DRAFT Recommendations for the Manure Treatment Technologies Expert Panel

Prepared for the Chesapeake Bay Program Partnership's Agriculture Workgroup
by the Manure Treatment Technology Subgroup

I. Introduction

Agriculture is the second largest land use in the Chesapeake Bay watershed, second only to forests. Manure from animal agriculture is the largest source of phosphorus loadings to the Chesapeake Bay and the second largest source of nitrogen. Traditionally, livestock and poultry manure has been a valuable resource for farmers, because it provides a cost-effective source of fertilizer. Applied appropriately, manure adds nutrients as well as organic matter, improving both soil fertility and quality. There is a threshold, however, to the amount of nutrients that can be applied and used productively on fields. Manure's ratio of phosphorus to nitrogen is higher than the ratio that crop's need. Thus a farmer who applies enough manure to meet the crop's need for nitrogen is over-applying phosphorus. The unused phosphorus builds up in the soil, and these elevated levels can increase phosphorus runoff and leaching. In addition, since manure is bulky and difficult to transport long distances, it is usually spread close to the farm where it was produced—which also can lead to excess nutrients in the soil, making them more susceptible to runoff.

The need to rebalance the use of nutrients and protect water quality in the Bay region has led to interest and investment in manure treatment technologies and alternate uses of manure. In addition, revisions to existing phosphorus management regulations (e.g., in Maryland) may restrict land application of manure even more, increasing the need for these technologies. Currently, the Chesapeake Bay Watershed Model does not give explicit "credit" for these projects toward a jurisdiction's pollution reduction obligations under the Chesapeake Bay Total Maximum Daily Load. In an effort to expand the number of manure management technologies included in the Chesapeake Bay Watershed Model, the Chesapeake Bay Program Partnership Agricultural Workgroup formed an ad hoc subgroup tasked with developing a scope of work for an expert panel to take on the challenge of recommending approach(es) that could be used by the Chesapeake Bay Program Partnership to quantify the nutrient reduction benefits of these manure treatment technologies. Specifically, the Manure Treatment Technology Subgroup's goals were to:

- Identify technologies for review;
- Recommend priorities for the order of review;
- Recommend areas of expertise that should be included on the Expert Panel; and
- Suggest the panel's charge (the assigned task) for the review process.

A call for nominations for members of the Manure Treatment Technology Subgroup was released in August 2013. The Chesapeake Bay Program Partnership Agricultural Workgroup selected a final list of members on September 26, 2013. From November of 2013 through April of 2014 the subgroup met eight times, and worked collaboratively to complete this draft report. They presented an intermediate reports to the Chesapeake Bay Program Partnership Agricultural

Workgroup in December of 2013, and solicited feedback at that time. The final report draft will be presented to the Agricultural Work group for feedback on May 1, 2014. Members of the workgroup are listed in Table 1.

While the subgroup was tasked with identifying technologies and suggesting a priority order for review, there were specific parameters guiding the subgroup with respect to technology selection. For example, the focus area for the manure treatment technology subgroup were those technologies that applied to manure after it was excreted from the animal, but before the manure was land applied. Further, the subgroup was instructed to focus on general technology categories, rather than specific patented technologies.

Table 1. Manure Treatment Technology Subgroup membership and affiliations.

Member	Affiliation
Kristen Hughes Evans, Chair	Sustainable Chesapeake
Glenn Carpenter	USDA Natural Resources Conservation Service
Ted Tesler	Pennsylvania Department of Environmental Protection
Peter Hughes	Red Barn Consulting
Marel Raub	Chesapeake Bay Commission
Dwight Dotterer	Maryland Department of Agriculture
Beth McGee	Chesapeake Bay Foundation
Mark Dubin, Coordinator	University of Maryland
Emma Giese, Staff	Chesapeake Research Consortium

II. Glossary of Terms

Baled Poultry Litter: A process whereby raw poultry litter is compressed and wrapped (usually in plastic) to form round or square bales. Baling poultry litter is typically done to facilitate transportation to end-users. Although weight will still limit the amount of poultry litter that can be transported in any one load, baled poultry litter can be transported on flatbed trailers whereas raw poultry litter is typically transported via walking floor trailers. Flatbed trailers weigh less, cost less to purchase, and are less costly to maintain than walking floor trailers.

Biological Nitrogen (N) Removal: A treatment process for liquid wastewater that facilitates microbially mediated removal of nitrogen. Depending on the form of nitrogen treated, microbial processes involved may include microbial decomposition, hydrolysis, assimilation, nitrification and/or denitrification. Organic nitrogen (such as proteins and urea) may be decomposed and hydrolyzed into ammonia nitrogen, which is then subject to both nitrification and microbial assimilation.Nitrifying bacteria can convert ammonia nitrogen (NH_4^+) to nitrate in the right conditions. Specifically, *Nitrosomonas* bacteria convert NH_4^+ to nitrite (NO_2^-), and nitrite Nitrobacter convert NO_2^- to nitrate (NO_3^-). The presence of oxygen and a relatively narrow optimal pH range (7.5 to 8.6) and temperature are required for nitrifying bacteria to thrive.

Alternatively, anoxic conditions (without oxygen) are required for denitrification, a process whereby NO_3^- is converted to N_2 by a range of heterotrophic bacteria. The presence of dissolved oxygen disrupts this process. Optimal pH lies between 7 and 8 and temperature affects the rate of removal. Achieving biological nitrogen removal for high-strength wastewaters such as animal manure generally involves the addition of oxygen to facilitate microbial decomposition of organic forms of nitrogen and nitrification.

Chemical Treatments –Dry Manure: Dry manure – particularly poultry litter – is commonly treated to reduce emissions of ammonia in the house to improve in-house air quality and improve bird production. Amendments such as sodium bisulfate($NaHSO_4$, marketed as PLT), aluminum sulfate ($Al2(SO_4)_3$, or alum), ferric sulfate ($Fe_2(SO_4)_3$□$9H_2O$ marketed as KLASP) reduce the pH of the litter, thereby reducing the volatilization of ammonia. Other amendments that are not widely used (because have note been demonstrated to be as effective as others for ammonia removal (and/or have the potential to cause environmental damage) reduce ammonia emissions by absorbing ammonia, inhibiting the conversion of organic nitrogen to ammonia, or increase the litter pH between flocks to facilitate volatilization (which in theory would be removed via ventilation before chicks are placed).

Some chemical amendments that reduce ammonia volatilization also reduce the solubility of manure phosphorus. For example, alum treatment reduces the solubility and potential for transport of poultry litter phosphorus to surface waters.

Chemical Treatments – Wet Manure: The process of precipitating inorganic phosphorus (and in some cases ammonia-nitrogen) from liquid wastewater using metal salt additives. Flocculants to facilitate settling may also be used. Commonly used metal salts include aluminum sulfate (alum), aluminum chloride ($AlCl_3$), ferric chloride ($FeCl_3$) and ferric sulfate ($FeSO_4$). This approach is technically feasible with animal manures but not used widely given the cost and material handling challenges associated with on-farm operation.

Phosphorus can also be precipitated a potentially marketable fertilizer in the forms calcium phosphate ($Ca(H2PO_4)_2$) and struvite ($MgNH_4PO_4 \bullet 6H_2O$). Calcium phosphate is formed using calcium hydroxide ($Ca(OH)_2$) and struvite is formed using magnesium chloride (MgCl) as the metal salt. These processes may require adjustment of manure pH. Struvite precipitation has been used with swine and dairy, with better success with swine due to calcium ion interference associated with dairy manure. Treatment with calcium hydroxide has been used with both liquid and solid manures. Solid-separation of liquid manures prior to chemical amendment is generally recommended to reduce the amount of metal salts required, as suspended solids will interfere with inorganic phosphorus removal rates.

Composting: The process of facilitating microbial decomposition of dry manure solids that results in a final product that has reduced volume, density, odor, and pathogen content. Some manure nitrogen may be lost to the atmosphere through volatilization. The nitrogen remaining is generally considered to be more stable in the environment. The composting process can also generate temperatures high enough to kill some weed seeds. Microbes that decompose manure are endemic in manure but maintaining the proper environment for them to thrive is important. Oxygen, moisture, and proper carbon to nitrogen ratio are important criteria for composting. Oxygen may need to be achieved by aerating the pile mechanically, and moisture may need to be added. Outside temperature affects the time it takes to achieve a finished product.

Enzymatic Digestion: Also called enzymatic hydrolysis. Enzymes are proteins designed to decompose specific organic compounds (i.e. the break molecular bonds) into water-soluble compounds. When this process is microbially mediated, enzymes are released by bacteria. Enzymes are important in digestion of food, and in the anaerobic digestion of manure where they are produced naturally by anaerobic bacteria. They have also been proposed for use in conjunction with anaerobic digestion, or as an additive to manure lagoons to facilitate decomposition of organic matter, reduce odors, or enhance methane production.

Solid-Liquid separation: Solid-liquid separation systems are designed to physically separate suspended solids from liquid manure. A variety of approaches are used with animal manure including engineered passive sedimentation systems (for example a settling basin that allows for periodic dry solids removal or a weeping wall) and mechanical separation systems such as screens, centrifuges, and presses.
The type of separation system appropriate for a farm depends on the type of manure removal system in place, the characteristics of the manure, the animal bedding used, and the treatment objective.

Generally, the primary function of solid-liquid separators is to separate coarse solid particles from manure. Removal of coarse solids can facilitate recycling of bedding, transport of solids for re-use on or off the farm, and can extend the storage capacity of liquid manure systems.

Microbial Digestion (aerobic/anaerobic): A liquid manure microbially-mediated process, digestion of manures converts manure carbon into either carbon dioxide (CO_2) or methane gas (CH_4), depending on whether the digestion occurs in an oxic or anaerobic environment. Because manure is rich in organic matter, addition of water generally results in anaerobic conditions. Hence, anaerobic digestion of manure is the most common digestion approach for liquid manures (aerobic digestion processes would require the addition of oxygen). Digestion processes are used to reduce volume and odor. Anaerobic digestion also reduces pathogen content and produces biogas, which is combustible and used as a source of fuel for generation of heat or electricity. Even if methane gas is not used as a source of fuel, because it has global warming capacity 23 times that of CO_2, even flaring methane gas can significantly reduce the carbon footprint of dairy production. While anaerobic digestion is more commonly proposed for liquid manures, it has also been successfully used with dry manures including poultry litter, where supplemental liquid is added to achieve anaerobic conditions.

Pelletizing: Pelletizing is the process of converting raw manure into a processed, pellet-sized product that is sold as a fertilizer or soil amendment. Generally, pelletizing facilities dry or compost manure or poultry litter to achieve temperatures that reduce pathogens, kill weed seeds, and reduce odor. Manure or litter is then generally processed (for example via a hammer mill) into smaller size fractions. Pelletizing equipment (often called a "pellet mill") then produces a pellet-sized product from the dried, fine manure material. The final product may be sold in bulk or bagged and sold as organic fertilizer for use in home gardening applications.

Thermal (or Thermochemical) Treatment: A term that encompasses a range of technologies that use thermal decomposition to treat manure and produce energy and other potentially useful co-products. Thermal technologies are generally used with manure that is relatively dry (such as poultry litter) because costs associated with drying litter are avoided. Types of thermal technologies include pyrolysis, gasification and combustion technologies, which can be adapted for farm, community or regional systems. Pyrolysis of manure occurs in oxygen deficient environments and is an endothermic reaction (i.e. it requires energy) and occurs at a lower temperature range than gasification and combustion. Temperatures for pyrolysis start in the range of 200 to 300°C (390 to 570°F) while gasification and combustion occur at higher temperatures at temperatures > 700°C (1300 °F) in systems with controlled rates of oxygen. Gasification and combustion are exothermic (energy producing) reactions. Pyrolysis systems can be designed to capture bio-oils and volatile, combustible gases (also called synthesis gas or producer gas) produced from the pyrolysis process. Gasification systems generally separate heat application to manure (designed to volatize combustible gases) and combustion of the resulting gas. Whereas in combustion systems, pyrolysis, gasification and combustion thermal processes generally occur in one chamber.

Thermal processes have been proposed as a manure treatment process because they reduce the volume and weight of manure, thereby facilitating transport of excess manure phosphorus out of highly concentrated areas of animal production. Phosphorus (and potash) minerals concentrated in ash or biochar can be used as fertilizers in nutrient deficient regions. While pyrolysis systems can conserve some of the original manure nitrogen in the biochar, generally most of the manure nitrogen is converted into atmospheric nitrogen (both reactive and non-reactive) in thermal treatment processes.

III. Methods

<u>Soliciting Partner Input</u>

We adopted a survey approach to solicit feedback from the Chesapeake Bay Program Partnership's Agricultural Workgroup members and affiliated partners. The intention was to use survey results, in addition to other factors (such as availability of monitoring data and proposed adoption rates) to determine priorities for technology review. To develop the survey, we drafted a list of manure treatment technologies that met the criteria for consideration (i.e. affected manure after excretion and before land application and that were general technology groups rather than specific patented patented technologies). Then, we developed a survey that requested responders to rank each technology as "high," "medium," or "low" priority. Responders were also asked to include additional comments for each of the technologies, as well as to include additional technology recommendations and an associated priority ranking. The survey was distributed to all members of the Chesapeake Bay Program Partnership Agricultural Workgroup. Additional partners (such as members of the Virginia Waste Solutions Forum) were also given an opportunity to participate. Manure Treatment Technology Subgroup subcommittee members did not participate in this survey. Results from the survey were presented to the Ag Workgroup on December 12, 2014 and additional feedback was solicited at that time.

<u>Manure Treatment Technology Subgroup Process for Prioritizing Technologies</u>

The Manure Treatment Technology Subgroup focused on three key considerations for ranking technologies: 1) partner input based on survey responses and Ag Workgroup feedback; 2) the availability of reliable monitoring data needed to develop nutrient reduction efficiencies; and 3) the level of current and proposed adoption of the technology.

With respect to the availability of reliable data, we were looking for performance monitoring data that was publically available and collected by reliable third parties. Evidence of performance over time was also a consideration, and in this respect we considered the commercial availability of the technology (as opposed to technologies still in the research and development phase) in the prioritization process.

Concerning the level of current and proposed adoption, we considered the amount of facilities impacted, the amount of manure proposed for treatment, and the relative nutrient reduction potential of the proposed implementation. In this respect, we considered the implementation of the technology now and implementation proposed for the near future. We also considered whether the technology was included as a significant component of state Watershed Implement Plans and/or whether states had committed significant funds to implementation.

<u>Additional Considerations</u>

In addition to prioritizing technologies, the Manure Treatment Technology Subgroup also developed recommendations for areas of technical expertise that should be included on the panel. These recommendations were based on feedback from the Ag Workgroup (from the December 12, 2013 meeting) as well as from our professional experience.

We also spent time developing recommendations for the panel's charge. These were based in part from our experience as well as from a conference call with Chesapeake Bay Program EPA Modeling staff on December 17, 2014, where we discussed modeling considerations for Phase 5.3.2 and Phase 6.0.

IV. Priority Technologies

<u>Discussion of Partnership Survey Results</u>

Twenty-one responses were received from the partnership survey. Technologies rankings based on survey results are presented in Table 2. The top three technology priorities according to partner recommendations were liquid/solid separation, anaerobic digestion, and composting.

The next three (virtually tied) are phosphorus removal, treatments for reducing ammonia volatilization and phosphorus solubility and thermochemical treatment.

Table 2. Partnership Survey Results

Manure Treatment	Priority Average Score*
Liquid/solid separation	**2.70**
Anaerobic digestion	**2.42**
Composting	**2.21**
Phosphorus removal	**2.11**
Treatments for reducing ammonia volatilization and phosphorus solubility	**2.10**
Thermochemical treatment	**2.10**
Pelletizing	**1.94**
Aerobic/liquid manure digester	**1.85**
Biological N removal	**1.60**
Enzymatic digestion	**1.56**

*Average priority score based on assigned values as follows: 3 = High; 2 = Medium; 1 = Low priority. Average score = sum of total values/# assigned priority values.

<u>Chesapeake Bay Program Agricultural Workgroup Feedback</u>

At the December 12th, 2013 meeting, results from the partnership survey were presented to the Chesapeake Bay Program Agricultural Workgroup and feedback was solicited. Suggestions from the workgroup included:

- Workgroup members supported the focus on general technology categories rather than specific patented technologies.
- Workgroup members noted that it would be important to distinguish whether the BMP applied to liquid or solid manure (on member noted specifically the differences between chemical amendments for poultry litter that can reduce soluble phosphorus and chemical amendments for phosphorus removal in liquid manure).
- They encouraged the subgroup to include a definition of each technology category in the final report.
- They also suggested the subgroup check with NRCS manure treatment technology experts and review recommendations from the 2025 Goal Line conference to ensure the technology list was complete.

<u>Discussion of Subgroup Prioritization Results</u>

The Manure Treatment Technology Subgroup prioritization results (in Table 3) differed somewhat from the survey prioritization results. For example, based on the Ag Workgroup feedback, we split phosphorus removal into two technology subgroups: “Chemical treatments – dry” and “Chemical treatments – wet” to indicate that there were two different approaches depending on whether the practice applied to liquid or solid manure.

Table 3. Manure Treatment Technology Subgroup recommended prioritization

High Priority Technologies:	**Level of Current and Proposed Adoption (3=high, 2=med, 1=low)**	**Monitoring Data Availability (Current and near future) (3=high, 2=med, 1=low)**
Microbial Digestion (aerobic/anaerobic)	3	3
Chemical Treatments - dry	3	3
Thermochemical	3	3-2
Liquid/solid separation	3	3-2
Composting	3-2	2
Chemical Treatments - wet	1	1
Other Technologies:		
Biological Nitrogen Removal		
Enzymatic digestion		

A discussion of the subgroup's rationale for the prioritization is as follows:

Microbial Digestion (aerobic/anaerobic): The subgroup ranked this technology as a high-priority because it has been adopted on multiple farms in the region (most notably Pennsylvania), state and federal cost share programs and energy contracts support their adoption, and these technologies were included in at least one of Bay state's watershed implementation plans. Research suggests that digesting manure increases the portion of total nitrogen that is plant available, potentially reducing supplemental fertilizer nitrogen requirements.

Chemical Treatments – Dry: This category was distinguished from the original, and more general technology category "phosphorus removal" based on recommendations from the Agricultural Workgroup. This treatment was ranked highly because cost share programs are currently available to support the practice (e.g. for ammonia emissions reduction in poultry houses) and the treatment is widely utilized by poultry growers as a means of reducing ammonia emissions in the house for improved environmental and bird health/production outcomes. Depending on what product is used, there is potential to reduce both ammonia emissions and soluble phosphorus in surface runoff from fields fertilized with treated poultry litter. There is research to document soluble phosphorus reductions in runoff from fields fertilized with poultry litter treated with some dry poultry litter chemical treatments (for example, alum).

Thermochemical Treatment: Several states provide federal and state financial support and/or cost share, it's mentioned in several state watershed implementation plans, and both larger and farm-scale systems are installed and proposed for installation in the future that are treating and have the potential to treat significant volumes of manure. Larger-scale systems require operational permits that require air emissions data collection and some smaller scale projects currently being implemented are a component of third-party performance monitoring efforts. Other projects where nutrient credits are being traded are also subject to monitoring and third party data validation.

Solid-Liquid Separation: These technologies are often associated with anaerobic digestion and composting projects and are relatively common in the region. State and federal cost share or financial assistance is available in several Bay states to support their implementation. Although data has not been collected on the performance of all solid-liquid separator designs, there is third-party performance data available for many systems available on the market. Note that many solid-liquid separators are patented designs. We suggest the Expert Panel develop a BMP efficiency for general categories of solid-liquid separation systems based on research for different types of separators. Also, we note that solid-liquid separators are components of a larger manure management system and suggest that that the Expert Panel assign BMP efficiencies for solid-liquid separation when used in conjunction with manure management systems that achieve nutrient reductions. We also note that the nutrient reduction value of solid liquid separation may be achieved via reduced land application or improved timing of manure application, or increase in manure transported off the farm. If so, these nutrient reductions may be captured in work done by other expert panels (nutrient management panel or waste storage for example).

Composting: Interest in composting manure is growing in the region as a means of transporting excess nutrients off the farm. Some states have federal or state cost share funding available to support the practice. Composting manure can potentially change the total amount of nitrogen, and the form of nitrogen and phosphorus in manure. Based on best professional judgment of subgroup members, we ranked this as a "2" for availability of monitoring data.

Chemical Treatments – Wet: Most of these technologies are currently in the pilot phase of development and few are available commercially for farm-scale deployment. Limited on-farm third-party monitoring data is available. These represent promising but emerging technologies.

Pelletizing: This technology is being used by Perdue Agricycle at a large-scale facility in Delaware and facilitates nutrient transport and alternative uses. However, pelletizing technologies preserve nutrient content of the manure and are not proposed for use at the farm-scale in the region. We suggest that nutrient reductions associated with the existing Perdue facility are most likely being adequately captured via the "manure transport" best management practice and suggested that no new work on this practice was needed at this time.

Baled Poultry Litter: Baling poultry litter is being considered by poultry growers in West Virginia as a means of facilitating new markets for excess poultry litter, but otherwise is not currently being utilized in the region. There may be nutrient reductions associated with storage and composting with respect to local use of baled poultry litter, albeit little third-party performance data is available. However, we suggest that most nutrient reductions associated with this practice would result from transportation, which is adequately captured by the existing "manure transport" best management practice. In addition, the process of baling may also facilitate composting. If so, this would be captured via development of a BMP efficiency for composting.

Biological Nitrogen Removal: This practice is not widely utilized for manure treatment or proposed for widespread adoption on farms in the Chesapeake Bay region. There is limited third-party performance data available for on-farm technologies.

Enzymatic Digestion: Treatment of liquid manure with enzymes has been used by some farmers in the region to reduce solids and odors in lagoon storage systems. However, enzymatic digestion does not remove nitrogen or phosphorus from manure, and there is limited third-party performance data available for expert panel review. Also, these technologies are not proposed for widespread adoption on farms in the region, cost share funding is not available for them, and they are not included in state watershed implementation plans.

Discussion of Technologies Not in Scope of Work

The expert panel will be charged with evaluating technologies within the livestock production area regarding the handling, processing, and treatment of manure. Earlier processes such as feed management, and later processes such as nutrient transport and application are addressed elsewhere in the model, and are therefore would not be in this Expert Panel's scope of work. Specific examples of technologies not proposed for consideration by the Expert Panel (but that were recommended by partners in the survey process) include:

- **Baled poultry litter:** Currently being evaluated by poultry growers in West Virginia as a means of expanding markets for excess litter nutrients, baling poultry litter would best fit in the transportation BMP category of the Bay Model and is thus outside of this panel's scope of work. Alternatively, baling may facilitate composting which would be captured under the composting BMP.

- **Fluidized co-digestion:** The subgroup considered this technology to be captured under the anaerobic digestion BMP.

- **Constructed wetland:** This BMP is already included in the model for habitat/water-quality restoration, albeit not as a manure treatment BMP. We noted that constructed wetlands are not generally recommended for treatment of concentrated animal manure and not widely utilized or proposed for treatment of manure on farms in the region. However, a separate panel will evaluate constructed wetlands for treatment of agricultural stormwater (potentially including dust from poultry house tunnel fans).

- **Feed management:** This BMP is already included in the model.

- **Improving crop uptake** is a later process, which would be handled separately in the model.

- **System changes**, such as shifting from a flush dairy manure removal system to dry pack system was also suggested. We noted that the trend in the industry is to move from dry to liquid. Dry pack systems have the opportunity to compost manure and reduce costs associated with storing liquid manure. We suggest that the composting BMP covers a component of this approach, and that the nutrient management expert panel would cover changes in the form and timing of manure application. Also, the ag workgroup intends to form a waste storage evaluation panel in the future that would also cover this approach.

- **Pelletizing** facilitates manure transport, which is modeled separately.

- **Manure injection** is currently an interim BMP, which will also be addressed by a future expert panel.

V. Expert Panel Charge and Scope of Work

Recommendations for Expert Panel Member Expertise:
The Manure Treatment Technology Subgroup recommends that the Manure Treatment Technology Expert Panel should include members with the following areas of expertise that represent the geographic diversity of the region:

- Biological/bio-systems engineering
- Manure nitrogen and phosphorus cycling through agricultural systems, and air and water resources
- Atmospheric emissions from manure treatment/handling systems including deposition and fate of manure ammonia and NOx emissions.
- Livestock production and manure management systems typical in the Chesapeake Bay region.
- Nutrient management planning and agronomy.
- Knowledge of how BMPs are tracked and reported, and the Chesapeake Bay Program partnership's modeling tools.

Expert Panel Scope of Work:
The Manure Technology Expert Panel will develop definitions and loading or effectiveness estimates, as well as define nutrient pathways for the technologies outlined above, based on the order of priority recommended by the Agricultural Work group.

The panel will work with the Agriculture Workgroup and Watershed Technical Workgroup to develop a report that includes information as described in 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 (with some modifications considering the specific application to manure treatment technologies identified in italics):

- Identity and expertise of panel members
- *Detailed definition of the technology*
- Recommended nitrogen, phosphorus, and sediment 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, etc)
  - Detailed discussion of how each reference was considered.
- Land uses *and manure types* 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:

- This 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 due to climate, hydrogeomorphic region, or other measureable factors.

- 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 and reported:
  - Include a clear indication that this BMP will be used and reported by jurisdictions
- Identification of any ancillary benefits or unintended consequences beyond impacts on nitrogen, phosphorus and sediment loads. Examples include increased, or reduced, air emissions.
- 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
- Operation and maintenance requirements and how neglect alters performance
- Discussion of how the practices will be verified

Additional guidelines:

- 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 eliminates a pollutant from surface transport but moves the pollutant into groundwater *or the air*.

In addition, we suggest the Expert Panel 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[1].

[1] available online at: http://www.chesapeakebay.net/documents/Nutrient-Sediment_Control_Review_Protocol_07162013.pdf