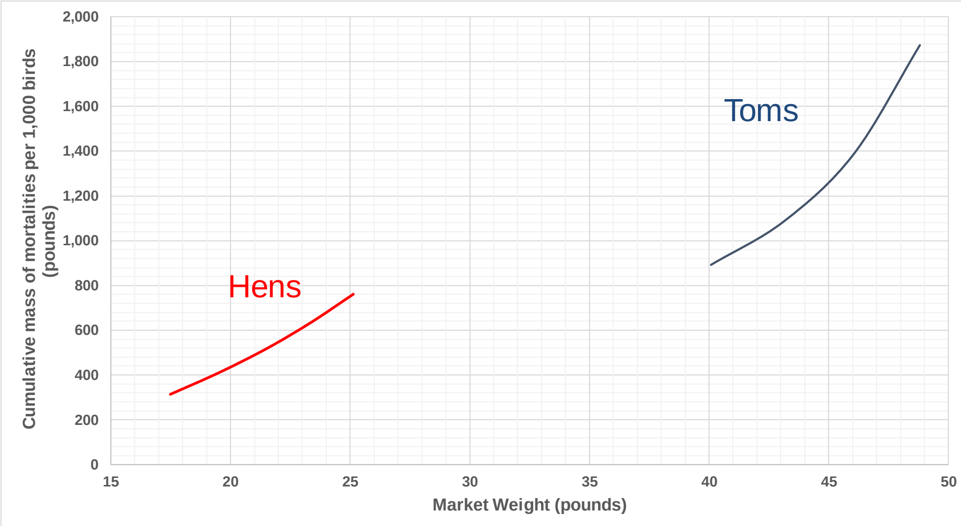

Figure I.2.23. Cumulative mass of mortalities collected from a flock of 1,000 turkey toms and hens versus common market weights (based on data of Figures I.2.18, I.2.21, and I.2.22).

Carcass Composition

Only one literature source was found reporting the nitrogen composition of turkey carcasses. Li et al. (2009) determined that the nitrogen composition of tom turkey carcasses ranged between 2.46 and 2.93 percent total nitrogen, and generally increased with age of birds. They did not measure nitrogen content of hens. No literature values were found for the phosphorus content of turkey carcasses.

Mass of N and P in Carcasses From 1,000 Bird Flock

Using the literature value (Li et al., 2009) for nitrogen carcasses for tom turkeys to represent both sexes (2.46% TN first 7 weeks, 2.93% TN thereafter for toms; 2.46% TN first five weeks, and 2.93% TN thereafter for hens), and assuming the phosphorus content of turkey carcasses is similar to broilers (0.375% regardless of sex or age), cumulative mass of total nitrogen and phosphorus contained in turkey carcasses is graphed versus market weight in Figure I.2.24. Expected mass of mortalities and nutrients contained in mortalities at common market weights for both sexes of turkeys is given in Table I.2.13.

2.4.c Annual Mass of N and P from Turkey Carcasses

Ogejo et al. (2016) state that the number of flocks a farm raises per year varies with market conditions. However, one can assume the maximum number of flocks per year based on the time to grow to a certain market weight plus an 18-day turn-around between flocks. For example, using the growth curve of Figure I.2.18, 16 weeks are required, on average, to raise a 25-pound turkey hen. Adding the 18-day turn-around time gives 130 days per flock, or 2.8 flocks per year. Annual mass of mortalities and nutrients contained in mortalities per 1,000 bird capacity and AU are given in Table I.2.14.

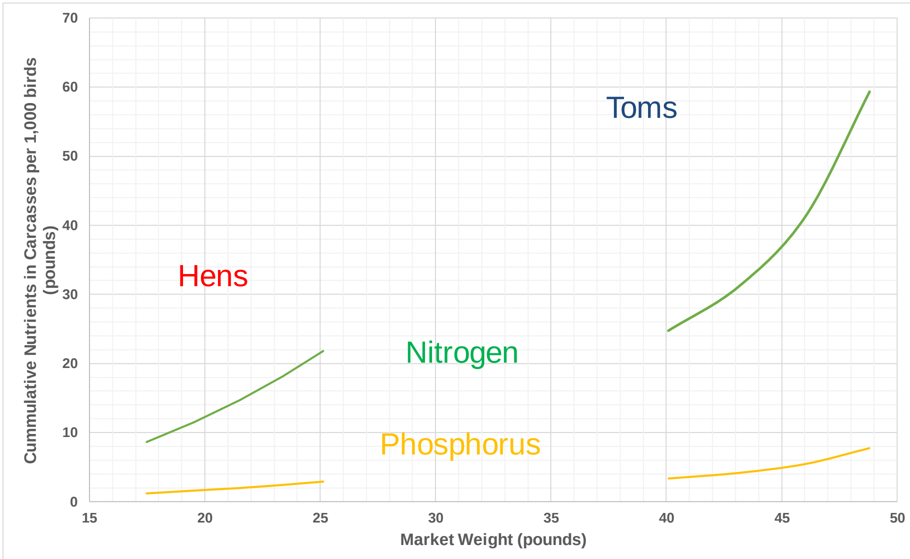

Figure I.2.24. Cumulative mass of total nitrogen and phosphorus contained in the carcasses produced from a flock of 1,000 birds based on market weight.

Table I.2.13. Estimated mass of mortalities and nutrients contained in carcasses during the grow-out of a 1,000 bird flock of turkeys.

Sex	Market Weight (lbs)	Mortalities (lbs)	Total Nitrogen (lbs)	Total Phosphorus (lbs)
Males (toms)	42	1,000	29	4.0
	44	1,200	34	4.4
	46	1,400	41	5.4
	48	1,700	50	6.5
Females (hens)	19	380	11	1.4
	21	480	14	1.8
	23	600	18	2.3
	25	760	22	2.9

Table I.2.14. Expected annual mass of mortalities produced and nutrients contained in carcasses for a 1,000 bird flock and one animal unit (AU = 1,000 lbs liveweight) of turkeys.

			Per 1,000 bird Flock (lbs $year^{-1}$)			Per Animal Unit (lbs $year^{-1}$)		
Sex	Market Weight (lbs)	Flocks per year	Mortalities	TN	TP	Mortalities	TN	TP
Toms	42	2.7	2,700	78	11	64	1.9	0.26
	44	2.6	3,100	88	11.5	70	2.0	0.26
	46	2.5	3,500	100	13.5	76	2.2	0.29
	48	2.4	4,100	120	16	85	2.5	0.33
Hens	19	3.3	1,250	36	4.6	65	1.9	0.24
	21	3.1	1,500	43	5.6	71	2.0	0.27
	23	3.0	1,800	54	6.9	78	2.3	0.30
	25	2.8	2,100	62	8.1	84	2.5	0.32

2.4.d Comparison of Results to the Simpson-Weammert Report

Felton et al. (2009) calculated the mass of turkey mortalities in the Chesapeake Bay watershed based on an average finished live weight of 24 pounds for toms and 15 pounds for hens. They assumed a 9% death loss for toms and 5% for hens. All deaths were assumed to occur when birds were in the 70% percentile of body weight (17 pound toms and 10 pound hens). Felton et al. (2009) did not report nutrient concentration of turkeys. The mass of mortalities estimated in this report are compared to estimates of Felton et al. (2009) for a flock of 1,000 turkey toms and hen in Table I.2.15. **Felton et al. (2009) underestimate the mass of mortalities from a flock of turkeys compared to the methods used in this report.** The discrepancy in the values lies in the market weights chosen by Felton et al. (2009), and the overall death losses experienced by both toms and hens. Based on the growth patterns of modern turkey breeds (Figure I.2.18), it would only take 11 weeks to reach the 24- and 15-pound market weights chosen by Felton et al. (2009). If raised for 11 weeks, death loss and mass of mortalities collected from modern birds would be much less than that estimated by Felton et al. (2009); however, since the estimates in this report are from the birds raised to higher market weights, both the death loss and body weight at time of death are higher than those assumed by Felton et al. (2009).

Table I.2.15. Comparison of mass of mortalities produced during the grow-out of a 1,000-bird flock of turkeys based on the method described in this report and the method of Felton et al (2009).

	Based on the method of this report		Based on the method of Felton et al.	
	Market Weight (lbs)	Mass of Mortalities (lbs)	Market Weight (lbs)	Mass of Mortalities (lbs)
Toms	48	1,700	24	1,500
Hens	25	760	15	500

2.4.e Comparison of Turkey Mortality Nutrients to Excreted Manure Nutrients

Table I.2.16 compares the nutrients contained in turkey carcasses to the mass excreted from a flock of 1,000 toms and hens. The American Society of Agricultural and Biological Engineers Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) and the USDA-NRCS *Agricultural Waste Management Field Handbook* (USDA-NRCS, 2008) were used to calculate excreted manure values. Based on the data contained in Table I.2.16, if carcass nutrients are combined with excreted nutrients, **approximately 4% of the nitrogen and 2% of the phosphorus produced on both tom and hen farms originate from mortalities**. The ASABE standard (2005) estimates the mass of nitrogen excreted by turkeys to be 1.2 pounds TN per finished tom and 0.57 pounds TN per finished hen. Phosphorus excretion is estimated at 0.36 pounds TP per finished tom and 0.15 pounds TP per finished hen. USDA-NRCS Guidelines (2008) assume market weight of toms to be 48 pounds and hens to be 25 pounds. Number of live turkeys contributing to excreted manure values in Table I.2.16 was estimated to be 893 toms and 935 hens.

Table I.2.16. Comparison of mass of nutrients contained in mortalities from a flock of 1,000 turkeys to the estimated mass of nutrients contained in manure excreted by the same flock (ASABE, 2005; USDA-NRCS, 2018).

	Nutrients Contained in Mortalities (lbs per 1,000 birds)		Nutrients Contained in Excreted Manure (lbs per 1,000 birds)	
	TN	**TP**	**TN**	**TP**
Toms **48 lbs market weight**	50	6.5	1,100	320
Hens **25 lbs market weight**	22	2.9	530	150

2.5 Assumed Values of Mortality Masses and Carcass Nutrients for Watershed

Without any further defining information, the values given in Table I.2.17 should be used for mass of mortalities and nutrients produced annually per 1,000 bird flock and AU of finished birds. For broilers, the numbers given in Table I.2.17 are for a six-pound market weight (the average for the states in the watershed, Table I.2.1). Laying hen population within a jurisdiction is assumed to remain stable; therefore, the values in Table I.2.17 can be used for a base population within a one-county jurisdiction. The values for turkey hens and toms in Table I.2.17 are based on the largest market size for each sex. If the sex of turkeys is not known for a particular jurisdiction, values for AU can be used interchangeably for both sexes.

Table 17. Assumed annual mass of mortalities and nutrients contained in mortalities produced by all types of poultry production systems.

	Annual Mortalities and Nutrients Produced per Flocks of 1,000 Birds (lbs $year^{-1}$)			Annual Mortalities and Nutrients Produced per AU (lbs $year^{-1}$)		
	Mortalities	*TN*	*TP*	*Mortalities*	*TN*	*TP*
Broilers	430	11	1.5	72	1.8	0.25
Layers	210	8.3	1.5	55	2.2	0.40
Turkey toms	4,100	120	16.0	85	2.5	0.33
Turkey hens	2,100	62	8.1	84	2.5	0.32

2.6 Future Research Needs

2.6.a Types of Farms Not Covered in This Report

This report does not include mortality nutrient estimates for pullet and breeder farms for broiler, layer, and turkey production. These farms may produce a significant amount of mortalities. Immature and mature breeding stocks are grown on these farms to produce eggs that hatch into the birds covered in this report and/or future breeding animals. These farms were not included in the report, because sufficient data was not available from USDA-NASS (2017) to assess their presence in the watershed. Some breeder farms supplying eggs to the watershed may not exist within the boundaries of the Chesapeake Bay Watershed. It is quite possible, for instance, that broiler eggs supplied to Delmarva hatcheries are produced from broiler breeder hens and pullets grown in other states, such as North Carolina.

2.6.b Need for On-farm Data Collection

Although we are confident in the data produced in this report, the values were primarily produced through unpublished industry estimations of death losses and information provided by breeders. Research should be undertaken to determine the actual mass of mortalities produced on farms under the cultural practices used in the watershed.

2.6.c Need for data on Whole Carcass Nutrient Content

No data for whole carcass nutrient content of turkey hens either living or dead were found during the literature review conducted for this report. Data on laying hen carcasses was also limited. Even though more literature was found on broiler carcasses, only two sources were found providing phosphorus content of carcasses.

2.7 References

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3. Swine

3.1 Definitions

Barrow: A castrated male pig or hog.

Boar: An intact, sexually mature male hog used for breeding purposes.

Breeder Farm: A farm whose main purpose is production of male or female breeding stock. A breeder farm that produces primarily replacement gilts for sale (or distribution to meat producing farms in vertical integration) is called a **multiplier farm** or **multiplier unit**. A breeder farm that raises replacement boars is called a **Boar Farm**. Boar farms may also produce semen for artificial insemination and conduct boar performance testing.

Farrow: The act of giving birth for swine. Farms with the term farrow in their descriptive title are farms where sows are bred to produce piglets that typically enter the food supply chain. A group of piglets born at the same time is called a **litter**. Sows and their litters are often counted as single unit whether they are housed in farrowing crates or open pens.

Farrow-to-Finish Farm: A farm in which all phases of production (breeding, gestation, farrowing, nursery, growing, finishing) are housed at the same location or under the same management. A self-contained or **Closed Herd** farrow-to-finish farm also raises its own replacement gilts, and occasionally boars.

Farrow-to-Feeder Farm: A farm whose purpose is the production of feeder hogs. Gestation, farrowing, and nursery units are located at the same location.

Farrow-to-Wean Farm: a farm that produces weaned pigs to be moved to off-site nurseries or sold to wean-to-finish farms.

Feeder Pig: A pig raised for meat production weighing approximately 55 pounds.

Finisher Farm: A farm or production unit whose purpose is to raise pigs to market weight, around 270 pounds or more. This is the final production phase before harvest of a hog for human consumption. Contemporary finishing farms receive **Feeder Pigs** from a **Nursery.**

Finishing: The final phase of meat production. **Finishing hogs**, or **Finishers,** are generally larger than 120 pounds on average. Fat deposition becomes a major component of weight gain during finishing.

Gilt: A female hog weighing more than 50 pounds that has not been bred, or a bred female that has never farrowed a litter in the past. Once a female farrows her first litter her status moves from gilt to sow.

Grower: A term not frequently used in modern swine farming meaning a swine animal raised for meat production (usually a barrow or gilt) weighing between 50 and 120 pounds.

Hog: a swine animal weighing more than 120 pounds

Market Hog: A hog that leaves the finisher destined for harvest at a processing plant.

Nursery: A farm or production unit whose purpose is to raise weaned pigs to feeder pigs in isolation. A nursery often serves a single farrow-to-wean farm and one that does is called an **Off-Site Nursery.**

Pig: A swine animal weighing less than 120 pounds.

Piglet: A newly born pig.

Porcine: Adjective referring to swine, hogs, or pigs.

Sow: A female pig that has already delivered its first litter of piglets. Sows typically weigh 450 to 500 pounds.

Sow Farm: A farm or production unit whose purpose is to produce pigs that are transported to Finisher Farms. Sows farms can be further divided between Farrow-to-Wean and Farrow-to-Feeder farms.

Swine: Domesticated animals of the genus *Sus scrofa domesticus*.

Weaning: The act of removing a piglet from its mother's milk and converting it to a solid diet. Newly weaned young pigs are sometimes called **Shoats** but are more commonly referred to as **Weaned Pigs or Nursery Pigs**.

Wean-to-Finish Farm: A farm whose purpose is production of market hogs. Pigs are purchased or brought to the farm after weaning.

3.2 Swine in the Watershed

Swine production in the Chesapeake Bay Watershed is described on a state-by-state basis in Table I.3.1. Pennsylvania has by far the largest swine production in the Chesapeake Bay Watershed, and Hawkins et al. (2016) estimated that 42% of all non-breeding inventory of hogs and pigs in Pennsylvania were located in Lancaster and Lebanon Counties. Figure I.3.1 shows a traditional hog farm in Lancaster County. Hawkins et al. (2016) stated that no pigs were raised in any Delaware counties that had more than 50% of its land area located within the watershed. Swine production in New York is much higher than is shown in Table I.3.1, but most of New York's swine production is located outside the watershed (Hawkins et al., 2016).

Table I.3.1. 2017 estimated swine inventory and sales in counties with more than fifty percent of their land area within the Chesapeake Bay Watershed, by state (USDA-NASS, 2019; Hawkins et al., 2016).

	Total Hogs and Pigs Inventory	Hogs and Pigs Sold per Year
Maryland	18,000	63,000
New York	2,900	11,000
Pennsylvania	1,100,000	4,800,000
Virginia	110,000	280,000
West Virginia	1,800	3,500
Total Watershed	**1,232,700**	**5,157,500**

3.2.a Animal Life Cycles and Types of Farms

Hog production is difficult to quantify using the USDA-NASS (2019) values of Hog and Pig Inventory and Hog and Pigs sold. The primary difficulty lies in the fact that the instantaneous inventory of hogs and pigs at any one time depends on the life cycles of breeding and non-breeding stock, which are not necessarily in sync with the calendar year.

Sows and boars live for multiple years, growing to breeding age in roughly six months to a year. Depending on intensity of production, sows may be bred to have between two and two-and-a-half litters per year (Pork Checkoff, 2019). Figure I.3.2 shows a modern swine farrowing building with sows and pigs housed in farrowing crates. Nationally, the replacement rate of sows (or the fraction of gestating sows replaced by new gilts) is 45%, meaning an individual sow will remain in production approximately two years and eleven weeks (Global Ag Media, 2010). Artificial insemination is widely

Figure I.3.1. Aerial view of Jeff and Sue Frey swine farm in Lancaster County, PA; 2012 Pork Industry Environmental Stewards (National Hog Farmer).

Figure I.3.2. Interior of a farrowing building with several sows and piglets in farrowing crates (Thepigsite.com Global Ag Media).

practiced by hog farms in the watershed. Using artificial insemination, the number of boars required per farm is greatly reduced. With artificial insemination (even if semen is collected from boars housed on the farm) the ratio of sows to boars is 1:100. Using natural "hand mating", sow-to-boar ratio is approximately 1:20 (Estienne et al., 2016).

The growth of market hogs is broken into five phases: farrowing, weaning, nursery (15 to 55 pounds), growing (55 to 120 pounds), and finishing (120 to 250-280 pounds). The entire life of a market hog from birth to slaughter lasts roughly six months. These days, piglets are weaned early at about three weeks. They spend roughly seven weeks in a nursery and become 55-pound feeder pigs. Feeder pigs are fed to market size over the span of sixteen to seventeen weeks (Estienne et al., 2016; Pork Checkoff, 2019). Often the growing and finishing phases are housed continuously in one facility.

Different parts of hog production can take place at several different locations, and farms are named based on what productions units are located on the farm. The entire breeding and feeding cycles are housed in one location on farrow-to-finish farms. Sow breeding and gestation, grow-out of replacement gilts, farrowing of baby piglets, and weaning take place on farrow-to-wean farms. Sometimes, grow-out of replacement gilts takes place on a special production unit called a multiplier or an isolation unit. The main product of farrow-to-wean farms are weaned pigs. A sow farm that also contains an on-site nursery is called a farrow-to-feeder farm.

Weaned pigs are raised to feeder pigs in nurseries. The interior of a nursery building is shown in Figure I.3.3. Most typically, nursery pigs are grown in an all-in-all-out fashion – weaned pigs arrive as a group, grow together, and leave in the same group. Empty all-in-all-out nurseries are completely cleaned and disinfected between groups. An off-site nursery will grow 6 to 8 groups, or turns, per year. In modern commercial production, a sow farm supplies pigs to a designated nursery in a scheme referred to as the sow farm's 'production flow'. This single sourcing philosophy greatly benefits animal health because animals are not introduced to disease challenges that may exist in other sow production flows. In turn, benefits are realized in production efficiencies, feed efficiencies, and decreased mortalities. Similarly, nursery pigs are moved to designated locations for finishing (Estienne et al., 2016).

Finisher farms produce market hogs from weaned or feeder pigs. A typical finisher facility is shown in Figure I.3.4. In the Chesapeake Bay Watershed, market hogs average 270 pounds (Etienne et al., 2016). A farm that receives weaned pigs from a farrow-to-wean farm is called a wean-to-finish farm. Finisher farms receiving feeder pigs from off-site nurseries or farrow-to-feeder farms are called a feeder-to-finish farms. Finisher farms are usually operated in an all-in-all-out fashion, with wean-to-finish farms having an average of 2.1 turns per year, and feeder-to-finish farms having 2.7 turns per year.

Types of farms within the state of Pennsylvania in 2017 are shown in Table I.3.2. The table lists number of farms and inventory housed on each type of farm segregated by size of farm. The distribution of farm types within Pennsylvania is taken to be representative of the entire watershed. Although small swine farms (less than 100 total hog and pig inventory) are greatest in number, more hogs are housed on farms with more than 1,000 animals in total inventory. Relatively few animals are housed on farrow-to-finish farms -- less than 8% of the total hog and pig inventory in Pennsylvania was housed on a farrow-to-finish farms in 2017. Multi-site production dominates swine farming in the watershed, particularly among larger farms. The most common combination of farms is farrow-to-wean, off-site-nursery, and finisher. Vertically integrated companies use multi-site production in complexes centered regionally around feed mills, with contract growers operating most production units.

Figure I.3.3. Chris Hoffman, 2019-2020 National Pork Board's America's Pig Farmer of the Year, in the nursery of his Pennsylvania hog farm (Farmanddairy.com).

Figure I.3.4. Interior of a finisher building (National Hog Farmer).

Table I.3.2. Hogs and pigs in Pennsylvania, inventory by type of operation, 2017 (From USDA-NASS, 2019).

Size of Individual Farm (Inventory)	Farrow-to-Wean		Farrow-to-Finish		Finish Only		Farrow-to-Feeder		Off-Site Nursery		Other	
	Number of Farms	**Total Inventory on Farm Type**	**Number of Farms**	**Total Inventory on Farm Type**	**Number of Farms**	**Total Inventory on Farm Type**	**Number of Farms**	**Total Inventory on Farm Type**	**Number of Farms**	**Total Inventory on Farm Type**	**Number of Farms**	**Total Inventory on Farm Type**
1 to 24	173	1,588	481	3,243	898	4,450	189	1,519	18	56	278	1,039
25 to 49	16	582	61	2,036	23	768	30	961	3	118	11	348
50 to 99	16	851	53	3,528	25	1,661	9	602	-	-	3	215
100 to 199	1	-	25	3,420	11	1,384	11	-	-	-	-	-
200 to 499	8	-	9	2,734	48	14,879	6	1,892	1	-	2	-
500 to 999	6	4,791	17	12,438	39	28,114	5	3,310	2	-	1	-
1,000 to 1,999	5	8,019	6	9,287	48	60,916	5	-	7	8,121	1	-
2,000 to 4,999	14	38,290	8	27,040	113	336,530	8	28,400	19	67,017	5	16,800
5,000 or more	14	176,793	4	29,531	34	276,420	2	-	3	21,388	2	-
Total	**253**	**234,039**	**664**	**93,237**	**1,239**	**725,122**	**265**	**56,898**	**53**	**98,233**	**303**	**31,739**

3.2.b Total Hogs and Pig Inventory

Inventory is the total number of animals housed on a farm or living within a political or natural boundary at one time. It is difficult to describe swine production systems (and in particular the number and mass of mortalities produced on a farm) based solely on inventory. One needs to understand the different groupings of animals found on various production units to determine mortality number and mass. Table I.3.3 gives the average number of each type of animal in a total inventory for a farrow-to-finish operation. The operation shown has a total of 1,150 sows in inventory, and is expected to produce 25,000 market hogs each year. These numbers are roughly equivalent to the Chesapeake Bay Program's population values of 1,150 hogs and pigs for breeding and 25,000 hogs for slaughter. The inventory shown was calculated using industry average values for litters per year, pigs born per litter, turns per year in nursery and finisher given in this section -- plus mortality values given in the following section. This table can be used to determine breakdown of groupings for other types of farms. To determine inventory for a farrow-to-wean farm, for instance, sum gestating sows, boars, gilts, sows with litters, and piglets in litters. Off-site nurseries and grow-finish farms have inventory equal to the head space available in barns, or the "number housed" value in Table I.3.3. Farrow-to-finish inventory can be used to estimate total numbers in each animal group for an entire state or watershed -- provided animals do not move across state or watershed boundaries during their lifetime. To estimate number of animals in each age or production group within a state, multiply total hogs and pigs inventory in Table I.3.1 by "percentage of total housed" for the group in Table I.3.3.

Table I.3.3. Approximate instantaneous inventory for a closed-herd, farrow-to-finish farm using artificial insemination with 1,150 sows in breeding and producing 25,000 market hogs (6,750 AUs) annually.

	Number Housed	Percentage of Total Housed	Liveweight (AUs)	Percentage of Total Liveweight
Gestating Sows	990	5.87	446	24.70
Boars	12	0.07	8.4	0.47
Gilts	115	0.68	34.5	1.91
Sows with Litters	160	0.95	72	3.99
Piglets in Litters	2,000	11.85	15	0.83
Nursery Pigs	3,900	23.11	130	7.20
Finisher Pigs and Hogs	9,700	57.47	1,100	60.90
Total	**16,877**		**1,805.9**	

3.2.c Hog Production – Hogs and Pigs Sold

Another complicating factor in understanding the number of hogs in the watershed is the use of hog and pig sales as a metric. The term "Hog and Pigs Sold" does not state exactly what is being sold. This term should not be taken to mean finished hogs marketed. A hog or a pig can be "sold" at any time in its breeding or growing cycle. In fact, a single hog can be sold several times: as a weaned pig, a feeder pig, and as a market hog. Breeding stock (replacement gilts, replacement boars, and sows destined for slaughter) can all be sold at some point in their life. The Chesapeake Bay Program's population value of "hogs for slaughter" is roughly equivalent to the annual number of hogs marketed in an equivalent farrow-to-finish farm.

3.2.d Type of Producer

Animals may be owned by individual family farms, by an integrator (vertically integrated, sometimes publicly owned corporations), and every permutation in between. A common form of ownership is "contract growing" where an independent contractor raises or grows animals owned by another individual or corporation. Table I.3.4 lists number of farms and inventory for the three most common ownership classes in Pennsylvania. As shown in Table I.3.4, small farms owned by an independent grower were the most common type of producer in Pennsylvania in 2017; however, most of the inventory was housed on relatively large farms (inventory greater than 2,000) and raised by contract growers.

Table I.3.4. Hogs and pigs in Pennsylvania, inventory by type of producer, 2017 (From USDA-NASS, 2019).

Size of Individual Farm (Inventory)	Independent Grower		Integrator or Contractor		Contract Grower	
	Number of Farms	Total Inventory on Farm Type	Number of Farms	Total Inventory on Farm Type	Number of Farms	Total Inventory on Farm Type
1 to 24	2,037	11,895	-	-	-	-
25 to 49	144	4,813	-	-	-	-
50 to 99	100	6,494	1	-	5	-
100 to 199	47	-	-	-	1	-
200 to 499	39	11,642	-	-	35	11,763
500 to 999	33	-	1	-	36	26,249
1,000 to 1,999	14	20,910	-	-	58	72,186
2,000 to 4,999	18	-	9	-	140	430,692
5,000 or more	16	102,131	9	160,862	34	265,139
Total	**2,448**	**242,997**	**20**	**189,832**	**309**	**806,472**

3.2.e Buildings and Management

Almost all swine production in the watershed takes place under roof in mechanically ventilated buildings with fully-slatted or partially-slatted floors. Most manure storage takes place in-building in deep pits. A few producers use shallow pits with manure flushed to outdoor storage ponds. Very little swine manure is stored and treated in lagoons in the watershed. There are a few anaerobic digesters. Older buildings are ventilated with a combination of cross or ridge and pit ventilation. Newer buildings are usually ventilated with a tunnel ventilation.

3.3 Nutrients Contained in Swine Mortalities

3.3.a Growth Rate of Hogs

Growth from farrowing to market weight is not linear. A representative growth curve (Figure I.3.5) was documented in *MWPS-8, Swine Housing and Equipment Handbook* (MWPS, 1983). At the time *MWPS-8* was published, the market weight of hogs averaged 230 pounds, compared to the most recent reported national average market weight of 280 pounds (USDA-AMS, 2019). In addition to larger carcass size, the time for hogs to grow to today's market weight has been shortened. In 1983, it took an average of 30 weeks for a hog to grow to the 230 market weight (MWPS, 1983); today's hogs reach 280 pounds in six months or 26 weeks (Pork Checkoff, 2019). Assuming today's faster growing pigs follow a similar "S" shape growth curve to that documented in MWPS (1983), a growth curve was devised for an average market weight of 280 pounds (Figure I.3.5) over a 26-week period. The average growth curve based on Pork Checkoff (2019) data shown in Figure I.3.5 was used in all further calculations.

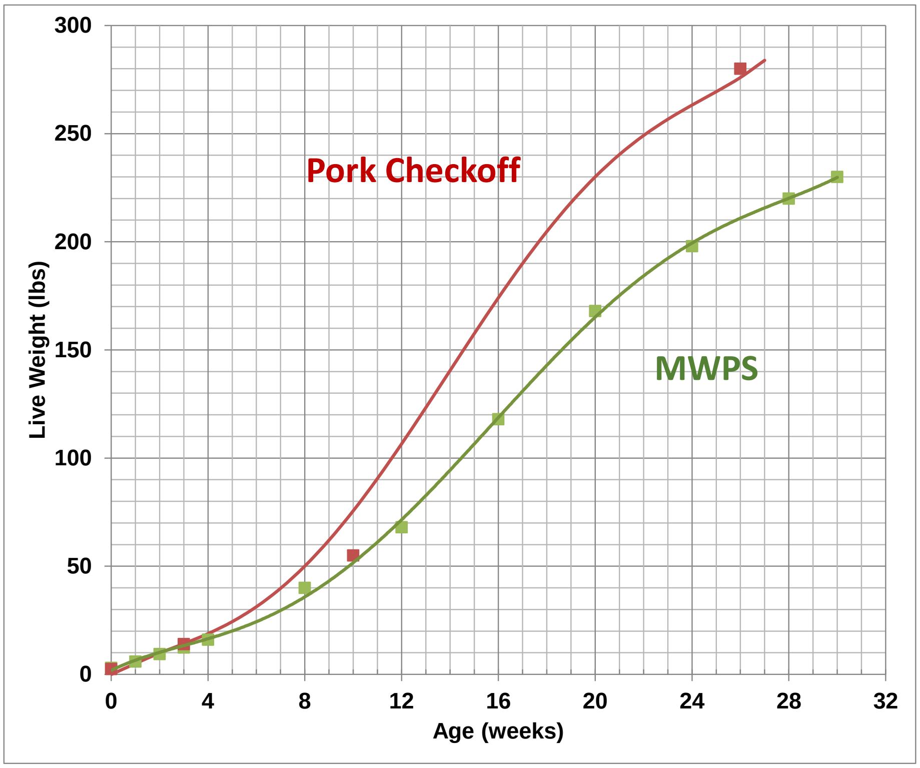

Figure I.3.5. Growth curve for swine fitted to data of MWPS (1983) and Pork Checkoff (2019).

3.3.b Mortalities

Few studies report death loss on sow farms in the Chesapeake Bay Watershed. However, it can be assumed that mortality rates reported from the following studies can be transferred to similar production systems in the Watershed.

Management and productivity of U.S. swine operations located in 13 states (The only watershed state included in the study was Pennsylvania) were estimated In the USDA National Animal Health Monitoring System (NAHMS) Swine 2012 study (USDA APHIS, 2012a). The Swine 2012 study was conducted on operations that had 100 or more swine in total inventory. The reported overall piglets born per litter was 11.3, of which 10.3 were born alive, and 9.3 were weaned. In addition, 3.6% of the piglets that entered nursery phase died, and 4.1% of the piglets that entered the grower/finisher phase died. For the wean-to-finish operation, 1.4% of wean-to-finish pigs died before the split, while nearly two-thirds of the deaths were attributed to respiratory problems. Overall, 4.2% of pigs in the wean-to-finish phase died after the split, and almost 60% of the deaths after the split were attributed to respiratory problems.

In contrast to the larger farms, the USDA NAHMS study for small-enterprise swine operations targeted operations with fewer than 100 pigs (USDA APHIS, 2012b). .. Overall, the study found that 7.8% of breeding animals (sows, gilts, and boars) died from June 2011, to May 2012. Within the same period, the percentage of pigs that died were 7.8% and 3.4% for pre-weaned and weaned pigs, respectively.

Maes et al. (2001) investigated mortality in 14 swine complexes, including 146 closeouts comprising 1,345,127 pigs. Overall mortality during the entire grow-finish period was expressed as deaths per 1,000 pig weeks. Weekly mortality was reported as the number of pigs that died during a week divided by the average inventory of pigs during that week. Mean overall weekly mortality during the 4 year study period (1996-2000) was 3.23 per 1,000 pigs. Mortality increased steadily from 2.6 (1996) to 3.6 per 1,000 pigs (1999) ($P<.001$). Late mortality was consistently greater than early mortality ($P<.001$), and increased from 3.1 (1996) to 5.5 pigs per 1,000 pigs (1999) ($P<.001$). The study was conducted in a three-site production system consisting of one sow complex, five similar nursery complexes, and 14 grow-finish complexes. The grow-finish complex consisted of eight barns with a capacity of 1150 pigs per barn (9200 pigs per complex). The grow-finish facilities, built in 1994 to 1995, contained 46 pens per barn. At about 10 weeks of age, nursery pigs were moved into the finishing barns, with 25 to 26 pigs per pen, and an initial stocking density of approximately 0.641 m^2 per pig. Barrows and gilts were not housed separately. The barns were tunnel-ventilated (i.e., plastic ducts with a fan in one end of the barn) and had fully slatted concrete floors. Manure was flushed daily to a lagoon. Pigs were fed a corn-soybean feed (meal) ad libitum using a wet-dry feeding system. Six different feeding phases were used during the grow-finish period, with bacitracin added to all phases as a growth promotant.

Data was collected from one large swine system in the Midwest from March 2013 (before PEDv had been reported in the USA) to June 2014. The study was conducted to evaluate the impact of porcine epidemic diarrhea virus (PEDv) infection on growing pigs' performance (Alvarez et al., 2015b). All sows and boars were cross-bred commercial genetics. All pigs were vaccinated for Mycoplasma hyopneumoniae, porcine circovirus (PCV) and porcine reproductive and respiratory syndrome (PRRS). PCV was present in all farms while PRRS virus (PRRSv) was occasionally detected in a proportion. Mortality was determined as percentage dying divided by the total pigs started. Before the PEDv outbreak overall mean monthly mortality ranged between 4.3–4.8%. Analysis of the mortality of the first PED-positive batches on each flow revealed an increase in the mortality up to 14.9% in nursery and 15.5% in wean-to-finish (WF) operation.

In a similar study, mortality rates of 9 wean-to-finish farms in the Midwest region of the United States were studied to evaluate the association between Influenza A Virus (IAV) and PRRSV (Alvarez et al., 2015a). All farms were managed by one firm and were relatively similar to each other in terms of management practices. Performance records from all pig batches weaned into WF sites between June 2011 and April 2014 were included. A total of 185 batches of WF pigs in which the IAV status of the sow farm at weaning had been determined within one week before or after their weaning were initially selected. Mortality in those batches ranged between 0 and 25%. Mean mortality was higher in the IAV + batches (5.92%) compared to IAV − batches (5.21%), and in PRRSV + batches (6.68%) compared to PRRS − batches (5.43%), although differences were not statistically significant ($P = 0.052$ and $P = 0.20$ respectively). Mean mortality was also higher in batches weaned in winter (5.61%) compared to summer season (5.34%), but again differences were not significant ($P = 0.46$).

Another Midwest-based study of 1010 weaned pigs reared in one nursery in Iowa from weaning (17 ± 2 days) until 10 weeks of age evaluated the likelihood of survival and low growth during the nursery phase (Larriestra et al., 2006). Weaned pigs from two sow units of 2,500 sows per unit were included in this study. In both sow units, the preweaning mortality was approximately 14% and clinical coccidiosis was the major disease concern in the progeny. The nursery mortality rate was reported as 7.03%. In both farms, porcine reproductive and respiratory syndrome (PRRS) was endemic.

In a more recent study death loss was recorded from 870 farms over a 52-week time period; the study reported average death loss for the time period at 9%, with the removal rate at 45.8% (Ketchem et al., 2019).

Mortality rates of various operational phases were provided from 2012 to 2017 in the Pork Checkoff Industry Productivity Analysis report (Pork Checkoff, 2018). Table I.3.5 summarizes the average annual mortality rates and average rate for the entire period.

Table I.3.5. Data from the Pork Checkoff Productivity Analysis Report (Pork Checkoff, 2018).

	Year						**Overall**	
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**Average**	**Std**
Piglets Born Alive (number per litter)	12.3	12.4	12.3	12.1	12.4	12.6	**12.35**	**0.164**
Piglets Weaned (number per litter)	10.3	10.2	9.7	10.0	10.2	10.3	**10.1**	**0.232**
Pre-weaning Mortality (%)	15.5	17.3	20.5	17.4	17.3	17.8	**17.6**	**1.62**
Nursery Mortality (%)	3.80	3.87	5.47	5.22	4.58	4.77	**4.615**	**0.685**
Grow-Finisher Mortality (%)	5.03	5.04	5.78	5.53	5.34	5.19	**5.32**	**0.269**

Cumulative death loss during the growth of meat swine from birth to market based on the mortality values of Table I.3.5 and the number born dead from USDA-APHIS (2012a) are shown in Figure I.3.6. The values plotted are cumulative dead collected at the end of the week (week zero for pigs born dead) for a group of 1,000 pigs. The group size resets at each phase of production, i.e. 1,000 pigs are born alive, and 1,000 weaned pigs enter the nursery.

The cumulative mortality mass (Figure I.3.7) measured at the end of week was calculated by multiplying number of mortalities per week (Figure I.3.6) by liveweight during the week (Figure I.3.5). Mass of mortalities collected during each phase of growth was taken from Figure I.3.7 and tabulated in Table I.3.6.

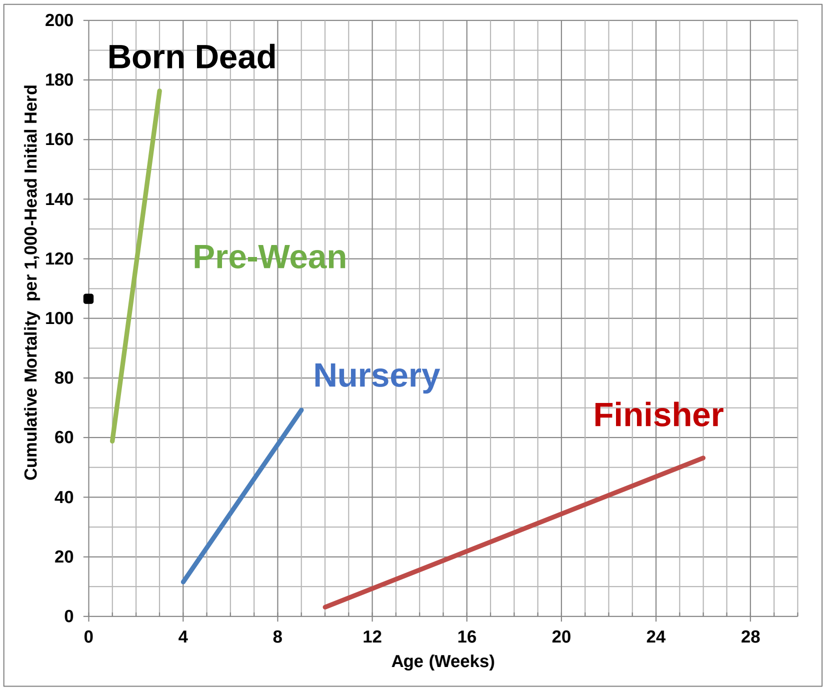

Figure I.3.6. Cumulative death loss measured at the end of each week during the three growth phases of production for groups of 1,000 animals (from Table I.3.5 and USDA-APHIS 2012a).

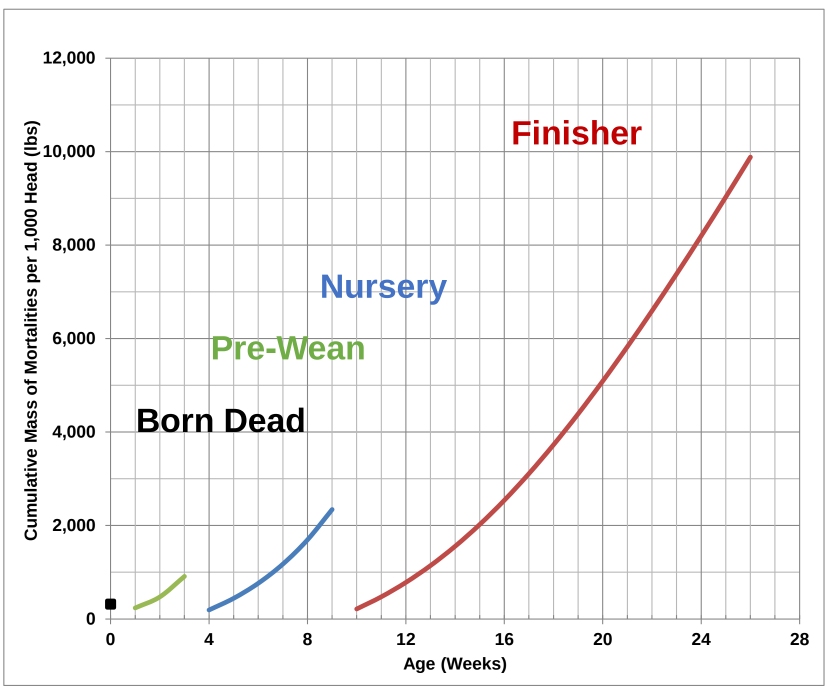

Figure I.3.7. Cumulative mass of mortalities measured at the end of each week during the three growth phases of production for groups of 1,000 animals (Figure I.3.5 multiplied by Figure I.3.6).

Table I.3.6. Mass of mortalities estimated for each phase of swine growth (group size at beginning of each phase equals 1,000 head).

	Mortality Mass Collected Over Entire Growth Phase (lbs. per 1,000 pigs)	Mortality Mass Collected Over Entire Growth Phase (lbs. per pig)
Piglets Born Dead	317	0.317
Pre-Wean	911	0.911
Nursery	2,340	2.34
Finisher	9,880	9.88

3.3.c Carcass Composition

Total body P content of cull sows was chemically determined in order to facilitate more accurate P mass balance calculations for swine breeding herd farms (May and Rozeboom, 2008). Fifteen sows were removed from a central Michigan swine breeding herd, following normal farm culling protocol, and slaughtered. Each sow's blood, viscera including digesta and carcass were individually processed and sampled such that each sow's individual components and each sow's total body content for protein, fat, ash, and nine minerals, including P, were analyzed. Average P content of the 15 cull sows was 0.563% P. A P mass balance model for an example 2,400-sow case farm using this value for cull sows, and those reported in the literature for other specific stages of production at the time when animals enter or depart the farm, were used to estimate annual accumulation of P_2O_5 in manure. The P mass balance model using stage-specific, chemically-determined values, estimated there would be 29,751-kg manure P_2O_5 accumulated annually by this farm, 9% to 31% greater than other estimates made using currently available methods.

A nutrient management plan developed using a mass balance model with stage-specific, chemically-determined total or whole body P requires a larger land base, but that estimation reduces the risks of P accumulating in the soil and future restrictions on the use of that land for manure applications because of high soil P levels. The data presented in May and Rosenboom (2008) provide a reasonable means to predict the amount of potential P from swine mortalities. The P ranges of values is between 3.76 g kg^{-1} to 5.63 g kg^{-1} of body weight.

The chemical whole-body composition of 20 Landrace × (Landrace × Large White) pigs of 20 kg liveweight was determined by Smits et al. (1988). Mean (± SD) body protein, lipid, ash, and water contents (%) were 15.9 ± 1.47, 14.2 ± 2.72, 3.7 ± 0.43, and 65.6 ± 2.61, respectively. These values agreed closely with mean estimates derived from a review of the world literature. Body lipid content (Coefficient Variation = 19.10%) was markedly more variable than the other chemical components. The TKN mass is then calculated using the reported mean body protein value of 15.9% in the literature (Smits et al., 1988), and a factor of 6.25 to convert protein to TKN value (Benedict ,1987). Following this procedure gives an average TN content per AU of 25.44 lbs.

3.4 Annual Mass of Nutrients Contained in Swine Mortalities

The annual mass of mortalities and nutrients contained in mortalities for a farrow-to-finish operation are given in Table I.3.7. These values were calculated using the instantaneous inventory of a farrow-to-finish operation (Table I.3.3), the annual death rate of breeding stock (7.8%), the average weight of breeding stock at time of death (sows = 450 lbs., gilts = 300 lbs., boars = 700 lbs.), and mass of mortalities per growth phase (Table I.3.6). Mass of mortalities for growing stock was determined using the number of animals entering the growth phase each year (not the number of animals leaving shown in Table I.3.7). For instance, we used 27,500 weaned pigs entering the nursery each year, and not the 26,000 pigs leaving the nursery each year (27,500 weaned pigs – 27,500 X 0.04615 death rate for nurseries = 25,808 ≈ 26,000 feeder pigs leaving). Nutrient mass was calculated using 0.0254 lbs. TN and 0.00563 lbs. TP per lbs. of carcass for all animals.

Table I.3.7. Expected annual mass of mortalities and nutrients contained in carcasses produced by a farrow-to-finish operation with a running average of 1,150 sows.

	Inventory	Number Leaving Phase Each Year	Animals Dying (Head yr^{-1})	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})
Sows	1,150	-	90	40,000	1,025	227
Gilts	115	-	19	2,700	68	15
Boars	12	-	1	700	16	4
Pigs Born Dead	0	-	3,200	9,450	240	53
Weaned Pigs	2,000	27,500	9,500	30,000	770	170
Feeder Pigs	3,900	26,000	1,500	64,000	1,600	362
Finishers	9,700	25,000	1,400	260,000	6,600	1,500
Total	**16,877**			**406,900**	**10,340**	**2,292**
Per Sow				**350**	**9.0**	**2.0**
Per Sow AU				**790**	**20**	**4.4**
Per Finisher Sold				**16**	**0.42**	**0.092**
Per Finisher AU				**61**	**1.5**	**0.34**
Per Inventory Unit				**24**	**0.61**	**0.14**

Mass of mortalities produced on common types of swine farms in the watershed are tabulated in Tables I.3.8 and I.3.9. Mass of mortalities resulting from farms housing breeding stock is given in Table I.3.8. Mass of mortalities on farms housing non-breeding stock is given in Table I.3.9. The mortality weights were calculated using the inventory of the type of animals housed on the farm based on the inventory of a farrow-to-finish farm. Size of every farm given in Tables I.3.6, I.3.7, and I.3.8 are matched to production of a 1,150-sow farrow-to-finish unit. For instance, 27,500 weaned pigs are produced by 1,150 sows per year, assuming seven turns for an off-site nursery per year results in an inventory (or pig space) of 3,900 for that nursery (rounded to two significant figures).

Table I.3.8. Annual mass of mortalities and nutrients contained in mortalities produced on farms housing breeding stock (based on 1,150 sow farrow-to-finish farm producing 25,000 market hogs per year).

	Farrow-to-Finish			**Farrow-to-Wean**			**Farrow-to-Feeder**		
Total Inventory	17,000			3,300			7,200		
	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})
Per Sow	350	9.0	2.0	73	1.85	0.41	130	3.3	0.72
Per Sow AU	790	20	4.4	160	4.1	0.91	290	7.3	1.6
Per Pigs or Hogs Leaving	16	0.42	0.092	3.0	0.077	0.017	5.6	0.14	0.032
Per Pig or Hog Leaving AU	61[1]	1.5[1]	0.34[1]	200[2]	5.1[2]	1.1[2]	100[3]	2.6[3]	0.58[3]
Per Inventory Unit	24	0.61	0.14	26	0.65	0.14	21	0.52	0.12

[1] Market Hog at 270 lbs.

[2] Weaned Pig at 15 lbs.

[3] Feeder Pig at 55 lbs.

Table I.3.9. Annual mass of mortalities and nutrients contained in mortalities produced on farms housing non-breeding swine production phases (based on 1,150 sow farrow-to-finish farm producing 25,000 market hogs per year).

	Off-Site Nursery			**Wean-to-Finish**			**Grow-Finish**		
Total Inventory	3,900			13,100			9,700		
Turns per year	7			2.1			2.7		
	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})	Mortality Mass (lbs. yr^{-1})	Mass of TN (lbs. yr^{-1})	Mass of TP (lbs. yr^{-1})
Per Pigs or Hogs Leaving	2.5	0.062	0.014	13	0.33	0.073	10	0.265	0.059
Per Pig or Hog Leaving AU	45[1]	1.1[1]	0.25[1]	48[2]	1.2[2]	0.27[2]	39[2]	0.98[2]	0.22[2]
Per Inventory Unit	16	0.42	0.092	25	0.63	0.14	27	0.68	0.15

[1] Feeder Pig at 55 lbs.

[2] Market Hog at 270 lbs.

3.5 Comparison of Swine Mortality Nutrients to Excreted Manure Nutrients

Comparison of nutrients contained in carcasses to nutrient excreted by swine is a true "apples to apples" comparison. The nutrients contained in carcasses calculated by the method outlined in this report are nutrients contained in the animal's body right exactly at the time of death - before losses from decay, storage, and treatment diminish its mass. Excreted manure nutrients are the nutrients leaving the animal - before weathering, ammonia volatilization, and a multitude of other factors diminishes its mass. Estimates using current formulas for excreted nutrients, which are based on nutrient intake, are highly dependent on assumptions of diet and management practices, and should be thought of as rough averages with a high degree of variability - just as this report has highlighted the variability of estimating the mass of carcass nutrients.

Table I.3.10 compares the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients excreted by the same 1,150 sow farrow-to-finish operation. The USDA-NRCS Waste Management Field Handbook (USDA-NRCS, 2008), which in turn is based on the American Society of Agricultural and Biological Engineers Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005), was used to calculate the excreted manure values. The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted by breeding stock per day. The nutrients excreted by pre-weaned pigs is considered to be part of the mother's excreta. These values are based on a mass balance of food intake, nutrients accumulated in the body, nutrients respired, and nutrients excreted. Mass of nutrients produced by growing swine is also estimated by a mass balance, but is given on a per animal finished basis.

Table I.3.10 shows that, if carcass nutrients are combined with excreted nutrients, **approximately 3.2% of the nitrogen produced by a farrow-to-finish swine operation originates with mortalities**. Likewise, **3.8% of the phosphorus produced by a farrow-to-finish operation comes from mortalities.**

3.6 Future Research Needs

3.6.a Types of Farms Not Covered in This Report

This report does not provide per farm mortality data for operations providing breeding stock for multi-site production such as boar farms and multiplier farms. However, nutrients produced on these farms can be estimated by considering the units making up a full farrow-to-finish operation housed on the farm.

3.6.b Need For On-farm Data Collection

Although we are confident in the data produced in this report, the values were primarily produced through limited published data on mortalities, and personal communication with top researchers in this area. Research should be undertaken to determine the actual mass of mortalities produced on farms under the cultural practices used in the watershed.

3.6.c Need For Data on Whole Carcass Nutrient Content

Very limited data exists for whole carcass composition of swine.

Table I.3.10. Mass of as-excreted manure nutrients produced by a farrow-to-finish operation with a running average of 1,150 sows compared to nutrients contained in carcasses produced by the same operation.

	Inventory	Annual Production	Nutrients Excreted per Animal[1]		Annual Nutrient Excretion (lbs. yr^{-1})	
	Head	**Head yr^{-1}**	**TN**	**TP**	**TN**	**TP**
Gestating Sows	990	-	0.071 lbs. hd^{-1} d^{-1}	0.020 lbs. hd^{-1} d^{-1}	26,000	7,200
Lactating Sows with Litters	150	-	0.190 lbs. hd^{-1} d^{-1}	0.055 lbs. hd^{-1} d^{-1}	11,000	3,200
Boars	12	-	0.061 lbs. hd^{-1} d^{-1}	0.021 lbs. hd^{-1} d^{-1}	267	92
Replacement Gilts	115	520	10 lbs. hd^{-1}	1.7 lbs. hd^{-1}	5,200	880
Nursery Pigs	3,900	26,000	0.91 lbs. hd^{-1}	0.15 lbs. hd^{-1}	24,000	3,900
Finisher Hogs	9,700	25,000	10 lbs. hd^{-1}	1.7 lbs. hd^{-1}	250,000	42,500
				Total Manure Nutrients (lbs. yr^{-1})	**316,467**	**57,772**
				[2]Total Mortality Nutrients (lbs. yr^{-1})	**10,340**	**2,292**
				Total Nutrients (lbs. yr^{-1})	**326,807**	**60,064**
				Portion of Total Nutrients from Mortalities	**3.2 %**	**3.8 %**

[1]USDA-NRCS (2008)

[2]From Table 7

3.7 Assumed Values of Mortality Masses and Carcass Nutrients for Watershed

Without any further defining information, the values given in Table I.3.11 should be used for mass of routine mortalities and nutrients produced annually for swine with routine mortalities. If type of farm is known, the values given in Tables I.3.8 and I.3.9 should be used. The values given in Table I.3.11 are mortalities produced during all phases of hog production from farrow to finish. Weight of mortalities, total nitrogen, and phosphorus produced per year are given per inventory unit, which can be used to determine weights given state and county hog inventory in the USDA-NASS Census of Agriculture. Values are also given on a per animal and per AU basis for the Chesapeake Bay Program's units of Hogs and Pigs for Breeding and Hogs for Slaughter.

Table I.3.11. Assumed annual mass of mortalities and nutrients contained in mortalities produced by all types of swine farms.

	Per Animal Basis			Per Weight Basis		
	lbs. $head^{-1}$ $year^{-1}$			lbs. AU^{-1} $year^{-1}$		
	Mortalities	**TN**	**TP**	**Mortalities**	**TN**	**TP**
Inventory	24	0.61	0.14	-	-	-
Hogs and Pigs for Breeding (Sows)	350	9.0	2.0	790	20	4.4
Hogs for Slaughter (Market Hogs)	16	0.42	0.092	61	1.5	0.34

3.8 References

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4. **Cattle**

4.1 Definitions

AFO: An Animal Feeding Operation smaller than the **CAFO** threshold

Animal Unit (AU): commonly used unit representing 1,000 pounds of live animal weight

Beef Cattle: bovine intended for meat production

Bull: intact male bovine

CAFO: Confined Animal Feeding Operation, an **AFO** usually housing more than 1,000 animal units.

Calf: young bovine stock (plural: calves)

Carcass: a deceased animal; in the context of mortality management, it is the whole animal including head, hide, feet and internal organs; in the context of meat production, it is the de-hided, beheaded, eviscerated, and cleaned carcass prepared for butchering

Confinement: animal production system where animals are confined in pens or houses and feed is brought to the animals; animals do not gain a majority of nutritional needs from grazing or environmental sources; may be referred to as **AFO** or **CAFO**; does not apply to fenced pastures or grazing operations

Cow: mature female bovine having produced one or more calves

Cow-Calf Operation: cattle enterprise defined by pastured animals (cows) producing calves for annual sale to be finished elsewhere at a feedlot

Dairy Cattle: female bovine intended for milk production; may include male breeding stock for herd reproduction, e.g. dairy bulls

Feeder Cattle: cattle on delivered/provided feed intended for eventual meat production; may be referred to as **Cattle on Feed**

Feedlot: confinement operation usually associated with cattle for eventual meat production; may be roofed, but more commonly uncovered pens and lots; synonyms: feed yard, feeding operation

Head: colloquial unit representing one agricultural animal, not age specific, most common for stock such as cattle, pigs, and small ruminants (goats and sheep)

Heifer: immature female bovine, not yet having produced a calf; a heifer may be bred and is often referred to as a **First Calf Heifer** or **Bred Heifer**

Herd: a group of cattle

Ruminant: multi-stomached animal with a large main stomach (rumen) that microbially digests fiber; ex: cattle, sheep, goats, bison, yaks, and similar wildlife

Steer: castrated male bovine; most common animal for meat production

Stocker Cattle: heifers and steers fed on pasture in preparation for placement on a feedlot -- usually off the farm on which they were born and weaned.

Weaned/Weaning: animal removed from mother's milk and transitioned to eating solid feed exclusively

4.2 Beef Cattle (Cow-Calf)

4.2.a. Beef Cattle in the Watershed

Eastern beef production is characterized by relatively small cow-calf herds, where the herd is described by the number of mother cows. Cattle are raised on pasture with some supplemental hay feeding when conditions warrant (Figures I.4.1 and I.4.2). Cattle are on pasture greater than 95% of the time. Under ideal conditions, each cow will yield one calf per year to be sold by year's end. Some female calves will be retained to replace culled cows from the herd, maintaining the same general herd size.

Table I.4.1 lists numbers of mature beef cows living in each state making up the Chesapeake Bay Watershed. This list includes all cattle living in each state, not just those in the watershed, but gives a snapshot of the widespread presence of cow-calf herds in the watershed.

Table I.4.1. Beef cow population by state in 2017 (USDA-NASS, 2020).

	Number of Beef Cows
Delaware	2,400
Maryland	48,000
New York	110,000
Pennsylvania	220,000
Virginia	640,000
West Virginia	210,000
Total	**1,230,000**

4.2.b Nutrients Contained in Cow-Calf Mortalities

Weight and Growth of Cattle

Common Hereford/Angus cross cattle were used in all calculations for this report. Common weights at life stages are given in Table I.4.2. Weaning time and weight, as well as other management practices, vary from producer to producer. The weights given in Table I.4.2 are considered averages. As some finishing may occur on a cow-calf operation or a feeding site, the weight of a finished steer is also given.

Cow-Calf Herd Mortalities

Annual beef mortality rates are reported by USDA-APHIS (2010) based on herd size. There is little difference amongst herd sizes of 1-49, 50-99, and 100-199 mother cows. The average mortality rates for three life stages of calves are given in Table I.4.3. It was assumed that, under normal circumstances, mother cows do not die in herds, but are rather culled and replaced before dying.

Figure I.4.1. Beef cows on pasture in Virginia (USDA-NRCS).

Figure I.4.2. Steers on pasture in Virginia (USDA-NRCS).

Table I.4.2. Weight of Hereford/Angus cross beef cattle at different life stages (Greiner, 2005; Hamilton, 2011; C. Sanford Personal Communication, June, 2019).

Life Stage	Weight (lbs)
Calf at Birth	80.4
Calf at Weaning	458
Heifer	840
Finished Steer	1,100
Mature Mother Cow	1,400

Table I.4.3. Average annual mortality rates of immature beef cattle for herds 1-199 mother cows (USDA-APHIS, 2010).

	Annual Mortality (%)
Born Dead	3.03
Died before Weaning	3.83
Died after Weaning	1.73

Using a 50-cow herd as the reference size, the mortality rates of Table I.4.3 are translated to a head per year basis as shown in Table I.4.4. The total weight of mortality from each life stage is the product of the average weight of cattle in the stage times the average number dying each year in that life stage group. The total weight of mortalities produced each year in a reference herd of 50 cows is the total of weights from each life stage group. Dividing the total mortality weight by 50 yields an estimate of annual mortality on a per mature cow basis. Calculations are summarized in Table I.4.4. On average, 32.3 pounds of cattle carcasses are produced per cow each year. Figure I.4.3 highlights the annual weight of mortality relative to life stage. Despite the low mortality rate after weaning, this stage represents a significant contribution to the weight of mortality to be managed.

Table I.4.4. Annual weight of mortalities produced by a 50-cow, cow-calf herd.

	Head dying	Average Life Stage Weight (lbs.)	Weight of Mortalities (lbs. yr^{-1})
Born Dead	1.52	80.4	122
Died Before Weaning	1.92	269	516
Died After Weaning	0.865	1,130[1]	977
		TOTAL ANNUAL MORTALITY WEIGHT	**1,615**
		TOTAL ANNUAL MORTALITY WEIGHT per MATURE COW	**32.3**

[1]Calculated as the average of heifer, finished steer, and mature cow weights (Table I.4.2).

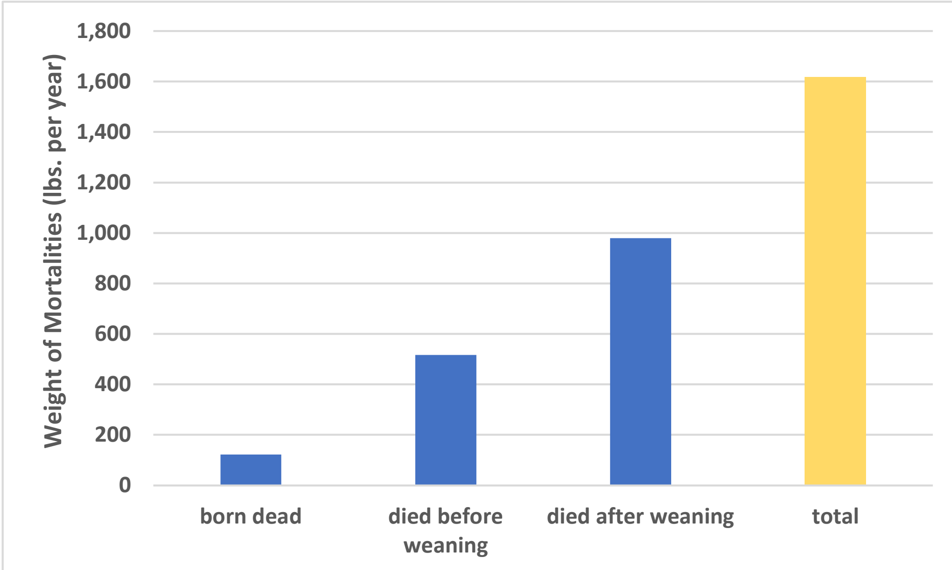

Figure I.4.3. Annual weight of beef mortalities at each growth stage for 50-cow cow-calf herd (from Table I.4.4).

Carcass Composition

Data on whole carcass composition in the literature is sparse, as whole dead cattle are seldom analyzed for this purpose. Even whole carcasses of calves are difficult to analyze, because, unlike poultry whose relatively small carcasses can be digested and rendered in a laboratory to fractionate and measure chemical and mineral components, cattle are large and exceedingly hard to digest whole.

Three estimates were used to determine the percent protein of whole cattle carcasses. Bonilla et al. (2011) estimated 18% protein. Rendering experts David Meeker and Janis Swan estimated 20% and 15% protein product rendered from a whole bovine carcass, respectively (D. Meeker and J. Swan, personal communication , 2019). Therefore, an average of 17.67% was used as the estimate of protein in a whole carcass. Benedict (1987) published the following equation to convert total protein to total nitrogen: *TKN (Total Kjeldahl Nitrogen) = TP (Total Protein) ÷ 6.25*. This equates to 28.27 pounds of N per 1,000 pounds of carcass weight, or 28.27 pounds of nitrogen per animal unit (AU).

Bonilla et al. (2011) also estimated whole bovine carcass ash at 4.56%, and Cohen (2009) estimated that bovine carcass ash is 18% phosphorus. The following equation was used to estimate the pounds of phosphorus in a 1000-pound bovine carcass: *0.0456 pounds ash per pound carcass X 0.18 pounds TP per pound ash X 1,000 pound carcass = 8.2 pounds of phosphorus.*

4.2.c Annual Mass of Nutrients Contained in Cow-Calf Mortalities

Combining the annual mortality values of Table I.4.4 with the estimated mass of nitrogen and phosphorus per cattle carcass, gives the estimated mass of nutrients contained in the carcasses produced by cow-calf herds per year. Estimates of mortalities produced and nutrients contained in mortalities on a per mother cow and per AU basis for cow-calf operations is given Table I.4.5, assuming 1,400 pounds per mother cow.

Table I.4.5. Estimated annual mass of mortalities and nutrients contained in carcasses from cow-calf herds.

Per Mother Cow (lbs. per year)			Per 1,000 pound AU (lbs. per year)		
Mortalities	**Total N**	**Total P**	**Mortalities**	**Total N**	**Total P**
32.3	0.905	0.265	23.1	0.646	0.189

4.2.d Comparison of Cow-Calf Mortality Nutrients to Excreted Manure Nutrients

Comparison of nutrients contained in mortalities to nutrient excreted by cattle is a true "apples to apples" comparison. The nutrients contained in mortalities calculated by the method outlined in this report are nutrients contained in the animal's body exactly at the time of death - before losses from decay, storage, and treatment diminish their mass. Excreted manure nutrients are the nutrients leaving the animal - before weathering, ammonia volatilization, and a multitude of other factors diminishes their mass on the pasture. Estimates using current formulas for excreted nutrients, which are based on nutrient intake, are highly dependent on assumptions of diet and cultural practices, and should be thought of as rough averages with a high degree of variability - just as this report has highlighted the variability of estimating the mass of carcass nutrients.

Table I.4.6 gives a comparison of the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients excreted by the same 50-cow, cow-calf herd. The American Society of Agricultural and Biological Engineers Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) was used to calculate excreted manure values. Table I.4.6 shows that, if carcass nutrients are combined with excreted nutrients, **approximately 0.45% of the nitrogen produced by cow-calf herds originates with mortalities**. Likewise, **0.58% of the phosphorus produced by cow-calf herds comes from mortalities.** The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted by mature beef cows and growing calves (in confinement) per day. The nutrients excreted by un-weaned calves are considered to be part of the mother's excreta. These values are based on a mass balance of food intake, nutrients accumulated in the body, nutrients respired, and nutrients excreted. Total nitrogen excreted is 0.42 pounds of TN per cow per day, and 0.29 pounds of TN per growing calf per day. Total phosphorus excreted is 0.097 pounds of TP per cow per day and 0.055 per calf per day. Therefore, the mass of excreted nitrogen estimated from a 50-cow, cow-calf herd is: 50 cows X 0.42 lbs. TN per cow per day^{-1} X 365 days = 7,700 TN per year, plus 47 calves (after still born and pre-weaned death loss) X 0.29 lbs. TN per calf per day X 180 days (post weaning) = 2,450 lbs. TN per year, for a herd total of 10,150 lbs. TN per year. Dividing by 50 gives the per cow mass of TN excreted as 200 pounds per year. Similarly, the mass of phosphorus excreted by 50-cow, cow-calf herd is 45 pounds TP per cow per year.

Table I.4.6. Mass of nutrients contained in mortalities from a 50 cow, cow-calf herd compared to the estimated mass of nutrients contained in manure excreted (ASABE, 2005) by the same herd.

Nutrients Contained in Mortalities (lbs. per cow per year)		Nutrients Contained in Excreted Manure (lbs. per cow per year)	
TN	**TP**	**TN**	**TP**
0.905	0.265	200	45

4.3 Cattle on Feed

4.3.a Feeder Cattle in the Watershed

Although most beef production in the watershed is cow-calf herds, some cattle finishing facilities do exist in the watershed (Figure I.4.4). Table 1.4.7 gives the state-level numbers for cattle on feed in the watershed, along with a measure of the relative size of feeding facilities in each state. This list includes the feeding capacity of feed yards in each state, not just those in the watershed.

If one assumes one calf is born to each beef cow per year, comparing Tables I.4.1 and I.4.7 indicates that less 15% of the cattle born in the mid-Atlantic region are finished there. The majority of beef cattle are shipped west as stockers and finished in feedlots in the upper Midwest and southern plains. The only state with a sizeable cattle feeding enterprise is Pennsylvania, and Hawkins et al. (2016) indicate that cattle feeding is concentrated in Cumberland, Lancaster, and York Counties in Pennsylvania. Larger farms, those feeding more than 200 head, do so under roof, with manure being scraped and stored in dry stacks, or stored in-house as bedded pack solid manure or deep pit liquid manure. Few farms currently finish cattle in open lots. The majority of those farms feeding less than 100 head finish cattle on pasture (Hawkins et al, 2016).

Table I.4.7. Cattle on feed in states in the watershed and the relative size of feeding facility in each state (USDA-NASS, 2020).

	Cattle on Feed	Percentage of Farms in Each State Feeding the Indicated Number of Cattle (head capacity)					
		1-19	20-50	50-100	100-200	200-500	500+
Delaware	1,500	12.5	12.5	25	0	12.5	12.5
Maryland	11,000	32	37	18	7	3	3
New York	24,000	26	36	19	11	7	1
Pennsylvania	120,000	20	31	24	17	6	2
Virginia	20,000	5	40	34	14	6	1
West Virginia	2,800	5	25	30	15	15	10
Total	**178,500**	**20**	**33**	**23**	**15**	**6**	**2**

Figure I.4.4. Cattle on feed in Maryland (USDA-NRCS).

4.3.b Nutrients Contained in Cattle-on-Feed Mortalities

Body Weights and Growth Rate

Cattle are generally on feed in a confinement facility for around 120 days. For the purposes of calculating mortality, a linear growth curve is used with cattle entering the feeding program at 400 to 600 pounds and leaving at 1,000 to 1,200 pounds.

Confined Beef Mortalities

The most comprehensive study on beef feedlot mortalities was conducted by Vogel et al. (2015). The data reflected lots in the Midwest and Great Plains; however, the data are expansive and suitable for estimates in the Chesapeake Bay Watershed. Annual mortality rates for a given capacity of cattle on feed are shown in Table I.4.8. With milder weather and more controlled conditions (feeding under roof), the watershed's rates could be lower.

Table I.4.8. Average annual mortality rates for a cattle feeding facility (Vogel et al., 2015).

	Annual Mortality (%)
First 30 days	0.67
Mid-feeding	1.59
60 to 31 days pre-harvest	0.19
Final 30 days	0.23

Using a 100-head feeding operation as the reference size, the previous mortality rates are translated to head dying per year in Table I.4.9. The live body weights in Table I.4.9are based on common or anecdotal weights at entry (400-600 lbs.) and goals for finishing weight (1,000-1,200 lbs.) over a linear growth curve. The total weight of mortality from each life stage is the product of the live weight times the average head dying per year. The total annual mortality weight for this reference herd represents the relative contribution of each listed life stage and respective mortality rate. Dividing the total by 100 yields an estimate of annual confined beef mortality on a head basis; 18.24 pounds of annual mortality is predicted for each finished beef animal in confinement on an operation.

Table I.4.9. Annual mortalities in a cattle feeding operation with 100 head capacity.

	Head dying	Average Live Weight (lbs.)	Weight of Mortalities (lbs. yr^{-1})
First 30 days	0.67	500	335
Mid-feeding	1.58	690	1,090
60-31 days pre-harvest	0.18	875	160
Final 30 days	0.22	1,100	240
		TOTAL ANNUAL MORTALITY WEIGHT	**1,825**
		TOTAL ANNUAL MORTALITY WEIGHT per Head in Confinement	**18.25**

Annual weight of mortality relative to time in or stage of feeding is illustrated in Figure I.4.5. The greatest contribution to annual mortality, approximately 60%, is in the mid-feeding stage where animals average 690 pounds.

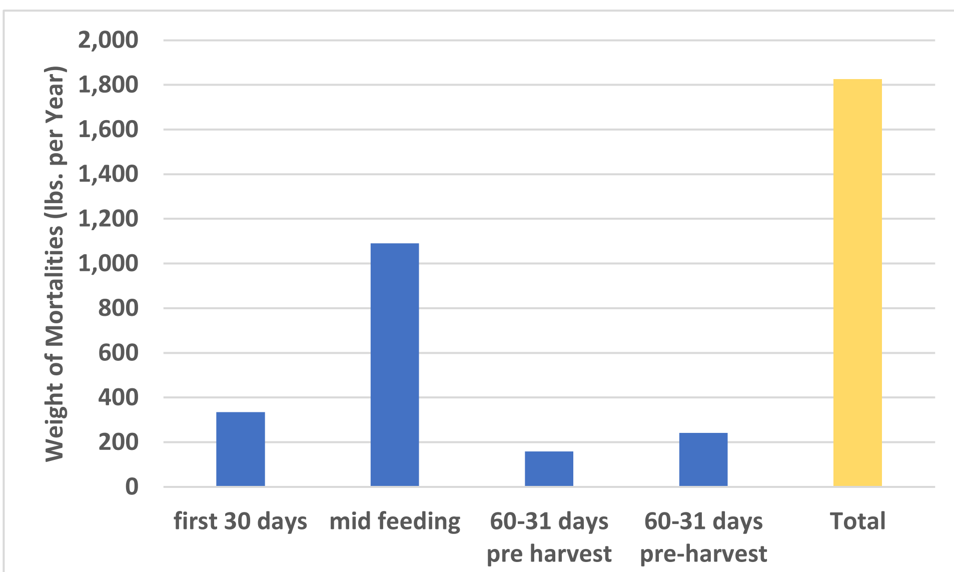

Figure I.4.5. Total annual weight of beef mortality at growth stage for a 100-head feedlot

Carcass Composition

Carcass nutrient composition specific to cattle on feed was not found in the literature. Therefore, the data of Bonilla et al. (2011), Meeker and Swan (D. Meeker and J. Swan, personal communication, 2019),Benedict (1987), and Cohen (2009) were used to estimate concentration of nutrients in finisher cattle carcasses.

4.3.c Annual Mass of Nutrients Contained in Cattle on Feed

Annual mass of total nitrogen and total phosphorus contained in carcasses produced in a feedlot with 100 head capacity was calculated by multiplying the data of Table I.4.9 by the estimates of cattle composition. Annual mass of nitrogen and phosphorus in carcasses of cattle on feed is given in Table I.4.10. Values per 1,000-pound AU were based on the weight of cattle upon finishing (1,100 lbs.).

Table I.4.10. Estimated annual mass of mortalities and nutrients contained in carcasses from a beef finishing operation with the capacity of 100 head.

Per Head (lbs. per year)			Per 1,000 pound AU (lbs. per year)		
Mortalities	**Total N**	**Total P**	**Mortalities**	**Total N**	**Total P**
18.25	0.52	0.15	16.5	0.47	0.14

4.3.d Comparison of Cattle on Feed Mortality Nutrients to Excreted Manure Nutrients

Table I.4.11 gives a comparison of the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients excreted by a feedlot with 100 head capacity. The American Society of Agricultural and Biological Engineer Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) was used to calculate excreted manure values. Table I.4.11 shows that, if carcass nutrients are combined with excreted nutrients, **between 0.26 and 0.32 percent of the nitrogen produced by cattle on feed originates with mortalities, depending on diet**. Likewise, **between 0.45 and 0.74 percent of the phosphorus produced by cattle on feed comes from mortalities.** The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted by cattle on feed as they grow from 400 to 1,100 pounds. These values are based on a mass balance of food intake, nutrients accumulated in the body, nutrients respired, and nutrients excreted. Since cattle remain on feed for an average of 120 days, the maximum number of cattle that can pass through a feedlot of 100 head capacity in one year is 304; minus 2.65 head lost from mortalities, gives a number of approximately 300 head per year. Total nitrogen excreted is 53 pounds of TN per finisher fed on a diet without supplements. Nitrogen excretion increases to 75 lbs per finished animal for a diet of 25% distillers' grains, and 66 per finisher for a diet of 30% corn gluten. Total phosphorus excreted is 6.6 pounds of TP per finished animal without supplementation, 10 pounds per finished animal fed a diet of 25% distillers' grains, and 11 per finisher for a diet of 30% corn gluten. Therefore, the mass of excreted nitrogen estimated from a 100 head capacity feedlot without feed supplementation can be represented by 300 finishers per year X 53 lbs. TN per finisher = 16,000 pounds TN per year. Dividing by 100 gives the per head capacity mass of TN excreted as 160 pounds per year. Similarly, the mass of phosphorus excreted by a 100 head capacity feedlot feeding cattle without supplements is 20 pounds TP per head per year.

Table I.4.11. Nutrients contained in mortalities produced by a feedlot with 100 head capacity versus mass of nutrients excreted by the same feedlot based on three diets (ASABE, 2005).

	Total Nitrogen (lbs. $head^{-1}$ $year^{-1}$)	Total Phosphorus (lbs. $head^{-1}$ $year^{-1}$)
Contained in mortalities	0.52	0.15
Excreted by cattle fed a diet without supplements	160	20
Excreted by cattle fed a diet with 25% distillers' grain	230	30
Excreted by cattle fed a diet with 30% corn gluten	200	33

4.4 Dairy Cattle

4.4.a Dairy Cattle in the Watershed

The majority of dairy production (Figures I.4.6 and I.4.7) in the watershed is found in Pennsylvania, representing 73% of the dairy cows within counties with at least half their land mass within the Chesapeake Bay Watershed (Table I.4.12). The two counties in Pennsylvania with the greatest concentration of dairy production are Lancaster and Franklin. Nearly a fourth of Pennsylvania production is on dairy farms larger than 200 head, with some on dairy farms with greater than 500 head. The remainder are traditionally sized herds under 200 head, with some very small herds in Lancaster County (Hawkins, et al., 2016).

Table I.4.12. Estimated number of mature dairy cows residing in counties with land mass at least 50% within the Chesapeake Bay Watershed (USDA NASS, 2020; Hawkins et al., 2026).

	Number of Mature Dairy Cows
Delaware	1,800
Maryland	45,000
New York	44,000
Pennsylvania	400,000
Virginia	52,000
West Virginia	2,750
Total	**545,550**

4.4.b Nutrients Contained in Dairy Cattle Mortalities

Herd Characteristics and Body Weights

Using a 100-cow milking herd as a reference, a dairy farm will have around 50 female calves and 50 heifers in development. Heifers are bred at 15 months and give birth around 24 months (2 years) of age. Male calves are generally exported from the farm as soon as possible for development as lower grade beef cattle. A conventional dairy has heifers and dry cows on pasture, with the active milking herd in free-stall barns or alternative confinement for a 300-day lactation. Grazing dairies do not confine animals in housing. As management practices, regional differences, and herd genetics influence body weight at different life stages, body weights for life stages were estimated from several sources. The average weight for various life stages of dairy cattle is given in Table I.4.13.

Figure I.4.6. Dairy cattle on pasture in Virginia (USDA-NRCS).

Figure I.4.7. Dairy cattle in confinement in Maryland (USDA NRCS).

Table I.4.13. Average live weights of dairy cattle (Jones and Hendricks, 2016; Jones and Hendricks, 2017; USDA-APHIS, 2016; M. de Haro-Marti, personal communication 2019).

Life Stage	Average Weight (lbs.)
Pre-Weaned Calf	122.5
Weaned Heifers	555
Mature Cow	1,300

Mortalities

Annual dairy mortality rates are reported by USDA-APHIS (2014) across all eastern dairy herds sizes 30-500+ head. The average mortality rates for three life stages are given in Table I.4.14.

Table I.4.14. Mortality rates for dairy cattle (USDA-APHIS, 2014).

Life Stage	Annual Mortality (%)
Pre-Weaned Heifers	5.8
Weaned Heifers	1.8
Mature Cow	6.2

Table I.4.15 gives mortality weight for a 100-cow dairy. The mortality rates are translated to head died per year. The total weight of mortalities from each life stage is the product of the average weight of the stage, times the average head dying per year. The total annual mortality weight for this reference herd represents the relative contribution of each listed life stage and respective mortality rate. Dividing the total by 100 gives the annual dairy mortality on a per mature cow basis. For each mature dairy cow on a farm, 89.15 pounds of annual mortality could be predicted.

Table I.4.15. Annual mortality (head and weight) for a 100-cow dairy herd.

	Head dying	Life Stage Weight (lbs.)	Weight of Mortalities (lbs. yr^{-1})
Pre-weaned heifers	2.9	122.5	355
Weaned heifers	0.90	555	500
Cows	6.2	1,300	8,100
		TOTAL ANNUAL MORTALITY WEIGHT	**8,955**
		TOTAL ANNUAL MORTALITY WEIGHT/MATURE COW	**90**

Figure I.4.8highlights the annual weight of mortality relative to life stage. Despite nearly equal mortality rates for pre-weaned heifers and mature cows, pre-weaned calf inventory is half that of mature cows and body weights are significantly less. Weaned heifers have a higher average body weight moving through this phase towards breeding and maturity, but a very low mortality rate. Finally, the bulk of mortality weight on an annual basis is in the death of mature cows, due to the higher rate of mortality and the larger body weight.

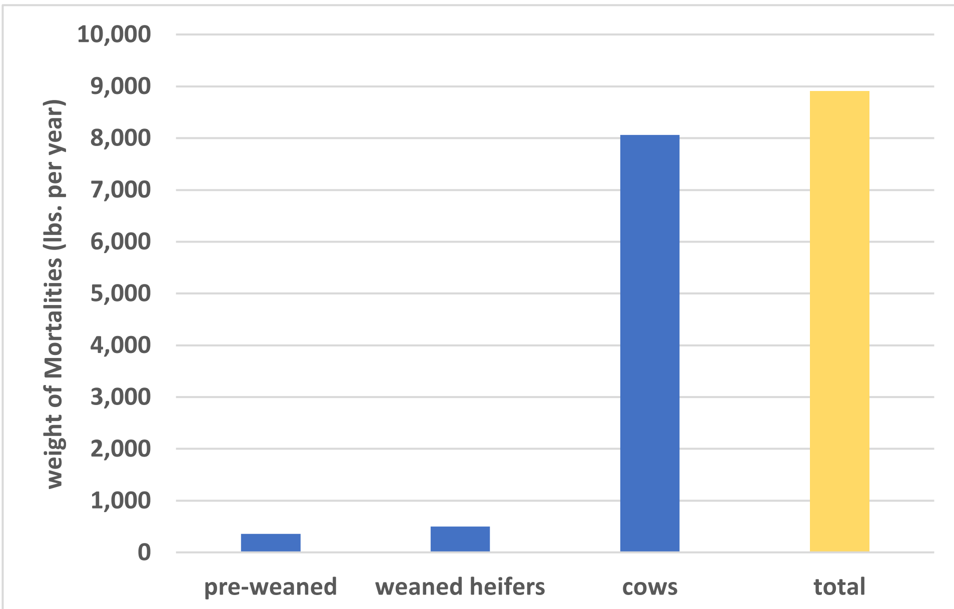

Figure I.4.8. Total annual weight of dairy mortality at growth stage for 100-cow herd.

Carcass Composition

Carcass nutrient composition specific to cattle on feed was not found in the literature. Therefore, the data of Bonilla et al. (2011), Meeker and Swan (personal communication, 2019), Benedict (1987), and Cohen (2009) were used to estimate concentration of nutrients in finisher cattle carcasses.

4.4.c Annual Mass of Nutrients Contained in Dairy Cattle Mortalities

Annual mass of total nitrogen and total phosphorus contained in carcasses produced in a 100-cow dairy herd was calculated by multiplying the data of Table I.4.15 by the estimates of cattle composition. Annual mass of nitrogen and phosphorus in carcasses per head of mature cows is given in Table I.4.16. Per animal unit values were based on the average weight of mature dairy cattle (1,300 lbs).

Table I.4.16. Estimated annual mass of mortalities and nutrients contained in carcasses from dairy herds.

Per Head (lbs. per year)			Per AU (lbs. per year)		
Mortalities	**Total N**	**Total P**	**Mortalities**	**Total N**	**Total P**
90	2.5	0.74	69	1.9	0.57

4.4.d Comparison of Dairy Mortality Nutrients to Excreted Manure Nutrients

Table I.4.17 gives a comparison of the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients excreted by a 100 head dairy herd. The American Society of Agricultural and Biological Engineer Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005) was used to calculate excreted manure values. Table I.4.17 shows that, if carcass nutrients are combined with excreted nutrients, **between 0.55 and 0.65 percent of the nitrogen produced by dairy cattle originates with mortalities, depending on milk production**. Likewise, **between 0.93 and 1.2 percent of the phosphorus produced by dairy cattle comes from mortalities.** The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted by dairy cattle on a pound per head per day basis. These values are based on a mass balance of food intake, nutrients accumulating in the body, nutrients respired, and nutrients excreted. For mature dairy cattle nitrogen and phosphorus excretion values are calculated on the basis of milk production, with 0.90 lbs. TN and 0.15 lbs. TP excreted per head per day with 15,000 lbs. milk per year production, and 1.11 lbs. TN and 0.21 lbs. TP excreted per head per day with 37,500 lbs. milk per year production. Milk-fed calves excrete 0.17 lbs. TN $head^{-1}$ day^{-1}. Calves (average weight 330 lbs.) excrete 0.14 lbs. TN and 0.02 lbs. TP $head^{-1}$ day^{-1}. Heifers (average weight 970) excrete 0.26 lbs.TN and 0.04 lbs. TP $head^{-1}$ day^{-1}. Dry cows excrete 0.50 lbs. TN and 0.07 lbs. TP $head^{-1}$ day^{-1}.

Table I.4.17. Nutrients contained in mortalities produced by a 100-cow dairy herd versus mass of nutrients excreted by the same herd at two levels of milk production (ASABE, 2005).

	Total Nitrogen ($lbs.\ head^{-1}\ year^{-1}$)	**Total Phosphorus ($lbs.\ head^{-1}\ year^{-1}$)**
Contained in mortalities	2.5	0.74
Excreted by cattle with a rolling herd average milk production of 15,000 lbs. $head^{-1}$ $year^{-1}$	380	61
Excreted by cattle with a rolling herd average milk production of 37,500 lbs. $head^{-1}$ $year^{-1}$	450	79

4.5 Future Research Needs

4.5.a Types of Farms Not Covered in This Report

Farms for small ruminants (goats, sheep) and exotic cattle, camelids, and other ruminants were not included in this report. These are niche enterprises, present in small numbers, often unaffiliated with producer groups, and poorly captured in agricultural census data.

Mortalities produced by veal feeding units were not investigated for this report due to lack of regional data, widely varying management practices and slaughter weights, and perceived low contribution to the overall mass of mortality across the watershed. However, it is an opportunity for future study and consideration. Veal production can often be associated with regions of dairy production, as a value-added enterprise utilizing dairy bull calves. Renaud, et al. (2018) reported that veal calves in Canada experienced an overall mortality rate of 7%, with 42% of deaths occurring within the first 21 days of arrival into the veal feeding program. Mean finish time in the Renaud, el al. (2018) study was 148 days; therefore, one could estimate that half of veal mortalities are in a weight range of 100 to 200 pounds body weight. Actual slaughter weights appear to vary widely, but the recent report from USDA-AMS (https://www.ams.usda.gov/mnreports/lswveal.pdf, accessed November, 2020) indicates an average slaughter weight of 232 pounds for the week of November 14, 2020.

4.5.b Need For On-farm Data Collection

Although we are confident in the data produced in this report, the values were primarily produced through limited published data on mortalities and personal communication with top researchers in this area. Research should be undertaken to determine the actual mass of mortalities produced on farms under the cultural practices used in the watershed.

4.5.c Need For Data on Whole Carcass Nutrient Content

Very limited data exists for whole carcass composition of any type of cattle.

4.6 Assumed Values of Mortality Masses and Carcass Nutrients for Watershed

Without any further defining information, the values given in Table I.4.18 should be used for mass of mortalities and nutrients produced annually per head and AU of defining head. For cow-calf herds the defining head is a mother cow. For cattle on feed the defining head is steer or heifer capacity. For dairy cattle, defining head is mature dairy cattle (lactating and dry).

Table I.4.18. Assumed annual mass of mortalities and nutrients contained in mortalities produced by all types of cattle production systems.

	Annual Mortalities and Nutrients Produced per Head (lbs. year^{-1})			Annual Mortalities and Nutrients Produced per AU (lbs. year^{-1})		
	Mortalities	TN	TP	Mortalities	TN	TP
Cow-Calf	32	0.905	0.265	23	0.65	0.19
Cattle on Feed	18	0.52	0.15	16.5	0.47	0.14
Dairy	90	2.5	0.74	69	1.9	0.57

4.7 REFERENCES

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5. **Equidae**

5.1 Definitions

Colt: intact male equid, less than four years of age

Dam: female parent of an equid

Donkey: domesticated animal of the species, *Equus assinus*. Donkeys have 62 chromosomes. The name Donkey is Interchangeable with **Ass**, but Ass usually refers to wild animals. Feral Asses in the US are called by their Spanish name, **Burro.**

Equid: animal of the family *Equidae*

Filly: intact female equid, less than four years of age

Foal: equid less than six months of age

Gelding: castrated horse or pony of any age

Horse: domesticated animal of the species, *Equus caballus*, greater than 14.2 hands in height at the withers. Horses have 64 chromosomes.

Jack: male donkey or mule

Jenny or Jennet: female donkey or mule

John: gelded male mule

Mare: intact female horse or pony, four years or older

Mule: a hybrid from a donkey sire and a horse dam, possessing 63 chromosomes -- generally cannot produce offspring.

Pony: domesticated animal of the species, *Equus caballus*, less than 14.2 hands high at the withers. Like horses, ponies have 64 chromosomes.

Sire: male parent of an equid

Stallion: intact male horse or pony four years or older

Weaning: the gradual replacement of mother's milk by another type of feed.

5.2 Equids in the Watershed

Horses, donkeys, and mules, unlike other livestock in the US, are bred for use and not for consumption. Because they are bred for a wide variety of purposes (e.g. work, racing, show, pleasure), there is great diversity in size and breed (Figures I.5.1 through I.5.6). A survey of baseline equine health and management conducted in 2015 collected equine data regionally across the United States (USDA-NASS, 2016). Four of the six Chesapeake Bay states (Delaware, Maryland, New York, Pennsylvania) were

Figure I.5.1. A team of draft horses stand at rest as an NRCS employee discusses conservation plans with an Amish farmer (Bob Nichols, USDA Natural Resources Conservation Service).

Figure I.5.2. Endurance race at the 2010 World Equestrian Games (Amanda Gumbert).

Figure I.5.3. Thoroughbred filly (University of Kentucky Agricultural Communications).

Figure I.5.4. Ponies in their shaggy winter coats (Amanda Gumbert).

Figure I.5.5. A donkey jenny and her foal enjoying a Delaware pasture (Alice Welch, USDA Natural Resources Conservation Service).

Figure I.5.6. A mule team pulls a canal barge in Bucks County, PA (ScenicBucksCounty.com).

included in the Northeast region. The top three types of equine operations in this region were farm/ranch (36.5%), a residence with equids for personal use (32.5%), and boarding stables/training facilities (16.2%). The Northeast region also had the highest percentage of draft horses nationwide (15.2%). Based on trends found in the Northeast, a typical operation with equids in the Chesapeake Bay watershed is a small (5-9 animals) farm/ranch or personal/recreational use facility (Figure I.5.7).

Figure I.5.7. Waredaca horse pasture in Montgomery County, Maryland (Will Parsons, Chesapeake Bay Program).

Table I.5.1. lists equid populations for the six states containing the Chesapeake Bay Watershed. The numbers in Table I.5.1 are for whole states, not the portion of the state in the watershed. Equine populations are challenging to innumerate in the Chesapeake Bay watershed, and numbers reported are variable. For example, the 2017 Census of Agriculture (USDA-NASS, 2017) reported a horse population of 88,343 in Pennsylvania, while the American Horse Council reported a horse population of 223,628 that same year (Smarsh, 2018). The American Horse Council estimates New York's horse population at 154,000 (AHCF, 2018), but USDA estimates 68,599 (USDA-NASS, 2017). The discrepancy in horse population numbers is likely attributed to accounting methodology. The USDA Census of Agriculture accounts for only horses on properties with $1,000 or more in agricultural products sold in the census year and does not account for operations with less than five animals. The USDA estimate (USDA-NASS, 2017) also excludes mules and donkeys. Horse population estimates conducted by groups such as the American Horse Council and state-specific equine commodity organizations include hobby farms, rescues and sanctuaries, boarding/riding facilities, and equine assisted therapy facilities. The majority of equids in Maryland are kept at facilities for personal use or at boarding/riding/training facilities, followed by racing facilities (MHIB, 2010).

Table I.5.1. Horse and pony population in the states containing the Chesapeake Bay Watershed based on USDA (USDA-NASS, 2019) and industry sources (MHIB, 2010; Rephann, 2011; AHCF, 2018; Pennsylvania Horse Council, 2019; Delaware Horse Properties, 2019; Smarsh, 2018; West Virginia Horse Properties, 2019).

	USDA Estimate[1]	Industry Estimate
Delaware	4,178	11,000
Maryland	27,635	79,100
New York	68,599	154,000
Pennsylvania	88,343	223,628
Virginia	65,588	215,000
West Virginia	23,472	43,000
Total	**277,815**	**725,728**

[1]Excludes mules and donkeys.

Lawful equine mortality disposal practices in the Chesapeake Bay watershed include burial, composting, landfilling, incineration, and rendering. Virginia has established a hierarchy for disposal, with rendering being the preferred disposal method, followed by composting. Not all landfills accept animal mortalities, and there is limited accounting of numbers accepted (G. Flory, personal communication, January 11, 2019). Rendering options are limited when euthanasia drugs are utilized to terminate the animal. Further, a concern of equine mortality disposal is that of secondary toxicosis associated with euthanasia drug residues remaining in the carcass following burial or composting. Payne et al. (2015) found sodium pentobarbital residue present in compost material and soil samples under composting treatment bins 367 days after death at concentrations of 25.15 mg/kg and 0.2 mg/kg, respectively, suggesting residues leached from the bins. Custom cremation is available in at least four states in the watershed. Pet crematories in Maryland, Virginia, New York, and Pennsylvania offer individual and/or group cremation with the option for horse owners to retrieve the cremains.

5.3 Nutrients Contained in Equine Carcasses

5.3.a Animal Growth Patterns

Equids grow rapidly during the first year of life, with the most intense period of growth occurring during the first three months (Kavazis and Ott, 2003). Full body weight is reached around 36-48 months of age (Figure I.5.8). Foals are weaned generally between 6-9 months of age. Equids are considered to have reached full height by age 2; muscling and bone development increases until full physical maturity is reached between 5-6 years old.

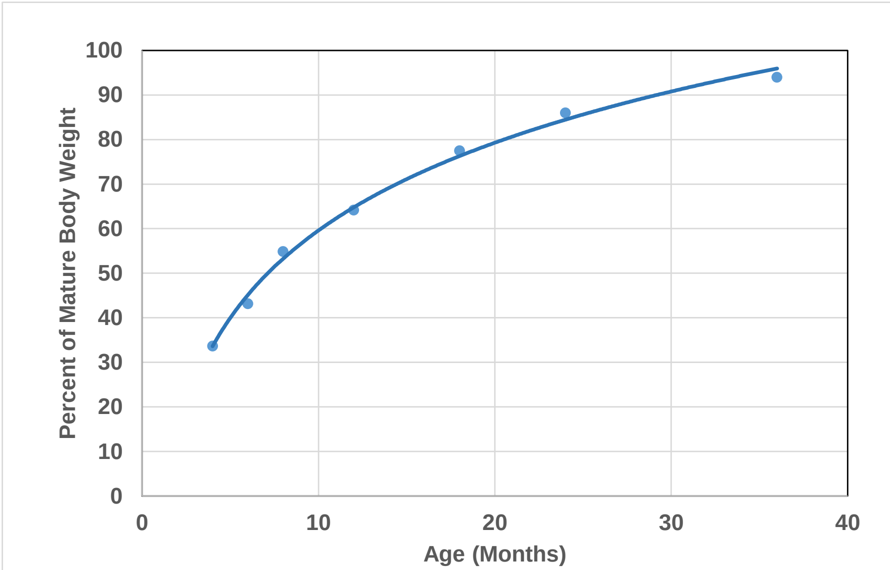

Figure I.5.8. Growth pattern of equids (NRC, 2007).

5.3.b Death Rate

The overall annual mortality rate of equids (including donkeys, mules, ponies, miniature horses, drafts, and full-size horses) in the United States is estimated at 1.4% (USDA-APHIS, 2017). The highest mortality rates occur in two seasons of life: 2.8% at less than six months of age, and 3.1% at 20+ years. Common causes of death for younger animals include injury, wounds, and trauma. Old age was the most common cause of death in animals greater than 20 years old. USDA-APHIS (2016) provided national and regional population distributions for equids (Table I.5.2). Within each population segment, the percentage of resident equids that died or were euthanized in the previous 12 months was estimated. Although regional differences occur in both population distributions and death rates, these differences were within the margin of error for the population sampled. The national average values for population distribution and death rate for population segments were used for all calculations in this report.

5.3.c Nutrient Composition

Data on whole carcass nutrient composition of equids is extremely limited, with most research studies focusing on body composition related to horse performance (Kearns et al., 2002). Lorenzo et al. (2013) reported the average body composition of the horse to be 69.6% muscle, 17.4% bone, and 10.4% fat (as a percentage of whole-body weight). Body fat appears to be the most variable tissue component, especially when comparing among breeds. A review of the literature by Kearns et al. (2002) reported a range in body fat of 5.1% for thoroughbreds (race breed) and up to 24.5% for Percherons (draft breed). Percent fat tends to increase with age (Lorenzo et al., 2014).

Grace et al. (1999) determined the phosphorus content of 5-month-old weaned foals to be 10.1 g/kg empty body weight, while Schryver et al. (1974) reported the P content to be 8 g/kg live full body weight of a young (24 months) horse. When converted to full body weight (assuming empty body weight equals 92% of full body weight (Schryver et al. 1974)), the phosphorus contents of foals and young horses were

Table I.5.2. Population distribution and death rates for equids (USDA-APHIS, 2016).

Age	Population Distribution (head per 100)	Annual Death Rate for Each Population Segment (%)	Number Dying Each Year in a Herd of 100 (head year^{-1})
0 to 30 days	1.4	2.8	0.039
30 days to 6 months	2.9	2.8	0.081
6 months to year	2.1	1.2	0.025
1 to 5 years	16.5	0.5	0.083
5 to 20 years	65.6	0.8	0.525
20 to 29	9.9	3.1	0.307
30 or older	1.5	3.1	0.047
Totals	**99.9**		**1.11**

1.1% and 0.8%, respectively. Cooper et al. (2001) reported P content of quarter horse rib bone to range from 13.1% in animals 1 to 20 years old to 20.6% in pregnant mares of unreported age, though these values reflect individual bone biopsy analysis and no data was available to convert to a whole animal carcass basis. The full body phosphorus content of mature horses was not available in the literature; therefore, calculations for mature horses was based on 0.8% of full live body weight.

The calculated masses of total nitrogen (TN) and total phosphorus (TP) expected for a young animal (0-6 months of age) and a mature animal (greater than 3 years) are shown in Table I.5.3. Values are reported on a pound per animal unit (AU) basis. One animal unit is equal to 1,000 pounds liveweight. Nitrogen content was calculated from protein content using the equation: *Total nitrogen = Total protein/6.25* (Benedict, 1987), utilizing protein percentage values reported by Lorenzo et al. (2014). Total nitrogen values are reported as the sum of muscle and bone protein, assuming muscle is 21.66% protein (Lorenzo et al., 2013) and bone is 30% protein on a mass basis. Fat content is not reflected in the nutrient calculations as it is assumed that fat contains no protein or mineral.

Table I.5.3. Mass of nutrients in equid bodies.

	Mass of Nutrient (lbs. AU^{-1})	
	TN	**TP**
Young animal (0 to 6 months old)	32	11
Mature animal (more than 36 months old)	32	8
Overall average	32	9.5

5.4 Estimated Annual Mass of Nutrients Contained in Mortalities from Equine Herds

What follows is a method to calculate the mass of mortalities produced by a population of equids and the nutrients contained in those mortalities. Population generally refers to equids living in a census designated entity such as a state or county. Death loss on individual farms is an episodic event. A farm may suffer no loss for many years, and suddenly be faced with the dilemma of disposing of a 2,000-pound draft horse.

The population distribution shown in Table I.5.2 is further expanded in Table I.5.4 to align with the growth pattern shown in Figure I.5.8. The assumption was made that each population segment could be broken down evenly. For instance, there are 2.9 animals in the 30 days to 6 months group in Table I.5.2. This was broken down into equal portions of 0.58 head for each month of age. The data from Figure I.5.8 was used to determine the weight of each animal in each population group, assuming a mature weight of 1,000 pounds (Table I.5.4). Total weight of animals in each population group was determined by multiplying number of animals in each group by the estimated weight of the individual animal. Summing group weights gives the weight of the entire population (or herd).

Table I.5.4. Expanded population distribution and weights of animals assuming 1,000-lb mature weight.

Age	Population Distribution (head)	Fraction of Mature Weight (From Figure I.5.8)	Weight of Animal (lbs.)	Weight in Each Population Group (lbs.)
0 to 1 month	1.4	0.300	300	420
1 to 4 months	1.75	0.350	350	613
4 to 5 months	0.58	0.370	370	214
5 to 6 months	0.58	0.426	426	247
6 to 8 months	0.7	0.495	495	346
8 months to year	1.4	0.596	596	835
1 year to 18 months	2.75	0.711	711	1,956
18 months to 2 years	2.75	0.807	807	2,218
2 to 4 years	5.5	0.908	908	4,993
4 to 5 years	5.5	1.000	1,000	5,500
5 to 20 years	65.6	1.000	1,000	65,600
20 to 29 years	9.9	1.000	1,000	9,900
30 and older	1.5	1.000	1,000	1,500
Total Animals	**99.91**	**Total Weight of Herd (lbs.)**		**94,342**

Likewise, the number of animals expected to die during the course of a year in each of the expanded population distribution groups is determined by multiplying the population of the group by the death rate for the group (Table I.5.5). Weight of mortalities in each group is the number expected to die multiplied by weight of individual animals. Summing the weight of mortalities of each group gives the annual weight of mortalities produced by the entire herd (Table I.5.5). Dividing the weight of mortalities produced by the herd by the number of animals in the herd gives the weight of mortalities per head. Dividing the weight of mortalities produced by the herd by the total liveweight of the herd (Table I.5.4) gives annual weight of mortalities per pound of liveweight. Multiplying annual weight of mortalities per pound of liveweight times 1,000 gives annual weight of mortalities per herd weight in units of AU.

Table I.5.5. Weight of mortalities and nutrients contained in mortalities for a population of equids with a mature weight of 1,000 pounds.

Age	Number Dying in Each Group per Year (head yr^{-1})	Weight of Animal (lbs.)	Weight of Mortalities in Each Group (lbs. yr^{-1})	Weight Fraction of Nutrients (lb. nutrient per lb. carcass)		Nutrients contained in mortalities (lbs. yr^{-1})	
				TN	TP	TN	TP
0 to 1 month	0.039	300	11.8	0.032	0.0110	0.38	0.129
1 to 4 months	0.049	350	17.2	0.032	0.0110	0.55	0.189
4 to 5 months	0.016	370	6.0	0.032	0.0110	0.19	0.066
5 to 6 months	0.016	426	6.9	0.032	0.0110	0.22	0.076
6 to 8 months	0.008	495	4.2	0.032	0.0109	0.13	0.045
8 months to year	0.017	596	10.0	0.032	0.0106	0.32	0.106
1 year to 18 months	0.014	711	9.8	0.032	0.0101	0.31	0.099
18 months to 2 years	0.014	807	11.1	0.032	0.0089	0.35	0.099
2 to 4 years	0.028	908	25.0	0.032	0.0086	0.80	0.215
4 to 5 years	0.028	1,000	27.5	0.032	0.0080	0.88	0.220
5 to 20 years	0.525	1,000	524.8	0.032	0.0080	16.79	4.198
20 to 29 years	0.307	1,000	306.9	0.032	0.0080	9.82	2.455
30 and older	0.047	1,000	46.5	0.032	0.0800	1.49	3.720
Totals for the Entire Herd			**1,007.5**			**32.24**	**11.62**
Weight of Mortalities per Head (lbs. yr^{-1})			**10.1**	**Weight per Head (lbs. yr^{-1})**		**0.32**	**0.12**
Weight of Mortalities per Herd Weight (lbs. AU^{-1} yr^{-1})			**10.7**	**Weight per Herd Weight (lbs. AU^{-1} yr^{-1})**		**0.34**	**0.12**

The literature (Grace et al., 1999; Schryver et al, 1974) shows that nutrient concentration per pound of carcass weight is not constant throughout the life of a horse. The mass fraction of phosphorus drops from 0.011 pounds TP per pound of carcass for young animals to 0.008 pounds TP per pound of carcass for horses five years and older (Table I.5.5). Multiplying the weight fraction of nutrients per carcass by weight of mortalities in each population group gives the annual weight of nutrients contained in mortalities produced by each group. Summing the weight of nutrients in mortalities for each group gives the weight of nutrients produced by the herd. Dividing the annual weight of nutrients produced by the herd by number of animals in the herd gives the annual weight of nutrients produced per head. Dividing the annual weight of nutrients produced by the herd by herd weight (Table I.5.4), and multiplying by 1,000 gives annual weight of nutrients per herd weight in units of AU.

The mass of mortalities per AU is constant at 10.7 pounds per year. The mass of nutrients contained in carcasses is also constant at 0.34 pounds TN and 0.12 pounds TP per AU per year. To find the values for different breeds of equids, one must go through the process outlined above using the mature weight for each breed. Weights of mortalities and nutrients contained in carcasses produced per head per year are given for several breeds of horses and donkeys in Table I.5.6. Mature weight of mules can be estimated by averaging the weight of the parents. Draft mules usually have a mammoth jack as a sire and a draft horse as a dam. Saddle mules are usually a cross between a mammoth jack and a saddle horse mare.

Table I.5.6. Annual weight of mortalities and nutrients contained in mortalities per head for several breeds of horses and donkeys (NRC, 2007; NMDA, 2020; OSU-ANSI, 2020)

Breed	Breed Type	Mature Weight (lbs)	Weight of Mortalities per Head (lbs yr^{-1})	Weight of Nutrient per Head (lbs. yr^{-1})	
				TN	TP
Belgian	Draft	1,899	19.2	0.61	0.22
Hanoverian	Warm blood	1,276	12.9	0.41	0.15
Thoroughbred	Race	1,276	12.9	0.41	0.15
Standardbred	Race	1,100	11.1	0.35	0.13
Quarter Horse	Light	1,221	12.3	0.39	0.14
Arabian	Light	1,001	10.1	0.32	0.12
Morgan	Light	999	10.1	0.32	0.12
Pony	Pony	429	4.3	0.14	0.050
Miniature	Donkey	275	2.8	0.089	0.032
Standard	Donkey	500	5.0	0.16	0.058
Mammoth	Donkey	950	9.6	0.31	0.11
Average of All Equids		**983**	**9.9**	**0.32**	**0.11**
Average of Horses		**1,150**	**11.6**	**0.37**	**0.13**

5.5 Comparison of Equid Mortality Nutrients to Excreted Manure Nutrients

Comparison of nutrients contained in mortalities to nutrient excreted by equids is a true "apples to apples" comparison. The nutrients contained in mortalities calculated by the method outlined in this report are nutrients contained in the animal's body exactly at the time of death - before losses from decay, storage, and disposal method diminish their weight. Excreted manure nutrients are nutrients leaving the animal - before weathering, ammonia volatilization, and a multitude of other factors diminishes their weight on the pasture. Estimates using formulas for excreted nutrients, which are based on nutrient intake, are highly dependent on assumptions of diet and cultural practices, and should be thought of as rough averages with a high degree of variability - just as this report has highlighted the variability of estimating the mass of mortality nutrients.

Table I.5.7 compares the mass of nutrients contained in mortalities based on the methods used in this report to the mass of nutrients excreted by the same 100-head herd with a mature weight of 1,000 pounds. The *USDA-NRCS Waste Management Field Handbook* (USDA-NRCS, 2008), which in turn is based on the American Society of Agricultural and Biological Engineer Standard 384.2 *Manure Production and Characteristics* (ASABE, 2005), was used to calculate excreted manure values. The ASABE standard (ASABE, 2005) estimates the mass of total nitrogen and phosphorus excreted by horses per day. These values are based on a mass balance of food intake, nutrients accumulating in the body, nutrients respired, and nutrients excreted. NRCS (2008) further divides excreted values based on the activity level of horses. Sedentary horses, horses that are not receiving any imposed exercise, are expected to excrete 0.18 pounds of TN and 0.026 pounds of TP per AU per day. Exercised horses excrete 0.31 pounds of TN and 0.066 pounds of TP per AU per day. Table I.5.7 shows that, if carcass nutrients are combined with excreted nutrients, **approximately 0.52% of the nitrogen and 1.3% of the phosphorus produced by stables housing sedentary horses originate from mortalities**. Likewise, **0.30% of the nitrogen and 0.51% of the phosphorus from training stables and working horse farms originate from mortalities.**

Table I.5.7. Nutrients contained in mortalities produced by a 100-head herd of equids with 1,000 pounds mature weight versus the mass of nutrients excreted by the same herd at two levels of activity (ASABE, 2005; NRCS, 2008).

	Total Nitrogen (lbs. $head^{-1}$ $year^{-1}$)	Total Phosphorus (lbs. $head^{-1}$ $year^{-1}$)
Contained in Mortalities	32	12
Excreted by Sedentary Equids	6,198	895
Excreted by Exercised Equids	10,675	2,273

5.6 Future Research Needs

Future work should include development of practical and specific guidance for end-of-life decision-making and disposal options for equid owners in the Chesapeake Bay watershed. Nationwide, only 59.8% of equid operations have an end-of-life plan, with equine boarding or stabling operations having a higher percentage of plans in place as compared to farms/ranches/residences with personal use equids (USDA, 2016).

5.7 Assumed Values of Mortality Masses and Carcass Nutrients for Watershed

Without any further defining information, the values given in Table I.5.8 should be used for mass of mortalities and nutrients contained in mortalities produced annually per head and per AU. The values given in Table I.5.8 are for an average horse weighing 1,150 pounds at maturity - assuming in most jurisdictions the population of horses greatly outnumbers the population of donkeys and mules. If the composition of an equid population is known - for instance, the population contains 50% quarter horses, 40% thoroughbreds, 8% draft horses and 2% standard donkeys - the average for the entire population can be estimated using the breed values of Table I.5.6 proportionally (i.e., 0.5 X 0.39 + 0.4 X 0.41 + 0.08 X 0.61 + 0.02 X 0.16 = 0.41 pounds TN per head per year.)

Table I.5.8. Assumed annual mass of mortalities and nutrients contained in mortalities produced by equids.

Annual Mortalities and Nutrients Produced per Head (pounds $year^{-1}$)			Annual Mortalities and Nutrients Produced per AU (pounds $year^{-1}$)		
Mortalities	**TN**	**TP**	**Mortalities**	**TN**	**TP**
11.6	0.37	0.13	10.7	0.34	0.12

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Part II

Disposal Methods

1. Introduction

1.1 Concept of Nutrient Movement from Disposal Methods

Routine Mortality Disposal is a best management practice for livestock operations. Within that practice there are several methods of mortality disposal. This expert panel investigated five methods of livestock and poultry mortality disposal: burial, composting, incineration, landfilling, and rendering. Some mortality disposal methods can be viewed as a treatment process, as stated in Hamilton et al. (2016); those treatment processes do not remove nutrients from the waste stream. Disposal methods change the form of nutrients (such as protein nitrogen to ammonia nitrogen), and transfer nutrients from animal carcasses to various environmental media such as air, water, and soil. Figure II.1.1 illustrates the concept of nutrient transfer during those routine mortality disposal methods.

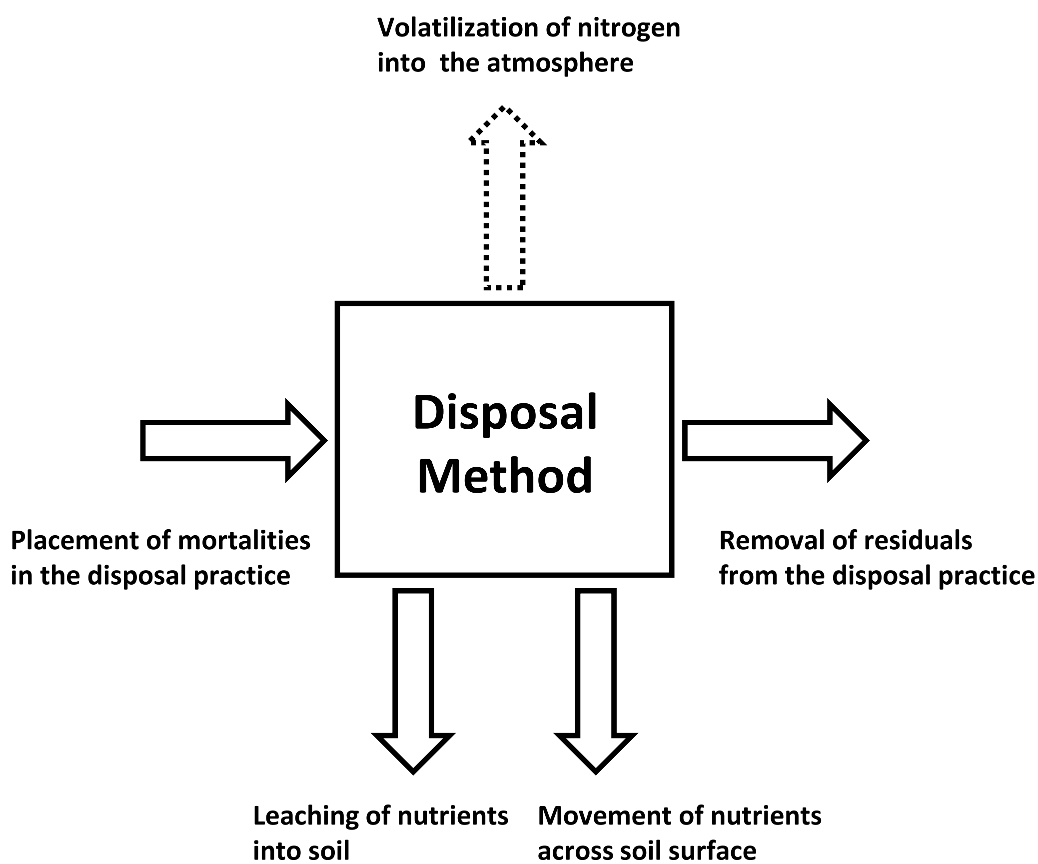

Figure II.1.1. Transfer of nutrients by a disposal method to various environmental media.

For the purposes of this report, the expert panel simplified the transfer scheme of Figure II.1.1 to only consider those pathways that are either inputs to the Chesapeake Bay Model or measurable during verification of a disposal method. Figure II.1.2 illustrates this simplified scheme. The arrows shown in Figure II.1.2 indicate movement of nutrients into environmental media and removal from the practice as useful end products. As you will see in the following chapters, diagrams drawn for each practice will not be identical. Some practices will have some arrows missing. For instance, it is not expected that residuals will be removed from a burial site; therefore, the arrow for removal of residuals will be missing from the burial process diagram. Likewise, thermochemical processes (incineration) take place within a watertight vessel; therefore, movement from the method does not occur except by reuse of end product and atmospheric emission -- although transfer to water resources may occur through improper disposal of ash or char.

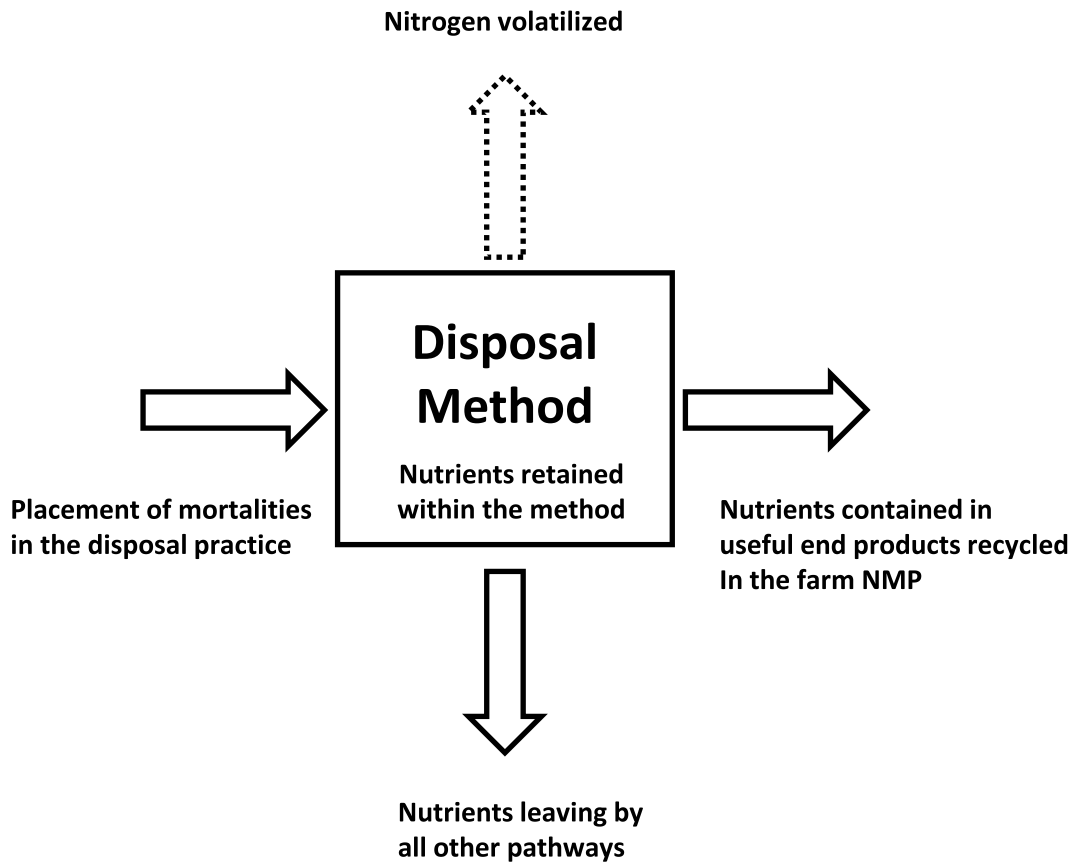

Figure II.1.2. Potential movement of nutrients during implementation of a disposal method.

Also, similar to Hamilton et al. (2016), the Expert Panel chose the concept of nutrient transfer efficiency to express the mass of nutrients leaving by various routes:

$$\text{Mass Transfer Efficiency} = \frac{(\text{Mass of Nutrients Indicated by Arrow Leaving the Method})}{(\text{Mass of Nutrients Entering the Method})}$$

With disposal methods, mass transfer efficiency is expressed as the percentage of nutrients leaving by a particular pathway. For example, for mass of total nitrogen (TN) emitted to the atmosphere:

$$\text{Percent TN Volatilized} = \frac{(\text{Mass of Nitrogen Leaving the Method via Volatilization})}{(\text{Mass of Nitrogen Contained in a Carcass Placed in the Method })} \text{ X } 100$$

1.2 Potential Movement of Nutrients within Methods

Estimated movement of carcass nutrients for each of the disposal methods will be discussed in the following chapters. Table II.1.1 lists the fallback (that is, estimates for a standard method without knowing all of the production and environmental factors pertaining to the method) percentages of nutrients exiting the method as shown in Figure II.1.2 for all of the disposal methods examined by this expert panel.

1.2.a. Nutrients Recycled in a Nutrient Management Plan (NMP)

As shown in Table II.1.1. only composting and incineration provide end-products that can be used on-farm and recycled in a nutrient management plan. Rendering produces a useful product (feed meal) but nutrients are not used on the farm in a land application system. Feed meal nutrients “disappear” from the Chesapeake Bay Model when carcasses are taken to a rendering plant, and could reappear as manure nutrients if the meal is fed within the watershed. Nutrients are retained within burial pits and landfills, and therefore, are not useful in any way to the producer.

1.2.b. Atmospheric Emissions

Both composting and incineration emit nitrogen to the atmosphere. Type of nitrogen emitted is discussed in the individual method chapters. Composting emits more nitrogen with more frequent turning or aggressive aeration of piles. Nitrogen from incineration will shift from emitted to useful end product with lowering incineration temperature. Minute amounts of nitrogen may be emitted from burial pits and landfills and is related to quality of cover. The rendering process may emit some nitrogen, but these emissions are covered by industrial air permits and, therefore, are not counted as agricultural emissions in the Chesapeake Bay Model. Farm incinerators generally do not have air control permits. Atmospheric emissions may occur from all methods if the carcasses are not refrigerated or disposed of quickly after death.

Table II.1.1. Potential movement of nutrients during implementation of a disposal method, fallback values.

	Mass Percentage of Carcass Nutrients Exiting the Method (%)				
	Nutrients recycled with end products in the farm nutrient management plan		Nutrients emitted to the atmosphere	Nutrients leaving the method by all other pathways	
Disposal Method	**TN**	**TP**	**TN**	**TN**	**TP**
Burial	0	0	0	15	5
Composting	80	100	10	10	0
Incineration	25	100	75	0	0
Landfilling	0	0	0	0	0
Rendering	0	0	0	0	0

1.2.c. All Other Pathways of Nutrient Movement

Some nutrients are leached from burial pits, but there is limited data presented in the literature. Little nutrients leave burial by overland flow due to proper placement and isolation of the pit. Some leaching and runoff of nutrients may occur with composting, but may be minimized by correct pile construction, placement of compost piles on constructed pads, and placement under roof. Nutrients do not leave incinerators except as volatilized nitrogen and useful end product; however, nutrient leaching and runoff may occur if the ash produced during incineration is not stored or handled properly. Leaching of nutrients from landfills is prevented by design, and point source discharge of nutrients from rendering plants is controlled through NPDES permits.

1.3 Other Considerations with Disposal Methods

The panel did not attempt to judge the superiority of one method over the others. In fact, movement of nutrients may not be the primary criteria by which disposal methods are judged. Biosecurity and removal of nuisance conditions from mortality disposal have the greatest value to society. Individual farmers are likely to place greatest emphasis on biosecurity, ease of operation, ability to use end products on-farm, and the existence of outside networks aiding in operation of a method. Each method has benefits and drawbacks that increase or decrease its likelihood of adoption.

1.3.a. Burial

A properly constructed burial pit is ideal for out of sight, out of mind management. Biosecurity and nuisance control are very high if carcasses are buried quickly. The major drawback to this method is land used for burial pits is tied up indefinitely. Recovery of materials from a burial pit is not recommended due to biosecurity concerns. Also, many farms may not have land suitable for burial. Equipment required for burial of large animals may also deter many from using this method. Poorly constructed burial pits can be a major environmental hazard, resulting in groundwater pollution in sandy soils with high water tables or areas underlain by karst geology.

1.3.b. Composting

Composting has the highest potential for on-farm recycling of nutrients of all the methods the expert panel examined. Creating high quality compost with adequate pathogen reduction requires a high level of knowledge, skill and labor commitment on the part of the farmer, however. Land requirement is lower than burial in that the same area may be used to compost many carcasses. Cost of equipment and/or buildings required to properly compost may be high for some farmers. The biosecurity cost of improper composting cannot be understated. Pathogens may be spread by scavengers or by land application of poorly composted material.

1.3.c. Incineration

Recycling of nutrients is also possible through incineration of carcasses. Of the methods this expert panel examined, incineration has the highest potential for control of pathogens when done properly. A fairly high level of skill is needed to properly incinerate carcasses. Poorly ashed carcasses can be a source of pathogens. The greatest drawback for incineration is the equipment needed to incinerate large carcasses. Atmospheric emission of particulates and volatile organic compounds may be a concern if a properly sized afterburner is not used with incineration. Also, a considerable amount of fossil fuel must be used to properly incinerate mortalities, resulting in release of greenhouse gases.

1.3.d. Rendering and Landfilling

Rendering and landfilling appear to be the ideal solution for livestock and poultry farmers: someone comes to the farm, takes the mortalities, and troubles disappear. The greatest drawbacks to landfilling are finding a landfill willing to take carcasses, a trucker willing to haul mortalities to the landfill, and the costs associated with these activities. To make rendering a viable disposal option a strong network for carcass collection and a sufficient number of rendering plants willing and able to receive farm mortalities is an absolute requirement. The greatest environmental and biosecurity hazards associated with landfilling and rendering are the storage, timely collection, and transportation of carcasses. These methods, particularly for smaller carcasses, are greatly improved if refrigerated storage containers are deployed on-farm.

2. Burial

2.1 Definitions

Burial in the context of normal livestock mortality is defined as the act of placing a dead animal below the ground surface for disposal. Burial involves excavation of a pit or hole, depositing the animal in the pit, and capping or covering the animal with material from excavation. The excavated pit may be constructed using more than one method dependent on the equipment and manpower available. Excavation may be in the form of a vertical hole, a trench or a pit. Excavation may vary in depth, and pits are generally unlined. After burial, the animal carcass will undergo decomposition. Decomposition rate will vary based on burial depth, soil texture, temperature, moisture and drainage conditions. As the carcass breaks down components of the animal will migrate into the surrounding soil. Some substances will be lost to air and water, some will be transformed, and some will become immobile. There is the possibility of some contamination of soil, groundwater and surface water within 1 – 2 m of the pit (Freeman et. al, 2003).

2.2 Movement of Nutrients

Figure II.2.1 is a schematic of the movement of nutrients based on the definition of burial. The greatest transfer of nutrients into the environment during burial is through leaching of nitrogen into the soil - although some volatilization of nitrogen occurs and there is the possibility of surface water contamination close to the pit. Much of the nutrients contained in carcasses remain interred in the pit with the decomposing carcass. Since the intention of burial is for the remains to never be removed from the pit, no nutrients exit with byproducts to be recycled in an NMP. Estimated losses to the environment are given in Table II.2.1.

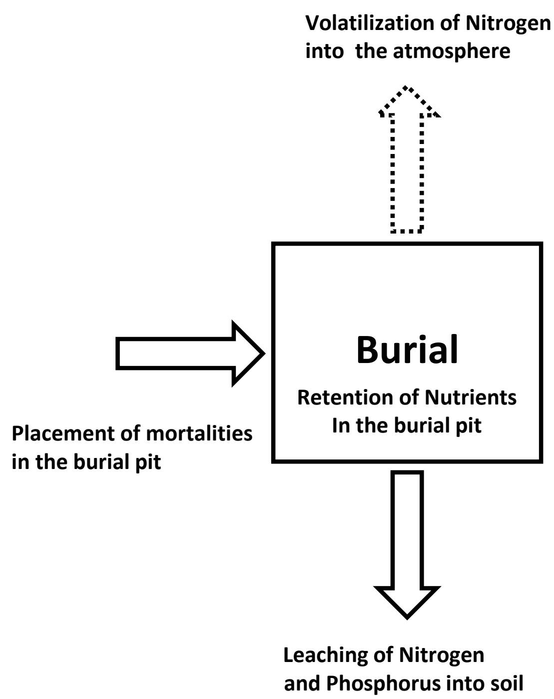

Figure II.2.1. Movement of nutrients using burial.

Table II.2.1. Estimated percentage of mortality nutrients transformed to useful end products and transferred to surrounding environment using the burial method of mortality disposal, assuming burial is conducted according to the Pennsylvania Domestic Animal Law (Williams, 2015).

	TN	TP
Mortality nutrients recycled with end products in the farm nutrient management plan (% of nutrients entering)	0	0
Mortality nutrients emitted to the atmosphere (% of nutrients entering)	0	0
Mortality nutrients leaving the method by all other pathways (% of nutrients entering)	15	5

2.3 Description of the Burial Method

Construction of the pit should comply with state and local regulations. A site should be selected where there are desirable soils, free of rocks and tree roots, as close to animal(s) as possible, but away from sensitive areas and concentrated surface water runoff. Use of the site will be limited for any purposes that will disturb the burial pit for some time. The bottom of the pit should be a minimum of 2 ft. above seasonal high water table, rock or highly permeable soils.

Other specifications for utilizing the burial method include the following:

- Excavate a hole or pit above ground water, deep enough to place animal and cover with a minimum of 2 feet of cap material.
- If desired, a layer of dry carbon material such as sawdust can be added to the bottom of the pit to retain leachate.
- Consolidate or pack the excavated material over the animal and mound the cap to shed runoff around the burial site and reduce infiltration Cap material should have lower permeability to protect the burial from infiltration of rainfall.

2.4 How Burial is Used with Different Animal Types

For small animals, more than one animal may be placed in the same excavation. Typically, with routine mortality, carcasses are be layered in daily until the excavation is at capacity. Smaller animals will have a smaller “footprint” and require less area for burial. Historically in the Delmarva area burial pits for poultry were constructed of a pit with a metal cover or lid for access. Loading rates were approximately 15 – 25 kg of dead birds per pit. Because of the high water-table, many of these pits were constructed into the water table (Ritter and Chirnside, 1995).

Larger animals are generally buried individually. Large animal carcass placement can be limited by the equipment and manpower available. Moving large carcasses can be awkward at least and difficult at worst. Ideally, producers need a tractor that can lift the carcass, a person to operate the tractor, and a person to assist with placement of the carcass.

2.5 Estimated Nutrient Mass (N and P) Lost along Pathways

Generally, the nutrient content of the animal (aside from that which may leach) remains buried, but may change form dependent on exposure to water or air. Research on burial has focused on leaching and groundwater as the pathway for nutrient movement. The research found as a result of this project focused on the nutrient content of the leachate as opposed to the carcass itself.

2.5.a Leaching

Ritter and Chirnside (1995) found that ammonia contamination was the greatest concern around poultry disposal pits, and measured ammonia concentrations greater than the EPA drinking water standard of 10 mg L^{-1} for nitrate in groundwater around half of the pits they evaluated. Although there is no standard for ammonia, ammonia at any concentration is not desirable in groundwater or drinking water. Pratt and Fonstad (2009) tested leachate from burial of three species (bovine, swine, poultry). Livestock mortality leachate on average contained concentrations of 12,600 mg L^{-1} NH_4-N, 1,500 mg L^{-1} total phosphorus, and 2,300 mg L^{-1} potassium. One pit for each species was assessed for leachate chemistry. For the first two months after burial, livestock leachate ammonium concentrations for each species were at their lowest at approximately 5,000 mg L^{-1}. The concentrations tended to increase between 4 and 9 months. At two years, bovine ammonium concentration was at 19,200 mg L^{-1}, swine ammonium concentration was 16,300 mg L^{-1}, and poultry was 10,100 mg L^{-1}. Phosphorus concentrations ranged from 1,200 mg L^{-1} (bovine) to 1,800 mg L^{-1} (poultry). Phosphorus concentrations fluctuated in the first 5 months and then levelled after 5 months. Potassium concentrations also did not fluctuate much during the two-year period.

Table II.2.2 Average mortality leachate concentrations per species over 25 months (Pratt and Fonstad, 2009).

	Poultry	Swine	Bovine	Average
Mass of Carcasses in Pit (kg)	1,300	5,900	3,920	1,300
Leachate pH	6.5	6.7	6.9	6.7
Analyte Concentration (mg L^{-1})				
Biocarbonate	39,133	48,467	50,733	46,100
Chloride	2,570	2,380	2,813	2,600
Total Alkalininity	22,500	39,700	41,600	34,600
NH_3-N	10,400	13,300	14,100	12,600
NO_3+NO_2-N	2.3	3.1	3.8	3.1
Inorganic Carbon	7,697	9,533	9,947	9,100
Organic carbon	79,000	65,000	68,000	71,000
Aluminum	0.50	0.50	0.50	0.50
Calcium	81	48	36	60
Copper	0.90	1.70	0.60	1.10
Iron	18	19	18	20
Magnesium	79	17	18	40
Manganese	0.50	0.10	0.10	0.20
Phosphorus	1,927	1,513	1,150	1,500
Potassium	2,400	2,400	2,000	2,300
Silicon, soluble	20	24	26	20
Sodium	1,600	1,700	2,000	1,800
Sulfate	3,970	3,900	2,900	3,600
Sulfur	1,300	1,297	963	1,200
Zinc	2.20	1.80	1.70	1.90

Pratt and Fonstad (2018) noted that livestock mortality leachate had ammonium concentrations 2 to 4 times higher than hog manure, and had much higher concentrations of phosphorus and potassium as compared to manure storages, lagoons, and landfills, with the highest concentrations exceeding drinking water standards by over 400 times. Alkalinity in livestock mortality leachate is 60 times higher than drinking water standards and exceeds the concentrations in hog manure and landfill leachate by 20,000 mg L^{-1}. Many other constituents found in livestock mortality leachate also greatly exceed the concentrations found in manure storages and landfills including sodium, sulfate, phosphorus, potassium, and chloride.

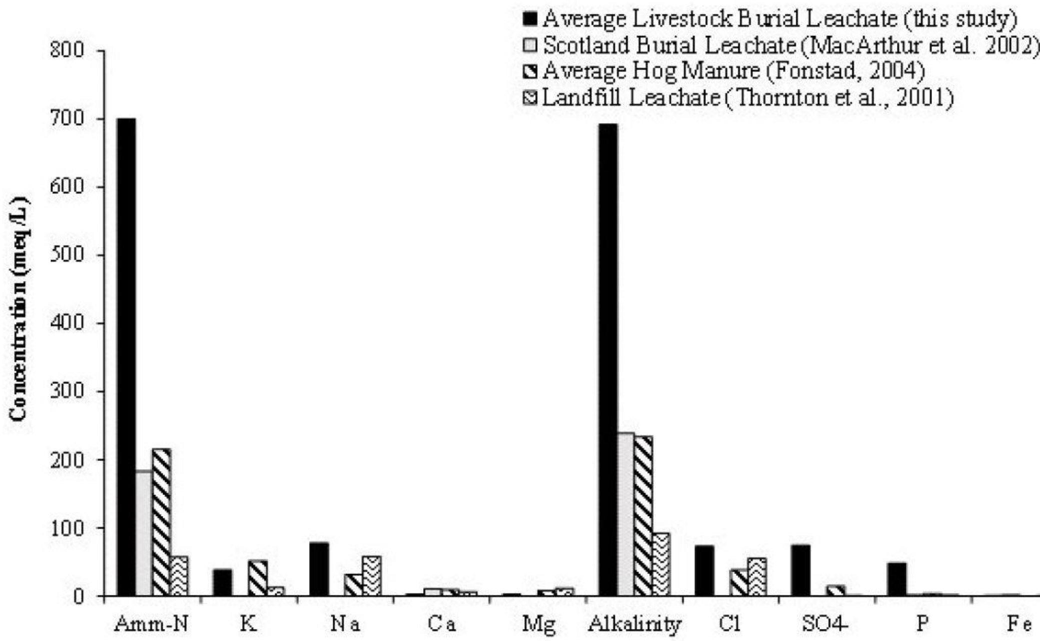

Figure II.2.2. Leachate from livestock burial pits to landfill leachate and swine lagoon effluent (Figure 3 in Pratt and Fonstad, 2018).

Yuan et al. (2013) reported much lower total phosphorus concentrations in burial pit leachate than Pratt and Fonstad (2009). Yuan reported estimated total mass of contaminants with mean concentration 4.1 g Kg^{-1} TKN and 3.71 g Kg^{-1} TP. Carcasses in the Yuan et al. (2013) study were surrounded by soil, mimicking actual on-farm conditions, unlike the Pratt and Fonstad (2009) study in which whole-carcass leachate was collected without soil interaction. Soil adsorption likely resulted in lower phosphorus concentrations in the Yuan et al. (2013) study and provides further justification for proper soil contact with animal carcasses upon burial.

Munro (2001) provided an estimate of leachate release per animal. Munro estimated that 50% of the total available fluid volume would "leak out" in the first week following death and the remainder would drain in the next two months (Table II.2.3). Assuming the majority of leachate will be released in the first two months after burial, and using the leachate volume from Munro (2001) and the concentrations found by Pratt and Fonstad (2009), an estimate of the quantity of nutrient per animal can be developed. The mass of nutrients leaching from a burial pit two months postmortem is given in Table II.2.4.

Table II.2.3. Estimated volume of leachate produced from burial pits in the first two months after Burial (Munro, 2001)

Species	Weight	1 week postmortem (L)	2 months postmortem (L)
Cattle - Adult	500-600 Kg	80	160
Cattle - Calf		10	20
Pig - Adult	170 Kg	6	12
Pig – Grower/Finisher	80 Kg	3	6
Pig - Piglet	12 Kg	0.4	0.8

Table II.2.4. Calculated weight of nutrients per animal leaving a burial pit as leachate two months postmortem based on the data of Pratt and Fonstad (2009) and Munro (2001).

Species – Life Stage	Weight of Animal (lbs.)	NH_3-N (lbs.)	TP (lbs.)
Cattle - Adult	1100-1300	4.97	0.41
Cattle - Calf		0.62	0.05
Pig - Adult	375	0.35	0.04
Pig - Grower/Finisher	176	0.18	0.02
Pig - Piglets	26	0.02	0.003

2.5.b Runoff

When the burial is properly constructed and surface water is diverted, surface water nutrient loss should be negligible.

2.5.c Nitrogen Volatilization

Gaseous products are generated in decomposing carcasses. Munro (2001) estimated that gas produced would be 10% N_2, 35% CH_4, and 45% CO_2. The majority of the gas is given off immediately after deposition when the stomach contents decompose. If properly constructed with a 2 ft minimum cap, loss to the atmosphere is minimized.

2.6 Other Important Considerations with Burial

2.6.a Short term effects

Burial should be performed as quickly as possible to prevent contact with other animals to minimize biosecurity issues. The carcass will start to decompose and bloat, making movement of the carcass more difficult. After placement in the burial pit the carcass should be lanced to allow for the release of gas. If the animal bloats, the excavation will have to be larger to accommodate the bloated carcass. State-specific rules and regulations generally state that burial should occur in the first 48 hours after death. Odor and risk of surface runoff of carcass leachate during rainfall events will increase with time. As a process, burial can be performed quickly if equipment and manpower are available. Once burial is performed properly it requires no other time from the producer. Odor dissipates quickly once the carcass is covered.

2.6.b Long term effects

Decomposition in burial is a long-term process that is site dependent and varies in length of time. The burial site is not available for use for any purposes that disturb the site. Burial can prevent other uses of the site for years. The remaining nutrients from the carcass will create a hotspot at the burial location. Yuan et al. (2013) reported substantial leachate production after 370 days (approximately 12 months) of decomposition, with the majority of leachate produced between 370 and 540 days.

2.6.c Equipment Availability

If hand tools are used, excavation will be limited to the extent possible. Where tractors or powered equipment are used, augers or backhoes can dig deeper and move more material faster with less human effort. Tractors make movement of the carcasses easier. A loader or bucket can be used to carry carcasses to the burial location. Large animals can be lifted and placed into the excavation. If the equipment is not large enough to lift the carcass, the carcass can be drug and pulled into place.

2.6.d Pharmaceuticals Used in Euthanasia

There is concern about the persistence of Phenobarbital or other drugs in euthanasia of animals. The concern is tied to drugs showing up in other products and places as a result of the disposal method. Because of this concern other methods of disposal such as rendering may not be available to producers or landowners when an animal is euthanized in this manner. Burial may be their only option of disposal.

2.6.e Biosecurity

If the carcass is not buried deep enough or covered sufficiently, scavengers will dig down to a carcass, unearthing it and allowing other vectors to feed off the remains. This poses a biosecurity as well as an odor issue. Odor will draw vectors to the carcass increasing the biosecurity hazard. Burial is preferable as a method to many producers because the mortality remains on site, which prevents transfer of disease between facilities.

2.6.f Closure

If the area of burial must be reclaimed, any remains should be excavated and disposed of properly in another location. The abandoned pit should be pumped out and filled to minimize impact on ground water (Ritter et al., 1995).

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3. Composting

3.1 Definitions

Composting: an aerobic biological process able to stabilize organic material including animal tissue. For proper composting to occur, dry carbon-rich material must be added to mortalities to control moisture released from the carcasses and supply a carbon source for the microbes. Composting of mortalities consists of two phases: active composting (110°F-160°F), and curing (ambient to 110°F). Additional water is generally not needed during the active phase of composting due to the high moisture content of carcasses.

Static Piles and Windrows: Sometimes called **Passive Piles**, static piles consist of mortalities placed on a bed of carbon-rich material and covered with additional carbon-rich material. Windrows are elongated piles (Figure II.3.1). Heat generated during the composting process rises and draws air into the pile. Piles are turned infrequently, if at all.

Turned Windrow Composter: Rows of mortalities are placed on a bed of carbon-rich material and covered with the same material. Aeration is through turning (Figure II.3.2). Turning is based on time and temperature, with the first turning coming after carcasses have disintegrated.

Static Aerated Windrow Composter: Similar to the passive windrow with the exception that oxygen is added through forced aeration (Figure II.3.3). Aeration may be either positive (blowing air into the windrow) or negative (removing air from the windrow). Negative pressure aeration requires biofiltration to remove odors.

Bin System: A passive composting system housed in a bin usually constructed of treated lumber atop a concrete slab. Most bin composters are constructed with a roof covering the bins. A common configuration is the "three bin system" (Figure II.3.4). The system is sized so that initial breakdown of the carcass takes place in one bin, the compost is mixed and aerated by moving the material to a second bin, and the compost is moved to a third bin after a second cooling. Curing usually takes place in a passive windrow or larger fourth bin. Bin systems are generally loaded by layering carcasses between carbon-rich material.

Tunnel Composter: A version of the bin system in which the bins are elongated to form long piles supported by concrete or treated lumber walls (Figure II.3.5). Aeration may be accomplished by augers,

Figure II.3.1. Static piles placed inside a poultry building (Mark Hutchinson).

Figure II.3.2. Turned windrow mortality composter (Mark Hutchinson).

Figure II.3.3. Negatively aerated compost pile with biofiltration (Washington State University).

Figure II.3.4. "Three Bin" mortality composter (Langston University).

Figure II.3.5. Tunnel composter treating broiler mortalities on the eastern shore of Maryland (Amanda Gumbert)

Figure II.3.6. Ecodrum™ rotating drum mortality composter (Mark Hutchinson).

turning, or forced aeration systems, but generally material is mixed and aerated by moving from one tunnel to another.

Rotating Drum Composter: A type of **In-Vessel Composter** in which mortalities and carbon-rich materials are loaded at one end of the tilted, rotating drum (Figure II.3.6). Aeration is accomplished by turning the bin several times a day. Material flows by gravity, sometimes with the aid of paddles. Given the cost of the system, rotating drums are primarily used for active composting. Curing takes place in passive windrow or a bin system.

3.2 Movement of Nutrients

Figure II.3.7 is a schematic of the movement of nutrients from compost mortality disposal. There is a large variability in the nitrogen loss from carcass compost piles. This variation is caused primarily by co-composting materials added to piles to aid in composting rather than the carcasses themselves. Nutrient movement also differs between types of composters and management. Piles and windrows constructed on natural earth have the potential to leach nutrients into groundwater. By design, there is no leaching of nutrients to ground or surface water from properly managed rotating drums, bins, and tunnels constructed on concrete pads; however, leaching and runoff may occur if curing takes place in open windrows constructed on natural earth. Although runoff from unroofed composters may cause nutrients to move into surface water, most farms are equipped with runoff retention basins with retained water used for moisture control. There is very little information in the literature to quantify nitrogen emissions from mortality composting. Glanville et al. (2006) estimated the total loss of nitrogen (both leaching and volatilization) during composting to be between 10 and 40%. Very little phosphorus is lost from composting systems apart from removal as useful end products. Table II.3.1 provides estimated movement of nutrients using composting to dispose of carcasses. Nutrient movement shown in Table II.3.1 is based on a static pile with little or no turning. Material removed from the pile is screened for bones and mixed with farmstead manure before spreading according to a Nutrient Management Plan.

3.3 Description of the Composting Method

3.3.a Mortality Composting Practices

Composting is a managed aerobic degradation process with an end product that is beneficial as a soil amendment. Composting carcasses requires specific management of pile moisture and structure and cover material. Composting has become widely accepted as a means to manage both routine and catastrophic mortality. It is an accepted USDA-APHIS practice. Composting is often preferred over other disposal options because it can be completed on site with minimal effort, is cost effective, and environmentally sustainable.

The Animal and Plant Health Inspection Service (USDA-APHIS, 2021) developed a matrix to determine carcass management options. Composting is listed as an approved method for routine and catastrophic events as well as foreign animal disease outbreaks, but was scored lower than several other options. After two significant national Foreign Animal Disease (FAD) events and flooding in several states, composting is often the first option for carcass management if at all possible. Composting has become a widely acceptable management practice as an alternative to less environmentally and economically sustainable practices such as burial, landfilling, and incineration.

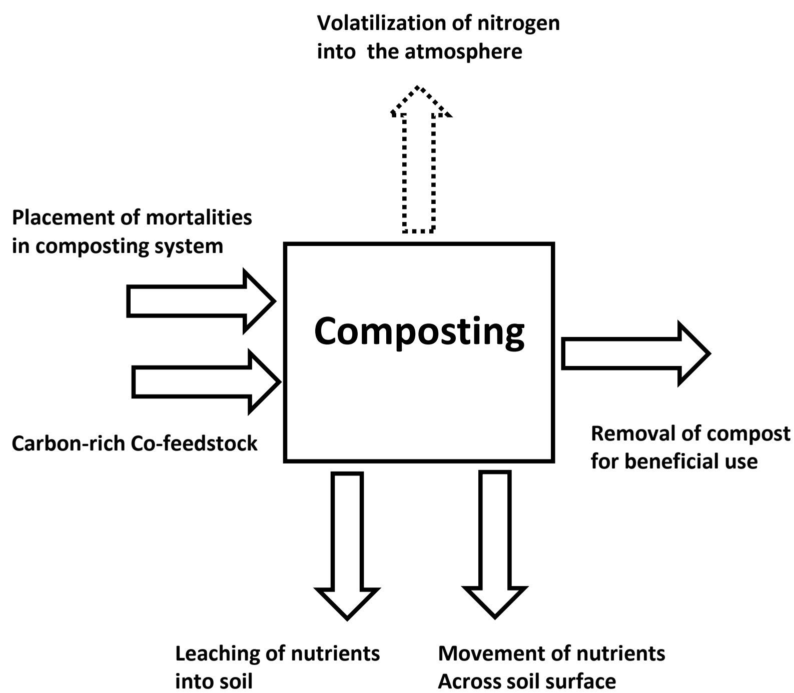

Figure II.3.7. Potential movement of nutrients during composting.

Table II.3.1. Estimated percentage of mortality nutrients transformed to useful end products and transferred to surrounding environment using the composting method of mortality disposal, following the best management practices for carcass composting (Seekins, 2011).

	TN	**TP**
Mortality nutrients recycled with end products in the farm nutrient management plan (% of nutrients entering)	80	100
Mortality nutrients emitted to the atmosphere (% of nutrients entering)	10	0
Mortality nutrients leaving the method by all other pathways (% of nutrients entering)	10	0

There is very little capital investment required to implement a compost program for carcass management. Most farm operations already have the infrastructure, land, co-composting materials, and material handling equipment necessary for composting. Composting on site reduces handling and transportation costs. Finished compost has value as a soil amendment which may be used in crop production systems.

3.3.b Composting Process Factors

To properly compost, certain environmental conditions must be established in the compost pile or windrow. The conditions (in order of importance) are moisture, porosity, and C:N ratio. Appropriate environment conditions and pile structure enhance the opportunity for microbial activity (Table II.3.2).

Table II.3.2. Environmental conditions necessary for proper composting.

Compost Characteristics Parameters	Acceptable Range
Moisture Content	40 - 60 %
Bulk Density	800 - 1,000 lbs. cubic yard^{-1}
Initial C:N ratio	25 - 40

There are two primary phases of animal tissue composting: active composting and curing. During active composting the carcass disintegrates and becomes more or less congruent with the carbon-rich material in the compost pile. The major groups of compost organisms are fungi, bacteria, and actinomycetes. Each group of organisms has specific functions in the decomposition process. The presence or absence and location of specific groups are indications of properly functioning compost. Thermophilic (110ºF-160ºF) organisms are dominant during the active phases; mesophilic (50ºF-110ºF) organisms are dominant during compost curing.

3.3.b Compost Methodologies

Three general methods of composting (windrow, bin, in-vessel) are used in the management of animal carcasses and tissue. The use of outside windrow composting for carcass management is now a routine practice for many large livestock farms. Poultry and swine farms also use bin as well as rotating drum composters for smaller carcasses and tissue. Each method requires knowledge of how the system works within the basic composting principles. Operators must be able to troubleshoot the system for timely and proper composting. Poor management of any of the systems can lead to negative environmental impacts including leaching and odors. All methods can be used for routine, catastrophic, and Foreign Animal Disease (FAD) events. Within each method there are variations.

Windrow Composting

Windrow composting is typically done in long trapezoidal rows 8-12 feet wide and 6-12 feet tall. This method can be conducted outside or inside of a building. Outside windrow systems are common for routine mortality management. They can be used with all poultry and livestock with no limits on space or equipment. Environmental features must be considered when locating an outside windrow compost system. Outside composting normally does not impede any other farm operations. Biosecurity could be a concern during a FAD event. Inside composting is commonly used with turkeys and broilers during a disease event using static aerated windrows. Inside windrow composting reduces the risk of airborne pathogen transmission. The size of the building limits composting capacity. Operation of equipment inside buildings for windrow construction, turning and cleanout can also be a limiting factor. Inside composting may also limit the farm’s ability to restock.

Static windrows are commonly used for livestock or poultry mortality management. The soft tissue needs to remain covered (bio-filter) to deter vectors and reduce potential odors. During the turning process, soft tissue has the potential to be exposed and needs to be recovered. This process is time consuming and may add an extra expense for cover material. However, turning accelerates the composting process by redistributing the moisture and food sources and aerating the piles. As Seekins et al. (2015) noted, pile structure is important in the upward movement of nutrients in a carcass compost pile. The redistribution of nutrients has the potential to put soluble nutrients in the bottom of the pile, the nutrients are then susceptible to leaching.

Bin Composting

Covered bins are constructed to hold daily routine mortalities for up to 180 days (typically). The systems have primary bins to start the composting process followed by secondary bins to serve as turning. Tunnels are elongated bins with ends open for loading mortalities and unloading. Tunnels are sometimes aerated through augers, turners, or forced air, but are generally aerated by moving material from a primary tunnel to several secondary tunnels.

In-Vessel Composting

There are a wide variety of in-vessel compost systems available for managing carcasses and animal tissue with rotating drums being the most common. Advantages of in-vessel composting are accelerated decomposition, odor control and less carbon input. These systems have less potential leachate to be discharged to the environment. With most of these systems, the operator is able to control the composting variables, specifically aeration. A major disadvantage for these systems is the limited throughput. These mechanical systems are designed to handle an average death rate on a farm. Most of these systems have no surge capacity. In most situations, in-vessel composting is used for the active stage of composting, with curing taking place in a bin or windrow system. A second disadvantage is that these are mechanical systems. Operators need a secondary management plan in the event of mechanical failure. These systems require considerable infrastructure and capital investment.

3.4 Estimated Nutrient (N and P) Lost along Pathways

3.4.a. Leaching

Kalbasi et al. (2005) stated, "Due to the high moisture content of carcasses … and effects of precipitation on the exposed compost pile, (open air composting) may produce a considerable quantity of leachate. This leachate may run off or percolate the soil and contaminate the surface or groundwater." This statement has been disproven by numerous research projects in a variety of conditions (Glanville et al. (2006); King (2014); Sanders et al. (2010); Hutchinson and Seekins (2021)).

Nitrogen is the nutrient most likely to be lost by leaching. Glanville et al. (2006, 2009), King (2014), and Sanders et al. (2010) examined the potential nutrient loss from leachate during composting and concluded that composting reduces the potential pollution risk to soil and groundwater when compared to burial. However, results were dependent on the type of co-composting material used during the process. Glanville et al. (2006), Gilroyed et al. (2016), and Hutchinson and Seekins (2021) all found that co-composting material, not the carcasses, significantly influenced leachate and air emission quality and quantity.

Glanville et al. (2006, 2009) found large differences in leachate from three different co-composting materials : silage, ground cornstalks, and yard waste compost. Corn stalks generated the most leachate while yard waste compost generated none. Leachate was collected in two areas just below the cover material and below the carcasses. They found the porosity of the co-composting material affected leachate volumes and nitrogen concentrations below the carcass. Corn stalk piles, which are highly porous, allowed greater amounts of N and ammonium to move downward through the pile. Yard waste compost was found to be an inadequate co-composting material because of poor porosity but did control leachate (Glanville 2003). Finer textured material captures leachate within the pile and repels rain water around the pile (King et al., 2014).

Hutchinson and Seekins (2021) constructed six compost piles on an undisturbed grass field with horse stall bedding and waste dairy feed. Carcasses were added to three of the piles. Pre- and post-composting soil samples at depths of 13 cm and 26 cm were analyzed for total nitrogen, nitrate, and ammonium. There was no statistical difference in any soil nitrogen level between the piles with and without a carcass. However, there was a statistical difference in all nitrogen species in the pre- and post-composting soil samples. This indicates that the carcass was not a major contributor to soil nitrogen under these conditions.

Glanville et al. (2006) took before and after soil samples from the locations in the field where compost piles were built. Leachate depth ranged from 3.8 to 28.5 mm, with the largest volumes coming from under piles containing corn silage. The least amount of leachate came using cornstalks as a carbon-rich co-composting material. Even the highest volume, however, was only a tiny fraction of the total precipitation received during the trial periods. This indicates that over 90% of the rainfall received was retained or shed from the pile. Nitrate nitrogen (NO_3-N) concentrations in the leachate ranged from 38.9 mg L^{-1} to 267.5 mg L^{-1}. The highest nitrate concentrations were found under the piles constructed with straw/cattle manure mix, and the lowest concentrations from the piles made up of corn silage. Ground cornstalks had an intermediate concentration in both trials: NH_4-N concentrations ranged from 186 mg L^{-1} to 1,361.7 mg L^{-1}. The highest concentrations were found under the straw/cattle manure mix, while the lowest were associated with the corn silage piles. They estimated that the nitrogen losses (both leaching and volatilization) amounted to between 10% and 40% of the total N in the piles depending on which co-composting material was used.

Glanville et al. (2006) concluded that in comparison to burial, which would place 100% of the nutrients from the carcasses close to the groundwater, the groundwater pollution potential was much lower for composting. Nitrogen leaching potential is highly dependent on co-composting material C:N. Expected nitrogen leaching is greater for low C:N materials such as poultry litter. Co-composting materials with a high C:N (e.g. wood shavings) would be expected to retain more N in the compost system. Hutchinson and Seekins (2021) found that there was no significant N contribution from carcasses to the soil profile when horse stall cleanings and waste dairy feed was used as a co-compost material.

There is limited information on phosphorus in carcass leachate in the literature. Phosphorus is not highly mobile in compost; therefore, a significant portion remains in the compost until field applied. Leachate from a platform interface study in Michigan had a total nutrient load of 8.7, 1.9 and 7.2% of N, P, K, respectively, of the estimated initial nutrients from carcass compost (Sanders et al., 2010). Morris, et al. (1996) found a total load of 6.5g and 10.1g of P in effluent from uncovered swine mortality compost bins. This is compared to straw piles that had total load levels of 34.9g and 64.4g. These levels of P loading are below annual crop removal for corn silage. Sanders et al. (2010) found that there was greater leachate loss on sandy loam soils than clay loam soils. This result is expected because of the larger macropores in sandy soil. Therefore, site selection and/or modifications are important prior to developing a compost location.

3.4.b. Runoff

Sanders et al. (2012) estimated the total P in runoff and infiltrating the soil from a 25-year, 24-hour storm event on a hypothetical uncovered mortality composting facility for a 1,000-cow dairy with 5% annual mortality (Table II.3.3). Given the assumption that fresh sawdust contributes no P to the system, then the carcasses contributed 3.14 lbs. of P in runoff and leachate. This indicates that the majority of P comes from carbon sources and bulking agents used in construction of the compost pile. Morris (1996) also observed levels of N, P, K, Mg, and Ca in the leachate of compost was substantially lower than what was found for cattle manure on 21 area farms in Ontario.

Table II.3.3. Mass of TP in runoff and leachate leaving an uncovered composting facility during a 25-yr, 24-hr rainfall event; the facility treated mortalities from a 1,000-cow dairy with a 5% annual mortality rate (Sanders et al., 2012).

Amendment	TP in runoff (lbs.)	TP infiltrating into soil (lbs.)
Fresh Saw dust	0.38	2.76
Corn Silage	23.68	592.26
Grass Clippings	2.46	61.50
Reused finished compost	0.39	4.46
Bovine manure pack	2.08	52.02
25% Bovine manure pack, 75% sawdust	0.61	15.40

3.4.c. Nitrogen Volatilization

There are very limited studies on air emissions from carcass composting. Nitrogen volatilization losses are influenced by the type of carbon-rich materials and bulking agents added to mortalities. Xu et al., (2007) found that the carcasses themselves contributed very little to atmospheric emissions when nutrient dense co-composting materials are used; however, these co-composting materials being low in carbon are only a portion of the entire mixture used to compost carcasses. Hamilton et al. (2016) found that nitrogen volatilization losses from manure composting ranged from 10 to 25%. In most cases, manure compost will be mixed more aggressively than mortality compost, particularly in the early hot composting phase; therefore, it is assumed nitrogen volatilization losses for mortality compost will be at the low end of the range. Rozeboom et al. (2012) compared ground carcasses with whole carcasses and found no significant differences in ammonia emissions between them. Seekins et al. (2015) found that nitrogen moved upwards in the compost pile and remained in the upper third of the pile when using a horse bedding, waste feed, and wood chip mixture. Ammonium was draw up through the compost windrow by the warm moist air. As the ammonium comes in contact with oxygen, it is converted to nitrate and adsorbs onto organic cover material therefore limiting volatilization.

3.4.d Nutrients in the End Product

Glanville (2006) estimated that 10-40% of the total N was lost to leachate or volatilization during the compost process. Using the values for mass of nitrogen per mass of body tissue for animal species given in Part I of this document, Table II.3.4 shows the amount of land needed to spread the nutrients from a one AU (1,000 pound) mortality at 100 pounds total N and 45 pounds P_2O_5 per acre per year. Table II.3.5 gives the estimated land needed to spread composted mortalities for various production schemes given in Part I of this document at 100 pounds total N and 45 pounds P_2O_5 per acre per year. Tables II.3.4 and II.3.5 show that phosphorus is usually the limiting element in land application of mortality compost, especially if mature animals are housed in the production system. However, total acreage needed for spreading depends on nutrients added with co-composting materials.

Table II.3.4. Land needed to spread mortality compost made from 1 AU (1,000 pounds live weight) carcass(s), assuming 100 pounds total nitrogen, 45 pounds $P_2 0_5$ per acre per year application rate.

	Nitrogen in Body Tissue	Phosphorus in Body Tissue	Total N in 1 AU of Tissue	Total P in 1 AU of Tissue	Low N losses – 10%		High N Loses – 40%			
					TN in Compost	Land Needed	TN in Compost	Land Needed	$P_2 0_5$ in Compost	Land Needed
	(%)	(%)	(lbs.)	(lbs.)	(lbs.)	(Acres)	(lbs.)	(Acres)	(lbs.)	(acres)
Broilers	2.82	0.375	28.2	3.75	25.3	**0.25**	16.9	**0.17**	8.25	**0.18**
Laying Hens	3.97	0.70	39.7	7.00	35.7	**0.36**	23.8	**0.34**	15.5	**0.39**
Tom Turkeys	2.93	0.375	29.3	3.75	26.3	**0.26**	17.6	**0.18**	8.25	**0.18**
Hogs	2.54	0.56	25.4	5.60	22.8	**0.23**	15.2	**0.15**	12.4	**0.28**
Cattle	2.83	0.82	28.3	8.20	25.5	**0.26**	17.0	**0.17**	18.1	**0.40**
Equid	3.20	0.95	32.0	9.50	28.8	**0.29**	19.2	**0.19**	20.9	**0.52**

Table II.3.5. Land needed to spread mortality compost for typical production systems, assuming 100 pounds total nitrogen and 45 Pounds P_2O_5 per acre per year application rate.

	Mortalities Collected	Mortality TN Collected	Mortality TP Collected	Low N losses – 10%		High N Loses – 40%		$P_2 0_5$ in Compost	Land Needed
				TN in Compost	Land Needed	TN in Compost	Land Needed		
	(lbs. $Year^{-1}$)	(lbs. $Year^{-1}$)	(lbs. $Year^{-1}$)	(lbs. $Year^{-1}$)	(Acres)	(lbs. $Year^{-1}$)	(Acres)	(lbs. $Year^{-1}$)	(Acres)
Broilers 25,000 Bird Flock 6 lb. Birds	11,000	275	37.5	250	**2.5**	165	**1.65**	83	**1.8**
Market Hogs 1,000 Head Barn 270 lb. Hogs	16,000	420	92	380	**3.8**	250	**2.5**	200	**4.5**
Dairy Cattle 200 Milkers Holsteins	18,000	500	150	450	**4.5**	300	**3.0**	330	**7.4**
Horses 1,000 Head Herd Quarter Horses	12,000	390	140	350	**3.5**	230	**2.3**	310	**6.9**

3.5 Other Important Considerations with Composting

At the end of the compost process, the producer has a valuable soil amendment. Producers have often raised concerns about the large bones and nutrients tied up in the soil. Bones become brittle during the compost process but do not completely decompose. Large bones from older animals that are well ossified are more difficult to compost and may require several passes through the compost process. These bones can also be screened out or run through a grinder. Nutrient tie up has not been documented with the use of animal carcass compost. In many areas, nutrients need to be exported, especially phosphorus. Compost has the potential to concentrate nutrients that can be used in the landscape and home horticulture industry. The mushroom industry is a large consumer of compost but are prohibited from using mortality compost in their production systems.

3.6 References

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4. Incineration

4.1 Definitions

Incineration*:* The burning or thermochemical conversion of mortalities to produce a gaseous and solid byproduct. Three types of thermochemical conversion may be used to dispose of livestock and poultry mortalities: combustion, gasification, and pyrolysis. Most mortality incinerators employ a hybrid of methods.

Combustion*:* Thermochemical conversion of organic material with a stochiometric excess of oxygen at temperatures between 1,500 and 3,000°F (815-1,650°C). The products of combustion are heat, carbon dioxide, water vapor, and ash.

Gasification*:* Thermochemical conversion of organic material in an oxygen-starved environment at temperatures between 1,400 and 2,700°F (760-1,480°C). The products of gasification are syngas and char or ash. Trace amounts of liquid and tar may also be produced during gasification. Syngas is a mixture of carbon monoxide, hydrogen, methane, and other light-weight hydrocarbons. In the context of mortality incineration, syngas produced by gasification is generally ignited with excess oxygen to produce carbon dioxide and water vapor.

Pyrolysis: Thermochemical conversion of organic material in an oxygen-free environment at temperatures between 575 and 1,475°F (300-800°C). The products of pyrolysis are syngas, a liquid product (bio-oil) and solid residue (bio-char). Fast pyrolysis, which occurs at higher operating temperature with a reaction time lasting seconds, results in a greater amount of bio-oil and a lesser amount of bio-char being produced. Slow pyrolysis, occurring at lower temperatures and reaction times lasting hours or days, produces almost no bio-oil and is mostly used to produce bio-char. To be considered bio-char, a char product must contain at least 10% organic carbon.

4.2 Movement of Nutrients

Figure II.4.1 is a schematic of the movement of nutrients from combustion-based incineration. Since incineration takes place in a sealed container, no movement of nutrients into or across the soil takes place. Some volatilization of nitrogen occurs during incineration. Assuming thermochemical conversion of mortalities is similar to that of manure (Hamilton et al., 2016), roughly 75% of the total nitrogen in livestock and poultry mortalities is volatilized during incineration and 25% remains with ash. One hundred percent of phosphorus contained in carcasses is transferred to ash. Table II.4.1 provides estimated losses of total nitrogen and total phosphorus to the environment by various pathways assuming mortality incineration most closely resembles fast pyrolysis of manure (Hamilton et al., 2016) based on temperature in the primary retort or primary combustion chamber. The possibility of either

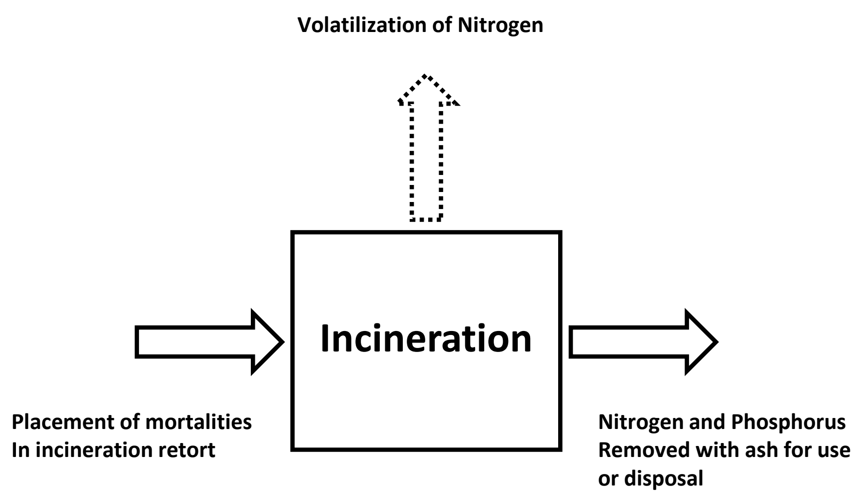

Figure II.4.1. Movement of nutrients during incineration.

Table II.4.1. Estimated percentage of mortality nutrients transformed to useful end products or transferred to the surrounding environment using the incineration method of mortality disposal, assuming incineration is conducted at a temperature similar to fast pyrolysis of manure (Hamilton et al, 2016).

	TN	TP
Mortality nutrients recycled with end products in the farm nutrient management plan (% of nutrients entering)	25	100
Mortality nutrients emitted to the atmosphere (% of nutrients entering)	75	0
Mortality nutrients leaving the method by all other pathways (% of nutrients entering)	0	0

nitrogen or phosphorus being transferred to water bodies may also occur if ash is mishandled during storage and land application.

4.3 Description of the Incineration Method

Mortality incineration does not fit easily into any of the thermochemical processes outlined in the definitions section. Based on operating temperature, air intake, and burner arrangement, most commercially available incinerators act as hybrid between the pyrolysis, gasification, and combustion processes.

Figure II.4.2 shows a popular model of on-farm incinerator. Animals are placed in the large metal-firebrick lined chamber (retort). The burner unit attached to the retort shoots flame into the chamber, heating the retort and burning the carcass. The burner is thermostatically controlled. When the retort temperature reaches 1,400°F, the burner shuts down and air is forced into the chamber so that the carcass continues to burn (R and K Incinerators Inc, 2020). The forced air and 1,400°F burn temperature make the process in the retort similar to low-temperature combustion. Most of the soft tissue volatilizes into particulates and shorter chained organic compounds. A second flame travelling through the afterburner (horizontal chamber attached to the vertical flue) burns particulates and gases before they pass out of the incinerator. Afterburner temperatures range between 735 and 1,600°F (R and K Incinerators Inc, 2020). The afterburner is critical in ensuring complete burning of particulates, reducing odors, and meeting local air quality standards.

Gasification of mortalities has been investigated by a number of researchers (Brookes, 2009; Lemeiux et al., 2009; Porter, 2009). The BGP (Brookes Gasification Process) is the most commonly used gasification system. Figure II.4.3 is a schematic of the BGP for mortality incineration. Mortalities pass through a pre-breaker that breaks the body into large pieces, followed by a finer that more fully masticates the carcass. The accumulator consolidates the material for auguring into the pre-heated primary combustion chamber or retort. Volatile gases and particles rise out of the primary chamber by a tortuous path where they are met by a downward pointing flame which also pulls combustion air into the gasifier. Combustion takes place in the secondary combustion chamber and combustion gases rise up through an exhaust stack. Minimum temperature of the secondary combustion chamber is 1,560 °F. Heat is transferred upward to the primary combustion chamber through an uninsulated hearth separating the chambers. Design temperature of the primary chamber is 840 °F or greater, but care must be taken so that large loads of moist material do not cause the temperature to drop in the primary chamber. Masticated carcass material is conveyed through the primary chamber with a drag chain atop the hearth. Organic matter volatilizes as the heated material is conveyed through the chamber, and ash is collected at the far end by a cross auger.

Figure II.4.2. Commonly used on-farm incineration unit sized to handle up to 1,200 pounds of mortalities (R&K Incinerator Inc, 2020).

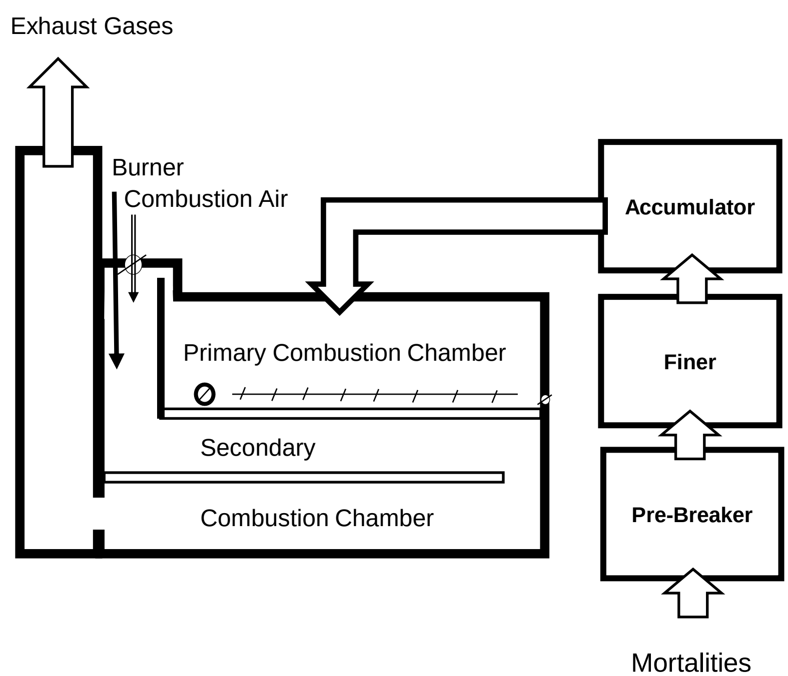

Figure II.4.3. Schematic of Brooks Gasification Process (BGP) for mortalities as modified by the US-EPA National Homeland Security Research Center (Brookes, 2009; Lemieux and Serre, 2016).

Perhaps the greatest hinderance to incineration of mortalities is the high moisture content of animal carcasses. Whereas biomass materials generally undergo a desiccation process to remove moisture before conversion by gasification and pyrolysis (Hamilton et al., 2016), mortalities are introduced to the retort "as is". Lemieux and Serre (2016) reported a temperature drop as great as 328 °F as wet, masticated mortalities are introduced into the primary combustion chamber of the BGP gasifier, followed by flash combustion at 1,850°F. More external fuel is used to keep a constant, high temperature during incineration of livestock and poultry mortalities compared to thermochemical conversion of dry feedstocks. European sources (https://www.funeralnatural.net/articulos/la-cremacion-y-la-calidad-del-aire) indicate that in cremation of human remains, of the estimated 880 pounds of CO_2 emitted into the atmosphere, only 59 pounds originate with the cadaver.

4.4 How Incineration is Used for Various Animal Types

The same basic type of incinerator is used for disposal of all animal types; the main difference between species is size of the incinerator. Several smaller animals (poultry, piglets) are placed in the incinerator at one time until the rated capacity is reached. Incineration is generally done one carcass at a time for larger animals, and incinerator capacity is determined by the largest carcass anticipated.

4.5 Estimated Nutrient Mass (N and P) Lost along Pathways

It is assumed that all of the phosphorus contained in mortalities exits the incineration process in the form of ash.

Incineration used for mortality disposal most closely resembles pyrolysis based on the temperature range (750°F to 1,100°F) found in the chamber where disintegration of the body occurs. As stated earlier in this report, retort temperature of the most common on-farm incinerators is limited to a maximum of 1,400°F (R and K Incinerators Inc, 2020). Although temperature of the primary combustion chamber of BGP gasifier may range between 512°F to 1,850°F due to fluctuations in wet mass loading, the design lower operating temperature of this gasifier is 840°F, which is below the operating range of dry biomass gasifiers (1,400 to 2,700°F). More thorough ashing of carcasses occurs in mortality incineration compared to pyrolysis, because oxygen is not limited in the process. Cantrell et al. (2012) showed that temperature had a greater impact on nitrogen retention in pyrolysis compared to source of biomass.

Given the temperature range of mortality incineration, and the fact that carcasses are incinerated over the course of hours rather than days, we assume that nutrient retention in ash most closely resembles that of fast pyrolysis. Hamilton et al. (2016) gave a fast pyrolysis of manure a defined nitrogen volatilization efficiency of 75% and a nitrogen separation efficiency (analogous to byproducts with potential to be used in agricultural land application in this report) of 25%.

Limited data exists for composition of nitrogen emissions from incineration of animal mortalities. The Farm Manure-to-Energy Initiative (Hamilton et al., 2016) reported on a limited number of air emission tests conducted on gasification and combustion systems for poultry litter. Di-nitrogen gas (N_2) accounted for 90% of all nitrogen emissions from combustion systems and 96% of nitrogen emissions from gasifiers. Results show that ammonia emissions were less than 0.05% for all operations. Nitrogen oxides varied from 2.5 to 5.2% for combustion and 0.6% from gasification. The European Environmental Agency (Trozzi et al., 2019) gives a NOx emission factor of 0.825 kg per human body for crematories; however, it was not determined whether the source of NOx emission is the nitrogen contained in bodies, caskets, or through high-temperature oxidation of atmospheric nitrogen. US-EPA (1999) states that "concentration of thermal NO_X (NO_x created from atmospheric nitrogen during combustion) is controlled by nitrogen and oxygen molar concentrations and the temperature of combustion. Combustion at temperatures well below 2,370 °C (1,300 °F) forms much lower concentrations of thermal NOx"; therefore, it is assumed that mortality incineration will result in lower NOx emissions than other, drier biomass.

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5. Rendering and Landfilling

5.1 Definitions

Landfilling: Municipal or private landfills are sometimes an option to dispose of animal carcasses, but there is a lot of variability in the willingness or policies that determine whether an operator – or contractor – can dispose of their mortalities at a landfill or transfer facility. The extent of the use of landfills for animal mortality disposal in the Chesapeake Bay watershed is not known. Indeed, variability in record keeping would make it difficult to estimate the extent of landfill disposal for animal mortalities even if the panel had made such an investigation one of its key points of focus.

Rendering: Rendering of animal mortalities recycles carcasses into three potentially marketable products: carcass meal, melted fat or tallow, and water. Rendering is a well-established industry that follows rigorous requirements and quality control practices to ensure the safety of their products in whatever marketable form they take and regardless of whether they use animal carcasses or other feedstocks. The process involves numerous physical and chemical transformations, such as the application of heat, extracting moisture, and fat separation.

5.2 Movement of Nutrients

5.2.a Rendering Facilities

For purposes of this report, it is understood that rendering facilities, like other industrial operations with large amounts of water use and disposal, are regulated under the Clean Water Act and subject to applicable federal, state and local laws and regulations. Therefore, any disposal of nutrients back into the watershed would be captured as part of the monitoring reports submitted by the facility to regulators. Additionally, any marketed products (meal, fat, tallow, etc.) are irrelevant for the Watershed Model and its inputs. The transformation of any nitrogen into air emissions from animal carcasses is assumed to be below negligible. Altogether, the panel assumes that any nutrient load associated with animal carcasses transferred to a rendering facility are either transformed into products that are removed from the system, or become a portion of the point source load. Therefore, their previous load as part of agriculture or the feedspace load source is reduced to zero. This avoids potential for double counting the nutrient load and follows the same logic applied to instances where loads are transferred outside the watershed or into landfills and zeroed out from the original load source. Table II.5.1 gives the mass of mortality nutrients transported to the watershed environment by the rendering process through the pathways shown in Figure II.1.2

Table II.5.1. Estimated percentage of mortality nutrients transformed to useful end products and transferred to surrounding environment using the rendering method of mortality disposal.

	TN	TP
Mortality nutrients recycled with end products in the farm nutrient management plan (% of nutrients entering)	0	0
Mortality nutrients emitted to the atmosphere (% of nutrients entering)	0	0
Mortality nutrients leaving the method by all other pathways (% of nutrients entering)	0	0

5.2.b. Landfills

It is known that public- and privately-owned landfills for municipal solid waste are designed with clay and synthetically lined areas that collect leachate and recover gases. Therefore, the transfer of nutrients into a landfill within the Watershed Model conceptually eliminates them from the system as if they were removed from the watershed entirely, i.e., a 100% reduction of TN and TP. The panel is confident enough with that conceptual logic to apply it to animal mortalities and therefore recommends that verified transfer of animal mortalities to a landfill reduces the load of those nutrients to zero from the original load source. The panel acknowledges, however, that the record keeping may be problematic for jurisdictions to know the number or total tonnage of routine animal mortalities disposed in landfills on a county- or state-wide annual basis. Table II.5.2 gives the mass of mortality nutrients transported to the watershed environment from landfills through the pathways shown in Figure II.1.2

5.4. How Landfilling and Rendering are Used for Various Animal Types

The specific method of rendering or placing a carcass in a landfill varies little between animal types. Size of animal, however, plays a large role in how carcasses are stored and transported. Large animals (e.g. mature swine, horses, and cattle) are handled on an individual animal basis. Some large carcasses, particularly swine, may be stored temporarily on-farm in refrigerated or un-refrigerated containers; however, most carcass are removed from the farm and taken to the rendering facility or landfill on the day of death. Small animals (e.g. piglets, poultry) are delivered to the facilities in mass, and may be stored for a considerable amount of time on-farm in refrigerated containers and then delivered to the facilities en masse.

Table II.5.2. Estimated percentage of mortality nutrients transformed to useful end products and transferred to surrounding environment using the landfilling method of mortality disposal

	TN	TP
Mortality nutrients recycled with end products in the farm nutrient management plan (% of nutrients entering)	0	0
Mortality nutrients emitted to the atmosphere (% of nutrients entering)	0	0
Mortality nutrients leaving the method by all other pathways (% of nutrients entering)	0	0

5.6 Important Considerations with Rendering

Rendering of animal carcasses will only be available in areas where a rendering plant is capable of accepting and rendering the mortalities. The ability to transport and render carcasses will vary by the animal size and the operation’s proximity to a rendering facility, which often coincide with areas that have a tradition of extensive animal production. Panel members communicated with rendering industry representatives, but were unable to obtain regional data for summary in this report. There are approximately 300 rendering facilities across North America that recycle a tremendous amount of inedible byproducts from the animal industry, transforming it into other products for the industry or other markets (Meeker and Hamilton, 2006).

The panel understands that some cost-shared practices such as poultry freezers are closely associated with rendering, as they enable a farmer to safely collect and store their mortalities until the rendering company or a third party transfers the frozen or refrigerated mortalities to the processing facility. While freezing or refrigerated storage is less common for larger animal carcasses, it may still be an applicable storage technique under the right circumstances to enable economical use of rendering as a disposal option.

Through panel members' discussions with local farmers and operators in Maryland, the panel was led to believe that when state cost-share funds are used to install freezers on a poultry operation there must be an agreement in place between the farmer and a rendering facility or contractor to collect and process the stored mortalities. Assuming such agreements are standard for mortality freezers, the panel recommends that states can track and report the implementation of mortality freezers as the mortality rendering BMP, which zeroes out the assumed nutrient load from the animal mortalities. However, the jurisdictions must have procedures in place to verify that the freezers were indeed utilized for mortality management on an active operation for the reported number (or percentage) of animals associated with that freezer.

If a jurisdiction has the ability to track and report the number of animals or tonnage of animal mortalities – and ideally, animal type – transferred from watershed farmers to rendering facilities, that may be the most effective method for tracking and reporting the animal rendering BMP. For example, Delaware's Nutrient Management Commission expanded its manure transport program to include mortality transport a few years ago. The program incentivizes the adoption of both practices by providing funds to offset the cost of transportation for individual growers. The invoices submitted for reimbursement contain the total tonnage and type of mortality diverted from land application, allowing the state to track and report the associated reduction in nutrients that would otherwise be attributed to Delaware's agricultural load.

Regardless of tracking or reporting method, the panel acknowledges the benefit of rendering from economic and environmental perspectives. Despite a lack, or complete absence, of specific literature on the water quality benefits of rendering, the panel is reasonably confident that it can recommend a 100% reduction of both TN and TP for animal carcasses that are rendered, based strictly on the panel's conceptual understanding of how point source loads are simulated and how the transferred mortalities are therefore removed entirely from the original load source.

5.7 References

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APPENDIX A

Recommendations for Livestock and Poultry Mortality Management

Prepared for the Chesapeake Bay Program Partnership's Agriculture Workgroup by the
Animal Mortality Management Expert Panel Establishment Group
Approved by Agriculture Workgroup, March 15th, 2018

Background
In the recently approved Chesapeake Bay Program (CBP) Phase 6.0 Watershed Model, animal mortality and associated mortality management practices are not fully represented for crediting purposes. The only existing partnership-approved Best Management Practice (BMP) associated with mortality management is termed "mortality composting" and is defined as: "A physical structure and process for disposing of any type of dead animals. Composted material is land applied using nutrient management plan recommendations. Enter units of the percent of dead animals composted, animal count, animal units, or number of systems." Efficiency values for nitrogen (N) and phosphorus (P) are not currently represented in the model for the mortality composting BMP.

The Agriculture Workgroup (AgWG) has requested a review of mortality management practices currently in use in the Chesapeake Bay watershed for the Phase 6.0 Model. This is in response to increased implementation of mortality composting systems and other alternative management processes for routine mortality management on agricultural operations. The review is also intended to address the current deficiency of available information in the Phase 6.0 Model that would allow for planning or crediting animal mortality management practices towards Total Maximum Daily Load (TMDL) goals.

The Animal Mortality Management Expert Panel Establishment Group (EPEG) was formed to:

- Determine the necessity for a Phase 6.0 Animal Mortality Management Expert Panel (EP).
- Identify priority tasks for the Phase 6.0 Animal Mortality Management EP,
- Recommend areas of expertise that should be included on the Animal Mortality Management EP, and
- Draft the Animal Mortality Management EP's charge for the review process.

From November 8, 2017 through January 19th, 2018 the EPEG met two times by conference call and worked collaboratively to complete this charge for presentation to the AgWG on February 15th, 2018. Final approval of the charge was obtained by online polling of all EPEG members (Table 1).

Table 1. Animal Mortality Management Expert Panel Establishment Group membership and affiliations.

Member	Affiliation
Frank Schneider	PA State Conservation Commission
Chris Brosch	Delaware Department of Agriculture
Shelly Dehoff	PA Agricultural Ombudsman Program
Gary Felton	University of Maryland
George Malone	Malone Poultry Consulting
John Moyle	University of Maryland Extension
EPEG Support Staff	
Loretta Collins	University of Maryland
Mark Dubin	University of Maryland
Lindsey Gordon	Chesapeake Research Consortium
Jeremy Hanson	Virginia Tech

Glossary of Terms

Farmstead: Area on commodity and livestock operations that includes service buildings (e.g., headquarters), feed and commodity storage, and other pervious and impervious areas not already addressed by BMPs designed for production areas. This does not include barnyards, loafing lots, or other production areas which are represented separately. Farmstead areas are not directly represented in the Phase 6.0 modeling support tools by a discrete agricultural land use.

Feeding Space: Livestock and poultry production and feeding areas associated with livestock operations which includes barnyards, loafing lots, and other pervious and impervious production areas. Feeding space areas are directly represented in the Phase 6 modeling support tools by a discrete agricultural land use for the application and crediting of BMPs designed for production areas (e.g., animal waste management systems).

Animal Mortality Management: This represents the management of routine agricultural animal mortality which protects ground and surface water from contamination by carcasses or runoff/leaching from areas containing carcasses. These practices can also prevent the spread of pathogens off the site as well as protect the biosecurity of the farm by preventing off-farm pathogens from being introduced during pickup or handling of carcasses by contractors or service providers. Mortality management can be accomplished by several methods, including composting, incineration or gasification, offsite disposal in permitted landfills, or on-farm freezing and removal for recycling or rendering to alternative uses.
Mortality Burial: Disposal method in which whole carcasses are buried underground and decompose via natural processes over a period of time, dependent on site conditions. Burial site factors such as distance from waterways and depth to groundwater are important considerations and are regulated in most states. Poor site selection can pose risks to water quality. Management by burial treats the whole carcass as a waste product, rather than a by-product with marketable value. Mortality burial is not recommended as a BMP for evaluation by the EP, but it may be considered a baseline from which to measure alternative mortality management practices.

Mortality Composting: Composting is a controlled, biological heating process that results in the natural degradation of organic resources (such as animal carcasses) by microorganisms. Microbial activity within a well-managed compost pile can generate and maintain temperatures sufficient to inactivate most pathogens. *Mortality composters* refer to specifically designed physical structures for composting routine mortality on the farmstead. Mortality composting can be applied to various species. The fate of the composted product is often land application under the guidance of a nutrient management plan. There is potential for the compost to be removed from the farmstead for use elsewhere as a value-added product.

Mortality Freezers: Routine mortality is temporarily stored in large on-farm freezer units for collection by a contractor or service-provider. Primarily used for smaller animal types like poultry, a bio-secure vehicle arrives between flocks to take the material off-site, presumably to a rendering facility.

Mortality Incineration or Gasification: The carcass is completely consumed by fire and heat within a self-contained incinerator utilizing air quality and emissions controls. Gasification is a high temperature method of vaporizing the biomass with no direct flame, with oxidation of the fumes in an after-burning chamber. Incinerators and gasifiers are subject to applicable state air quality/emissions requirements. The remaining solid by-product of incineration is ash, which should be spread in accordance with a nutrient management plan or disposed of by other means acceptable to water quality protection goals. Gasification by-products include syngas and char or ash, depending on the feedstock and design of the system.

Mortality Landfill: Off-site disposal of carcasses at a licensed and permitted landfill that accepts animal mortalities and is designed to be protective of surface and groundwater sources. Unlike mortality burial, appropriate landfilling removes nutrients associated with the carcass from the agricultural nutrient stream. Similar to burial, however, no valuable by-product is produced.

Rendering: Typically refers to the process of breaking down animal by-products (e.g., fat, bone, and hides) from animal processors and slaughter facilities. For the purposes of the EP, rendering would refer to the processing of animal mortalities via pick-up and removal of the remains from the farmstead by the rendering facility or an intermediary. The rendering industry as a whole reduces the burden on regional landfills that would otherwise serve as disposal sites for these products.

Animal Groups: The EPEG recommends to the AgWG that the forthcoming EP organize consideration of animal mortality practices and subsequent water quality benefits into two general groupings:

- Primary Animal Group (PAG): Swine and poultry.
- Secondary Animal Group (SAG): All other animal groups. It is left to the discretion of the EP to assess the BMP efficiencies and verification for these animal groups and/or group components.

Method

The Animal Mortality Management EPEG developed its recommendations in accordance with the process specified by the AgWG in 2014[1]. This process is informed by the strawman proposal presented at the December 11, 2014 AgWG meeting, the Water Quality Goal Implementation Team (WQGIT) Best

1 http://www.chesapeakebay.net/channel_files/22323/january_8_2015_agwg_expert_panel_process.pdf

Management Practice (BMP) protocol, input from existing panelists and chairs, and the process recently undertaken by the AgWG to develop the charge for the Manure Treatment Technologies EP.

The collective knowledge and expertise of EPEG members formed the basis for the recommendations contained herein. Several of the EPEG members have had experience on BMP expert panels or subcommittees. EPEG members and the technical support team also have knowledge and/or expertise in state and federal programs, the Chesapeake Bay model, and livestock and poultry mortality management practices within the Chesapeake Bay watershed.

Communication among EPEG members was by conference call and email. All decisions were consensus-based.

Recommendations for Expert Panel Member Expertise

The Animal Mortality Management EPEG recommends that the AgWG establish an Expert Panel to evaluate routine animal mortality and associated mortality management practices currently being implemented in the Chesapeake Bay watershed by livestock and poultry operations, and develop a recommendation report of its findings following standard CBP partnership protocols.

The AgWG expert panel organization process directs that each expert panel is to include eight members, including one non-voting representative each from the Watershed Technical Workgroup (WTWG) and Chesapeake Bay Program modeling team. Panels are also expected to include three recognized topic experts and three individuals with expertise in environmental and water quality-related issues. A representative of USDA who is familiar with the USDA-Natural Resources Conservation Service (NRCS) conservation practice standards should be included as one of the six individuals who have topic- or other expertise.

In accordance with the WQGIT BMP protocol, panel members should not represent entities with potential conflicts of interest, such as entities that could receive a financial benefit from Panel recommendations or where there is a conflict between the private interests and the official responsibilities of those entities. All Panelists are required to identify any potential financial or other conflicts of interest prior to serving on the Panel. These conditions will minimize the risk that Expert Panels are biased toward particular interests or regions.

The Animal Mortality Management EPEG recommends that the Phase 6.0 Animal Mortality Management EP should include members with the following areas of expertise:

- Expertise in design/engineering/implementation of mortality management systems.
- Experience with carrying out scientific research projects relating to mortality management.
- Expertise in fate and transport of N and P from farmsteads.
- Knowledge of effectiveness of livestock and poultry mortality management practices implemented in the Bay jurisdiction(s).
- Knowledge of how BMPs are tracked and reported, and the Chesapeake Bay Program partnership's modeling tools.
- Experience with verification of livestock and poultry mortality management practices used at farmsteads.
- Knowledge of and experience with relevant USDA-NRCS conservation practice standards and codes.

Expert Panel Scope of Work

The general scope of work for the Animal Mortality Management EP will be to define and configure the Animal Mortality Management BMPs in the Phase 6 model. Specifically, the Animal Mortality Management EPEG recommends the following charge with associated tasks for the Phase 6.0 Livestock and Poultry Mortality Management EP:

1. Determine scope of the EP based on available data and impact on water quality
    - Animal groups and/or group components to be addressed
        - Definitions available on CBP's Chesapeake Assessment Scenario Tool (CAST)[2]
    - Mortality management practices to be addressed (Table 2)
2. Define load reduction efficiencies for N and P of selected practices for agricultural feeding space areas.
    - Consider fate of N and P across selected practices
        - Decomposition and mineralization
        - Leachate
        - Volatilization
        - Field application
        - Removal from agricultural system
3. Determine how the selected mortality management practices can be represented in the model.
    - Consider the information necessary to address Options 1 and 2 (Figure 1)
        - Option 1: applicable to 2020-2021 milestone planning
        - Option 2: applicable to post-Phase 6.0 Watershed Model

Figure 1. Potential Crediting Mechanisms Presented to the AgWG on October 19th, 2017

Potential Credit Mechanisms:

Option 1: If an EP finds a water quality benefit, that benefit could be added as a % reduction to feed space loads in a future milestone period.

Option 2: Ag Workgroup could request a change to the manure calculations from the Water Quality GIT and Modeling Workgroup in a future milestone period if an EP defines:

- % mortality
- nutrients available in carcasses
- water quality benefit

[2] http://cast.chesapeakebay.net/Home/SourceData

Table 2. Data Needed for Animal Mortality Management Representation in the Phase 6.0 Watershed Model

General Animal Group (defined by EPEG)	BMP Animal Groups	% N per Carcass	% P per Carcass	Mortality %	Avg. Dead weight?	Mortality Management Baseline (1984)	Mortality Management Today**	
Primary Animal Group	Poultry	?	?	?	?	Burial	Burial	Yes
							Freezer	Yes
							Compost	Yes
							Incineration	Yes
	Swine	?	?	?	?	Burial	Burial	Yes
							Freezer	Yes[#]
							Compost	Yes
							Incineration	Yes
Secondary Animal Group	Cattle	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No
	Equine*	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No
	Other? (e.g. Sheep, Goats)	?	?	?	?	Burial	Burial	Yes
							Freezer	No
							Compost	Yes
							Incineration	No

*Direct-to-rendering also practiced

** Current mortality management in the Bay watershed, as understood by EPEG members

[#]Piglets (nursery) only

Consider incorporating relevant USDA-NRCS conservation practice standards and codes and other established practices in recommending BMPs for livestock and poultry mortality management practices, e.g., NRCS Conservation Practice Standard 316 (Animal Mortality Facility).

The following resources should also be considered by the EP as part of developing its recommendations in addition to any relevant peer-reviewed or gray literature identified and reviewed by the EP:

File Resources accessible from: Chesapeake Bay Program's OneDrive Cloud Storage. Access available upon request from AgWG Coordinator.

1. Previously approved CBP documents relating to animal mortality management
2. Mortality and carcass nutrient data
    a. Poultry
    b. Swine
    c. Cattle

Online Resources:
1. Spartan Compost Optimizer
   http://www.canr.msu.edu/managing_animal_mortalities/composting_tools

Timeline and Deliverables
The Expert Panel project timeline for the development of the panel recommendations is based on reasonable expectations informed by previous CBP BMP Expert Panels.

- **Spring 2018** – EPEG recommendations approved by AgWG; Virginia Tech issues Request for Proposals (RFP) to solicit panel membership
- **Summer 2018** – Virginia Tech selects proposal and shares proposed panel membership with CBP partnership for feedback; final proposed panel membership brought to AgWG for approval
- **Fall 2018** – Panel hosts open stakeholder session and face-to-face meeting
- **Summer 2019** – **Target date** for panel to release full recommendations and final report for approval by the AgWG, WTWG, and WQGIT. This process is expected to take three to six months.
- **Summer/Fall 2019** – If approved by the partnership, panel recommendations are final and will be represented in the Phase 6.0 modeling tools in 2019 as part of the model updates.

Separately, during spring and summer of 2018, CBPO staff and the AgWG will work to update the previously approved interim BMP for mortality management[3] to clarify the nutrient reductions that can be used for planning purposes.

Phase 6.0 BMP Verification Recommendations:
The panel will utilize the Partnership approved ***Agricultural BMP Verification Guidance***[4], as the basis for developing BMP verification guidance recommendations that are specific to the BMP(s) being evaluated. The panel's verification guidance will provide relevant supplemental details and specific examples to provide the Partnership with recommended potential options for how jurisdictions and partners can verify livestock and poultry mortality management practices in accordance with the Partnership's approved guidance.

Attachment 1: Outline for Final Expert Panel Reports

- Identity and expertise of Panel members
- Practice name/title
- Detailed definition of the practice
- Recommended nitrogen and phosphorus loading or effectiveness estimates
    - Discussion may include alternative modeling approaches if appropriate
- Justification for the selected effectiveness estimates, including
    - List of references used (peer-reviewed, unpublished, etc.)
    - Detailed discussion of how each reference was considered, or if another source was investigated, but not considered.
- Description of how best professional judgment was used, if applicable

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3 https://www.chesapeakebay.net/channel_files/23293/mortality_management_interim_bmp_recommendation_04212016_5.pdf

4 http://www.chesapeakebay.net/documents/Appendix%20B%20-Ag%20BMP%20Verification%20Guidance%20Final.pdf

- Land uses to which the BMP is applied
- Load sources that the BMP will address and potential interactions with other practices
- Description of pre-BMP and post-BMP circumstances, including the baseline conditions for individual practices
- Conditions under which the BMP works:
    - Should include conditions where the BMP will not work, or will be less effective. An example is large storms that overwhelm the design.
    - Any variations in BMP effectiveness across the watershed.
- Temporal performance of the BMP including lag times between establishment and full functioning (if applicable)
- Unit of measure (e.g., feet, acres)
- Locations within the Chesapeake Bay watershed where this practice is applicable
- Useful life; effectiveness of practice over time
- Cumulative or annual practice
- Description of how the BMP will be tracked, reported, and verified:
    - Include a clear indication that this BMP will be used and reported by jurisdictions
- Suggestion for a review timeline; when will additional information be available that may warrant a re-evaluation of the estimate
- Outstanding issues that need to be resolved in the future and a list of ongoing studies, if any
- Documentation of any dissenting opinion(s) if consensus cannot be reached
- Operation and Maintenance requirements and how neglect alters performance

Additional Guidelines

- Identify ancillary benefits and unintended consequences
- Include negative results
    - Where studies with negative pollution reduction data are found (i.e. the BMP acted as a source of pollutants), they should be considered the same as all other data.
- Include results where the practice relocated pollutants to a different location. An example is where a practice removes nutrients from the farmstead but moves the nutrient into subsurface water flow and/or groundwater via burial.

In addition, the Expert Panel will follow the "data applicability" guidelines outlined Table 1 of the Water Quality Goal Implementation Team Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model[5].

References

Hamilton, D., K.Cantrell, J. Chastain, A. Ludwig, R. Meinen, J. Ogejo, and J. Porter. 2016. Manure Treatment Technologies: Recommendations of the Manure Treatment Technologies Expert Panel to the Chesapeake Bay Program's Water Quality Goal Implementation Team to define Manure Treatment Technologies as a Best Management Practice. With J. Hanson, B. Benham, C. Brosch, M. Dubin, A. Toy, and D. Wood for EPA Chesapeake Bay Program. Agriculture Workgroup. https://www.chesapeakebay.net/documents/MTT_Expert_Panel_Report_WQGIT_approved_Sept2016.pdf (accessed 2 Feb. 2018).

[5] https://www.chesapeakebay.net/documents/CBP_BMP_Expert_Panel_Protocol_WQGIT_approved_7.13.15.pdf

LPE Learn Center. 2017. Animal Mortality Management Conservation Practices: A Virtual Tour. LPELC.org. United States Cooperative Extension System. https://lpelc.exposure.co/animal-mortality-management-conservation-practices (assessed 2 Feb. 2018)

NRCS. 2016. Animal Morality Facility (No.)(316)(9/15). Conservation Practices. USDA. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849 (accessed 1 Feb. 2018).

Payne, J. 2015. What Are Common Animal Disposal Options. eXtension. United States Cooperative Extension System. https://articles.extension.org/pages/66140/what-are-common-animal-mortality-disposal-options (accessed 31 Jan. 2018).

Statement of Work (SOW)
Animal (Livestock and Poultry) Mortality Management BMP Expert Panel
Submitted for consideration to the
Chesapeake Bay Program (CBP) partnership
Water Quality Goal Implementation Team (WQGIT), Agriculture Workgroup (AgWG),
Watershed Technical Workgroup (WTWG) and advisory committees

Approved by the AgWG on August 16, 2018

Overview

Fate of nutrients (Total Nitrogen, TN, and Total Phosphorus, TP) released by animal mortality disposal are not explicitly covered in the Chesapeake Bay Program (CBP) Phase 6.0 Watershed Model (CB Model). The only disposal method currently covered by the Bay Model is composting, and there is no mechanism for entering the mass of TN and TP contributed by mortality composting to the model.[1]

This statement of work describes how the proposed expert panel will be brought together to write a report to the CBP Agriculture Workgroup (AgWG) recommending estimated loadings and BMP effectiveness values of TN and TP to the CB Model from disposal of routine poultry and livestock mortalities.

As requested by the AgWG[2] the panel will evaluate, define and describe disposal methods, which will include (but may not be limited to): burial, composting, landfilling, incineration or gasification, and refrigerated storage followed by rendering. The panel will determine the environmental fate of TN and TP in the defined disposal methods relative to a background method (burial). The panel will recommend how mortality management can be represented in the CB Model. The panel will provide Best Management Practices (BMP) verification guidance for the defined mortality management methods to supplement existing AgWG BMP Verification Guidance as needed. The panel will address other hazards and concerns with mortality disposal, such as potential microbial contamination of surface and ground waters and spread of animal and human diseases.

The total panel will consist of seven members identified here: the panel chair, five land grant university panelists representing a wide range of expertise, and a representative of USDA who is familiar with relevant USDA-Natural Resources Conservation Service (NRCS) conservation practice standards. Three additional non-voting representatives from the CBP Watershed Technical Workgroup (WTWG), the CBP modeling team, and EPA Region III office will be identified by the CBP prior to formation of the panel.

The panel will be supported under Virginia Tech's cooperative agreement with the EPA-CBP for Expert Panel Management. This includes facilitation and administrative support by Virginia Tech's Panel Coordinator (Jeremy Hanson), plus resources for panelists' travel to in-person meetings and a portion of the Panel Chair's time to compensate for the significant effort required as Panel Chair.

Proposed Expert Panel Membership

Letters of collaboration, curriculum vitae and Conflict-of-Interest Disclosure forms for the proposed panel members are provided in Attachments A, B and C for consideration by the CBP partnership.

Douglas W. Hamilton (Panel Chair), PhD, PE Doug Hamilton is Associate Professor and Extension Waste Management Specialist at Oklahoma State University. Dr. Hamilton has previously chaired the CBP expert panel on Manure Treatment Technologies, and served on the Animal Waste Management Systems expert panel. He has developed guidance for successful operation of routine poultry mortality composters and lead carcass disposal efforts during recovery from wildfires in Oklahoma during spring 2018. Dr. Hamilton will provide expertise in evaluating Nutrient Management Plans and document preparation.

Thomas M. Bass Tommy Bass is an Associate Extension Specialist at Montana State University. He conducts research and provides extension programming in environmental and emergency management of livestock and poultry production, as well as, sustainability in local/regional food systems. He has conducted agricultural and food waste composting research and consulting for 12 years, including routine and mass animal mortality composting. He has also been a nutrient management planner and CAFO permit coach in Montana and Georgia. Mr. Bass will provide expertise in sustainable livestock systems, nutrient management planning, and carcass disposal methods.

Amanda Abnee Gumbert, PhD Amanda Gumbert is an Extension Specialist for Water Quality at the University of Kentucky. Dr. Gumbert currently serves as lead co-chair of SERA-46, a multi-state land grant university team focused on reducing nutrient losses in the Mississippi River Basin. She provides leadership on agricultural water quality policy in Kentucky and develops educational materials with practical approaches for farmers (including two extension publications focused on proper disposal of animal mortalities). Dr. Gumbert will provide expertise in on-farm water quality best management practices and task group facilitation.

Ernest P. Hovingh, PhD Ernest Hovingh is an Associate Research Professor and Extension/Field Investigation Veterinarian at the Pennsylvania State University. He is leader of the Veterinary Extension Program Team at Penn State. Dr. Hovingh has conducted research in the epidemiology of antimicrobial-resistant and zoonotic bacteria from livestock facilities. He has been trained as an expert in large animal carcass management. Dr. Hovingh will provide expertise in biosecurity and lend the perspective of veterinary medicine to the panel.

Mark Hutchinson Mark Hutchinson is Extension Professor at the University of Maine. He is director of the famed Maine Composting School and a USDA Subject Matter Expert in Animal Carcass Composting. He has also provided extension programming in organic vegetable production. Mr. Hutchinson will provide expertise in carcass composting methods, compost quality evaluation, and incorporation of composting in sustainable livestock systems.

Teng Teeh Lim, PhD, PE Teng Lim is an Associate Professor of Agricultural Systems Management at the University of Missouri. Dr. Lim has extensive research experience in dust, odor, and gaseous emissions in animal agriculture. He has conducted research and has provided extension programming in biosecurity and animal mortality management. He co-wrote the ASABE standard for animal mortality composting. Dr. Teng will provide expertise on engineered systems for sustainable production and mortality disposal methods.

George (Bud) Malone Bud Malone is retired Extension Poultry Specialist with the University of Delaware. He currently consults part time as Malone Poultry Consulting. Mr. Malone has extensive experience working with poultry litter and mortality management. He will provide expertise on poultry production and general animal agricultural practices on the DelMarVa peninsula.

Sandra L. Means, PE Sandy Means is an Environmental Engineer on the National Animal Manure Nutrient Management Team for USDA-NRCS at the East National Technical Support Center in Greensboro, North Carolina. Her responsibilities include development of policy, review of standards, and delivery of technical assistance and training nationally to assist in the transfer of innovative technologies to the field. She will act as representative of USDA and as an expert on USDA-NRCS practice standards, programs, and policy.

Narrative of Initial Timeline and Tasks to Fulfill Scope of Work

The process to create the recommendation report will adhere to *Protocol for the Development, Review and Approval of Loading and Effectiveness Estimates for Nutrients and Sediment Controls in the Chesapeake Bay Watershed Model*[2] *(BMP Protocol)*. Sequential steps to achieve this process are outlined as follows. An initial timeline to meet narrative goals is given in Table 1. As the panel progresses the timeline is subject to change to reflect partnership needs or panel capacity.

Kick-off Meeting: A two day, face-to-face meeting will initiate the project. The meeting location will be in a central location in the Chesapeake Bay Watershed (CBW). Before the meeting, the panel chair will provide an outline of project goals; the BMP Protocol; USDA-NRCS 590 Nutrient Management Standards, USDA-NRCS 316 Animal Mortality Facility Standards, and state rules for disposal of livestock and poultry carcasses for each state in the CBW. On the first day of the meeting, the panel member representing the CBP modeling team will brief expert panelists on the CBP model and how recommendations from the panel may affect the model. The panel will outline specific water quality and biosecurity concerns related to carcass disposal, and develop a specific timetable for panel goals. On the morning of the second day, the panel will finalize disposal options for consideration, form task groups to tackle goals, and assign tasks to achieve before the first panel conference call.

Public Forum: An open forum to garner input, aid in data set identification, and to identify any additional carcass disposal methods for consideration will be held in the CBW. This forum will be held on the afternoon of the first day of the initial face-to-face meeting. This forum will be organized and advertised by CBP.

Task Groups: In order to facilitate efficient collection of data, the expert panel will divide itself into several smaller task groups. These groups of two or three individuals will be self-forming. Task groups will collect data on fate of TN, TP, and pathogens, and will recommend BMP verification and biosecurity procedures for each carcass disposal method. Task groups will remain intact until the recommendation report is written.

Panel Communication: The panel chair will establish a common protected virtual space (for example a Google Team Drive or One Drive/Sharepoint) where panelists can securely share information and data. In addition to face to face meetings, panelists will communicate in monthly conference calls.

Collection of Data Sets: Task groups will gather data sets for the selected disposal methods and rank their validity using criteria of Table 1 of the *BMP Protocol*.

Analysis of Data: Using data sets and best professional judgment of the panelists, selected disposal methods will be analyzed. Each group will prepare a written report giving a detailed definition of the disposal method and results of data analysis. This report will also include a list of references and a discussion of how each reference was considered.

Consensus of Results: A second face-to-face meeting will be held in which task groups will orally present the reports created during the data analysis phase. Draft reports will be available to all panelists before this meeting on the common virtual space. The panel will evaluate and provide feedback to each task group. Dissenting opinions of panelists will be noted and preparation will be made to add these dissenting views as an appendix to the recommendations report. The second face to face meeting will be held in a central location in the CBW.

Preparation of Draft Report: The Panel Chair will coalesce the task group reports into a draft final report. The Panel Chair will send the draft report to entire panel via the common virtual space. Panelists will return written comments to chair in one month.

Approval of Final Recommendation Report: After one month's review time, the expert panel will approve or disapprove of the document via voice vote in a conference call. In the case of non-unanimity, a separate dissenting report will be attached as an appendix. The Panel Chair will then forward the report to Agricultural Work Group as prescribed by the *BMP Protocol*.

References:

1. *Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model.* July 14, 2014. Chesapeake Bay Program Water Quality Goal Implementation Team.

2. *Recommendations for Livestock and Poultry Mortality Management*. March 15, 2018. Chesapeake Bay Program. Animal Mortality Expert Panel Establishment Group,

Table 1. Timeline to Meet Expert Panel Goals.

	2018			2019												2020		
	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Kick-Off Meeting	■																	
Public Forum	■																	
Final List of Disposal Methods and Animal Groups	■																	
Collection of Data Sets		■	■	■														
Analysis of Data				■	■	■	■	■										
Initial Reports Delivered to Panel by Task Groups								■										
Second Meeting to Come to Consensus on Nutrient Delivery, BMP Verification, Potential Modelling of Practice									■									
Panel Chair Coalesces and Writes Draft Report to CMP AgWG									■	■	■							
Approval of Draft Report by Panel											■	■						
Report Delivered to CBP AgWG												■						
CBP Partnership Review and Approval													■	■	■	■	■	■

Appendix B: Technical Requirements for Entering the Animal Mortality BMPs into CAST

Version: August 8, 2023 (Final)

Background: In June 2013 the Water Quality Goal Implementation Team (WQGIT) agreed that each BMP expert panel would work with CBPO staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert panel report. The focus on the Expert Panel's report is focused on animal units and their associated nutrients. However, the purpose of this technical appendix is to describe how the expert panel's recommendations will be integrated into the modeling tools including NEIEN, CAST and the Watershed Model. This involves how a load source reduction value for animal mortality BMPs can be incorporated as an approved BMP in the next version of CAST after CAST-21/23. The expectation is that the Expert Panel recommendations will be approved in Fall 2023. Some aspects of the panel's recommendations may not be applicable until Phase 7 of the Watershed Model.

Q1. What practices will be available for planning scenarios in CAST-21/23 and as approved BMPs in a future CAST update? Are any current planning or approved BMPs affected or superseded by these new practices?

A1. Following adoption of the panel's recommendations of the following BMPs to be available in CAST, and reportable to NEIEN, but will not be simulated as part of official Progress scenarios until the next version of CAST is released.

The previously existing Mortality Composters BMP will be replaced with the new Animal Mortality Disposal by Composting practice (see below for definition).

The current planning-only BMP for broiler mortality freezers will be eliminated and replaced in favor of the rendering BMP, which includes the use of freezers or refrigeration units to store mortalities prior to transfer to the rendering facility.

Animal mortality disposal by landfill or rendering is the handling, storage and disposal of poultry, livestock, or other routine animal mortalities by internment in a landfill or processing at a rendering facility. Report units of animal units or tons of carcasses of dead animal by animal type for an annual practice or in units of systems for a structural system.

Animal mortality disposal by burial is the handling and disposal of poultry, livestock, or other routine animal mortalities by placing the carcass or carcasses below ground into an excavated pit, hole, or trench, which is then covered or capped. This practice is considered a baseline management practice and not as a reportable CBP BMP for nutrient reduction credit.

Animal mortality disposal by incineration is the handling, storage and disposal of poultry, livestock or other routine animal mortalities by thermochemical conversion using combustion, gasification, pyrolysis, or some combination of those methods. The methods result in gaseous and solid byproducts. It is expected that most nitrogen is transformed and lost to the atmosphere, while all phosphorus remains available for land application or for transport. Report units of animal units or tons of carcasses of dead animal by animal type for an annual practice or in units of systems for a structural system.

Animal mortality disposal by composting is the handling, storage and disposal of poultry, livestock or other routine animal mortalities by composting including one or more of the following, alone or in combination: static piles and windrows (a.k.a. passive piles), turned windrows, static aerated windrows, a bin system, a tunnel composter, or in-vessel composter such as a rotating drum. Report units of animal units or tons of carcasses of dead animal by animal type for an annual practice or in units of systems for a structural system.

The guidelines for structural systems related to animal mortality management under the current NRCS Conservation Practice (CP) 316 practice can be found here. These should be referenced when determining eligible structures to report. The CP listed above has additional criteria specific to mortality management practices on pages 2-3 that should be reviewed.

Resource Improvement (RI) practices are also eligible for mortality composting. The CBP standards can be found here on page 11-12.

**Note: CP 316 is the national standard and individual states can include additional standards and restrictions. These state-specific standards should be examined before data is reported.

Q2. What are the reductions a jurisdiction can claim for planning purposes under these practices in the Phase 6 Watershed Model?

A2. The panel's recommended transfer efficiency values had unintended consequences when applied in Phase 6, which does not have a dedicated nutrient load source for animal mortalities. To streamline the reporting and simulate the recommended effects for each BMP, an analysis between the panel's recommended nutrient pathways was performed using burial as a baseline, which yields the relative efficiency values shown in Table B.1 (see Attachment A; Mortality Memo Efficiency Recommendations; Table 1 for more details). These efficiency values are proposed for the animal mortality BMPs for the Phase 6 Watershed Model and can be adapted or replaced if an explicit animal mortality load source is added in the next model version (Phase 7).

Table B.1. Proposed mortality BMP efficiency values for application to feeding space load source in Phase 6 Watershed Model.

Pollutant	**Burial**	**Compost**	**Incineration**	**Rendering**
TN	0	0.124%	0.372%	0.372%
TP	0	0.059%	0.059%	0.059%
TSS	N/A	N/A	N/A	N/A

In this case, it is assumed that the system is a mortality composter, and the number of animals is determined with the following conversion (from CAST detailed source data – Animal):

Table B.2 – CAST conversion rates of animals per system

State	Animal Name	Average animal count per system	Animals per Animal Unit (AU)	Acres per animal count
All	turkeys	3,744	38.33866	0.000023

All	beef	22	1.14	0.001890
DC	Broilers	198,096	163.93	0.000003
DE	Broilers	198,096	136.9826	0.000003
MD	Broilers	198,096	163.93	0.000003
NY	Broilers	198,096	178.0822	0.000003
PA	Broilers	198,096	178.5749	0.000003
VA	Broilers	198,096	175.4352	0.000003
WV	Broilers	198,096	256.3884	0.000003
All	dairy	84	0.74	0.002881
All	Goats	13	15.38	0.000344
All	Swine (Hogs and pigs for breeding)	428	2.222222	0.000311
All	Swine (hogs for slaughter)	74	3.703704	0.000111
All	horses	7	1	0.006765
All	layers	1,720	250	0.000040
All	other cattle	43	3.34	0.002385
All	Pullets	9,734	352.5	0.000010
All	Sheep and lambs	33	10	0.000574

Applying those animal counts and the panel's recommendations (mortality nutrients per AU) translate to the above estimates, using CAST values.

Q2. What types of projects are eligible to receive credit in the Phase 6 Watershed Model?

A2. Any mortality management practice or method mentioned that meets the definitions above in Q1/A1 and treats routine animal mortalities from one of the animal groups listed in Table B.2 above. Practices or methods used for catastrophic mortality events are not eligible under this set of practices. Practices or methods that are also used to treat manure should not be reported twice, i.e., they should not be reported as both mortality and manure treatment practices.

Q3. **How do the new BMPs relate to existing NEIEN practices and what will jurisdictions need to submit to NEIEN to receive credit for these practices upon approval for progress?**

A3. For now, these BMPs are for planning purposes only until the next version of CAST, anticipated in 2024, but they can be reported into NEIEN immediately, though they will not be credited for progress until next progress assessment after the CAST version release.

The jurisdictions will need to report the following into NEIEN:

- BMP Name:
  - Animal mortality disposal by incineration

- Animal Mortality Facility (NRCS316), Animal Compost Structure RI, Composter Facilities, Composting Facility, Dead Bird Composting Facility, Animal mortality disposal by composting
- Animal mortality disposal by rendering or landfill

- Measurement Name: Any one of the following can be used.
  - au , Unit = count
  - beef , Unit = count
  - broilers , Unit = count
  - dairy heifers , Unit = count
  - goats , Unit = count
  - hogs and pigs , Unit = count
  - hogs for slaughter , Unit = count
  - horses , Unit = count
  - layers , Unit = count
  - livestock , Unit = count
  - no , Unit = count
  - no systems , Unit = count
  - no. systems , Unit = count
  - number , Unit = count
  - other cattle , Unit = count
  - poultry , Unit = count
  - pullets , Unit = count
  - sheep and lambs , Unit = count
  - st , Unit = count
  - swine , Unit = count
  - systems , Unit = count
  - turkeys , Unit = count

- NEIEN geographic BMP site location: [Latitude, Longitude; County; County (CBWS Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBWS Only)]
- Year the animal mortality management practice was implemented.
- *Load source Group*: Permitted feeding operation, non-permitted feeding operation, feeding operation

Q4. What should a jurisdiction include in CAST in order to receive credit for these practices?

A4. Jurisdictions must include the animal type and either the animal count or animal number (AUs) of mortality of the production/inventory of the operation during the reporting period, or the weight (tons) of carcasses disposed using the BMP. All systems, tons, animal counts, or AU are converted to acres using the standard conversions, above.

Q5. Which land use categories are eligible to receive nutrient reduction credit from mortality BMPs in the Phase 6 Watershed Model?

A5. In the Phase 6 Watershed Model, nutrient reductions from mortality BMPs can be applied to permitted feed operations or non-permitted feed operations. If neither land use is provided in NEIEN, the credit will be applied to the default category, “feed operations”, and the reduction is distributed proportionally between permitted and non-permitted feed operation land uses.

Q6. Are these BMPs annual or cumulative practices?

A6. These practices are cumulative with a model credit duration of 5 years.

Q7. How does this relate to the previous planning BMP for “Broiler Mortality Freezers”?

A7. In 2019, the Agricultural Workgroup established a planning BMP for “broiler mortality freezers” that used values from Felton et al (2009) – part of the Simpson and (Weammert) Lane (2009) report – to estimate a manure transport credit of 29 lbs N and 4.9 lbs P per ton of dead broiler carcass transported out of the county or watershed. The proposed new BMP for “mortality disposal – landfill or rendering” encompasses the same practice, but as part of the larger “rendering” practice that will be available as an approved BMP with the next release of CAST.

Q8. Is this practice mutually exclusive with other practices?

A8. Each mortality BMP is mutually exclusive from one another, but these mortality practices are not mutually exclusive with other practices applied to the feeding space load source. In other words, a maximum of one type of mortality BMP can be applied for a given set of animals, but other non-mortality BMPs can also be applied (e.g., barnyard runoff control or loafing lot management).

Checks are in place to ensure that the sum of all three mortality BMPs does not exceed the domain of dead animals. The maximum number of animals that these BMPs, as a group, can be applied is the number of animal units times the mortality fraction, since the mortality BMPs are mutually exclusive with each other.

Q9. Are reported mortality BMPs assumed to have an Animal Waste Storage Facility on the property?

A9. No. The Animal Waste Storage BMPs must be reported separately in order to receive simulated reductions for those practices.

Q10. How do mortality BMPs relate to other barnyard practices in the Phase 6 Model, such as Animal Waste Management Systems, Barnyard Runoff Controls and Loafing Lot Management?

A10. These practices should be tracked and reported separately. It is likely that many facilities with a mortality storage or disposal systems will also have a combination of other barnyard practices employed on-site to control runoff from feeding and loafing lot areas. States may report multiple barnyard practices and mortality practices for the same site if applicable.

Q11: How does the existing “Mortality Fraction” in CAST relate to the panel recommendations?

A11: The mortality fraction in CAST determines the maximum portion of dead animals eligible for mortality practices. It is a single value for each animal type (seen below in Table B-4).

Table B-4. Current CAST mortality fraction and proposed new mortality fraction, based on the Expert Panel’s mortality estimates.

Animal Name	Mortality Fraction	Proposed mortality fraction
turkeys	0.07	0.15
pullets	0.10	0.08 (using layers as proxy)
dairy	0.06	0.10
goats	0.06	0.03 (using other cattle as proxy)
broilers	0.05	0.05
beef	0.06	0.09
hogs for slaughter	0.06	0.05
layers	0.10	0.08
hogs and pigs for breeding	0.06	0.08
horses	0.06	0.01
other cattle	0.06	0.03
sheep and lambs	0.06	0.03 (using other cattle as proxy)

The proposed change to the mortality fraction will be incorporated in the next version of CAST.

In Phase 6, the mortality fraction acts as an upper limit for the amount of nutrients from the feed space load source and can be removed through the mortality disposal BMPs described in this appendix.

Appendix C: Conformity of report with BMP Protocol

1. **Identity and expertise of panel members***:* See Background, Expert Panel Process section, Table B.1.1.
    - **Practice name or title:** See Appendix B
    - **Detailed definition of the practice***:* See Appendix B
    - **Recommended N, P and TSS loading or effectiveness estimates:** See Appendix B for how the loading estimates can be applied in Phase 6 CAST.
2. **Justification of selected effectiveness estimates***:* Described throughout the report.
3. **Description of how best professional judgment was used, if applicable, to determine effectiveness estimates:** Described throughout each section of the report.
4. **Land uses to which BMP is applied:** See Appendix B
5. **Load sources that the BMP will address and potential interactions with other practices:** See Appendix B
6. **Description of pre-practice and post-practice circumstances, including the baseline conditions for individual practices:** Described in each respective section of Part II.
7. **Conditions under which the practice performs as intended/designed:** Described in each respective section of Part II.
8. **Temporal performance of BMP including lag times between establishment and full functioning:** Disposal methods described in Part II generally have immediate intended effect as long as they remain in use and maintained during life cycles of the relevant animal types.
9. **Unit of measure: Locations in CB watershed where the practice applies:** See Appendix B
10. **Useful life; practice performance over time**: Design life depends on the practice and effective life may exceed design life depending on operations and maintenance.
11. **Cumulative or annual practice:** See Appendix B
12. **Recommended description of how practice could be tracked, reported, and verified:** Described in multiple places where appropriate.
13. **Guidance on BMP verification***:* N/A, will follow relevant agriculture sector verification guidance as it relates to given jurisdictional programs and BMP tracking/reporting.
14. **Description of how the practice may be used to relocate pollutants to a different location:** Mentioned throughout the report, particularly for each disposal method in Part II. Each disposal method or practice type has slightly different impact or nutrient transformations.
15. **Suggestion for review timeline; when will additional information be available that may warrant a re-evaluation of the practice effectiveness estimates:** Incorporation of animal mortalities as a

potential load source using the panel's recommendations should be considered by relevant partnership groups during development of Phase 7 watershed model.

16. **Outstanding issues that need to be resolved in the future and a list of ongoing studies, if any:** Indicated in *Review of science and literature* and *Future research and management needs* sections.

17. **Documentation of dissenting opinion(s) if consensus cannot be reached:** Full consensus on recommendations was achieved.

18. **Operation and Maintenance requirements and how neglect alters the practice effectiveness estimates:** Described in Part II.

19. **A brief summary of BMP implementation and maintenance costs estimates, when this data is available through existing literature:** Not provided in the report given the wide scope of practices and animal types

20. **Technical appendix:** See Appendix B for incorporation in Phase 6 CAST

Appendix D. Compilation of panel minutes

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Thursday, November 15, 2018, 12:00PM-1:00PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance. Doug thanked everyone for agreeing to serve on the panel. Participants introduced themselves.

Overview of Chesapeake Bay Program, BMP expert panel process

- Jeremy described the Chesapeake Bay watershed, the Chesapeake Bay Program (CBP) partnership structure, and introduced the Chesapeake Bay TMDL to participants. He explained the basic process for BMP expert panels like this one. He noted the recent CBP Quick Reference Guide for BMPs is a useful resource for understanding BMPs in the Model. Detailed data and documentation can be found on the Chesapeake Assessment Scenario Tool (CAST) website: http://cast.chesapeakebay.net/
- *Post-meeting note*: A recording of this meeting was shared with panelists, but the presentation also closely resembles the one Jeremy gave at the panel's open stakeholder session, which can be viewed here: https://www.chesapeakebay.net/what/event/open_stakeholder_session_animal_mortality_management_bmp_expert_panel

Timeline and next steps

- Doug reviewed the panel's basic charge and tasks, noting that the group will get into the specifics at their face-to-face meeting in two weeks.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, November 28 to Thursday, November 29, 2018
Meeting

Name	**Affiliation**	**Present? Day 1**	**Present? Day 2**
Doug Hamilton	Oklahoma State University	Y	Y
Thomas Bass	Montana State University	Y	Y
Amanda Abnee Gumbert	University of Kentucky	Y	Y
Ernest Hovingh	Pennsylvania State University	Y	Y
Mark Hutchinson	University of Maine	Y	Y
Teng Teeh Lim	University of Missouri	Y	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y	Y
Panel Support			
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y	Y
Jeff Sweeney	EPA, CBPO	Y (online)	Y (online)
Mark Zolandz	EPA, Region 3	Y	Y
Loretta Collins	UMD, CBPO	Y	Y
Mark Dubin	UMD, CBPO	Y	Y

Welcome and introductions, review panel charge and meeting objectives

- Jeremy and Doug welcomed participants and verified attendance.
- Everyone introduced themselves and Doug led ice-breaker exercise.
- NRCS jargon, practice is animal mortality management; incineration and other approaches are "methods."

Overview Chesapeake Bay Watershed Model

- Jeremy described how the Chesapeake Bay Watershed Model simulates animals and animal manure nutrients. He explained the difference in livestock and poultry data. They are both simulated at a county scale, but the states report litter nutrient content for poultry, whereas livestock is based on as-excreted values.
- He mentioned the Chesapeake Assessment Scenario Tool (CAST), which provides all source data and documentation on a public website at cast.chesapeakebay.net. In the Phase 6 Model, CAST is equivalent to the full Watershed Model. He encouraged panelists to explore the tool if they want more detailed information.

Animal agriculture in the CBW

- Jeremy walked through 2017 population data with the panelists for the 12 animal types in the Watershed Model. He mentioned the data is all publically available on CAST, and he explained how he summarized the data. There was discussion about which areas and animal types are dominant and should be priorities for the panel.

Role of NRCS and state agencies

- Sandy described the role of NRCS, and how to find and understand national and state conservation practice standards. She noted NRCS online field technical guide (eFOTG) is in transition. She reviewed Conservation Practice Standard (CPS) 316 for Animal Mortality Facility and CPS 368 for Emergency Mortality Management.
- Mark Z. and Teng noted that VA and other states forbid burial for routine mortality management for any state permitted poultry operations.
- Doug asked the group for thoughts about the scope and direction thus far. Tommy recalled concerns he had about the probable lack of refereed literature or data sources about routine mortality and nutrients. Doug agreed, noting the panel will have to struggle with that. Amanda asked if panels identify research gaps or make recommendations to EPA or others. Jeremy noted that every panel does include future research and management needs in their report.

Public stakeholder session

This portion of the meeting was recorded and is available to view along with other materials at https://www.chesapeakebay.net/what/event/open_stakeholder_session_animal_mortality_management_bmp_expert_panel

Debrief and next steps

- Doug: as we know, there are other experts or colleagues with related expertise. We can contact people if needed. Can cite personal communication and acknowledge others' contributions as appropriate.
- There was discussion if burial is indeed the baseline. Mark D. noted that the EPEG and Simpson & Weammert (2009) used burial as a baseline, so that was assumed to be the starting point, but now the panel may want to consider options for alternative baseline for comparison.
- The discussion continued to how to define the system, and when or where the nutrients are removed from the system, or moved to another sector, e.g., if hauled to landfill or captured as part of permitted discharge facility. Teng asked if there is enough data about burial and those nutrient loss pathways. Mark D. noted that there were difficulties with that information as well. Teng noted if there is no data for the baseline the task becomes even more difficult.
- Doug noted that the group may decide to challenge the assumption that manure nutrient include the nutrients from mortality. As-excreted values from ASABE would not even include bedding material, and definitely not mortalities. Mark D. and Bud noted the litter samples for poultry on Delmarva Peninsula would likely include mortalities though.
- There was discussion about how often farmers compost correctly; some experience suggests that majority of farmers in some areas do not compost correctly and this is a common reason for nuisance complaints.
- Doug noted that renderers in his region no longer accept animal mortalities. Based on discussion, maybe consider rendering as the method, with storage or freezers as components. Do we distinguish between landfill? Mark D. and Bud noted that they are not aware of any haulers or collectors that take animal mortalities to landfills, so that may not be common or done at all.

- There was continued discussion about how to group the methods, e.g., export/transport of the mass, composting, incineration/gasification. Freezers would be a supporting method that enables export/transport. Rendering would be a part of export.
- Bud noted that on Delmarva the freezers are installed with capacity for a whole flock, whereas in Midwest they do not have that much capacity planned, and that increases risk due to traffic while birds are present, as opposed to collection after flock is gone.
- Bud also pointed out that this region does have collection and rendering options for large animals. Delaware and Maryland have been spending some EQIP funding for freezers in recent years. Jurisdictions have already spent many resources on composting facilities. There was discussion about litter brokers; Doug and Amanda noted that if a broker finds a beak or evidence of dead birds they are either not allowed or they refuse to take it off farm. It would violate health or biosecurity codes/rules.
- It was noted that the Perdue pellet plant closed about a year ago, after operating at a loss for over a decade. They operated under capacity and could market it some places but were unable to make it profitable.
- Bud noted there is very limited published data on whole carcass nutrients. Perhaps a little more information on some of the components. Bud will share what he has with the group as far as literature.
- Doug described the approach for dividing the methods and data components up for tomorrow, start assigning groups for those tasks.

Adjourned, Day One

Day Two
Discussion of meeting and conference schedule

- The group discussed options for the next call and agreed to Thursday, December 13, 11:00AM – 12:00PM, EST.
- The group discussed recurring call time and agreed to second Wednesdays starting with January 9^{th}, 12:00PM – 2:00PM EST.
- The group agreed to reserve the last week of June as potential time for a second face-to-face meeting in the Annapolis area. Dates and details TBD.
- **ACTION**: Jeremy will send calendar invitations to panelists for the agreed-to dates.

Project scope, break into tasks and sub-tasks, report chapters, group assignments etc.
Doug led discussion about the organization of the eventual group report and agreement on writing assignments which are captured below.

- Exec. Summary
  - No assignment discussed as this will be a final piece.
- Charge, introduction, definitions and terms
  - Jeremy noted that he will assist with early sections and some of the boilerplate language.
- Death rates, masses, nutrients: what is the (potential) contribution of mortalities to total animal nutrients
  - A question was raised for ongoing consideration/thought from the group: how do NMPs account for carcass nutrients, if they do at all? Do they, or how often do

they? There was some discussion of this but the group will need to investigate and consider in more detail.

  - Poultry (broilers, layers, turkeys, pullets) – **Bud; Doug**
  - Cattle (dairy, beef, other cattle) **Ernest, Tommy**
    - Small ruminants (explain why considered but not addressed in recommendations). While the group discussed the exclusion of these animal types from the recommendations – given priorities, available data and the effort required – it was noted the animal types should still be acknowledged with an explanation about why they are not incorporated in final recommendations.
  - Swine – **Teng, Mark H**.
  - Horses – **Amanda, Sandy**
  - Small ruminants (goats, lambs, sheep)
- Biosecurity – **Tommy, Ernest, Bud**
- Laws and Regs (could be located elsewhere in report) – **Jeremy, Doug**
- On-farm storage, handling and transport
  - **Tommy, Bud will help on transport**
- Methods of disposal (each of these will be separate group; see next section for working outline and template)
  - Burial or disposal pit – **Amanda, Sandy**
    - Mark H. noted shallow burial as a method used in Virginia, but the group agreed that is only applicable to emergency or mass mortality situations.
  - Composting – **Mark H., Ernest**
    - Bud noted that the mushroom industry does not accept any compost with mortalities. They want consistent product. So the only real available alternative is land application.
  - Landfill – **Amanda, Doug**
  - Incineration or gasification – **Teng, Sandy**
  - Rendering – **Doug, Bud**
  - Emerging technologies – **Mark H., Teng**
    - Alkaline hydrolysis
    - Anaerobic digestion

Method chapters, working outline/template

Doug led discussion about the organization and content of the specific chapters for respective mortality management methods.

- Process Description
  - Describe the method/process
  - Describe common techniques
- Methods depending on animal types (considerations for different types of animals)
- Nutrient pathways and/or transformations (nitrogen and phosphorus)
- End use or fate (land application, transport, animal feed, etc.)
- Biosecurity issues specific to that method (landfill, composting, etc.)
- Current level of adoption within the Bay watershed,
  - …in relation to elsewhere, over or under utilized?
- Feasibility→practicality of the method

    - Cost information, when found or available. No analysis, just reference/cite available resources.
- Quality control
- Data gaps, research and management needs
- Hazards/Risks, ancillary benefits

Bud mentioned the Council for Agricultural Science and Technology (also referred to as CAST) has three reports on mortality management that will be useful references; Jeremy added them to the Google Team Drive (one report each for swine, poultry and bovine).

Discussion of literature, data quality characterization

- Doug and Jeremy reviewed Table 1 from the BMP Protocol with the group, explaining that all panels are expected to categorize the available literature sources using the criteria in Table 1. Most panels take a qualitative approach while some explicitly rank or score the literature in their assembled database.

Wrap-up, review actions and next steps

- Jeremy recapped the schedule for calls and meetings agreed to earlier in the day.
- Doug and Jeremy thanked everyone for their attendance and engaged participation for the two-day meeting.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Thursday, December 13, 2018, 11:00AM-12:00PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.
- Doug thanked everyone for joining and explained the goal for the short call, which is ensure everyone is comfortable with Google Team Drive and how to organize/share literature prior to the holiday break.

Literature review and organizational strategy, Google Team Drive

- Doug walked through the "Animal Mortality Management BMP Expert Panel" Google Team Drive. He explained he created an "unsorted literature" folder with everything uploaded so far, mostly from Mark H., Jeremy and Loretta, including information from the EPEG.
  - Doug explained the other folders he created within the Literature folder, labeled according to the sections/assignments discussed at the previous meeting.
  - Doug discussed the mortality composting chapter from Simpson & Weammert (2009) study as an example row for the poultry death rates, masses and nutrients literature.
  - The Team Drive saves changes automatically to Google Spreadsheets or other documents. If something is deleted accidentally, it can be restored from the trash within 30 days.
  - Bud mentioned a recently published study on poultry carcass composition that he will share with the group.
  - Doug: Panelists can upload files/folders to the relevant areas, or the unsorted literature folder to start.
  - Panelists should update the literature summary spreadsheets for each subgroup as they add reviewed articles to the subgroup folders. It will improve organization and the group's efficiency when compiling and writing the report later.

Recap and next steps

- Doug and Jeremy noted the panel's next call, scheduled for January 9th.
- **ACTION**: Panelists should begin uploading and reviewing literature for their respective assignments and also share relevant materials with other sub-groups.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, January 9, 2019, 12:00PM-1:00PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y

Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.
- Doug thanked everyone for joining asked participants to share their status and updates.

Literature status and updates

- *Poultry*. Bud noted there was one poultry nitrogen and phosphorus source up there, and that he added another review. Others welcome to read and share their input with him. He has reached out to Roseline Angel (sp?) at UMD who may know of other studies or information given her expertise with poultry and mass balances with N and P. Bud noted that many of the publications so far have different units, or measure dry weight while others do not. The group will have to do conversions. About 70% of the body weight is added in the last 10 days.
    - Amanda mentioned she found studies by Ritter in DE from the mid-90s investigating burial pits and groundwater quality. She asked if that would be helpful. Bud recalled the study, noting it wouldn't be relevant to practices done today. Doug noted that the study may still inform baseline, and since it is in DE it is worth looking into.
- *Swine*. Mark H. noted a study he found.
- *Equine*. Sandy mentioned it was difficult to find information for horses, but she had some general resources about the industry that she will upload.
- Bud gave an update on his efforts to speak with Valley Protein, who is a major renderer nationally and active in the watershed. He was exploring what kind of services they provide and other background information they might have.
- Mark H. noted he had been working on the spreadsheet template from Doug, inputting the information he gathered from the composting literature. He will upload to the Team Drive soon. He mentioned that Cornell has a spreadsheet of applicable various livestock and poultry waste management regulations.
- Doug noted that at least in Oklahoma, the state tracks when animals are sent to landfills.
- Teng and Sandy still had to get into gasification and incineration.
- Tommy mentioned he had technical difficulties with Zoom, but was on the call. He plans to dig into the literature at the end of January and will have more to share next time.
- Bud mentioned that the Proceedings of the National Poultry Waste Symposium would be a valuable source of information. He will look into getting digital copies of the proceedings.

Recap and next steps

- Doug noted that Jeremy had lost connection to Zoom. Doug thanked everyone and encouraged them to continue making progress on their assigned topics and the group will speak again in February.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, February 13, 2019, 12:00PM-1:00PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	Y
Mark Hutchinson	University of Maine	N
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.
- Doug thanked everyone for joining asked participants to share their status and updates.

Literature progress updates

- *Poultry*. Bud noted he was waiting for a response from Rosalina Angel (UMD). Jeremy will follow up with Loretta and Mark D. to see if they can get in touch with her via UMD. Bud explained Mark D. had been looking into poultry mortality rates and Bud is waiting for an update from him on that. Bud acknowledged Dr. Blake at Auburn for providing complete Proceedings of National Poultry Waste Management Symposium.
- *Cattle and small ruminants.* Ernest noted he has not had a chance to dig into this yet, but he will have more opportunity soon. Tommy had spent his time on his other assigned topics so far. He did have some decent basic data at national or some regional scales, mostly from APHIS. Some cattle composting sources did turn up. Still have to dig in further.

- *Swine*. Teng is still looking and has found some good data, but hopes to find more recent sources if they exist.
- *Equine*. Amanda noted that whole carcass analysis is not done, or very rarely done, based on what colleagues have told her. There are some analyses of horse meat and muscle mass in Europe, which might help us piece together some assumptions. Population data exists, but nothing yet for mortality rate.
- *On-farm storage and handling.* Only stuff on freezers so far is from the companies. Not much on transport or hauling. Bud explained that there are maybe half a dozen companies in PA that provide hauling or burial type services. He is still collecting more information about what is done. Tommy noted that aside from what is available in grey literature, extension publications, etc., the panel may have to rely on Bud and narrative information or personal communication.
- *Burial.* Sandy is placing calls to see if there is more specific information for the Bay watershed, but she has found some sources about burial pits and groundwater quality.
- *Landfilling.* Amanda reached out to Gary Flory, and she got some information …she has contact info for someone in Shenandoah County that should have some insights about landfills. Good accounting is not available.
- *Composting.* Mark H. was not on the call, but Doug noted that Mark H. has been working and updating his files regularly on the Team Drive.
- *Incineration/Gasification.* Sandy has uploaded what she located so far, but still has to transfer that info into a spreadsheet.
- *Rendering.* Valley Protein appears to be the largest protein renderer in the country, not just the watershed. Mortalities from Lancaster County in PA and Virginia are also transported to Valley Protein. A contact at National Renderers Association, provided some publications that Bud still needs to review. Valley Protein has multiple facilities, and in this area their facility in Winchester, VA receives the mortalities.
- *Emerging technologies.* Teng had to leave the call, and Mark H. was not on the line for an update.
- *Biosecurity.* Tommy has at least five decent papers to work from as a starting point. Bud noted there is a forthcoming paper from authors at UMD. They looked at birds and poultry farms on the Delmarva and may have relevant information for us when that is published.

Rules and regulations

- Jeremy shared a preliminary draft of "snapshot" profiles for mortality management in each of the Bay states. He noted he will continue to fill them in, and will be reaching out to state contacts. The profiles will be used as background, in report or as an appendix.
- Amanda suggested Jason Hubbard at WVU Extension as a contact for WV.

June meeting plans

- Doug suggested the panel might consider an afternoon trip or site visit on the second day of the meeting. Others preferred to avoid weekend travel, so the current plan is travel on Monday June 24, a full day meeting on Tuesday June 25, and then a half-day meeting Wednesday June 25 with optional site visit that afternoon, with an overnight for those who would need it to travel on Thursday.

Recap and next steps

- Jeremy noted the panel's next call is Wednesday March 13.
- Doug thanked everyone for their hard work and encouraged them to keep it up.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, March 13, 2019, 12:00PM-1:30PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	N
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.
- Doug thanked everyone for joining

June Meeting Plans

- There was general discussion of meeting plans for the end of June.
- Doug reminded panelists that the June meeting would be to reach consensus on draft key recommendations. Between now and then, the group needs to continue reviewing the literature, drafting summaries and answer the key questions charged to the panel (nutrients in carcasses, effects of the disposal methods).

Disposal methods

- Doug noted that composting is pretty far along given Mark H.'s efforts.
- Bud: antiobiotic free approach requires different methods for addressing stressors. Bud asked a colleague who will provide some more information to him. Bud is waiting to hear back from Mark D. about mortality numbers for animal types in the watershed.

- Doug asked about the end of life for laying hens, which is a completely different cycle than broilers. Jeremy noted that there are large populations of layers in the watershed, particularly in southeast PA, and the panel should investigate layers for recommendations. Broilers are the largest population of
- Bud has been reaching out to Rosalyn Angel; he knows she has some data from previous research, but could use some help from Mark or Loretta to follow-up with her. He recalled Mark D. was looking into possible mortality data, but waiting to hear back from Mark D. on that.
- Bud has talked with experts in MD and VA, along with some rendering company representative. He offered to share his rough notes with the group, but without individuals' names for sake of their confidentiality. He reiterated concerns from around the watershed about the proper management of composting on-farm.
- Tommy summarized some papers and research he added to the Team Drive. He had success finding beef and cattle mortality rates, but less success finding whole-carcass nutrient values. Tommy is asking some animal nutritionist colleagues to see if they are aware of unpublished data or other resources.
- Mark H. noted research by Tom Glainville at Iowa States for analysis of beef cattle carcass nutrient composition; he retired about 4 years ago.
- Tommy noted that he and Bud had a productive discussion about transportation in the region, and that Bud was compiling some really excellent information about regional practices that wouldn't be available through a lit review. Tommy could only find commercially available, largely promotional, materials or gray literature as far as temporary storage and transportation.
- Jeremy explained that everyone's default permission on the Team Drive only allowed them to add or edit files, but he will upgrade the panel members' permissions so that they can also move or delete files. The Team Drive does track activity, so if anyone deletes or moves something by accident, it can be restored within 30 days.
    - Post-meeting note: Panel members' permissions on the Team Drive have been upgraded to "content manager" so they can now move, add or delete files.
- Mark H. described some recent information he found about swine production.
- Doug asked about swine production in the region. Bud noted that hogs in Maryland are a small and declining population. Jeremy suggested referring back to the summary data for animal populations he compiled for the group's November meeting.
- Amanda described some data she and Sandy found for horses from APHIS for 2015, which includes death rates by age.
    - Doug suggested searching for that citation to identify any refereed articles that cite it, which might be good for swine too. Jeremy suggested Google Scholar as a starting point. Amanda agreed that Google Scholar works well for journal articles, but might not be as effective for a government publication like the APHIS report.

Recap and next steps

- Jeremy noted the panel's next call is Wednesday April 10.
- Doug asked everyone to work on an introduction and outline for next time.
- Doug thanked everyone for their hard work and encouraged them to keep it up.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, April 17, 2019, 12:00PM-1:30PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	N
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	N
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.
- Doug thanked everyone for joining

Updates

- Doug noted that Bud had provided a written update that will be shared with the panel.
- Doug recalled that Tommy spoke with him a week ago.
- Mark H. is waiting to hear back from Ernest so nothing new on swine.
- Amanda recalled the APHIS data source that was mentioned last time; found a few places where that data is referenced. Sandy is updating the spreadsheet for equine.
- Sandy has uploaded some resources on burial and is inputting the info into a spreadsheet.
- Mark H. is ready to start writing the compost chapter.
- Sandy has been unable to catch up with Teng on ___
- Bud and Doug continue to work on rendering; working to nail down those pathways.
- For alkaline hydrolysis, Mark H. and Doug recalled that the panel can include a paragraph or so to explain it as a "future technology" or something that might be worth visiting in the future, but not enough information at this time for a full review.
- Mark D. noted Virginia Tech is researching shallow burial for cattle and swine with woodchips. No peer-reviewed publications yet, but they may have some initial information in fact sheets. Mark H. noted he's part of that research group; the success rate was less than hoped, so it is premature to treat that method as a separate practice.

Doug agreed and suggested it can perhaps be mentioned as something that is currently being researched and may be pertinent to the region in the future. Gary Flory, Bob Pierre (sp?) and Bobby Clark.

- Mark D. noted he's looking into mortality information for turkeys and swine using some data collected for a CBP study.

Section outlines

- Doug discussed possible outlines for the panel's report; using the 2016 Manure Treatment Technologies panel report as an example for disposal methods chapters.
  - He pointed out that each chapter can mention types of systems that are excluded for the panel's purposes. The MTT panel provided a conceptual diagram of the flows/pathways for N and P; the mortality panel can discuss if we want to do something similar in June.
  - Doug walked through the sub-sections in the MTT report's composting chapter as an example.
- Amanda asked for clarification about the logistics for writing. Doug explained that the panel members will be the primary authors on the sections as we've previously assigned them; Doug and Jeremy will work as editors to put all the sections together.
- Doug shared a draft outline for June's reports, for the group to discuss and understand what we want to have ready for June.
- For the death rate, body composition and nutrients available questions
  - Death rate
    - Overall
    - Pattern within production system
  - Animal growth patterns
  - Carcass nutrient composition
  - Mass of carcass nutrients per typical farm per year
  - Mass of manure nutrients per typical farm per year
  - References
- There was discussion about the outline and Doug suggested that panelists save the manure nutrients item for later and focus on everything else between now and June. Jeremy noted that the CBP has extensive data about animal populations and manure that the panel can use in its analysis later.
- https://www.nass.usda.gov/Publications/AgCensus/2017/index.php
- Here's the detailed manure data for anyone who's curious: https://s3.amazonaws.com/cast-reports.chesapeakebay.net/public/Detailed-SourceData-Animal.xlsx
- ACTION: Jeremy will send outline to the group along with other supplemental information. Panelists can contact Doug or Jeremy with questions about the outline.
- Amanda: laws and regs, do we want that included somewhere
- Jeremy: we can include that kind of information in the report

June meeting logistics

- Doug noted that Oklahoma State will reimburse panelists for the June meeting. He will provide instructions to the panelists for how to get reimbursed.

Recap and next steps

- Jeremy noted the panel's next call is Wednesday May 8.
- Doug
- Doug thanked everyone for their hard work and adjourned the meeting.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, May 8, 2019, 12:00PM-1:00PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	N
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Updates

- Doug reminded everyone that the goal for the June meeting will be to review and discuss draft chapters, ideally reaching agreement on key conclusions and recommendations.
- Teng: Need to revisit some of the materials that were found a few months ago. He asked about the preferred format and organization.
- Doug recalled the outline discussed in April. Jeremy had emailed the outline to the group on April 17 alongside other links and documentation.
- Doug: for June, we want to focus mainly on first three items (death rates, animal growth patterns, carcass nutrient composition). The estimated mass of carcass nutrients or manure nutrients can come later based on the panel's compiled data and the CBP's data for manure and nutrients. Doug noted that the AWMS panel had described a "model farm" or typical farm for each of the animal types they considered. For our purposes,

panelists can consider the AWMS panel's typical farms, or look at a more aggregate level.

- Tommy: struggling to find whole carcass composition data. There's plenty of data for edible animal parts, but not whole carcass. Bud can check with National Renderer's Association, they are most likely to know about any resources, if available.
- Bud: Sent an update to Doug via email last month, but Doug has been unable to review that. Bud feels he has data to feel comfortable about overall growth patterns for broilers. Have average rates and weights for the watershed, adjusted for placement. The values were much different than what Simpson and Weammert (2009) found. Heard that Gary Felton has been doing full carcass analysis of frozen birds on the shore, curious if the group was aware of that effort and what that project or publication timeline might be.
- Amanda: we have death rates and growth information for equine, but the carcass composition is more difficult. Unsure right now how to consolidate the data for young and older horses.
- Tommy: Not much published for transport and storage, aside from industry publications or popular literature. Need extensive input from somebody in the watershed to fill in the blanks and details.
  - Doug: need to focus on potential loss pathways for any storage or transport of the dead animals. Bud: there are probably some ammonia losses once the animal starts to decay, but doubt there is any data on that.
  - Bud: have worked for the past couple years to track what is done in the watershed for handling mortalities. There are a couple facilities in WV and VA, and a couple facilities in PA that will compost large animals.
- Doug recalled the disposal method questions for June. Important to consider potential nutrient loss pathways (atmospheric, surface water or runoff, leaching, or other).
  - Sandy has a good start on burial for the first two items.
  - Doug noted that Mark H. was relatively far along for composting, but he wasn't on the line.
  - Teng: Can start writing soon. Not much data for incineration as far as nutrient content. Some NCSU extension data that at least has P and K data. Will keep looking, but not too hopeful about finding much data.
  - Bud: Still need to consider some of the materials in more detail before writing draft for rendering. There are cremation services for equine, especially for higher value horses; tradition is to bury the head, heart and hooves. Composting is often the encouraged method for managing the carcass. May have to consider certain chemicals that can linger in the compost.
- Doug noted there is more work to do on the biosecurity and the laws/regs section, but he felt the group was in better shape overall.

June meeting logistics

- Doug noted that the hotel room block and the meeting location are set. He has instructions that he will send to the group after the call.
- Bud: discussed visiting a broiler farm that composts; a dairy operation near Chestertown; may also visit a nearby farm with freezers if possible.

Recap and next steps

- Jeremy and Doug recapped the actions and next steps.
- Doug thanked everyone for their hard work and encouraged them to keep it up.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, June 12, 2019, 12:00PM-1:00PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Updates

- Doug
- *Swine:* Mark H. noted that Teng is taking the lead on swine so no updates at this time.
- *Cattle:* Have some decent mortality data for dairy and beef. Working with someone at the rendering association, and they have various data for carcasses down to proteins but not exactly what we need for our purposes and will need to extrapolate.
    - Bud and Mark H. noted some assumptions they are familiar with.
- Composting: Mark H. has a good outline and is starting to draft some paragraphs.
- Sandy: outlined and starting to draft for burial. Mark H. noted he has some interesting new research studies from Korea about burial and soil health. He will share with Sandy.
- Bud: Gary F. has students that have collected carcasses of C and N in the frozen birds at different ages. The paper is not yet complete, but may be ready to submit to a journal in the next month.
- Sandy and Teng need to touch base about combustion.

- Doug: Rendering and landfilling, still in the works.
- Doug shared draft of what he's been working on with Bud, including estimated mass of N and P in mortalities from a flock of 1,000 birds, with estimates based on typical finished weights.
- Doug and Tommy discussed possible differences between how the mortalities and data differ between cattle and poultry.
- Amanda agreed with Doug that horses are a special case from poultry and the other livestock. Will probably need to make some assumptions to get at the same type of bottom line information.
- Mark H. suggested that the data could be presented in terms of AU, so that there is some more consistency in the mortalities rates and suggested nutrient load estimates for each animal type.
- Mark H. for the Ag Census it is based on production not capacity.
- Mark D.: Ag Census is the head count on Dec 31 of that year.
- Bud: can use NRCS spreadsheet to calculate total pounds of mortality based on average age.
- Doug: each section/animal can have their own assumptions, graphs and steps based on the production parameters of that animal, but the end result should be in terms of AU.
- Doug: when we meet in two weeks, we'll discuss the logic for each animal type and the results for estimated N and P content/loads for that animal type per AU.
    - That's what we ultimately want to understand: how much N and P are potentially contributed by dead animals to the watershed.
- Doug: At the end of the composting process, want to understand what is left and retained for land application. For rendering, the remaining amount may be 0, at least from the ag perspective since that load would be part of a point source load.
- There was discussion of manure and mortality loads in current model:
- Doug: by doing this analysis it will be possible to compare carcass loads per AU to manure.
- Mark D: we do have some new management systems now, and the panel will help us understand how to simulate those different systems within the model, since some of the systems treat all the mortalities on site while others are full transport.

June meeting logistics

- Doug and Jeremy reviewed meeting logistics.

Recap and next steps

- Doug thanked everyone for their hard work and encouraged them to keep it up.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Day 1: Tuesday, June 25, 2019, 9:00AM-5:00PM
Day 2: Wednesday, June 26, 2019, 8:30AM-12:00PM
Meeting

Name	Affiliation	Present? Day 1	Present? Day 2
Doug Hamilton	Oklahoma State University	Y	Y
Thomas Bass	Montana State University	Y	Y
Amanda Abnee Gumbert	University of Kentucky	Y	Y
Ernest Hovingh	Pennsylvania State University	Y	Y
Mark Hutchinson	University of Maine	Y	Y
Teng Teeh Lim	University of Missouri	Y	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y	Y
Panel Support			
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y	Y
Jeff Sweeney	EPA, CBPO	N	N
Mark Zolandz	EPA, Region 3	Y	Y
Loretta Collins	UMD, CBPO	Y	Y
Mark Dubin	UMD, CBPO	Y	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Data to determine mass of nutrients from carcasses

Poultry

- Doug led discussion of the working draft about broilers, along with Bud. They had some initial estimates based on some NRCS spreadsheets. The NRCS may release a simplified version of that spreadsheet for 4, 6 and 8-lb birds. So far NRCS (Delaware) is just doing it for broilers.
- Some production data for turkeys is available. Mark D. has placement numbers

Swine

- Teng and Mark H. discussed the summary and draft report they have so far. Mark H. noted 3 of the references are still the "go-to" for body composition of swine; there hasn't been any new research to improve on those estimates so far. Need agreement on units. Ernest mentioned National Animal Health Monitoring System (NAHMS) as a potential resource.
- Teng and Mark H. noted that most of the sources only had P content, very little N data. Asked if they should use protein conversion approach or alternate method.

Horses

- Amanda reviewed what she and Sandy had so far. CBP uses horse council data at state level. They divided into the age categories for young and mature horses, noting a wide range of breeds in the data that was available. Jeremy pointed out the estimate of TN and TP per AU of horses was not adjusted for mortality like the poultry values.

- Mark H. noted that there is at least one custom compost facility in Pennsylvania that takes equine and other livestock to compost at their facility, and use or market the compost.

Cattle

- Tommy shared a draft spreadsheet and data. Virginia had some data for beef but he pulled from national data like NAHMS where available. Ernest noted that PA is part of the NAHMS survey. There was more difficulty finding body nutrient content data, had to reach out to outside experts for some numbers, getting some basic estimates of about 20% total protein from carcasses, which leads to some estimates of lbs N per 1000 lbs. Mark D. suggested that body composition could be higher for the region compared to range systems out west. Limited citations available for ash and protein content.
- Bud recalled the analytical chemistry papers that Tommy shared via email with the group, and asked if the group wanted to discuss methods or values to use for things like protein and ash.

Discussion

- Doug led discussion of the preferred units for the panel's recommended estimates. Mark D. suggested keeping it on AU-basis.
    - Doug: can provide the lbs per AU, but also more granulated data in relation to animal size or similar factors. Important to document the technique, steps and data used to calculate the estimates. **Lbs-nutrient per AU per year.**
    - Chapters for each animal type, followed by chapters for disposal methods. Will get into biosecurity, policy/regs and ancillary benefits/impacts.
    - Ideally, would like to have some comparison of a typical production system, comparison of dead animal nutrients to manure nutrients. Jeremy noted that comparison would be useful to help estimate or simulate the effect of the practices in the current Model and feed space load source.
    - Are there values for % N for protein and % P for ash? 16% TKN for protein and 18% P for ash? Estimates of protein in the animal are 18-20%
    - Mark H. noted the 16% conversion is pretty set and used by industry.

Review of data on disposal losses

- Doug highlighted some questions and considerations for disposal methods and turned it over for round robin updates.

Burial

- Sandy noted that burial is variable depending who performs it. She noted that most resources reference one particular study (Munro, 2001) for atmospheric losses, but have been unable to get a copy of that paper so far. (I can help with that, via iLLiad). Most research done has focused on leachate. Negligible surface water loss. There was information about leachate concentrations, and some concentrations were very high, but the load. One study found that the soil plays important role but they did not attribute that affects to soil microbes or other specific factors. Teng pointed out the climate and temperature is a factor; warmer areas without winter would decompose the …Mark H. noted that the soil microbes would be major factor too. Sandy felt the leachate volume was surprising on the early end. Mark H. noted that for composting systems most of the moisture is lost right around day 3, so the moisture may actually leach more in the early days or weeks and less after the first few weeks.

- Discussion of nutrient loss pathways. Burial is still used in some places, but is mainly only used for mass mortality anymore. Available studies tend to be piecemeal or incidental, like when they find concerning concentrations in groundwater or wells. How much of the total estimated carcass nutrient load is lost? Glanville has some information in his work.

Landfilling

- Doug noted he did not have much ready to share yet. The eventual chapter will need a good discussion about potential ancillary effects, and role of landfilling. Landfills with methane capture would have ammonia capture.

Composting

- Mark H. reviewed his outline and summary thus far. A big difference for mortality composting is the presence of the animal tissue, and therefore less of a homogenous mix as you compost. He plans to build from the animal type chapters. Expects he will need to do analysis with animal types individually, given the differences in how the smaller and larger animals compost, even among types of poultry. Might be able to pool the animal types back together if the numbers work out that way. Cows and horses basically compost themselves from the inside out, with the microbes in their guts. Poultry is from the outside-in. Discussion of grinders that can be used to increase surface area and make the composting process go faster for the carcasses. Mark H. noted that compost piles with the desired pyramid structure will be hydrophobic and water runs off them and does not run vertically through the piles, so the only loss is in the bottom few inches where the water runs underneath and can extract nutrients.

Rendering

- Mark H. does the bonemeal get sold back as animal feed within the watershed? Bud noted that that kind of information is not available. Doug: for our purposes that wouldn't matter.
- Doug noted that rendering or industrial facilities may use sludge or biosolids for land applied nutrients. Mark D. noted that biosolids are tracked separately within the model. If rendering facilities do transport biosolids for field application, then it would fall to the point sources to track and report that data. Discussion of possible air emissions.

Incineration

- Teng described the two sources they located so far, including a poster from Jeff Porter. The other reference had some dry matter ash P content and there was discussion that those values may be applicable or at least compared to the other P content for ash.

Discussion

- Continue with monthly conference calls on normal schedule but with 1-week delays in July and October: July 17, August 14, September 11 and October 16.
- Doug reminded the group to include future research and management needs in their sections, which can be combined into a separate chapter for the report.
    - Bud noted there has been a growing number of producers on the Eastern Shore that has been a challenge for extension and outreach to work with effectively. Even many scheduled trainings or workshops are forced to cancel due to lack of interest or participants.

- The group noted the major lack of resources and studies about animal mortality in general.
- There was discussion of possible programs or funding opportunities for research projects related to animal mortality. Bud noted that litter brokers are valuable knowledge resource for understanding the situation on the ground within the watershed.
- There may be some industry funding sources for research, like through US Poultry and Egg.

DAY TWO

Additional considerations

- There was discussion of other topics the panel wished to cover.

Biosecurity

- Ernest described some of the initial resources he gathered so far. Bud mentioned some regional work about scavengers and biosecurity; risk of vultures or other scavengers.
- Doug: see us having a separate chapter with some basics, like what animals die of, risk vectors, etc. We should make some recommendations on the biosecurity subject.
- Jeremy encouraged the group to consider including basic visual indicators for when certain practices are not being done correctly.
- Mark D. noted that while the panel's main charge is for nutrients and water quality, the panel does have to consider verification which will
- Tommy: we could have an extended list, or a table to summarize the basic information and have a case study or two to highlight some of the pathogens/diseases as they can potentially move through the environment.
- Ernest asked if antimicrobial resistance would be an issue of interest. Jeremy indicated that it is an emerging subject among the CBP, so it would help to include at least some basic information that is available.
- Doug: it would be helpful to provide information that does clarify risks in a constructive way.
- Sandy clarified that it is recommended that the narrative section of a CNMP address mortalities, and the practices are listed, but otherwise it is basically considered as a nutrient source for the plan.
- Doug encouraged the biosecurity panelists to focus on the general methods and concerns, and the animal type authors to include any animal-specific biosecurity concerns within their drafts.

Storage and transport

- Tommy noted that Bud has done a lot of great work speaking with folks involved with transportation and industry service providers. Tommy asked for advice or guidance on how to gather information and craft the narrative for this section of the report.
  - Sandy mentioned storage of processed or post-material and the group should consider that.
  - Doug: the section may need to be more descriptive in nature. It will be beneficial to describe how storage and transport fits with the disposal methods, to clarify how things like freezers are not the disposal method, but the interim step. Description of the proper or expected handling for fresh dead. An explanation of

who hauls/transports the mortalities to rendering or other disposal facilities, including description of storage on the farm before the mortalities are picked up by a service provider.
    - There was discussion of how to construct the section. Jeremy suggested a chronological description to fill the gap between death and disposal, with the biosecurity chapter to elaborate on risks or vectors within that process. The storage and handling chapter would capture who, what, when and how for the mortality management between death and disposal.

Current regulations

- Dead animal disposal is a regulated entity. Jeremy noted that he has yet to do more outreach to state contacts for more information. Virginia has some clear guidance and documentation, but the other jurisdictions are more difficult to locate the best information.

Discussion and where we go from here/completing report

- Doug: try to get as much done as possible by mid-October, which will give us a few months for the review and approval. Jeremy described the CBP partnership review and approval process for BMP panel reports.
- Doug asked the group for thoughts and feedback on how to complete the report, and what
- Discussion of how manure nutrient and manure generation assumptions, and preferred units (lbs nutrient per AU per year). Mark D. noted that the modeling team is already diving into the 2017 Census data for manure generation and population numbers; should have those results in July or August and the panel can do the conversions to consistent units to compare with mortality estimates.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, July 17, 2019, 12:00PM-1:00PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	N
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N

Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Updates

- Doug recalled the goal to have the draft report ready by the October conference call. He asked if anyone had questions.
    - Mark H. noted he found one citation from a Canadian source that he was unable to locate the full text for. It looks like a promising government report on swine, nutrient losses and composting. Have tried multiple approaches with no results; he will share the citation with the group to see if anyone else can find it.
    - Teng asked if Doug or Bud would be able to share the spreadsheet they've been working on. Doug clarified that he has a spreadsheet he and Bud have been working on, and NRCS has a second spreadsheet. Doug can upload both to the Google Team Drive.
        - Sandy clarified the NRCS sheet is specific to freezers, and only for estimating the capacity of freezers needed, not for composting.
    - Amanda asked if the CBP would be providing the animal population data for them to use, by county.
        - Doug: …our results will be two different forms. Per AU production, this is how much N and P is from carcasses. Then a more detailed recommendation if more refined data is available, e.g., bird size, etc. Between now and October, do the best you can and note the references you use.
        - Jeremy asked if the panel would like the whole time series of animal populations or just the latest year. Doug felt the latest year would be fine.
    - Tommy noted his surprise in how the poultry industry has changed since he worked in the southeast, e.g., with changes in bird weights, stocking, etc.
        - Doug agreed and noted that providing the panel's recommendations in terms of AU will help simplify things.
    - Animals per county, all inventory data, extended out for the whole year. Whole county populations. Not CBWS-only.
- Doug noted that those being reimbursed for the June meeting through Ok State should receive their checks soon.
- Jeff explained the CBP population data.
- Rules that we use to count, just for 2017. Each county. We follow the states.
- Mark H. would be interested in mortality rates from the commodity groups. Want to be consistent in the disposal chapters with the mortality rates from the commodity/animal type chapters.
- Doug: we can provide that. For poultry we expect to have the annual and weekly mortality rates.

- Still looking for the one Munro reference with no luck. Also having difficulty with surface water runoff information for burial sites. Unable to find anything on that so far. In an ideal situation there would be no surface runoff for something that is buried.
    - Jeremy: if the panel feels that surface runoff losses would be negligible then we can acknowledge that and assume that it is essentially zero.
    - Doug: surface runoff would be more of a concern for composting. Mark H. agreed. There was discussion of the considerations for nutrient losses from compost piles.
- *Swine:* Progress continues.
- *Cattle:* Progress continues.
- Composting: Progress continues.
- Combustion: Sandy and Teng need to touch base about combustion.
- Doug shared draft of what he's been working on with Bud, including estimated mass of N and P in mortalities from a flock of 1,000 birds, with estimates based on typical finished weights.
- Doug and Tommy discussed possible differences between how the mortalities and data differ between cattle and poultry.
- Amanda agreed with Doug that horses are a special case from poultry and the other livestock. Will probably need to make some assumptions to get at the same type of bottom line information.
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- Mark D.: Ag Census is the head count on Dec 31 of that year.
- Bud: can use NRCS spreadsheet to calculate total pounds of mortality based on average age.
- Doug: each section/animal can have their own assumptions, graphs and steps based on the production parameters of that animal, but the end result should be in terms of AU.
- Doug: when we meet in two weeks, we'll discuss the logic for each animal type and the results for estimated N and P content/loads for that animal type per AU.
- That's what we ultimately want to understand: how much N and P are potentially contributed by dead animals to the watershed.
- Doug: At the end of the composting process, want to understand what is left and retained for land application. For rendering, the remaining amount may be 0, at least from the ag perspective since that load would be part of a point source load.
- Discussion of manure and mortality loads in current model:
- Doug: by doing this analysis it will be possible to compare carcass loads per AU to manure.
- Mark D: we do have some new management systems now, and the panel will help us understand how to simulate those different systems within the model, since some of the systems treat all the mortalities on site while others are full transport.

Recap and next steps

- Doug thanked everyone for their hard work and encouraged them to keep it up.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, August 14, 2019, 12:00PM-1:30PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Example

- Doug walked through his latest draft for the poultry section with the group. He described his draft figures and analysis for broilers.
    - Bud noted that the Caldas study only looked at male birds.
    - Bud mentioned that the NRCS spreadsheet carries out mortality rates until 10 weeks (70 days).
- Doug pointed out the greater uncertainty in the death rates and data for larger/older birds, starting at 6-lbs or more. He summarized the elemental composition data for N and P in carcasses. The larger birds have more feather cover which increases the N content compared to younger birds.
- Tommy: beef in mid-atlantic and SE, we have a good sense of the life cycle for the beef and dairy herds.
- For final number, need to report back to number of female cows.
- Use the NASS data and proportion based on area of the county.

- Jeff clarified the animal population data is not proportioned to the CBWS portion only since the manure general is at a county level. We can proportion the populations in cases where that's useful, as it may be for this panel.
- Doug encouraged others to include the confidence intervals when possible in their respective graphs (95% CI), though he noted he sometimes displayed the range, not the CI. Only applies in cases with more than a few data points.

Updates

- Doug noted he and Bud have to get to the other bird types, with the bulk of effort spent on broilers thus far.
- Tommy noted he has sufficient information for beef and dairy and is ready to start putting that narrative and graphs together. He also has a good amount of general BMP information for biosecurity. Need to work with Ernest on getting that put together.
- *Swine & Cattle:* Progress continues.
- Composting: Mark H. has been uploading documents to the Drive and is piecing together that narrative. Waiting to get more information about the animal types to help fill in some blanks in the composting calculations. There is more composting work for cattle than poultry, it seems. He noted he will be gone for 3 weeks after this week, so will have very limited opportunity to write before the next call.
- *Equine:* Amanda noted they have made progress but are still tracking down some references.
- Teng was not present to update on the incineration/gasification.
- Overview, definitions, most of the section spent discussing potential losses and pathways for the nutrients in the disposal method. As for unintended consequences, biosecurity will be the primary point of concern.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, September 11, 2019, 12:00PM-1:00PM
Conference Call

Name	**Affiliation**	**Present? Y/N**
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	N
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y

Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Group Updates

- Tommy shared an update from Ernest. They've been working together on the general biosecurity chapter, dealing with biosecurity concerns with mortality management generally, not specific to the management practices that will be discussed in the respective chapters.
- Doug noted he will upload his latest draft to the Google Drive soon, and that Bud has been working hard to obtain the latest data for broilers.
- Tommy shared and discussed his draft Cattle mortality chapter with the group. His outline describes the cattle life stages and associated mortalities for a reference eastern cattle herd. He started with beef then walked through what he has for dairy cattle. He reiterated that there is very little available data about nutrient composition for whole carcasses.
    - Tommy: reported by NASS as all cattle and calves; the reference herd is done in life stages.
    - There was discussion with Doug and Tommy about how to present and summarize the data.
    - Jeremy asked Tommy who confirmed he was used the same whole carcass nutrient composition estimates for beef and dairy. There is very little data available and it is not possible to differentiate between the animal types
    - Mark D. noted that if Tommy wants more information about beef production in Virginia, we can put him in touch with an AgWG member who's familiar with that industry through Virginia Cooperative Extension (Jeremy Daubert).
- *Swine:* Doug noted that he's been in contact with Teng and there has been progress on swine, though Teng wasn't able to join today.
- *Equine:* Amanda recalled they did have some rough estimates from last time, unsure if it is possible to improve them further with available information, but considering how to build things together for next month.
- Burial: Sandy noted that she had a rough draft and figures back in June, and just need to update it now that she's received the missing reference.
- Tommy expanded on his earlier update, explaining that the biosecurity chapter would provide background and context for the readers and audience, and wouldn't be about providing specific data or information that would be used for modeling. Doug recalled that, as the group has discussed many times, mortality management is primarily about biosecurity and not nutrients or water quality.
- Tommy described his status on the storage and transport chapter.
- ACTION: Jeremy will provide documentation about animal types crosswalk.

- Bud noted two data gaps on poultry side. One is broiler breeders. Not sure how to get those numbers. Turkey mortality numbers. Have some approximate numbers from personal communication, but working to track down other sources that we can cite.
    - Mark D. noted he doesn't have the broiler breeder info, but he thinks he can get it. We do have some turkey mortality data for 2016 and can get that for Bud.
- Doug asked people to share/upload their respective draft chapters by October 15, the day before our next call (on October 16).

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, October 16, 2019, 12:00PM-1:00PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	N
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	N
Sandra Means	NRCS, East Nat'l Tech Support Center	N
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Status updates and report out for respective draft chapters

- Doug summarized what he's seen uploaded to the Google Shared Drive so far. He noted that Teng has almost all the data he needs for swine, just needs a final number or two for animal sizes. He should be back in the country next week. Tommy has most of the estimates ready for beef and dairy, just needs to do some additional conversions for AU and per farm.
    - Amanda noted that she still needed a few values to finish calculated estimates for equine, but she explained the tables they have so far for horses.

- Bud noted there are still some gaps for turkey data. He did get some cumulative death loss estimates from Virginia Tech, but not the full pattern. Doug noted that the cumulative mortality may be the best we'll get for turkeys.
    - Doug noted that Sandy shared a draft chapter for burial, which is pretty well underway.
    - Mark H. has worked on his outline for composting. There are some estimates of loss from leachate and atmospheric pathways from composting. Getting close, like Sandy's draft for burial, and can work to figure out the remaining conversions and calculation steps.
    - Doug encouraged everyone to continue working on their estimates for animal type deaths/nutrients. Can work together on remaining conversions from there. Doug will work to do the comparison back to overall manure nutrients.
    - Doug: for incineration, can look at the Manure Treatment panel's report. Perhaps that literature is still applicable and we can use that heavily for our recommendations as the systems
- Doug felt confident the chapters can still wrap up in December if people continue working as they have. He encouraged panelists to gather any photos that can be used for the report. There are some photos from the panel's site visits in June that can work, and other sources may include the CBPO or the NRCS photo gallery.
- Jeremy mentioned that Jeff S. provided the Ag Census animal populations, by state, for all Ag Census years. Jeremy posted the spreadsheet to the Shared Drive.
- Bud gave an update on the NRCS spreadsheet and methods for broilers. Bud noted that it seems the data available online is older than what he's seen more recently. Doug described that we'll be transparent about our methods and steps for anyone that has issues with our estimates and values compared to what the industry or NRCS uses, but the methods are basically the same. Doug pointed out that the current standards and specs for sizing mortality compost bins are way off from what they should be; he felt some of the panelists should work together on an article for that topic after the panel is done. Mark H. noted that someone from NRCS recently participated in the composting course and is currently working to update the NRCS standard, so the timing is excellent to collaborate on that topic.
- Mark D. mentioned that the current standard often overlooks the water source.

Next steps and scheduling

- There was discussion about upcoming meetings, as recurring meetings were only scheduled through the current call. Mark H. felt the regular calls helped to motivate his work, and Doug agreed we should schedules calls for November and December. After some discussion the tentative dates for the calls was set for Wednesday November 13 and Wednesday December 4. Jeremy will email the group to confirm the best start times for both dates, and to see if new dates are necessary.
- Doug and Jeremy thanked everyone for their time and participation.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Wednesday, November 13, 2019, 1:30PM-3:30PM
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	N
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	N
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	N
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	N
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	N

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Status updates and report out for respective draft chapters

- Doug and Teng discussed the status of the swine chapter and the next steps for calculations.
- Doug noted that he added layers to the poultry chapter, so the chapter is nearly complete after Bud responds to a couple questions.
- Amanda described the status for equine, and discussed with Doug some minor tweaks to the tables to have comparable values per AU.
- Doug noted that Mark H. uploaded his latest draft for the composting chapter and it is fairly complete.

Next steps and scheduling

- Next call: Wednesday December 4, noon to 2 Eastern. Amanda is unavailable then.
- Doug and Jeremy thanked everyone for their time and participation.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Friday, October 2, 2020, 1:00 – 3:00PM Eastern Time
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	Y
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	N
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Discussion of report sections and status, approach for finishing report

- Doug noted he had shared the draft animal type chapters (poultry, swine, cattle) with the panelists.
- Doug shared a comparison table of nutrients by animal type using the info from the respective chapters, in terms of mortality lbs TN and TP per year per AU.
    - He noted the longer-lived animals like equine and beef had the lowest TN and TP values, though the values for dairy was noticeably higher than beef.
    - He showed a similar table that compared the mortality nutrients to the manure nutrients for each animal type. In this comparison, he pointed out the relatively higher, but still low, values for turkeys and swine.
        - Amanda clarified: this suggests that the highest contribution of mortalities to overall nutrients is 4% of the TN. So is this even greater than a margin of error for modeling purposes?
        - Doug agreed that the mortality contribution is certainly low compared to the nutrients from manure.
        - Jeremy asked and Doug confirmed that the comparison to manure is based on as-excreted manure estimates (ASABE).
        - Mark D. mentioned that the CBP has looked at regional manure nutrients for poultry and swine, and they differ quite a bit from the as-excreted values.
    - Mark H. asked Doug to return to the first table. He felt these values will be incredibly useful to have. Doug agreed, even though the values are very general there does not seem to be other estimates like this out there in the literature.

- Teng noted we'll have to be careful how to apply these values if some are based on building capacity versus liveweight, for example.
- Doug: do we want to have a table comparing all the values like this that tries to compare the species like this, knowing it's not really apples-to-apples?
  - Mark H. noted he tends to get questions based on commodities
- Jeremy felt that these comparison tables will be necessary to include somewhere in the report, either an executive summary or in an appendix; the modelers will look to this kind of summary table when they subsequently include this into the modeling tools.
- Ernest asked about veal calves. They are smaller, but it is a significant industry here in Pennsylvania and they can have significant death losses. Ernest reached out to a veal company to see if they have any data they would be willing to share.
  - Mark D. mentioned that veal production is also relatively common among plain sect producers.
  - Doug asked Tommy to look into it, especially if Ernest does receive some data.
  - Jeremy suggested we can do our best to fit veal calves into one of our existing animal types
  - Mark Z. noted there is only one CAFO in PA that is a veal operation, other operators are all smaller.
- Mark D. mentioned that the CBP does distinguish swine for breeding and swine for finishing. We will need to consider splitting out the swine categories.
  - Doug agreed. It may not be too difficult to go into the chapter and use the CBP's swine report to help split out the panel's estimates into the breeding and finishing categories used by the CBP.
- Mark D. also mentioned that Gary Felton (UMD) has some additional data from an upcoming publication that may help in the poultry chapter. He'll check if that can be shared.
- Mark D. asked how differences in bird weight over time or between states may affect how to apply the panel's estimates.
  - Doug noted that the chapter has data that would allow someone to choose a different market weight and derive the estimates from there.
- Ernest pointed out a possible calculation error in Table 7 of the swine chapter.
- **ACTION**: Possible changes/updates for next version of animal type chapters, by end of October—
  - Ernest will look into available data for veal calves, to see if that might affect the cattle category.
  - Doug will break swine into breeding and finishing categories.
  - Doug will revisit and double-check the math in Table 7.
- **ACTION**: By end of October, panelists should check the steps and calculations in their respective animal-type chapters. We want to be sure the values are correct.

- Doug moved on to the disposal method sections. He noted that the initial plan to have full chapters probably won't work, and it will make more sense to condense the disposal methods into possibly one combined section that walks through each disposal method.
  - Doug noted that Sandy has basically finished the burial section. We should be able to use what we have to arrive at some final estimates for burial.

- Doug noted that Mark H. has also mostly wrapped up the composting discussion, but we may need to determine what our final estimates might be as far as the nutrient pathways. Doug recalled that there are values for manure composting and incineration from Manure Treatment Technologies expert panel report. Mark H. agreed that those estimates should be applicable for mortality composting, especially since there are typically co-feedstocks in practice. The presence of a carcass in the compost pile doesn't seem to impact what is lost to groundwater. There are very low losses to groundwater from composting.
- Doug asked the group if the MTT panel's work for incineration would also be applicable.
  - Jeremy asked if there would be any differences in the temperature ranges or incineration methods.
  - Mark H. wondered how the different feedstock could matter, since the carcass is much different than a treated or separated manure feedstock.
  - Mark D. if the operator has a gasification system they are likely to put dead birds into the unit anyway, so it would be a co-feedstock for the few operators with that kind of system.
  - Sandy noted that Jeff Porter did present a poster at a conference, and she can check if what he had from that project would be applicable. It would not be much data.
- Doug moved on to landfilling and rendering. Doug recalled that rendering facilities are NPDES permitted, and their outputs would be captured through point source data. Landfills
  - Mark H. noted that PA does allow for it, at least in limited cases. Amanda recalled that there may not always be landfill records. Mark D. noted there are landfill records, at least in Virginia.
  - Doug asked for volunteers to draft 3 pages or less. Ernest offered to write the first draft of the section text.
- Tommy asked about a biosecurity chapter. Doug noted that we won't have a separate biosecurity chapter. There was discussion among the group, noting there's some language currently in the Google Drive folder, which can be rolled into the introductory chapter.
  - Ernest offered to look at what Tommy drafted and build from there, for inclusion within the background section of the report.
- **ACTION**: Some updates and changes needed for disposal method chapters—
  - By end of October, Ernest will draft initial text for landfill and rendering section, as well as biosecurity language building on what Tommy has shared so far.
  - By November 13, panelists and Doug will work to update the incineration draft chapter. Other updates to composting or burial chapters if needed.

Next steps and scheduling

- Jeremy described the general process for when the panel releases its report: there's a webinar hosted by the panel chair and 1-2 other panelists with Jeremy, and a 30-day or longer comment period. Jeremy will coordinate the feedback and work with Doug or the panel as needed to make revisions and respond to the feedback. Then the report goes to three groups for their approval; once it is approved by the Water Quality Goal Implementation Team, the report is finalized and published on the CBP website. Doug and Jeremy will reach out to the panel if there are substantive comments that conflict with the panel's main recommendations, but will respond to minor comments and make minor edits as needed. The process can take at least a few months total, but depends on the nature of feedback received.

- Doug suggested that the outstanding pieces discussed today by end of October or first two weeks of November (mid-November for composting, burial, other disposal sections). Sandy noted that Teng did have a draft paragraph or two regarding incineration so Doug will check on that.
- Jeremy will work up intro and background sections by mid-November.
- Amanda offered to help Jeremy and Doug with editing of the full report.
- The panel will need at least one more meeting after Thanksgiving or in early December. Jeremy suggested targeting the week of Nov. 30^{th}-Dec. 4^{th}, following Thanksgiving.
- Tommy and Mark H. offered to help with the webinar.
- Doug and Jeremy thanked everyone for their time and participation.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Tuesday, December 1, 2020, 11:00 – 1:00PM Eastern Time
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	Y
Mark Zolandz	EPA, Region 3	N
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Discussion of report sections and status, approach for finishing report

- Doug: Pretty much done with the first part of the report, for the animal type chapters. He's working on an introduction piece for the animal type chapters.
- Doug is turning attention to the second part, the disposal methods. He's talked with Sandy on the updated burial chapter. There is not much information to inform recommendations in relation to burial.
    - Tommy do we feel that the overall contribution of nutrients from mortalities is significant enough to be handled or simulated outside of general nutrient management planning?
    - Doug: Our charge is to provide numbers where available. Turkeys appear to have the largest contribution of carcasses, compared to manure nutrients, and they are only about 3 percent. With those small contributions, it may be fine to assume the mortality nutrients are captured with existing estimates. Our biggest impact may be in adding greater detail to how the nutrients might be better accounted for in NM planning.
    - Jeremy noted the jurisdictions may still be interested in estimating the contribution of animal mortalities and mortality management methods; when compared to manure it may seem small, but that can still be a relatively worthwhile source for the jurisdictions to reduce and meet their goals.
    - Doug: For each of the disposal methods, we can conceptually look at it like the MTT panel did, with the different pathways and inputs/outputs for the disposal methods. But given what we were able to find, am now backing off on providing tabulated nutrient efficiencies.
    - Doug: For all the methods, we were asked to compare to burial as the baseline. We will show the predominant pathways for each of the methods. For example, it would be leaching for burial. We could qualitatively say that changing from burial to incineration, there could be transfers.
    - Doug noted that Jeff Porter has unpublished data on ash composition for mortalities. Unpublished data gets less weight under the CBP's BMP Review Protocol though.
    - Jeremy noted that the panel was asked to consider burial as the baseline, but the panel could determine that burial is not a reasonable conceptual baseline.
    - Doug agreed. The panel could instead base its recommendations using the carcass nutrients as the baseline, rather than using burial as the baseline.
    - Sandy: nobody has done the research for all the species on leachate losses from burial; there's been pieces of the research done over the years but it is incomplete. Agree that burial makes a poor baseline to compare to for the other practices.
    - Doug asked Mark H. to go back and look at what he has for composting and see if he can add more quantitative information.
    - Mark H. noted he has composting data for broilers, dairy, hogs, layers and turkeys. The data is largely based on mass die-off composting, but the cattle composting is from controlled research piles. The co-composting materials will be different for mass events than for routine composting, so that's an important caveat. It is replicated data with multiple piles. Mark H. noted there is an internal report from New Brunswick that he might get permission to share.

- Doug: There is a lot of data on incineration, mostly symposium data, from the '00s, including human cremation and we may be in a good enough spot to come up with some estimates.
- Doug recalled that for landfill and rendering, we need a little background on the process and an explanation of the fate/removal of the nutrients from the agricultural system.
  - ACTION: Jeremy volunteered to develop basic paragraphs that the panel can work from.
- There was discussion that landfills do not keep consistent records of animal carcasses. Individual private landfills can make case by case decisions. Landfills may be more willing to accept the routine mortalities, but mass mortalities raise more concerns. Amanda mentioned there are transfer stations in Kentucky and that adds another layer of tracking difficulty. It's unclear what the transfer station does if a landfill refuses carcasses.
- Mark D. noted he has received some detailed data in the past from Virginia about private landfills that received mortalities. Unclear how well other areas might keep similar records.
- Doug noted that the EPEG asked for estimates of what portion of the animal types are handled through the respective disposal methods. He felt there was no data to support estimates like that, so the panel will need to steer away from making estimates unless new info is found.
  - Mark D. agreed, and the methods will vary by area and what practices are available or common.
- Tommy: would it help to have a master flowchart of the processes within the model and within these disposal pathways?
  - Doug offered to take a stab at a flowchart and share it with Tommy and Jeremy for initial feedback.
- Tommy mentioned he had a rough outline of the biosecurity discussion, and Ernest was going to take it from there. It was roughly 9 months ago. Tommy offered to go back and try to fill that out a little more for a simple biosecurity section (1-2 pages).
- **DECISION**: Panelists agreed to move away from burial as the conceptual baseline.

- There was discussion of the timeline and next steps. It was agreed that everyone would dig into their respective disposal methods sections and work to revise the sections by December 18th. From there, Amanda can help Doug with editing and putting the report together over December and January, with Jeremy helping as able around parental leave.
  - Doug will work to get the incineration chapter done by the 18th
  - Burial (Sandy and Doug) and composting (Mark H.) updates by the 18th.
  - Jeremy: draft landfill and rendering language by the 18th
  - Amanda asked Doug to start sharing pieces with her in late Dec and early Jan, so can help with editing as we go along.
  - General goal: try to have a complete draft product by end of January.
  - The panel will likely schedule another call for early February, but will schedule it after the new year when Jeremy knows more about the timing of his leave.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Thursday, April 22, 2021, 11:00 – 1:00PM Eastern Time
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	Y
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	Y
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	Y
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance.

Discussion of report sections and status, plans to finish report and release

- There was discussion about Part 1 of the report, which covers nutrients in the animal mortalities. Doug and Amanda described some editorial updates to the swine section, and that overall Part 1 should be ready for release.
    - Jeremy explained that the panel cannot afford to delay the release of their report beyond June at the absolute latest, given the time it takes to get a report through workgroup approval. The panel must try its best to get approval by the end of September.
- Doug recapped the methods intro for Part 2 of the report, which conceptually breaks nutrient pathways into different paths for the panel to consider for each disposal technique.
- The panel discussed the composting section. Mark H. and Tommy described how they were most comfortable with recommending a range, given the variability in published studies and available data. There is the added complication of co-feedstocks. Mark H. noted that mortalities contribute very little nutrients compared to manure co-feedstocks. The range they were most comfortable was 10-40% loss for TN and 6.5-64.4 g for P, representing loss from all mechanisms.
    - Doug showed how presentation of a range might work in the composting chapter's tables. The group discussed how the CBP ultimately uses a single value for BMPs simulated in the model. The group discussed standards and qualifying

conditions for composting, and how the range of values apply to composting systems that are properly managed. Teng referenced the updated ASABE guidelines, which refer to the NRCS field handbook. Mark D. noted there is often a desire to utilize more specific regional or local standards instead of more general national standards, when possible. Tommy mentioned Cornell and some other relevant guidance materials.

  - For all the different methods, will need to add statements about what the panel considers "proper" management or operation of these disposal methods, referring to national, regional, state or local standards.
  - There was discussion that the CBP model ultimately needs a single value for a BMP to simulate its effect; the panel can recommend varying levels or versions of a practice like composting, if they wish to differentiate lower- and higher-performing systems. Whatever the panel is comfortable with doing as far as how it portrays and describes the mass balance, pathways and estimated performance. The CBP does want to know the range or variability of the practices though.
  - Doug asked the panel how they would like to handle default value recommendations for the methods. Tommy explained he would be comfortable with specific numbers as long as the narrative frames it as an estimate within the overall range. Sandy explained that the value she presents in the burial chapter represents a well-constructed pit, because if the farmer doesn't follow that standard the values can be all over the place. Her draft chapter explains what proper construction looks like based on the states' standards. Mark H. felt that he would support a single number if the value is presented as representative of proper management, which is better than assuming worst-case. He suggested focusing on the compost process itself and address outside factors narratively.
  - Doug suggested the panel could streamline the tables and pathways presented in Part 2; panelists agreed with that approach provided that the narrative describes the full information and range.
  - Doug recommended downloading files from the Drive and editing in Word, since editing on Google Docs can create issues with drafts, especially to figures.
- There was discussion of the timeline. Jeremy mentioned he starts parental leave soon and will only be working one day a week until June 11. Hopefully the panel can still release its report and host its webinar in June at the latest.
- Doug asked for updates to draft sections by Friday May 7. **ACTION**: Panelists should send their revised part 2 sections (disposal methods) to Doug by Friday May 7.

Adjourned

SUMMARY OF ACTIONS AND DECISIONS
Animal Mortality Management Expert Panel
Tuesday, July 20, 2021, 2:00 – 3:00PM Eastern Time
Conference Call

Name	Affiliation	Present? Y/N
Doug Hamilton	Oklahoma State University	Y
Thomas Bass	Montana State University	Y
Amanda Abnee Gumbert	University of Kentucky	Y
Ernest Hovingh	Pennsylvania State University	N
Mark Hutchinson	University of Maine	Y
Teng Teeh Lim	University of Missouri	Y
Sandra Means	NRCS, East Nat'l Tech Support Center	N
George "Bud" Malone	Malone Poultry Consulting; University of Delaware Extension (retired)	Y
Panel Support		
Jeremy Hanson (Coord.)	Virginia Tech, CBPO	Y
Jeff Sweeney	EPA, CBPO	N
Mark Zolandz	EPA, Region 3	Y
Loretta Collins	UMD, CBPO	N
Mark Dubin	UMD, CBPO	Y

Welcome and introductions

- Jeremy welcomed participants and verified attendance. He noted that Sandy retired since the previous call; will check offline if anyone has contact info for her, in case we need to contact her.

Discussion of report, next steps to finish and release

- Doug explained the objective for the call: to discuss any final issues, concerns or edits the panelists might want to see in the report. If everyone is comfortable with the report then the report can be released for feedback and approval by the CBP. Suggested edits from group:
    - Exec summary, 2nd para page 2: cost is an important factor worth mentioning as part of the last sentence.
    - Suggest title of Table ES3 should start as "potential <u>on-farm</u> movement of nutrients." Would need to update title when the same table appears in later section of the report as well.
- Teng noted he made some edits on the Google drive version of the ES. Doug will check on those and transfer them to the Word version.
- No other edits or comments on the draft report were raised during the call.
- Mark H. noted he had to leave the call early and asked about the timeline for next steps.
- Jeremy reviewed the next steps and possible schedule for review and decisions. If the report is ready and released by next Tuesday, could see the report approved by the AgWG in October, and the WTWG and WQGIT in November. The "roll-out" webcast would ideally be the week of Aug. 9 or 16. Tommy and Mark H. agreed they can still

assist with the webinar and there was discussion of the possible dates/times, to be confirmed offline prior to release of report.

- Jeremy noted that panelists appeared comfortable with release of the report and that since there were no objections or concerns aside from some minor edits, we'll consider this a decision point that the panel is ready for release of the report after today's call. **DECISION:** The panel agreed the report can be released for partnership review and feedback.
- Jeremy and Doug thanked all the panelists and other participants for their time and invaluable input. Panelists also expressed their thanks for the group. It was noted this would likely be the final call for the panel.

Adjourned

Appendix E. Compilation of partnership feedback on draft report and responses

Note: This appendix includes comments and responses through the end of 2021, when the cooperative agreement supporting the panel expired. Additional context and supplemental materials can be found on the calendar pages for decisional meetings listed in Appendix F.

Some text from commenters, including greetings and email signatures, have been left out, but the comments are verbatim unless stated otherwise in cases where summarized/abridged feedback is presented. Responses from the Panel Coordinator and Panel Chair are in blue. Please note that page number references in this appendix are not updated and therefore may not reflect page numbers in revised or final versions of the report.

> We want to thank everyone who took time to read the draft report, especially those readers who took the time to offer written feedback compiled in this appendix.

Comments entered into chat during August 13 webinar:
Frank Schneider, PA SCC :
just note in Pa, burial is not used often except for large animals

Dave Montali, Tetra Tech:
Are there any concerns regarding the animal weights considered by the panel not matching the weights in place in the CBP manure generation protocols? Any remaining concerns that nutrients from mortalities are double counted in the manure nutrients (poultry)

Chris Brosch, DE Dept. of Ag:
Excellent and comprehensive discussion. I am interested in diving into a few assumptions and generally about considerations for Ches Bay regional issues compared to national average conditions or areas where animal production is centered outside Mid-Atlantic.

What sources were used for the characteristic animal data based? This was a part of some of the animal manure panels, poultry, turkeys and pigs done in the latest version of the Model by expert groups engaged with by the Ag Workgroup.

What is the justification for the 70% figure used as a basis for weight of a carcass?

Are the TN and TP values elemental or NO3/P2O5 equivalent?

For broiler sizes how were the flocks/yr calculated or gathered from production data? Integrated poultry are more market driven than capacity.

How relevant is the cow/calf operation relevant to cattle production systems across the Ches Bay region? Were local considerations made?

> Panelists responded to the above questions during the August 13 webinar, which can be viewed here, with the responses beginning at approximately 1:49:30:

https://www.chesapeakebay.net/what/event/animal_mortality_management_bmp_expert_panel_recommendations_roll_out_webin

Victor Clark, Farm Freezers & Greener Solutions
Part 1 of feedback
[*From email*]
I would be happy to help with it in any way I can. If you give me specific examples of data that you need or references to source material I will do my best to find them for you. Some I already have. For example, I attached the AgWG presentation again because it contains a lot of information regarding how the model reflects manure (and mortality) transport. I even have references in there to sections of Model documents I think, so you can cross reference the docs – instead of citing the presentation. It had to be cut down to be short for the presentation, but I can find the source material for each point and forward if helpful?

In a similar vein, I added the last three sentences to the report's text (first sentence) on page 129. Not sure the panel will include it but the text seemed to be begging for a real world example. Maybe it would help you, even if they don't use it?

> If a jurisdiction has the ability to track and report the number of animals or tonnage of animal mortalities – and ideally, animal type – transferred from watershed farmers to rendering facilities, that may be the most effective method for tracking and reporting the animal rendering BMP. For example, Delaware's Nutrient Management Commission expanded its manure transport program to include mortality transport a few years ago. The program incentivizes the adoption of both practices by providing funds to offset the cost of transportation for individual growers. The invoices submitted for reimbursement contain the total tonnage [and type] of mortality diverted from land application, allowing the state to track and report the associated reduction in nutrients that would otherwise be assigned to Delaware's ag load.

I also attached practice code 316 so you have that as a reference too, if helpful?

> The panel combed through many sources of data using the Chesapeake Bay Program's protocol for BMP evaluation. The panel already possessed and considered the NRCS 316 practice standard as part of their deliberations.

There are some big issues that take time to first understand – and then explain. For example, I don't think the panel realized that the poultry mortality load is already in the model as part of the manure/litter load. That has big implications.

> The panel was fully aware poultry mortality load is counted as part of the manure in poultry operations. This is not the case for other types of animal farms, however. The panel went through the process of comparing manure nutrient loads to mortalities nutrients to provide information for decision makers to split the mortality nutrients out of manure for poultry or include mortalities with manure in other species. A point that was brought out in the comments we received appended to the draft of the report stated that the panel should consider other Chesapeake Bay sponsored data when comparing manure nutrients to mortality nutrients. Both the AGWG poultry litter subgroup data (PLS report, 2015, Chapter 3, Appendix A of P6 Watershed Model documentation) and turkey litter report (Ogejo et al., 2016) provide nutrient

values for collected litter – after bedding has been added, many flocks have been added to the manure, and the excreted manure had been stored for a considerable period of time. The only way to compare the amount of nutrients contained in mortalities at the time of death to manure is to use freshly excreted manure – before losses and dilution take effect. This point was made in each section of the report in which manure and mortality nutrients were compared.

I point this out because I will try to submit all of my comments by the end of the day today, but Is anyone really going to read my comments over the holiday weekend? Many of my comments are accurate I believe, but I need time to double-check or find citations so it's not just me saying it. Has anyone else asked for a little more time? Or has everyone already gotten their comments in?

Let me know if there's wiggle room.

I also have comments on the report from a hog farmer in Delaware (who uses freezers) – very positive about the report – and I think it helps broaden the scope beyond chickens. Can I just forward the email to you – he gave me permission to share it with you.

The panel did not limit the use of freezers for storage to any particular animal type or disposal method.

[*the following portion of comments is copied from a provided attachment to the above email]*

Feedback from Farm Freezers and Greener Solutions on Expert Panel Report Titled Estimates of Nutrient Loads from Animal Mortalities and Reductions Associated with Mortality Disposal Methods and Best Management Practices (BMPs) in the Chesapeake Bay Watershed

Who We Are

I write on behalf of Farm Freezers and Greener Solutions, local companies that provide equipment and hauling services in connection with routine mortality management on farms in the watershed. My partner also operates a poultry farm in Millsboro, DE, so our comments set forth below are not only informed by our knowledge of freezer equipment and the rendering industry, but by his knowledge of on-the-ground daily operations of farming – including routine mortality management. In fact, it was his realization, shortly after buying the farm – that there was a better use for routine mortality than composting and land application – that started us down this path a decade ago.

Others saw the beneficial aspects of this management method too, and, therefore, in 2016, Delaware and Maryland jointly petitioned the Bay Program to grant poultry mortality freezers interim status pending an expert panel. This is important to note because (i) data about poultry growth rates, poultry mortality rates and nutrient content was readily available –and, in fact, had been adopted by prior panels, (ii) poultry mortality was already reflected in the model as part of an existing load (manure/litter), thanks to one of those prior panels, and (iii) the use of freezers (with transport to rendering) was identical to manure transport out of the watershed vis-à-vis how this new BMP would be reflected in the model.

The scope of the original petition was later expanded to include many more animal types and four other management methods. A comprehensive review of mortality management made sense, however, data for those other animal types and data reflecting how those other management methods would be reflected in the model was severely limited – making the task extremely difficult, but also making the panel's achievement all the greater.

Why This Panel's Work Is So Important

The panel's work has brought this previously unseen aspect of both agriculture and nutrient generation out into the light.

Though the panel modestly downplayed the importance of its work – "The nutrients contained in mortalities are a minor component of the water pollution potential of animal production." -- the reality is that conservation solutions rarely come in the form of a silver bullet. Reducing a load by 5% or 10% is actually a big deal.

But more importantly, as the panel would no doubt agree, a great majority of the litter that is generated in the watershed is actually needed for land application as a soil amendment.

So, our task as supporters of both agriculture and the watershed, is not to figure out how to zero out 80% or 90% of the manure/litter load; our task is finding a way to zero out the nutrients from that portion of the manure/litter load that mass balance studies say we have in excess.

It is for that reason, that while mortality may be an insignificant part of the manure/litter load, zeroing out the nutrients from mortality could be a significant part of the solution.

We appreciate the panel's work and respectfully ask that the comments we are submitting (below and attached) be fairly considered and hopefully adopted where appropriate. We have done our best to be clear and thorough, but welcome questions when we have fallen short of that goal.

> Mortality nutrients were compared to manure nutrients so that modelers and CBP partners have a sense of the relative contribution of mortalities and decide how best to add mortality nutrients to the watershed model, if so desired in a future update. The fact is mortality nutrients are a minor component of the pollution potential of animal agriculture. Totally eliminating mortalities from the waste stream, would at best, reduce nutrient load by 4% (farrow-to-finish swine farms), based on available data.

More Context for Each Method Will Increase the Value of the Report

Though the panel's charge discussed reviewing various mortality management methods that have historically been employed in the watershed, not all methods discussed deserve equal billing.

First, some methods have fallen out of favor or have been outright banned since their introduction. For example, pit burial was commonly used for routine poultry mortality on Delmarva, until it was deemed to be a hazard to ground water and surface water resources about three decades ago. In fact, composting owes its creation in part to pit burial's demise on the Peninsula.

Second, some methods discussed in the report are viable options for catastrophic losses, but are never used for routine mortality. For example, windrowing inside a chicken house is used only in mass mortality disease situations because it takes the chicken house out of production for a long time.

Thorough discussion of each method is understandable from an academic perspective; however, giving each method equal billing – with occasional caveats about limitations embedded here and there -- does not reflect the reality on the ground. For example, a new poultry operation in Delaware is in essence limited to either freezing/rendering or composting, and even within the category of composting, only bins, channels and rotary drums are used for routine mortality. But those limitations are not apparent from the report.

Pit burial, landfilling and incineration may be options in other states for routine poultry mortality, but setting forth which states and under what circumstances, would increase the value of the report.

The confusion is compounded when some aspects of mortality management are discussed watershed-wide (e.g., Table I.2.1. sets forth broiler production in the Chesapeake Bay Region). It's hard for the reader to remember that the management methods cannot be deployed watershed-wide when those methods are set out as equals. For example, that same table says the largest producer of chicken is Delaware, however, producers in Delaware are essentially limited to two options for mortality management, rendering discussion about the other three poultry mortality management options moot for the most relevant group.

Our suggestion is the inclusion of a chart or table that sets out each method and identifies each state in which its use is allowed and for which animal types. This would allow the reader to cross reference the panel's findings to put into perspective the potential impact on nutrient reduction each method is capable of achieving for each state. This would make the panel's work even more valuable. For example, while landfilling routine poultry mortality may, in theory, zero out the associated nutrients, if landfilling routine poultry mortality is banned in most poultry producing states – then its impact is not accurately reflected in the report.

As for practices that are limited to catastrophic losses, those should be removed as outside the scope of the charge for the same reason – the impact of those practices on the routine mortality load is not accurately reflected in the report. If discussion of those practices is preserved, maybe drop those comments into footnotes so it's obvious to the reader that the topic is not about routine mortality.

> The purpose of Part II of the report is to provide estimates for potential nutrient transfer to water bodies given a particular standard of practice. Attempting to determine losses for every non-standard or historic practice is beyond the scope of this panel's charge. If a producer, modeler, or jurisdiction wants to compare potential nutrient transfers between disposal methods (broilers in Delaware or instance), they can use the mortality and nutrient production information in Part I combined with the potential movement fractions in Part II. This information is universal and is transferable to all parts of the watershed. Implementation or use of these practices will naturally vary by state or local conditions and programs, and the priorities or policies are determined by the jurisdictions and are outside the scope of this panel. Additionally, the standard for burial provided in the burial chapter states that the method is not feasible in sandy soils with a high-water table.

Final Disposition Is Critical to the Value of the Panel's Work

The primary goal of the Bay Program is nutrient reduction in the watershed. So, while it's important to understand intermediate steps in the nutrient's life cycle, the actual impact on the watershed – the end result – is why BMPs are created, vetted and incorporated into the model.

The panel has focused on the final disposition of the nutrients attributable to routine mortality. For example, the panel determined – rightly so – that the freezer shed was an interim step on the way to final disposition at a rendering plant, and renamed the BMP accordingly.

But the composting shed is an interim step too. Composted mortality does not stay in the shed, it is ultimately land applied. (We're not asking that the composting BMP be renamed "land application," though to be fair, that would be analogous to renaming freezers as the rendering BMP.)

What we are suggesting is that the composting process reflect the reality on the ground – that we follow the nutrients in composted mortality (along with its co-composting material) to their final disposition, for the following reasons:

First, the process simply cannot happen without co-composting material, as explained in the report at page 107: "For proper composting to occur, dry carbon-rich material must be added to mortalities to control moisture released from the carcasses and supply a carbon source for the microbes."

Second, the full process is necessary to have a true apples-to-apples comparison as between the five methods – three of which already are discussed in terms of final disposition of nutrients. Like freezing/rendering, the process doesn't end in the composting shed. Ignoring the final disposition of composting mortality is not a fair comparison on the factor most important to bay restoration efforts and by extension to this three-year endeavor – nutrient impact.

Third, the finished product of composting affects nutrient reduction in three ways:

1. The composted carcasses will be land applied,
2. But so too will the litter mixed in with it
3. Moreover, pure litter on a farm – without mortality mixed in – will not necessarily be land applied; it may be diverted from land application to an alternative use.

To illustrate, consider two identical poultry farms – each produces 100 lbs. of mortality and 1,000 lbs. of litter per flock – but one uses freezing/rendering and the other composting.

At the first farm, it's possible to contribute nothing to the nutrient load. 100 lbs. of mortality is zeroed out at the rendering plant and 1,000 lbs. of manure is zeroed out at the mushroom farm.

At the second farm, to compost 100 lbs. of mortality, ~300 lbs. of manure must be used. At the end of the process, some N escapes to the watershed via leaching, runoff and volatilization per Table II.3.1, but all the P in the 100 lbs. of mortality – and all of the P in the 300 lbs. of manure – is kept, and in fact concentrated, and then land applied. Only the remaining 700 lbs. of pure litter can be zeroed out at the mushroom farm.

This is a very unsophisticated illustration but it demonstrates that the composting process creates an additional and new source of nutrients – and that the process also taints a co-composting material that could otherwise be zeroed out if transported to an alternative use.

Nutrient losses and transfers during land application is not within this panel's scope. Other panels have looked at land application in detail and the panel plays no part in assessing those existing model procedures. The system considered in the panels' work was drawn around the production unit in order to give each disposal method equal footing. The panel did provide estimates of nutrients available for land application either on the farm or elsewhere in or out of the watershed. A more detailed response concerning carbon-rich material being brought into the system is addressed below. The case studies brought up by Greener Solutions helps to illustrate the use of this panels work by modelers. The mortalities stored frozen and rendered is in fact "zeroed out" of the agricultural sector of the model (the nutrients discharged to the atmosphere and surface water by the rendering plant will reappear in the model via other data inputs). In the case of the second farm composting litter, phosphorus in the litter generated on the farm and land applied goes into the land application part of the model. The phosphorus in mortalities created on the farm is currently considered as part of the manure stream, but could be counted separately in later updates to the model based on the work of this panel. The nutrients from litter sent to the mushroom farm is not zeroed-out, unless it's a case where the modeling teams advises that those should be considered "outside the watershed" or effectively "zeroed out."

Fourth, as stated repeatedly in the panel's report, the co-composting material is MORE important than the carcasses when it comes to

1. Nutrient content – See, e.g., report at 116 "total acreage needed for spreading depends on nutrients added with co-composting materials."
2. Volatilization – See e.g., report at 111 ("There is a large variability in the nitrogen loss from carcass compost piles. This variation is caused primarily by co- composting materials added to piles to aid in composting rather than the carcasses themselves.")
3. Leaching and runoff – see, e.g., report at 114 ("Glanville et al. (2006), Gilroyed et al. (2016), and Hutchinson and Seekins (2021) all found that co-composting material, not the carcasses, significantly influenced leachate and air emission quality and quantity.")

To repeatedly declare the importance of the co-composting material in every facet of the analysis of the composting methodology and then overlook its impact in the final result of the process seems inconsistent and reduces the value of the panel's conclusions.

The report did state the importance of co-composting materials in nutrient losses from mortality composting. If the impression is that co-composting materials are more important than mortalities in the final deposition of mortality composting, perhaps the panel should reconsider the wording used in this section. Going back to the sources cited, the co-composting material influencing air emissions and leachate is manure and other "green" materials and not carbon-rich "brown" material. In the case of broiler mortality composting, poultry litter and recycled mortality compost are used as inoculum. Since these materials are generated in the production area of the farm, nutrients contained in inoculum will not alter the land needed for application of the litter-mortality waste stream. One of the challenges Extension specialists advising poultry producers on mortality composting face is convincing farmers that they should use less inoculum and more carbon-rich material. The farmers see litter as a free resource and wood chips, sawdust, etc. as an expense to be avoided. The purpose of the carbon-rich material is to add Carbon to the mixture and add as little N and P as possible. Going through the calculations to determine the amount of carbon-rich material needed to bring the poultry mortality compost mixture up to an initial C:N to induce the composting process, shows that very little P (compared to carcasses and litter) is added. Considering off-farm carbon material added to mortalities in the calculations used to generate Table II.3.5 and would not significantly increase the acreage needed to spread the nutrients contained in mortalities.

Fifth, without considering the fate or final disposition of the compost, the analysis misses a significant issue: once the process is done where will the compost be land applied?

As the report states at page 118, "[a]t the end of the compost process, the producer has a valuable soil amendment." Finding a destination for that soil amendment, however, can be challenging. First, many modern poultry growers focus solely on poultry and grow no crops. Therefore, these "no-land" operations have no need (and often no land) for spreading this soil amendment. Second, even some farms that grow crops are prohibited from using manure/litter/compost on their fields because of high legacy nutrients in the soil. Third, according mass balance studies, supply of nutrient rich material is outstripping crop demand, so finding a home for this excess material is becoming more and more challenging.

Most poultry farms in North America produce more nutrients than is able to be assimilated on land owned by the farm. However, finding a solution to this situation is not within the charge of this panel. This panel's report can help shed light on the additional land needed to assimilate mortality nutrients if their final disposition is in fact land application.

Sixth, poultry mortality is already reflected in the model as part of the manure/litter load, so the results of the panel's analysis could be plugged directly into load calculations and/or modeling scenarios. (That may not be true for other animal types, but that's not a reason to leave out valuable information the poultry industry could use.) This makes sense as litter, manure and mortality are already combined – and as the report states at page 113 "the carcass disintegrates and becomes more or less congruent with the carbon-rich material" so all three sources are considered a homogenous mix – from both the perspective of the panel and the model.

Not certain what valuable information the panel did not provide.

Seventh, the "fate," i.e., final disposition, of N and P across selected practices includes "Field application" of compost, according the panel's charge on page 8.

This was taken into account by the panel. The approach taken provides this information for all disposal methods not just composting.

Finally, the data should reflect the reality on the ground so the analysis could be used by nutrient management professionals and policy makers for planning purposes. Table II.3.4. and Table II.3.5 on page 117, which calculates how many acres are needed to properly land apply the nutrients found in a carcass – after the carcass has gone through the composting process, but without the nutrients created by the co-composting material – really illustrates why the real value in the analysis is in the final disposition of the process. No one can use the data in those tables. It's not possible to spread just carcasses post-composting.

The difficulty the panel encountered, presumably, is that there are several potential sources for co-composting material and identifying and analyzing all of them would be a huge separate assignment; however, it cannot be that the solution is to forgo the analysis with co-composting material, especially when it has been established that the co-composting material is the bigger factor vis-a-vis nutrient content, leaching and volatilization.

Instead, a common co-composting material could be used to run the acreage calculations, and explain in a footnote that other co-composting materials will skew the results up or down (and that that analysis is a separate research project in the future). For example, nearly all poultry farms on Delmarva (and probably elsewhere) primarily use litter/cake for composting. This makes sense because, as the report explains on page 112:

There is very little capital investment required to implement a compost program for carcass management. Most farm operations already have the infrastructure, land, co-composting materials, and material handling equipment necessary for composting.

In other words, most producers use what they have on hand, i.e., poultry growers use litter/cake rather than pay to have outside materials brought in. So, the panel could use the litter/cake research on nutrient content, leaching and volatilization already found elsewhere in the report to run the numbers and create an example – an example that also happens to be accurate for a large majority of poultry growers. Those numbers would reflect the reality on the ground and could be used by nutrient management professionals, bay modelers and policy makers for planning purposes.

> The question of nutrients introduced from off-farm carbon-rich materials has been answered above. The individual members of this panel have performed the calculations for compost nutrient composition numerous times.

Part 2 of feedback: individual comments and suggested edits in the report

[Editor's note: We are currently working to extract the extensive comments and suggestions made in the report itself and summarize them into this appendix for a narrative record of the comments and responses. For now, and for the AgWG's reference, the PDF of Victor Clark's feedback in track-changes is posted on the September 16 calendar entry.]

[Editor's note: The following farmer's input was forwarded by Victor Clark with the farmer's permission (see above). The input is copied verbatim, but anonymously, as the individual may not have been aware that their input would be included in this appendix for publication.]

I do think 1 term that can be used is protein recovery or protein recycling. Ultimately with the swine that product is kept fresh and high quality and then is recycled back into the protein supply chain. basically that is completing the loop.

ALL this is done safely. As I have thought about this system. Its really a asset to that operation as they did away with all the composting management and the endless turkey vultures that were hanging around. (they are a real problem.) and we were upsetting the balance of nature here.

We Like the system and if we could get cost share moneys would expand it into PA.

The panel has reviewed the comments attached to the report provided by Greener Solutions. Most of the comments are contained within the general areas to which we have responded above in this appendix. An exception is the size of broilers grown on the Delmarva peninsula. We are aware that many farms grow birds larger than 8 pounds. Figures I.2.6 and I.2.10 provide data on mortalities collected weekly and cumulative nutrients produced through the grow-out of market weights beyond 8 pounds (7-week birds). Table I.2.4 provides annual production data for 4, 6, and 8-pound market weights to reflect the range of average weight of broilers marketed in each state (Table I.2.1.). The average weight of production is most important in the regional modeling of nutrients. Data on on-farm production of mortalities will be addressed in additional publications authored by individual panelists.

Frank Schneider, PA State Conservation Commission

[Editor's note: Copied here is text of the letter that was submitted on PA-SCC letterhead. Received via email on August 13, 2021.]

Reference: Estimates of Nutrient Loads from Animal Mortalities and Reductions Associated with Mortality Disposal Methods and Best Management Practices (BMPs) in the Chesapeake Bay Watershed

Jeremy,

Thank you for the time to provide a review and comments on the report titled "Estimates of Nutrient Loads from Animal Mortalities and Reductions Associated with Mortality Disposal Methods and Best Management Practices (BMPs) in the Chesapeake Bay Watershed"

Overall we found the report to be well done, informative, and an asset moving forward.

Pennsylvania offer the following editorial comments for suggestion, as no technical issues were identified

1. When the report discussed the different species (Broilers, Layer, Swine), they call out Lancaster Co specifically, which is not exactly the case. In general, Lancaster and the surrounding counties in the South Central part of the state contain the largest populations.
2. The layer housing descriptions may be outdated, or at least in Pennsylvania. Most new or remodeled facilities are now cage free and belt dried manure systems.

Again, Thanks for the opportunity to comment.

Sincerely,

Frank X, Schneider
Director, Nutrient and Odor Management Programs

CC: Jill Whitcomb, Pa DEP
Kate Bresaw, Pa DEP

The panel relied primarily on the 2017 Census of Agriculture (USDA-NASS, 2019) and a previous Chesapeake Bay Expert Panel report, *Animal Waste Systems, Recommendations from the BMP Expert Panel for the Animal Waste Management Systems in the Phase 6 Watershed Model* (Hawkins et al., 2016), for providing information on animal populations and operating systems. Both of these publications used aggregate data on a county-by-county basis, and perhaps unfortunately, Lancaster County came out on top on each of those animal groups. Perhaps it would be more descriptive to state that South Central Pennsylvania contains the heaviest concentration of animal agriculture in the state, but we stated data on a county basis.

The statement in the laying hen section about housing and manure collection types, again was taken from Hawkins et al. (2016) and reflects the state of the industry in 2010-2015. It will be updated to read, "Almost all layers raised in the Watershed are housed in large confinement buildings (Figure I.2.11), most commonly in cages (although in recent years cage-free housing is becoming dominant). The most common manure handling system for layers is a two-level, high-rise house. Caged birds are housed in the upper level of the high-rise house (Figure I.2.12). Manure is dried and stored in the lower level (Hawkins et al., 2016). Most of the newer, cage-free facilities use belt-dried manure handling systems."

Appendix F. Record of Decisions

Partnership review and approval process, starting with most recent decision

Water Quality Goal Implementation Team
July 24, 2023
Approved by consensus
https://www.chesapeakebay.net/what/event/water-quality-goal-implementation-team-git-3-meeting-july-2023

Watershed Technical Workgroup
July 6, 2023
Approved by consensus
https://www.chesapeakebay.net/what/event/watershed-technical-workgroup-meeting-july-2023

Agriculture Workgroup
October 21, 2021
Approved by consensus
https://www.chesapeakebay.net/what/event/agriculture-workgroup-conference-call-october-20211

“Roll-out” webcast and presentation of recommendations
August 13, 2021
https://www.chesapeakebay.net/what/event/animal-mortality-management-bmp-expert-panel-recommendations-roll-out-webin

Panel deliberations (See Appendix D)

Panel formation and open stakeholder meeting

Open stakeholder meeting
November 28, 2018
https://www.chesapeakebay.net/what/event/open-stakeholder-session-animal-mortality-management-bmp-expert-panel

Agriculture Workgroup
August 16, 2018
The AgWG approved of the panel membership.
https://www.chesapeakebay.net/what/event/agriculture-workgroup-test

March 15, 2018
The AgWG approved the charge and scope for the expert panel (see Appendix A).
https://www.chesapeakebay.net/what/event/agriculture-workgroup-conference-call-march-2018