Draft BMP Panel Report

Definitions and Recommended Nutrient Reduction Efficiencies of

Manure Injection & Incorporation Practices
For Use in Phase 6.0 of the Chesapeake Bay Program Watershed Model

Recommendations for Approval by the Water Quality Goal Implementation Team's Watershed Technical and Agricultural Workgroups

Submitted by the Phase 6.0 Nutrient Management BMP Expert Panel

Submitted to:
Agriculture Workgroup
Chesapeake Bay Program

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Contents

Acronyms and Abbreviations

ac	Acre
AgWG	Agriculture Workgroup
ARS	USDA Agricultural Research Service
BMP	Best Management Practice
CBP	Chesapeake Bay Program
CBPO	Chesapeake Bay Program Office
CBPWM	Chesapeake Bay Program Watershed Model
CBW	Chesapeake Bay Watershed
CRC	Chesapeake Research Consortium
DE	Delaware
ft.	Feet
ha	Hectare
kg	Kilogram
lbs.	Pounds
LGU	Land-Grant University
MD	Maryland
MII	Manure Incorporation and Injection
N	Nitrogen
NEIEN	National Environmental Information Exchange Network
NRCS	USDA Natural Resources Conservation Service
NY	New York
P	Phosphorus
PA	Pennsylvania
Panel	Manure Injection & Incorporation Expert Panel
QAPP	Quality Assurance Project Plan
TN	Total Nitrogen
TP	Total Phosphorus
USDA	U.S. Department of Agriculture

VA	Virginia
WTWG	Watershed Technical Workgroup
WQGIT	Water Quality Goal Implementation Team
WV	West Virginia

Summary of Recommendations

1 Introduction

In the current version of the Chesapeake Bay Program (CBP) Partnership's Watershed Model (version 5.3.2), manure injection is recognized as an interim practice used for planning purposes only. This document summarizes the recommendations of the Phase 6 Manure Injection & Incorporation Expert Panel (the Panel) for revised definitions and credits for manure injection & incorporation practices. The Panel, whose members are identified in Table 1~~Table 1~~, proposes that the Chesapeake Bay Program's (CBP) existing definitions associated with MII be replaced by the three new annual practices defined below.

Table 1. CBP Phase 6.0 Manure Injection & Incorporation Expert Panel Membership

Name	Jurisdiction	Affiliation	Role
Curt Dell		USDA-Agricultural Research Service	Panel Chair
Art Allen	Maryland	University of Maryland – Eastern Shore	Panel Member
Dan Dostie	Pennsylvania	USDA – Natural Resources Conservation Service	Panel Member
Robb Meinen	Pennsylvania	Penn State University	Panel Member
Rory Maguire	Virginia	Virginia Tech University	Panel Member
Chris Brosch	Delaware	Delaware Department of Agriculture	Watershed Technical Workgroup representative
Jeff Sweeney		CBPO	Modeling Team representative
Technical support provided by Mark Dubin (University of Maryland, CBPO), Lindsey Gordon (CRC Staffer), and Don Meals (Tetra Tech).			

CBPO – Chesapeake Bay Program Office; CRC – Chesapeake Research Consortium; USDA – U.S. Department of Agriculture

2 Practice Definitions

The Panel recommends the following definitions for three annual manure injection & incorporation (MII) practices for use in Version 6 of the model:

- Manure Injection
- Manure Incorporation High Disturbance
- Manure Incorporation Low Disturbance

Manure injection is a specialized category of placement in which organic nutrient sources (including manures, biosolids, and composted materials) are mechanically applied into the root zone with surface soil closure at the time of application. Injection is expected to provide the greatest level of nutrient loss reduction to both atmospheric and surface runoff pathways (including both dissolved and sediment bound nutrients), as well as odor reduction, due to limited quantities of material left on the soil surface, limited soil disruption, and immediate soil closure. Total soil surface disturbance for injection plus planting and any other field operations should be less than 40% so that the practice is compatible with the Low Residue, Strip Till/No-Till practice.

Manure incorporation is defined as the mixing of dry, semi-dry, or liquid organic nutrient sources (including manures, biosolids, and compost) into the soil profile within a specified time period from application by a range of field operations =24hr for full ammonia loss reduction credit and 3 days for P reduction credit(s)). These methods can provide loss reductions that may differ for P and N by method used. Nutrient loss reductions are primarily due to lower ammonia-N volatilization and in many cases lower dissolved P and N losses in surface runoff. Nutrient loss reductions may vary with timing between application and soil mixing, degree of soil mixing, and percent soil surface disturbance. The Panel has established two categories of incorporation:

- **High disturbance incorporation**, providing the highest degree of mixing of organic nutrient sources into the root zone, but effectively eliminating the erosion control benefits of conservation tillage. Incorporation plus additional field operations retain <30 % of residue cover at planting.
- **Low disturbance incorporation**, leaving greater quantities of organic nutrient sources on the soil surface, but maintaining most of the benefits of conservation tillage. Incorporation plus additional field operations retains at least 30 % of residue cover at planting to meet criteria for the Phase 6 Conservation Tillage practice.

Only N and P loss reduction efficiencies have been established for these practices. Any sediment loss reductions associated with adoption of injection or low disturbance incorporation are addressed through credits for corresponding conservation tillage BMPs.

Baseline condition for these practices is surface application of organic nutrient sources after a conventional tillage operation (no mixing with soil) or incorporation of organic nutrient sources by a tillage operation outside the established time window (>3 days after application).

In fully defining the practice(s), the Panel specifies the following qualifying practice conditions, including:

- Appropriate manure application technologies
    - **Injection**: Several companies (DSI, Yetter, and others) manufacture shallow disk or narrow shank injectors with closing disks that provide closed slot injection of liquid slurry with limited soil disturbance. There is currently no commercially available equipment for injection of solid or semi-solid organic nutrient sources. The USDA-ARS prototype poultry litter injector has been tested extensively in Manokin River (Maryland) and other watersheds and meets criteria for the category, but the design is not yet commercially available. It should be recognized that most injection technologies will leave some manure on the surface, but this exposure is a small compared to broadcast techniques.
    - **Low-disturbance incorporation**: A wide range of conservation tillage implements could be used. Vertical tillage and rolling tine aerators are expected to be the most widely used implements in the category. Rolling tine aerators, and potentially other implements, have adjustable toolbar angles (in reference to direction of travel) and can produce variable amounts of soil disruption and residue burial. When used in offset configurations, implements may cause more soil disturbance/residue removal than is allowed for credit under this BMP.
    - **High-disturbance incorporation**: Any tillage system is appropriate for this category. Chisel plowing followed by secondary tillage with disk harrow or field cultivator is expected to be the most commonly used practice.
- Incorporation must be within 24 hours after application for full credit for ammonia emission reduction and within 1 to 3 days for reduced credit. To receive credit for P loss reduction, incorporation must be within 3 days of application.
- Soil disturbance and residue management criteria for injection should be consistent with the USDA-NRCS practice standard for no-till/strip-till (329), and low disturbance incorporation should be consistent with the reduced tillage standard (345).
- Sediment loss can be high with high disturbance incorporation, causing reductions in dissolved nutrient losses to be offset by increased losses of sediment-bound nutrients. Sediment-bound P losses are expected to be high with full width tillage in upland regions of the watershed (Piedmont, Ridge and Valley, and Appalachian Plateau) due to the extent of sloping landscapes and erodible soil textures, therefore P loss reduction credit is recommended with high disturbance tillage only on the Coastal Plain.

3 Effectiveness Estimates

Loss reduction efficiency values are listed in Tables 2 and 3 below. The panel determined that primary benefits of incorporating organic nutrient sources are derived from reducing N losses due to ammonia volatilization and P losses with surface runoff (dissolved and/or sediment bound P). Incorporation has not been shown to influence subsurface (leaching) losses of N or P, therefore reduction efficiencies are applied only to the portion of nutrients transported with surface water runoff. Due to limited data, conservative reduction efficiency values were assigned for runoff N loss reduction. Because nutrient loss reductions with injection and incorporation are achieved only for the portion nutrients lost with runoff (both dissolved and sediment-bound), it was necessary to scale loss reduction factors to the portion of total nutrients lost with surface runoff. A greater proportion of P losses occur with runoff in upland portions of the watershed compared to the Coastal Plain, therefore separate P reduction values were determined for the Coastal Plain. Scientific background and detailed explanation of the determination of reduction factors are provided in Section 4.

Table 2. Nutrient loss reduction efficiency values for upland regions of the Chesapeake Bay Watershed.

	Nitrogen			**Phosphorus**	
Category	Time to incorporation	Ammonia emission reduction	Reduction in N loading[1]	Time to incorporation	Reduction in P loading[2]
Injection	0	85%	12%	0	36%
Low Disturbance Incorporation	=24 hr 24-72 hr	50% 34%	8% 8%	=72 hr	24%
High Disturbance Incorporation	=24 hr 24-72 hr	75% 50%	8% 8%	=72 hr	0%[3]

[1] Reduction in N loading water achieved only for losses with surface runoff. The portion of total N loss through leaching is not impacted by the practices. 25% of total N losses to water are assumed to be lost with runoff (both dissolved N and sediment-associated organic matter N).

[2] Reduction in P loading water achieved only for losses with surface runoff. The portion of total N loss through leaching is not impacted by the practices. 80% of total P losses to water are assumed to be lost with runoff (both dissolved and sediment-bound P) in upland regions of the watershed.

[3] Reduction in dissolved P losses typically offset by greater sediment-bound P losses due to greater soil erosion with tillage incorporation in upland landscapes.

Table 3. Nutrient loss reduction efficiency values for Coastal Plain region of the Chesapeake Bay Watershed.

	Nitrogen			Phosphorus	
Category	Time to incorporation	Ammonia emission reduction	Reduction in N loading[1]	Time to incorporation	Reduction in P loading[2]
Injection	0	85%	12%	0	22%
Low Disturbance Incorporation	=24 hr 24-72 hr	50% 34%	8% 8%	=72 hr	14%
High Disturbance Incorporation	=24 hr 24-72 hr	75% 50%	8% 8%	=72 hr	14%

[1] Reduction in N loading water achieved only for losses with surface runoff. The portion of total N loss through leaching is not impacted by the practices. 25% of total N losses to water are assumed to be lost with runoff (both dissolved N and sediment-associated organic matter N).

[2] Reduction in P loading water achieved only for losses with surface runoff. The portion of total N loss through leaching is not impacted by the practices. 48% of total P losses to water are assumed to be lost with runoff (both dissolved and sediment-bound P) in Coastal Plain.

4 Review of Literature and Data Gaps

The full literature review developed by the Panel is contained in a separate document (Attachment 1 "MIIP lit summary.xlsx). All citations used in the literature review are listed in the References section of this report. The following sections discuss the justification for effectiveness based on a review of the literature and the application of best professional judgement by the Panel members.

4.1 Identification of practice categories

Removal of organic nutrient sources from the soil surface and mixing them into the soil profile with tillage has been shown to very effectively reduce losses of N as ammonia when done shortly after application. In some cases, the mixing of manures can also greatly reduce P and N losses with surface runoff. This can be accomplished with various injection equipment that open slots in the soil and place the organic nutrient sources directly into the slot or by incorporating applied materials into the soil with a tillage operation. (Literature review summarized in Attachment 1).

Because a wide range of methods have been referred to as manure injection, the panel used professional judgment to adopt a definition. Greatest reduction in ammonia volatilization and runoff losses occur with full coverage of organic nutrient sources by soil, leading the panel to require concurrent injection slot closure to qualify for the injection category. Immediate incorporation also provides maximum potential to reduce N and P losses with surface runoff, so it was decided that coupled one-pass application and incorporation were required for the category. The panel also felt that the injection category should be limited to low disturbance injection systems to allow compatibility with the no-till/strip till BMP. All other manure incorporation approaches were considered to fall within categories for high or low disturbance tillage incorporation. Because of the large potential to increase erosion losses with increasing tillage intensity, the panel felt that full-width tillage systems (high disturbance and low residue retention) should be considered separately from incorporation with conservation tillage operations (low disturbance, high residue retention). To be compatible with the Conservation Tillage BMP, low disturbance incorporation plus any additional field operations must retain 30% or more residue at planting. Because tillage incorporation operations are normally separate from application, allowable time lapses between application and incorporation were determined (see below).

4.2 Reduction factors considered

Both results of published studies (summarized in Attachment 1) and panelist's professional experience indicated that various injection and incorporation methods can have significantly different impacts on N and P losses. Therefore, separate loss reduction factors were used for the two nutrients. However, the Panel decided that sediment loss reduction should not be considered for these practices, because soil erosion control is not the direct function of these practices and sediment loss reduction is more appropriately addressed by the Conservation Tillage Panel. However, practice impacts on losses of N and P associated with sediment were directly considered by this panel when determining reduction efficiencies. Some studies reported both nutrient and sediment impacts. In these cases sediment related results are included in Attachment 1and are available for other panels and for future considerations.

The Panel also concluded that the impacts of injection and incorporation practices could differ across the watershed due to differences in topography, drainage, and soil type, particularly for P losses. Therefore, the upland portions of the watershed (Piedmont, Ridge and Valley, and Alleghany Plateau) and the Coastal Plain were addressed separately when considering P loss reduction factors.

4.3 Organic nutrient source form or animal manure type

The panel initially looked at data for liquid slurries and solid poultry litter separately, but found that data fell within similar ranges for the two groups. Therefore, it was determined that animal and manure types can be lumped within a practice category. Data for biosolids and organic amendments other than livestock manures are very limited. Therefore, incorporation of all organic nutrient sources is assumed to provide similar effects.

4.4 Ammonia loss reduction factors

A number of studies indicated that closed-slot manure injection typically reduced ammonia emission by over 90% (e.g., Thompson et. al. 1987, Weslien et al. 1998, Pote et al. 2011, Dell et al. 2012, Carozzi et al. 2013, and Kulesza et al. 2014). To address the potential for somewhat lower performance of the practice at the field scale compared to plot scale, the panel assigned an ammonia reduction efficiency of 85% for injection, where the injection slot is immediately covered with soil. Literature values for ammonia reduction with low disturbance incorporation ranged widely from near zero to nearly 100% (Attachment 1). Practices in the category can leave substantial amounts of manure on the soil surface, with the amount greatly influence by soil conditions and manure properties, leading to smaller and less consistent reductions in ammonia emissions compared to injection. Because of the wide range in reported reductions, the panel assigned an efficiency value of 50% for incorporation within 24 hours and 34% for incorporation in 1 to 3 days. A wide diversity of equipment can be included in this category, also hindering precise estimation of reduction credits.

High disturbance incorporation has been shown to be highly effective at reducing ammonia emissions, with nearly complete elimination of emissions if manure is incorporated immediately. The range in reported reduction efficiencies appeared to be related to the length of time between manure application and incorporation. Because of the expectation of high ammonia emissions rates between application and incorporation, reduction values of 75% for incorporation within 24hr and 50% for incorporation in 1 to 3 days were assigned.

Determination of two reduction factors for the tillage incorporation categories, based on time between application and incorporation, were made to allow states flexibility in reporting. For consistency with nutrient management guidelines from LGU's within the watershed, full credit was given for incorporation within 24 hours. A single, lower factor for delayed incorporation (1 to 3 day after application) was selected after consultation with State representatives on the Agriculture Workgroup, who did not anticipate a benefit from being able to report acreage with a longer delay before incorporation. The decreased efficiency value for delayed incorporation was derived from Maryland nutrient management guidelines (http://mda.maryland.gov/resource_conservation/Documents/nm_manual/2009%20I-C%20p1-3%20s6.pdf) and were consistent with N conservation values with tillage used by other states in the watershed.

The amount of organic nutrient source left on the soil surface is the primary control over ammonia emission (Dell et al. 2012), with soil type and slope having little impact. Therefore, efficiency values are expected to be similar across soil types and landscape positions, and the same values for ammonia loss reduction were assigned to upland and Coastal Plain

portions of the watershed.

4.5 Consideration of leaching

Information on the impacts of injection or tillage incorporation on N and P leaching is limited, and no data exist from the watershed suggesting that incorporation has the potential to decrease leaching losses. For example, a 4-year study in Pennsylvania showed no significant differences between leaching losses of N between shallow-disk injected and unincorporated dairy manure (Dell et al. 2012, Duncan 2016). Some resources indicated a potential to increase N leaching (e.g. Powell et al. 2011, Staver 2004) when incorporation is used, especially if manure is applied in excess of recommended rates (Ball-Coelho 2007) or applied over shallow tile drains. When appropriate application rates are used and areas of excessive drainage are avoided, the practices are not expected to adversely impact leaching losses of N or P. Only one study indicated a reduction of N leaching with injection (Weslien 1998). Several panelists agreed that occasional soil disturbance in no-till systems can destroy soil macropores, which act as preferential pathways to subsurface drainages (Geohring et al. 2001). Because of limited and conflicting scientific data and no mechanistic reason to expect load reductions, the panel determined that leaching should not be considered as a factor in determination of efficiency values.

4.6 P loss reductions

P loss reductions factors are based on the runoff reduction efficiency and scaled to the proportion of total P loss due to runoff for the region of the watershed (regional differences discussed in the following section). Reduction factors were determined as follows:

Reduction in P loading = (P runoff reduction) x (fraction of total P losses with runoff)

Injection: The range of reduction in runoff P loads was wide, from a nearly complete elimination of loss in several studies to substantial increases in a limited number of papers. Typically, loss reductions for both manure slurries and poultry litter was in the 70-90% range (Attachment 1, Maguire et al. 2011). Studies reporting increases in P losses with injection (due to increased sediment-bound P losses) were conducted in another country with very different soils and weather conditions compared to the Bay Watershed (McConnell et al. 2013) or had mechanical issues in the year where increased P losses was reported (Johnson et al. 2011). Most studies on this P loss pathway were conducted on small plot or laboratory scale observational studies, with many relying on simulated rainfall to generate runoff. The Panel believed that reduction efficiencies should be more conservative than values typically observed in plot experiments for several reasons: 1) Plot experiments are closely controlled and BMP performance can be optimized; 2) Weather impacts/soil conditions and mechanical issues can reduce efficiency at the field/farm scale; 3) Most research data have been generated with simulated rainfall, which is very effective for treatment comparisons but likely produces P loss amounts that differ from those resulting from natural rainfall. Given these considerations, the Panel assigned a runoff P reduction factor of 45% for injection. When scaled to account for the fractions of total P losses with runoff, reduction in P loading for injection is 36% for upland regions of the watershed and 22% for the Coastal Plain.

Low disturbance incorporation: The range of reduction reported in the literature was similar to that with injection, but panel felt greater conservatism should be added since published data did not represent the full range of equipment that could be used and still meet the disturbance/residue cover criteria for the category. Since this category does not require coverage of the manure by soil, there was an additional need for conservatism in the reduction efficiency value. Therefore, the panel assigned a runoff P loss reduction factor of 30%. When scaled to account for the fractions of total P losses with runoff, reduction in P loading with low disturbance incorporation is 24% for upland regions of the watershed and 14% for the Coastal Plain.

High disturbance incorporation: Full width tillage is consistently effective in reducing water soluble P losses because of enhanced P sorption due to mixing of manure and soil (Attachment 1). However, increased soil erosion and loss of particulate P was shown to frequently increase overall P losses (Bundy et al. 2001, Kleinman e al. 2009, Verbree et al. 2010). The Panel determined that no reduction credit should be given for this practice in upland regions where the potential for increased erosion P loss was likely with intensive tillage. Because erosion potential is decreased due to lower slope and greater water infiltration, a moderate reduction credit was given for the Coastal Plain. However, data for the Coastal Plain are limited. Kibet et al. (2011) showed a reduction of 61% in soluble P loss with incorporated poultry litter, while Staver

and Brinefield (2001) showed soluble P losses that were typically 30-50% lower from a tilled watershed compared to a paired no-till watershed. Given the limited data, the Panel determined that a conservative runoff reduction credit of 30% was appropriate for the Coastal Plain. When scaled to account for the fractions of total P losses with runoff, reduction in loading with high disturbance incorporation on the Coastal Plain is 14%.

4.7 Regional Differences in P loss

While the same efficiency for reducing runoff P loss was applied to both upland regions and the Coastal Plain, runoff in upland regions were considered to make a larger contribution to total P losses because of greater slope and less internal drainage. The Panel assumed that 80% of P losses were typically associated with runoff in the upland portions of the watershed (personal communication from Peter Kleinman, USDA-ARS). Surface runoff accounts for only about 10% of P losses on poorly drained soils, which are typically ditch or tile drained, on the Coastal Plain (Vadas et al. 2007). Soil survey data indicates the about 25% of the Coastal Plain soils are poorly drained. Runoff losses of P are typically much greater on naturally-drained Coastal Plain soils than the artificially drained areas (personal communication from Ken Staver, UMD). The ratio of surface to subsurface P losses is not well established for the naturally-drained Coastal Plain soils. Because those soils typically have better infiltration than soils from the upland regions of the watershed and more leaching is expected, we are assuming runoff losses are responsible for 60% of P loss on the naturally-drained soils on the Coastal Plain (about 75% of the total area). Therefore, the panel estimated that 48% of the P losses on the Coastal Plain result from runoff: ((25% poorly drained x 10% of P loss) + (75% better drained x 60% of P loss)).

4.8 Timing of incorporation for P credit

The Panel decided that incorporation was required within 3 days of application for P reduction credit to be given. The time frame was set to be consistent with longest delay allowed for N reduction credit.

4.9 Runoff losses of N

Data reporting injection and incorporation impacts on N losses with runoff water (either in dissolved forms or in sediment associated organic matter) are limited and variable, but reduction in N losses of 19-98% have been reported (Gilley et al. 2013. Kulesza et al. 2014, Pote et al. 2009, Staver et al. 2004). Because the mechanisms of reduction of dissolved N losses with runoff are similar to those controlling runoff P losses, the Panel recommends that runoff reduction factors determined for P be applied to runoff N (45% for injection and 30% for high and low disturbance incorporation). However, runoff is typically expected to account for a smaller fraction of total N loss as compared to P. Coupled measurement of surface and subsurface N losses are very limited. Runoff accounted for less than 10% of total N lost in water flow from plot scale lysimeters on a well-drained site in central Pennsylvania (Duncan, 2016). To account for the range of soils and landscapes across the watershed, the panel is assuming that runoff contributes 25% of the total N load in both upland and Coastal Plain regions of the watershed.

4.10 Outstanding Issues and Gaps

The panel struggled with the best way to address trade-offs between dissolved and sediment-bound P loss pathways for surface runoff. Measurements are showing P stratification in the soil profile with no-till is frequently leading to concentrated accumulations of P near the soil surface, which can lead to greater losses of dissolved P in runoff. Tillage is effective in mixing the P deeper into the soil profile and reducing soluble P load in runoff, but the reduction in dissolved P can be offset by greater sediment-bound P losses, especially with high disturbance incorporation. Some researchers in the region are suggesting periodic tillage in no-till systems (such as once or twice per decade) to prevent accumulation of P near the soil surface, assuming that the tillage operations would be done based on soil test information and erosion risks are carefully considered. Guidelines for periodic tillage have not yet been developed, so the panel was unable to address periodic incorporation practice at this time. However, future panels should consider the developing knowledge addressing impacts of tillage and other practices, such as cover cropping, for reducing problems related to P stratification.
Data regarding leaching losses of both N and P is limited, with very few studies integrating both measurements of surface and subsurface flow over the entire year. While the panel does not anticipate emerging research showing that injection or incorporation can significantly and consistently reduce N or P losses, a better understanding of the special circumstances where the practices can lead to increased nutrient losses would be beneficial. Since reduction of N and P loading with these

practices are achieved by reducing losses with surface water flow, additional data on fraction of total N and P losses from surface (runoff) and subsurface (leaching) flow should improve reduction efficiency estimates in the future. Additional studies addressing full, annual N and P balances with these practices under natural rainfall are needed.

5 Application of Practice Estimates

5.1 Load Sources

Manure injection and incorporation practices are simulated as BMPs with associated nutrient and sediment reduction efficiencies. Manure injection and incorporation practices are annual practices.

Manure injection and incorporation practices apply to all land uses that include manure eligible crops for the following Phase 6.0 Agricultural Land Uses:

Full Season Soybeans	Soybeans ineligible for double cropping
Grain with Manure	Corn or sorghum for grain eligible for manure application and ineligible for double cropping
Legume Hay	Legume forage crops eligible for manure
Silage with Manure	Corn or sorghum for silage eligible for manure application and ineligible for double cropping
Small Grains and Grains	Small grains and grains other than corn or sorghum eligible for manure and ineligible for double cropping
Specialty Crop High	Specialty crops with relatively high nutrient inputs with some crops eligible for manure
Specialty Crop Low	Specialty crops with relatively low nutrient inputs with some crops eligible for manure
Other Agronomic Crops	Other high commodity row crops such as tobacco, cotton, etc., with some crops eligible for manure

5.2 Practice Baseline

Baseline condition for the MII practices is surface application of organic nutrient sources after a conventional tillage operation (no mixing with soil) or incorporation of organic nutrient sources by a tillage operation outside the established time window (>3 days after application).

5.3 Hydrologic Conditions

The Panel represented manure injection and incorporation BMPs that can be applied across all hydrologic conditions in the CBW. However, wet conditions can reduce effectiveness of injection by impeding infiltration of manure slurries into the soil and through poor closure of the injection slot, leaving greater quantities of manure on the soil surface.

5.4 Sediment

The Panel did not specifically address changes in sediment losses or reductions resulting from implementation of MII BMPs, except to note that high disturbance incorporation effectively eliminates the erosion control benefits of conservation

tillage. Any sediment loss reductions associated with adoption of injection or low disturbance incorporation are addressed through credits for corresponding conservation tillage BMPs.

5.5 Species of Nitrogen and Phosphorus

While the Panel considered and discussed loss pathways of different forms of N (ammonia, total) and P (dissolved, particulate), the Panel report focused on reductions in losses of total N and total P.

5.6 Geographic Considerations

Manure injection and incorporation practices can be applied to specified land uses everywhere within the Chesapeake Bay watershed. However, because of regional differences in P loss pathways, the Panel provided different P loss reduction efficiency estimates for upland and coastal plain regions of the CBW.

5.7 Temporal Considerations

Temporal considerations - the delay between manure application and incorporation – are key criteria in the proposed efficiency values (see Tables 2 and 3). Overall, the Panel report represents MII BMPs that may or may not have temporal considerations depending on the sequence of BMP implementation within the constraints of farm management operations. There is no lag time anticipated between establishment and full functioning of the BMPs.

5.8 Practice Limitations

The practices may have localized limitations on applicability, including steep slopes, stony soils, and wet conditions. Soil texture, drainage class, and slope influence impacts of the practices on nutrient loss reductions. Weather conditions, as they influence soil moisture, runoff generation, and ammonia volatilization, also impact practice performance.

5.9 Potential Interactions with other Practices

The Panel recognizes that manure application and incorporation BMPs interact with other agricultural practices for all agricultural land use categories in the CBW. Interactions with conservation tillage practices (especially high disturbance incorporation) are particularly important, as full-width tillage reduces the extent of soil residue cover and eliminates the erosion control benefits of conservation tillage.

5.10 Unintended Consequences and Ancillary Benefits

Unintended consequences: Expanded incorporation, especially with conventional tillage methods, could increase sediment, nutrient, and soil organic matter losses on soil with moderate to high erosion risk. Injection over shallow drain tiles or other preferential flow pathways could also lead to increased leaching losses of N and P. Injection has been shown to increase emissions of the greenhouse gas nitrous oxide for short periods following application.

Ancillary benefits: Odor emissions are reduced; N to P ratio of soils improved; need for supplementary applications of commercial N fertilizer reduced; and losses of hormones, pathogens and emerging contaminants reduced.

6 Practice Monitoring and Reporting

6.1 Phase 6.0 Manure Injection & Incorporation Tracking, Verification, and Reporting

Because incorporation within a specified time period is a requirement, verification will require a review of operational records in addition to visual confirmation. Because timely incorporation is usually a component of nutrient management planning, the verification for injection or incorporation practices should be done in conjunction with verification of nutrient management.

In Phase 6, states are responsible for reporting county acres or percentages for manure incorporation and injection practices to the National Environmental Information Exchange Network (NEIEN) for all years. If a state does not currently have historic implementation information, they should consider obtaining historic BMP implementation information where possible, and tracking and reporting for future years. However, the full implementation of CBP BMP verification requirements in 2018 will necessitate the tracking, verification, and reporting of practice implementation data for future reduction credits.

The Panel recommends manure incorporation and injection practice implementation tracking, verification, and reporting on a county-by-county or state-by-state basis be based on the premise that the practices represent Visual Assessment (Single Year) BMPs. States will report BMP implementation annually to the CBPO as the number or percentage of acres meeting the definitions and qualifications set forth by the Panel in this report for injection, low disturbance incorporation, and high disturbance incorporation BMPs.

Manure Incorporation and Injection BMPs represent a new reportable suite of BMPs for the CBP modeling tools over the history of the Program. Manure injection and incorporation practices have not been historically tracked and implementation reported to the Chesapeake Bay Program models. Manure injection technologies are relatively new, with only limited current use and no significant use in the past. Therefore, the panel recommends that injection BMPs only be considered for future crediting. Manure incorporation by tillage has long been common, but timing of incorporation must be considered to determine eligibility for historic implementation. Timely incorporation on organic nutrient sources is likely to be a component of nutrient management plans and documented in recent farm records, but documentation of incorporation timing is unlikely to be documented prior to implementation of nutrient management planning requirements. As such, manure incorporation and injection BMPs may and/or may not be included in the jurisdictions' verification plans that were submitted to the CBP in late 2015. As with all BMPs, the jurisdictions will be expected to document their verification protocols and procedures in their Quality Assurance Project Plans (QAPP) for manure incorporation and injection BMPs that are reported to the CBPO for N and P crediting reductions. The jurisdictions will determine if modifications of those verification plans are required after this Expert Panel recommendation report is approved by the CBP partnership following the WQGIT BMP Protocol, and before the jurisdictions are able to start reporting these BMPs in the Phase 6 modeling tools for annual progress implementation. As the states consider how to verify manure incorporation and injection BMPs and as they document those procedures in their QAPPs, state partners should follow the existing Agriculture Workgroup's (AgWG) BMP Verification Guidance (http://www.chesapeakebay.net/about/programs/bmp/additional_resources).

The current verification guidance from the AgWG organizes BMPs into three general categories: Visual Assessment BMPs (Single Year), Visual Assessment BMPs (Multi-Year), and Non-Visual Assessment BMPs. The complete AgWG guidance is quite extensive and is not restated in this section; the Panel refers to the AgWG guidance for additional detail and definitions of these assessment methods. The Panel is not proposing any new or unique aspects of BMP verification for purposes of the BMPs described in this report. This section simply explains how the recommended BMPs correspond to the existing BMP verification guidance.

Manure incorporation and injection practices are often part of a larger nutrient and soil conservation management system or

plan that often involves multiple management and physical components (e.g., animal waste storage systems, nutrient management plans, conservation plans, crop rotations) that can be visually assessed over time. Manure incorporation and injection practices as part of systems or plans also incorporate single year visual components (e.g. manure appl tillage, crop residue management), in addition to other documentation as needed under applicable state or federal agricultural programs, and/or permits. Thus, manure incorporation and injection BMPs can reasonably be verified using elements of the Visual Assessment (Single-Year) category described by the AgWG.

Each state will determine the most appropriate methods for verifying manure incorporation and injection BMP implementation given their specific priorities, programs, needs, and capacity. For example, one state may leverage existing farm site visits to also verify that the operation meets applicable manure incorporation and injection BMP definitions as recommended by the Panel. Another state may compile verified manure incorporation and injection implementation data derived from the verified oversight of nutrient management plans, conservation plans and agricultural erosion and sedimentation plans, or field transect surveys based on the CTIC standards to provide sufficient verification on a county-scale basis, incorporating quality assurance and quality control (QA/QC) spot-checks. Ideally states will leverage multiple existing and perhaps new avenues to verify that manure incorporation and injection practices are sufficient to meet the BMP criteria as determined by a trained and/or certified independent third party, and that the data records are accurate and up-to-date.

Jurisdictions can follow the AgWG's guidance for Visual Assessment (Single Year) BMPs to verify the injection, low disturbance incorporation, and high disturbance incorporation BMPs recommended in this report for N and P reduction credits in the Phase 6 Chesapeake Bay Watershed Model. Verification for Visual Assessment (Single Year) BMPs depends more on an annual visual assessment of physical features, but may need to also consider incorporating oversight and checks on operational records or documentation for this suite of BMPs, as evidence of the physical features may be short-lived due to other field management activities.

The N and P reductions for manure incorporation and injection BMPs described in this report are to be based on the verified required elements of the manure incorporation and injection BMPs following the AgWG's guidance for Visual Assessment (Single Year) BMPs. Because manure incorporation and injection are an annually reported BMP, the most important criteria (i.e., soil residue cover and disturbance) could be documented in records available to the applicable state agency. Given the close association between conservation tillage and other CBP-approved BMPs (e.g., conservation planning, nutrient management) the state agency can potentially use relevant data or associated verification methods for other reported BMPs to verify the type and acres that were managed via one of the manure incorporation and injection BMPs described by the Panel. If the state agency finds that this basic information cannot be verified through its spot-checks, transect surveys, or other annual BMP verification procedures described in its QAPP, then the BMP cannot satisfy the definitions and expected N and P reductions described in this report.

For more information about the CBP Partnership's BMP Verification Framework
The full CBP partnership BMP Verification Framework is available online at http://www.chesapeakebay.net/about/programs/bmp/additional_resources (scroll down to October 2014 Basinwide BMP Verification Framework Document).
The current AgWG's BMP Verification Guidance is included in Appendix B of the full Framework Document, available at http://www.chesapeakebay.net/documents/Appendix%20B%20-Ag%20BMP%20Verification%20Guidance%20Final.pdf.

6.2 Future Verification of Manure Injection & Incorporation Practices

The Panel envisions that potential opportunities may exist in the future for utilizing alternative forms of BMP verification, including examples such as remote sensing from satellite, aerial, and drone imagery.

7 References

Aita, C., R. Gonzatto, E.C.C. Miola, D.B. dos Santos, P. Rochette, D.A. Angers, et al. 2014. Injection of Dicyandiamide-Treated Pig Slurry Reduced Ammonia Volatilization without Enhancing Soil Nitrous Oxide Emissions from No-Till Corn in Southern Brazil. *Journal of Environmental Quality* 43:789-800. doi:10.2134/jeq2013.07.0301.

Allen, B.L. and A.R. Mallarino. 2008. Effect of liquid swine manure rate, incorporation, and timing of rainfall on phosphorus loss with surface runoff. *Journal of Environmental Quality* 37:125-137. doi:10.2134/jeq2007.0125.

Andraski, T.W., L.G. Bundy and K.C. Kilian. 2003. Manure history and long-term tillage effects on soil properties and phosphorus losses in runoff. *Journal of Environmental Quality* 32:1782-1789.

Beegle, D.B., P.J.A. Kleinman, C.J. Dell, J. Schmidt, L. Saporito, A. Rotz and M. Reiner. August 2009. Controlling Odor and Nutrient Losses to Surface Runoff, Groundwater and Air with New and Conventional Manure Injection Technologies on No-Till and Sod Soils. Final Report USDA NRCS Conservation Innovation Grant Agreement No. 68-3A75-5-190.

Bhandral, R., S. Bittman, G. Kowalenko, K. Buckley, M.H. Chantigny, D.E. Hunt, et al. 2009. Enhancing Soil Infiltration Reduces Gaseous Emissions and Improves N Uptake from Applied Dairy Slurry. *Journal of Environmental Quality* 38:1372-1382. doi:10.2134/jeq2008.0287.

Bittman, S., L.J.P. van Vliet, C.G. Kowalenko, S. McGinn, D.E. Hunt and F. Bounaix. 2005. Surface-banding liquid manure over aeration slots: A new low-disturbance method for reducing ammonia emissions and improving yield of perennial grasses. *Agronomy Journal* 97:1304-1313. doi:10.2134/argonj2004.0277.

Bundy, L.G., T.W. Andraski and J.M. Powell. 2001. Management practice effects on phosphorus losses in runoff in corn production systems. *Journal of Environmental Quality* 30:1822-1828.

Burcham, M., R. Maguire, M. Alley, W. Thomason, and B. Jones. 2008. Injecting dairy manure to decrease nitrogen and phosphorous in runoff. Virginia Tech Crop & Soil Environmental Sciences (poster).

Butler, D.M., D.H. Franklin, M.L. Cabrera, A.S. Tasistro, K. Xia and L.T. West. 2008. Evaluating aeration techniques for decreasing phosphorus export from grasslands receiving manure. *Journal of Environmental Quality* 37:1279-1287. doi:10.2134/jeq2007.0289.

Carozzi, M., R.M. Ferrara, G. Rana and M. Acutis. 2013. Evaluation of mitigation strategies to reduce ammonia losses from slurry fertilisation on arable lands. *Science of the Total Environment* 449:126-133. doi:10.1016/j.scitotenv.2012.12.082.

Coelho, B.R.B., R.C. Roy, E. Topp and D.R. Lapen. 2007. Tile water quality following liquid swine manure application into standing corn. *Journal of Environmental Quality* 36:580-587. doi:10.2134/jeq2006.0306.

Costa, M., F. Shigaki, B. Alves, P. Kleinman and M. Pereira. 2014. Swine manure application methods effects on ammonia volatilization, forage quality, and yield in the Pre-Amazon Region of Brazil. *Chilean Journal of Agricultural Research* 74: 311-318. doi:10.4067/s0718-58392014000300009.

Daverede, I.C., A.N. Kravchenko, R.G. Hoeft, E.D. Nafziger, D.G. Bullock, J.J. Warren, et al. 2004. Phosphorus runoff from incorporated and surface-applied liquid swine manure and phosphorus fertilizer. *Journal of Environmental Quality* 33:1535-1544.

Dell, C.J., P.J.A. Kleinman, J.P. Schmidt and D.B. Beegle. 2012. Low-Disturbance Manure Incorporation Effects on Ammonia and Nitrate Loss. *Journal of Environmental Quality* 41:928-937. doi:10.2134/jeq2011.0327.

Dell, C.J., J.J. Meisinger and D.B. Beegle. 2011. Subsurface Application of Manures Slurries for Conservation Tillage and Pasture Soils and Their Impact on the Nitrogen Balance. *Journal of Environmental Quality* 40:352-361. doi:10.2134/jeq2010.0069.

Duncan, E.W. 2016. Nitrogen Cycling and trade-offs with alternative manure application methods. Ph.D. Dissertation. Pennsylvania State University. University Park, PA.

Fangueiro, D., S. Surgy, V. Napier, J. Menaia, E. Vasconcelos and J. Coutinho. 2014. Impact of slurry management strategies on potential leaching of nutrients and pathogens in a sandy soil amended with cattle slurry. *Journal of Environmental Management* 146:198-205. doi:10.1016/j.jenvman.2014.07.027.

Feyereisen, G.W., P.J.A. Kleinman, G.J. Folmar, L.S. Saporito, T.R. Way, C.D. Church, et al. 2010. Effect of direct incorporation of poultry litter on phosphorus leaching from coastal plain soils. *Journal of Soil and Water Conservation* 65:243-251. doi:10.2489/jswc.65.4.243.

Franklin, D.H., M.L. Cabrera and V.H. Calvert. 2006. Fertilizer source and soil aeration effects on runoff volume and quality. *Soil Science Society of America Journal* 70:84-89.

Franklin, D.H., M.L. Cabrera, L.T. West, V.H. Calvert and J.A. Rema. 2007. Aerating grasslands: Effects on runoff and phosphorus losses from applied broiler litter. *Journal of Environmental Quality* 36:208-215. doi:10.2134/jeq2006.0012.

Garcia, A.M., T.L. Veith, P.J.A. Kleinman, C.A. Rotz and L.S. Saporito. 2008. Assessing manure management strategies through small-plot research and whole-farm modeling. *Journal of Soil and Water Conservation* 63:204-211. doi:10.2489/jswc.63.4.204.

Geohring, L.D., O.V. McHugh, M.T. Walter, T.S. Steenhuis, M.S. Akhtar and M.F. Walter. 2001. Phosphorus transport into subsurface drains by macropores after manure applications: Implications for best manure management practices. *Soil Science* 166:896-909. doi:10.1097/00010694-200112000-00004.

Giddens, J. and A.M. Rao. 1975. Effect of Incubation and Contact with Soil on Microbial and Nitrogen Changes in Poultry Manure. *Journal of Environmental Quality* 4:275-278.

Gilley, J.E., S.L. Bartelt-Hunt, S.J. Lamb, X. Li, D.B. Marx, D.D. Snow, et al. 2013. RUNOFF NUTRIENT TRANSPORT AS AFFECTED BY LAND APPLICATION METHOD, SWINE GROWTH STAGE, AND RUNOFF RATE. *Transactions of the ASABE* 56:1295-1303.

Ginting, D., J.F. Moncrief, S.C. Gupta and S.D. Evans. 1998. Interaction between manure and tillage system on phosphorus uptake and runoff losses. *Journal of Environmental Quality* 27:1403-1410.

Glaesner, N., C. Kjaergaard, G.H. Rubaek and J. Magid. 2011. Interactions between Soil Texture and Placement of Dairy Slurry Application: II. Leaching of Phosphorus Forms. *Journal of Environmental Quality* 40:344-351. doi:10.2134/jeq2010.0318.

Johnson, K.N., P.J.A. Kleinman, D.B. Beegle, H.A. Elliott and L.S. Saporito. 2011. Effect of dairy manure slurry application in a no-till system on phosphorus runoff. *Nutrient Cycling in Agroecosystems* 90:201-212. doi:10.1007/s10705-011-9422-8.

Kaiser, D.E., A.P. Mallarino, M.U. Haq and B.L. Allen. 2009. Runoff Phosphorus Loss Immediately after Poultry Manure Application as Influenced by the Application Rate and Tillage. *Journal of Environmental Quality* 38:299-308. doi:10.2134/jeq2007.0628.

Kibet, L.C., A.L. Allen, P.J.A. Kleinman, G.W. Feyereisen, C. Church, L.S. Saporito, et al. 2011. Phosphorus Runoff Losses from Subsurface-Applied Poultry Litter on Coastal Plain Soils. *Journal of Environmental Quality* 40:412-420. doi:10.2134/jeq2010.0161.

Kleinman, P.J.A., A.N. Sharpley, B.G. Moyer and G.F. Elwinger. 2002. Effect of mineral and manure phosphorus sources on runoff phosphorus. *Journal of Environmental Quality* 31:2026-2033.

Kleinman, P.J.A., A.N. Sharpley, L.S. Saporito, A.R. Buda and R.B. Bryant. 2009. Application of manure to no-till soils: phosphorus losses by sub-surface and surface pathways. *Nutrient Cycling in Agroecosystems* 84: 215-227. doi:10.1007/s10705-008-9238-3.

Kovar, J.L., T.B. Moorman, J.W. Singer, C.A. Cambardella and M.D. Tomer. 2011. Swine Manure Injection with Low-Disturbance Applicator and Cover Crops Reduce Phosphorus Losses. *Journal of Environmental Quality* 40:329-336. doi:10.2134/jeq2010.0184.

Kulesza, S.B., R.O. Maguire, W.E. Thomason, S.C. Hodges and D.H. Pote. 2014. Effects of Poultry Litter Injection on Ammonia Volatilization, Nitrogen Availability, and Nutrient Losses in Runoff. *Soil Science* 179: 190-196. doi:10.1097/ss.0000000000000058.

Little, J.L., D.R. Bennett and J.J. Miller. 2005. Nutrient and sediment losses under simulated rainfall following manure incorporation by different methods. *Journal of Environmental Quality* 34:1883-1895. doi:10.2134/jeq2005.0056.

Maguire, R.O., P.J.A. Kleinman, C.J. Dell, D.B. Beegle, R.C. Brandt, J.M. McGrath, et al. 2011. Manure Application Technology in Reduced Tillage and Forage Systems: A Review. *Journal of Environmental Quality* 40:292-301. doi:10.2134/jeq2009.0228.

McConnell, D.A., C.P. Ferris, D.G. Doody, C.T. Elliott and D.I. Matthews. 2013. Phosphorus Losses from Low-Emission Slurry Spreading Techniques. *Journal of Environmental Quality* 42:446-454. doi:10.2134/jeq2012.0024.

Morken, J. and S. Sakshaug. 1998. Direct ground injection of livestock waste slurry to avoid ammonia emission. *Nutrient Cycling in Agroecosystems* 51:59-63. doi:10.1023/a:1009756927750.

Myers, T.L., C.J. Dell and D.B. Beegle. 2013. Evaluation of ammonia emissions from manure incorporated with different soil aerator configurations. *Journal of Soil and Water Conservation* 68:306-314.

doi:10.2489/jswc.68.4.306.

Nichols, D.J., T.C. Daniel and D.R. Edwards. 1994. Nutrient Runoff from Pasture After Incorporation of Poultry Litter or Inorganic Fertilizer. *Soil Science Society of America Journal* 58:1224-1228.

Nyord, T., M.N. Hansen and T.S. Birkmose. 2012. Ammonia volatilisation and crop yield following land application of solid-liquid separated, anaerobically digested, and soil injected animal slurry to winter wheat. *Agriculture Ecosystems & Environment* 160:75-81. doi:10.1016/j.agee.2012.01.002.

Pote, D.H., W.L. Kingery, G.E. Aiken, F.X. Han, P.A. Moore and K. Buddington. 2003. Water-quality effects of incorporating poultry litter into perennial grassland soils. Journal of Environmental Quality 32: 2392-2398.

Pote, D.H. and J.J. Meisinger. 2014. Effect of poultry litter application method on ammonia volatilization from a conservation tillage system. *Journal of Soil and Water Conservation* 69:17-25. doi:10.2489/jswc.69.1.17.

Pote, D.H., T.R. Way, P.J.A. Kleinman, P.A. Moore, J.J. Meisinger, K.R. Sistani, et al. 2011. Subsurface Application of Poultry Litter in Pasture and No-Till Soils. *Journal of Environmental Quality* 40:402-411. doi:10.2134/jeq2010.0352.

Pote, D.H., T.R. Way, K.R. Sistani and P.A. Moore. 2009. Water-quality effects of a mechanized subsurface-banding technique for applying poultry litter to perennial grassland. *Journal of Environmental Management* 90: 3534-3539. doi:10.1016/j.jenvman.2009.06.006.

Powell, J.M., W.E. Jokela and T.H. Misselbrook. 2011. Dairy Slurry Application Method Impacts Ammonia Emission and Nitrate Leaching in No-Till Corn Silage. *Journal of Environmental Quality* 40:383-392. doi:10.2134/jeq2010.0082.

Ross, I.J., S. Sizemore, J.P. Bowden and C.T. Haan. 1979. Quality of Runoff from Land Receiving Surface Application and Injection of Liquid Dairy Manure. *Transactions of the ASAE* 22:1058-1062.

Rotz, C.A., P.J.A. Kleinman, C.J. Dell, T.L. Veith and D.B. Beegle. 2011. Environmental and Economic Comparisons of Manure Application Methods in Farming Systems. *Journal of Environmental Quality* 40:438-448. doi:10.2134/jeq2010.0063.

Shah, S.B., J.L. Miller and T.J. Basden. 2004. Mechanical aeration and liquid dairy manure application impacts on grassland runoff water quality and yield. *Transactions of the ASAE* 47:777-788.

Shah, S.B., M.D. Shamblin, H.N. Boone, S.A. Gartin and D.K. Bhumbla. 2004. Runoff water quality impacts of different Turkey litter application methods. *Applied Engineering in Agriculture* 20:207-210.

Singer, J.W., C.A. Cambardella and T.B. Moorman. 2008. Enhancing Nutrient Cycling by Coupling Cover Crops with Manure Injection. *Agronomy Journal* 100:1735-1739. doi:10.2134/agronj2008.0013x.

Sistani, K.R., C.H. Bolster, T.R. Way, H.A. Tobert, D.H. Pote and D.B. Watts. 2010. Influence of Poultry Litter Application Methods on the Longevity of Nutrient and E. coli in Runoff from Tall Fescue Pasture. *Water Air and Soil Pollution* 206:3-12. doi:10.1007/s11270-009-0078-9.

Staver, K.W. and R.B. Brinefield. 2001. Agriculture and Water Quality on the Maryland Eastern Shore: Where

Do We Go from Here? *BioScience* 51:859-868.

Staver, K.W. 2004. Efficient utilization of poultry litter in cash grain rotations. Final report submitted to Maryland Grain Producers Utilization Board, Delmarva Poultry Industry, and Maryland Center for Agro-Ecology. University of Maryland Wye Research and Education Center, Queenstown, MD.

Tabbara, H. 2003. Phosphorus loss to runoff water twenty-four hours after application of liquid swine manure or fertilizer. *Journal of Environmental Quality* 32:1044-1052.

Tarkalson, D.D. and R.L. Mikkelsen. 2004. Runoff phosphorus losses as related to soil test phosphorus and degree of phosphorus saturation on piedmont soils under conventional and no-tillage. *Communications in Soil Science and Plant Analysis* 35:2987-3007. doi:10.1081/lcss-200036527.

Thompson, R.B. and J.J. Meisinger. 2002. Management factors affecting ammonia volatilization from land-applied cattle slurry in the mid-Atlantic USA. *Journal of Environmental Quality* 31:1329-1338.

Thompson, R.B., J.C. Ryden and D.R. Lockyer. 1987. Fate of Nitrogen in Cattle Slurry Following Surface Application or Injection to Grassland. *Journal of Soil Science* 38:689-700.

Vadas, P.A., M.S. Srinivasan, P.J.A. Kleinman, J.P. Schmidt, and A.L. Allen. 2007. Hydrology and groundwater nutrient concentrations in a ditch-drained agroecosystem. *Journal of Soil and Water Conservation* 62:178-188.

van Vliet, L.J.P., S. Bittman, G. Derksen and C.G. Kowalenko. 2006. Aerating grassland before manure application reduces runoff nutrient loads in a high rainfall environment. *Journal of Environmental Quality* 35: 903-911. doi:10.2134/jeq2005.0266.

Verbree, D.A., S.W. Duiker and P.J.A. Kleinman. 2010. Runoff Losses of Sediment and Phosphorus from No-Till and Cultivated Soils Receiving Dairy Manure. *Journal of Environmental Quality* 39:1762-1770. doi:10.2134/jeq2010.0032.

Watts, D.B., T.R. Way and H.A. Torbert. 2011. Subsurface Application of Poultry Litter and Its Influence on Nutrient Losses in Runoff Water from Permanent Pastures. *Journal of Environmental Quality* 40:421-430. doi:10.2134/jeq2010.0089.

Weslien, P., L. Klemedtsson, L. Svensson, B. Galle, A. Kasimir-Klemedtsson and A. Gustafsson. 1998. Nitrogen losses following application of pig slurry to arable land. *Soil Use and Management* 14:200-208.

Zhao, S.L., S.C. Gupta, D.R. Huggins and J.F. Moncrief. 2001. Tillage and nutrient source effects on surface and subsurface water quality at corn planting. *Journal of Environmental Quality* 30:998-1008.

Appendix A: Technical Requirements for Reporting and Simulating Manure Injection & Incorporation BMPs in the Phase 6 Watershed Model

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 report. The purpose of the technical appendix is to describe how the expert panel's recommendations will be integrated into the modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Q1. What are the definitions of the Phase 6 manure injection and incorporation practices?

A1. The definitions for each practice are included below.

Manure Injection – The mechanical application of organic nutrient sources (including manures, biosolids and composted materials) into the root zone with surface soil closure at the time of application. Injection is expected to provide the greatest level of nutrient loss reduction from both atmospheric and surface runoff pathways, as well as odor reduction, due to limited quantities of material left on the soil surface, limited soil disruption, and immediate soil closure.

Immediate High Disturbance Manure Incorporation – The mixing of dry, semi-dry or liquid organic nutrient sources (including manures, biosolids and compost) into the soil profile within 24 hours resulting in less than 30 percent residue retention following incorporation. This practice may be combined with low residue tillage, but may not be combined with conservation tillage or high residue tillage management due to residue retention of less than 30 percent.

High Disturbance Manure Incorporation– The mixing of dry, semi-dry or liquid organic nutrient sources (including manures, biosolids and compost) into the soil profile within 72 hours resulting in less than 30 percent residue retention following incorporation. This practice may be combined with low residue tillage, but may not be combined with conservation tillage or high residue tillage management due to residue retention of less than 30 percent.

Immediate Low Disturbance Manure Incorporation – The mixing of dry, semi-dry or liquid organic nutrient sources (including manures, biosolids and compost) into the soil profile within 24 hours resulting in greater than 30 percent residue retention following incorporation. This practice may be combined with low residue tillage and conservation tillage, but may not be combined with high residue tillage management due to residue retention that likely does not equal or surpass 60 percent.

Low Disturbance Manure Incorporation – The mixing of dry, semi-dry or liquid organic nutrient sources (including manures, biosolids and compost) into the soil profile within 72 hours resulting in greater than 30 percent residue retention following incorporation. This practice may be combined with low residue tillage and conservation tillage, but may not be combined with high residue tillage management due to residue retention that likely does not equal or surpass 60 percent.

Q2. What are the nutrient reductions associated with these practices, and how are they simulated?

A2. The panel recommended simulating reductions to phosphorus runoff due to the incorporation of organic sources. These reductions vary by hydrogeomorphic region. These reductions can be found in the table below.

The panel recommended simulating nitrogen reductions in two ways. These reductions can be found in the table below.

First, incorporating or injecting manure is expected to reduce the amount of ammonium lost to the atmosphere (volatilized) following application. This will be simulated as a percent reduction in ammonium volatilization in the modeling tools, which will in turn conserve more ammonium for use by the crops. These reductions will not vary by hydrogeomorphic

region.

Secondly, the panel recommended simulating reductions to nitrogen ru f due to the incorporation of organic sou These reductions will not vary by hydrogeomorphic region.

Nutrient Reductions from Manure Injection and Incorporation Practices

	Ammonium Loss Reduction					Nitrogen Runoff Reduction					Phosphorus Runoff Reduction				
HGMR	Manure Injection	Imm. High Disturb. Incorp.	High Disturb. Incorp.	Imm. Low Disturb. Incorp.	Low Disturb. Incorp.	Manure Injection	Imm. High Disturb. Incorp.	High Disturb. Incorp.	Imm. Low Disturb. Incorp.	Low Disturb. Incorp.	Manure Injection	Imm. High Disturb. Incorp.	High Disturb. Incorp.	Imm. Low Disturb. Incorp.	Low Disturb. Incorp.
Appalachian Plateau, Siliciclastic	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Appalachian Plateau, Carbonate	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Blue Ridge	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Coastal Plain Dissected Upland	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.22	0.14	0.14	0.14	0.14
Coastal Plain Lowland	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.22	0.14	0.14	0.14	0.14
Coastal Plain Upland	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.22	0.14	0.14	0.14	0.14
Mesozoic Lowland	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Piedmont Carbonate	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Piedmont Crystalline	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Valley and Ridge Carbonate	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24
Valley and Ridge Siliciclastic	0.85	0.75	0.5	0.5	0.34	0.12	0.08	0.08	0.08	0.08	0.36	0	0	0.24	0.24

Q3. Which land uses can receive reductions for qualifying manure injection or incorporation practices.

A3. All crop land uses which are eligible to receive manure are eligible to receive credit for these practices.

- Full Season Soybeans
- Grain with Manure
- Silage with Manure
- Small Grains and Grains
- Double Crops
- Specialty Crop High
- Specialty Crop Low
- Other Agronomic Crops

Q4. Are the manure injection and incorporation practices considered annual practices for NEIEN reporting purposes?

A4. Yes. States should submit acres which qualify under each practice each year.

Q5. Can manure injection and incorporation practices be combined with other practices to treat runoff from agricultural land uses?

A5. Yes. For example, a single acre of cropland could be eligible for reduction credits from conservation tillage, manure injection, nutrient management, cover crops and upslope reductions from buffers.

Q6. The practice definitions state that high disturbance manure incorporation practices cannot be combined with conservation tillage or high residue management practices. Likewise, low disturbance manure incorporation practices cannot be combined with low residue tillage. How should states plan to track these practices to adhere to these restrictions? Can the modeling tools be employed to ensure crediting adheres to these restrictions?

A6. States should track manure injection and incorporation using the definitions included above, which will require knowing the residue remaining after incorporation.

As currently designed, the modeling tools cannot be employed to ensure that an acre of one type of conservation tillage does not also contain an acre of one type of manure incorporation. The only way for the modeling tools to do so would be to create unique BMPs which would combine each type of conservation tillage with each type of manure inc poratio This would require combining efficiencies and changing the way states track and report conservation tillage. Neither the conservation tillage panel nor the manure incorporation panel suggested this type of reporting.

Q7. What information should a state report to NEIEN in order to receive credit for manure injection and incorporation practices?

A7 States should report the following information to NEIEN.

- *BMP Name:* Manure Injection; Immediate High Disturbance Manure Incorporation; High Disturbance Manure Incorporation; Immediate Low Disturbance Manure Incorporation; Low Disturbance Manure Incorporation
- *Measurement Name:* Acres
- *Land Use:* Approved NEIEN agricultural land use classes; if none are reported, the default land use group will be "Row with Manure"
- *Geographic Location:* Approved NEIEN geographies: County; County (CBW Only); Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4); State (CBW Only)
- *Date of Implementation:* Year practice was observed.

Q8. Can an acre qualify for multiple manure incorporation and injection practices?

A8. No. Each acre may qualify for only one manure incorporation or injection practice based upon the definitions included above.

Appendix B: Methods to Estimate Historic Implementation

Representing new BMPs, manure injection and incorporation practices have not been historically tracked and implementation reported to the Chesapeake Bay Program models. Manure injection technologies are new, with only limited current use and no significant use in the past. Therefore, the panel recommends that injection only be considered for future crediting. Manure incorporation by tillage has long been common, but timing of incorporation must be considered to determine eligibility for historic implementation. Timely incorporation on organic nutrient sources is likely to be a component of nutrient management plans and documented in recent farm records, but documentation of incorporation timing is unlikely to be documented prior to implementation of nutrient management planning requirements.

Appendix C: Manure Injection & Incorporation Phase 6.0 Expert Panel Charge Document

Charge and Scope of Work
Manure Injection and Incorporation Phase 6.0 Expert Panel

Prepared for the Chesapeake Bay Program Partnership's Agriculture Workgroup by the
Manure Injection and Incorporation Expert Panel Establishment Group
March 6, 2015

Background

In the current version of the Chesapeake Bay Program (CBP) partnership's Watershed Model (version 5.3.2), manure injection is recognized as an interim practice used for planning purposes only. Manure injection incorporates multiple application methods for the subsurface upper soil horizon placement of solid, semi-solid, or liquid livestock manures. These methods are used to reduce organic nutrient losses to the environment from both atmospheric and surface runoff pathways, as well as reduce odor concerns. Injection application methods may also minimize soil surface crop residue losses over incorporation application methods. The placeholder effectiveness values are 25% TN, 0% TP and 0% TSS. Effectiveness values were based on a conservative estimate informed by university and USDA-ARS research from the Beltsville Agricultural Research Center.

The practice of manure incorporation is not currently recognized in the Phase 5.3.2 Model as an existing or interim BMP. Manure incorporation involves multiple application methods for the mixing of solid, semi-solid or liquid livestock manures in the upper soil horizon and available crop residues. These methods are used to reduce organic nutrient losses to the environment from both atmospheric and surface runoff pathways, as well reduce odor concerns. Incorporation application methods may also substantially reduce soil surface crop residues over injection methods. Due to recent increased implementation of this practice by recommendation of several state nutrient management programs, the Agriculture Workgroup has requested a review for the Phase 6.0 Model.

The Manure Injection and Incorporation Expert Panel Establishment Group (EPEG) was formed to:

- Identify priority tasks for the first Phase 6.0 (P6.0) Manure Injection and Incorporation Expert Panel (EP),
- Recommend areas of expertise that should be included on the Manure Injection and Incorporation EP, and
- Draft the Manure Injection and Incorporation EP's charge for the review process.

From February 10, 2015 through March 6, 2015 the EPEG met 3 times by conference call and worked collaboratively to complete this charge for presentation to the Agriculture Workgroup (AgWG) on March 18-19, 2015. Members of the EPEG are listed in Table 1.

Table 2. Manure Injection and Incorporation Expert Panel Establishment Group membership and affiliations.

Member	Affiliation
Kristen Hughes Evans	Sustainable Chesapeake
Dwight Dotterer	Maryland Department of Agriculture
Rory Maguire	Virginia Tech University
Kenneth W. Staver Jr	University of Maryland
EPEG Support Staff	
Emma Giese	Chesapeake Research Consortium
Mark Dubin	University of Maryland
Don Meals	Tetra Tech, Inc.

Method

The Manure Injection and Incorporation EPEG developed its recommendations in accordance with the process specified by the AgWG (AgWG 2014). This process was informed by the strawman proposal presented at the December 11, 2014 AgWG meeting, the Water Quality Goal Implementation Team (WQGIT) Best 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. A number of EPEG members have had experience on BMP expert panels. Other EPEG members have knowledge and/or expertise in state and federal programs, the Chesapeake Bay model, and manure injection and incorporation 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 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. Panelists' areas of expertise may overlap.

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 Manure Injection and Incorporation EPEG recommends that the P6.0 Manure Injection and Incorporation EP should include members with the following areas of expe

- Manure injection and incorporation technologies for both liquid and dry manures and their practical application.
- Nutrient and sediment transport (via air and water) associated with the application of manure injection and incorporation technologies.
- Various physiographic regions of the Chesapeake Bay and their relationship to nutrient and sediment transport.
- How BMPs are tracked and reported, and the Chesapeake Bay Program partnership's modeling tools.
- Knowledge of and experience with NRCS practice standards and codes.

The collective expertise of panel members should cover the range of the physiographic regions found and the agricultural crops produced within the Chesapeake Bay watershed.

Expert Panel Scope of Work

The general scope of work for the Manure Injection and Incorporation P6.0 EP will be to define and configure the Manure Injection and Incorporation BMPs in the P6.0 model. Specifically, the EP will develop definitions, and loading or effectiveness estimates for manure injection and manure incorporation practices.

1. Identification and definition of appropriate manure injection and incorporation technology categories for liquid, solid and semi-solid manures.
2. Evaluation of nutrient and sediment transport (via air and water) associated with the application of manure injection and incorporation technology categories for relevant effectiveness estimates.
3. Consider potential variations of technology applications and effectiveness estimates associated with the physiographic regions and cropping systems of the Chesapeake Bay, and their relationship to nutrient and sediment transport.

In defining the practice(s), the EP shall consider the following issues (among others):

- Compatibility with the NRCS definitions of manure injection and incorporation and how the recommended practice(s) will impact residue management and soil disturbance, as defined by either NRCS or the states. For example, the NRCS Practice Standard 345 for reduced till requires that no full-width tillage occurs during the time interval starting with harvest or termination of the previous crop until harvest or termination of the reduced-till crop, regardless of the depth of the tillage operation. The only soil disturbance during this time interval is tillage in strips and slots. Tilled strips or slots are no wider than one third of the row width. Furthermore, the potential for incorporation to influence the efficiency of previously applied BMPs during a given year (e.g., practices designed to promote high-residue/minimum soil disturbance) should be considered;
- The effect of the recommended practice(s) on sediment losses with regard to assigning reduction efficiencies for incorporation. As erosion potential increases, incorporation will increase the potential for sediment and sediment-bound nutrient losses, which will offset reductions in dissolved nutrient losses; and
- The permissible elapsed time between initial manure application and incorporation.

The Expert Panel will be provided a project timeline for the development of the panel recommendations based on the Phase 6 development schedule. This timeline may include the development of a provisional recommendation for this BMP prior to the finalization of a fully documented recommendation report with effectiveness values. Provisional panel recommendations will be used only for initial Phase 6 model development and calibration, and not for future implementation progress reporting by the jurisdictions.

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's *Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model*[1] (see Attachment 1 for an outline of the final report).

Timeline/Deliverables

May 2015 – Panel stakeholder kickoff meeting

January 2016 – Based on their written EPEG charge, the panel will develop a proposed scope of work including BMP structure and type, draft BMP definition(s), and initial elements of the BMP such as associated components and conservation practices, and USDA-NRCS associated CP codes. Initially identified literature citations will be included to provide a range of potential effectiveness values that the panel will consider and supplement with further evaluation. The panel will present their provisional BMP paper to the AgWG, WTWG, and WQGIT for informational purposes, and for initial partnership comments on the proposed direction of the panel's evaluation. The paper will not represent a full recommendation report, and the partnership will not be asked for formal approval at this time.

May 2016 – **Target date** for panel to release full recommendations and final report for approval by the AgWG, WTWG, and WQGIT.

August 2016 – If approved by the partnership, panel recommendations are final and will be represented in the final Phase 6 modeling tools.

Phase 6.0 BMP Verification Recommendations

The panel will utilize the Partnership approved ***Agricultural BMP Verification Guidance***[2], 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 the recommended potential options for how jurisdictions and partners can verify recommended manure injection and incorporation practices in accordance with the Partnership's approved guidance.

References

AgWG. 2014. Agriculture Workgroup expert panel organization – DRAFT January 8, 2014. Agriculture Workgroup, Chesapeake Bay Program.

[1] http://www.chesapeakebay.net/documents/Nutrient-Sediment_Control_Review_Protocol_v7.14.2014.pdf
[2] http://www.chesapeakebay.net/documents/Appendix%20B%20-Ag%20BMP%20Verification%20Guidance%20Final.pdf

Attachment 1: Outline for Final Expert Panel Reports

- § Identity and expertise of Panel members
- § Practice name/title
- § Detailed definition of the practice. For example, the Expert Panel should clarify when a practice is compatible with no-till where the definition of no-till is compatible with both state and NRCS definitions.
- § 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, 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
- § 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 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, 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 eliminates a pollutant from surface transport but moves the pollutant into groundwater.

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

Appendix D: Approved Nutrient Management Expert Panel Meeting Minutes

6/23/2015

Actions & Decisions:
ACTION: Curt will share the list of known references with the Panel prior to the in-person meeting.
ACTION: Emma will send doodle poll to find the exact dates for the face-to-face meeting.

Introductions
Panel members briefly introduced themselves. Curt Dell will be serving as chair.
Mark Dubin is the Agriculture Workgroup coordinator and will provide technical support and travel reimbursements. Emma Giese will be providing staff support. Jeff Sweeney is a member of the Chesapeake Bay Program Modeling Team and will be part of translating the panel's recommendations in to the CBP Modeling tools.

Panel Charge
Curt reviewed the charge to the Panel (distributed to members on 6/22 in an email from Emma) and the proposed approach.
Members agreed that Rory Maguire's 2011 published review of literature would be a good start for this panel.
The Panel will need to outline verification options in their recommendations
Part of the Panel's charge is to complete a preliminary paper outlining the direction of the recommendations. This short paper can largely be a product of the in-person meeting this summer.

Scheduling stakeholder meeting
Target dates July 21st – August 17th
Location: TBD in the Baltimore/Frederick, MD area
Panel members agreed to hold a half day meeting with stakeholders (AM), followed by a half day with panel only (PM). In general, the group thought extending the panel only portion in to the second day would be helpful.

Participants

Curt Dell	ARS Panel Chair
Mark Dubin	UMD
Rory Maguire	VT
Robb Meinen	PSU
Dan Dostie	NRCS
Emma Giese	CRC
Jeff Sweeney	EPA

8/10/2015 – 8/11/2015

Tuesday, August 10

Panel charge, work plan, and timeline
Curt Dell and Mark Dubin reviewed the charge to the Panel and their scope of work.

General overview of the use of BMP efficiency values in CBP modeling tools
Jeff Sweeney, CBPO modeling team, gave an overview of the use of BMP efficiency values in the model,

and the specific questions the panel will need to answer.

Begin discussion of practice definitions and list of practices to consider

- Begin the categorization with liquid vs. dry
- Leave injection with liquid or dry. Suggest not calling poultry litter injection, just incorporation.
- Distinguish between low disturbance methods.
- It is easier to measure residue than disturbance. Especially those who don't use RUSLE2, may not have easy access to the STIR tool
  - Dubin: One option is to use a range of values instead.
- Suggest using the categories defined by the conservation tillage panel.

Liquid vs. dry:

- Full width tillage incorporation (>33% disturbed) – liquid or dry
- Low disturbance incorporation (narrow width) – liquid or dry
- Closed slot injection – liquid

Public forum

Panel members introduced themselves. Curt Dell gave an overview of the practice and how the Panel will approach their task. Mark Dubin described the Panel process and how the recommendations will be incorporated in to the Bay Program Partnership's modeling tools. Virgil Gutshall, guest presenter, discussed the manure incorporation and other practices in place on his farm.

Continue discussion of practice definitions - injection

Definition of injection:

- Related to timing – is the ground immediately closed over?
- Is there a depth parameter?
  - Panel felt that a depth parameter was not needed for the definition.
- Mark recommended using NRCS language for the definition.
- Suggest defining the technologies broadly, because the technology is going to evolve and make the definitions obsolete otherwise.
- Panel discussed that injection should be defined as occurring within the root zone.

Criteria for injection

- Liquid organic nutrient sources only
- Surface soil closure at time of application
- Application within root zone

Brosch: Recommend including biosolids in the injection criteria.

- Dubin: States are supposed to be collecting their data on biosolids.
- Would there be a difference between biosolids and other manure?
  - Only in concentration.
  - Biosolids are being applied to crop fields and should be accounted for.
- Should the panel consider organic food waste?
  - Use the term organic nutrient source (rather than manure) to include all sources other than chemical fertilizer.
  - Brosch: Note that the panel needs to make sure we're not crediting something that does not have a load in the model (organic food waste not simulated).

Continue discussion of practice definitions - incorporation

Conventional tillage

- Represents the highest level of burial or soil mixing, disregarding erosion.

Criteria for incorporation – liquid or solid

- Suggest that the states probably have similar requirements for timing of incorporation.
- Within 24 hours as a starting point, the Panel will work out the exact timing portion.

Vertical tillage

- Vertical tillage has less surface disturbance but less efficiency with burial.
- There's not likely to be much literature on vertical tillage.
- MD is required to incorporate all manure, vertical tillage is a common practice.
- Does MD have a way to assess whether there is sufficient incorporation? If they have criteria the Panel could consider those.
- Coupled application and incorporation could be a different category than ones that use any kind of post application tillage.

Panel members did not think there was sufficient literature to support dividing the manure incorporation category in to too many subcategories.

- Address amount of burial and the timing in the manure incorporation definition.
    - Timing could be a range: immediate to within 24 hours
- State in definition that there are a range of practices where the loss reductions depend on how quickly they are incorporated.
    - May need to require no more than a certain percent of manure on the surface.
- A full incorporation system could be defined by conventional tillage (0-15% residue)
- Suggest width, depth, and timing factors to differentiate categories of incorporation. There would be a default if state could not track and report all the factors.
- Timing factors should be consistent with agronomy tables.
- Does the Panel need to address time of year?
    - No because this will already be accounted for in the model.
- If any scenarios would be detrimental, the Panel will need to point those out in the report (such as tile drains in coastal plain).

Wednesday, August 12

Discussion of practice definitions

- Is injection a subset of incorporation?
    - Mark will check with Maryland about their incorporation law and whether it is meant to include injection.
        - Post meeting note: Maryland considers injection to be separate, but injection can be used to fulfill in the incorporation requirement.
    - Whether or not it is being mixed may be an important distinction.
- Panel decided that there was no need to specifically mention subsurfer within injection. It is already captured by the definition, and leaves the definition open for future technologies.
- Do we need to define the depth of the root zone?
    - Will be described in glossary.
- Based on an initial draft by Curt Dell, the Panel developed the following definitions during the meeting as a starting point:
-

Incorporation *is defined as the mixing of dry, semi-dry, or liquid organic nutrient sources[1] into the soil profile within the Panel's specified time period by a range of field operations. These methods can provide nutrient loss reductions and may differ for P and N by method used. Nutrient loss reductions are*

primarily due to lower ammonia- N volatilization and in some cases P losses with surface runoff. Nutrient loss reductions vary with timing between application and soil mixing, degree of soil mixing, and percent soil disturbance. Incorporation methods alone are not expected to reduce sediment losses.
High disturbance incorporation *methods provide the highest degree of mixing of organic nutrient sources into the root zone, but the benefits of conservation tillage are eliminated.*
Low disturbance incorporation *methods may leave greater quantities of organic nutrient sources on the soil surface, but are compatible with conservation tillage programs.*
Injection *is a specialized category of placement in which organic nutrient sources are mechanically applied into the root zone with surface soil closure at the time of application. Injection is expected to provide the greatest level of nutrient loss reduction, due to limited quantities of material left on soil surface, limited soil disruption, and immediate soil closure.*
[1]Including manures, biosolids, or composed materials

Report Outline
The Panel will use Jeff Sweeney's list of model needs, as well as the outline from the BMP protocol. The Panel will come back to the question of title of BMP at a future meeting – should it be organic nutrient sources rather than just manure?
Land Uses

- Should all land uses with manure be eligible for manure injection?
    - Yes.

Literature

- Some literature available from TetraTech (from Nutrient Management Panel), Curt Dell and Rory Maguire have additions. Thompson & Meisinger 2002.
- All panel members will look through the literature list, and highlight those that are relevant (or not relevant) to this effort. Panel members will add their own papers to the existing list.
- Emma will update columns in the existing spreadsheet and upload to the VT document sharing site:
    - Add a column for physiogeographic region
    - Add ammonia columns
    - Add column to check if practice increased sediment losses

Participants

Curt Dell	ARS
Rory Maguire	VT
Dan Dostie	NRCS
Chris Brosch	VT/VADCR
Robb Meinen	PSU
Arthur Allen	UMES
Mark Dubin	UMD
Jeff Sweeney	EPA
Emma Giese	CRC
Don Meals	TetraTech

9/1/2015

- Purpose: Discuss literature searches and determine additional literature searches that may be needed
- Curt will add Nitrogen to "P losses with surface runoff" in the practice definition of the report.

- Curt suggested keeping dry poultry litter separate from the liquids for the literature searches.
- Discussion on how physiographic regions will affect efficiencies.
    - Curt: We should be incorporating this information, and the template from the Tetra Tech searches should have some geographic information in it.
    - Chris: Physiographic regions are distinct by state/political boundaries. So MD has 3, DE has 1, etc.
    - Rory: So maybe we could split everything into 2 regions: coastal plain and essentially everything else.
        - Chris: The model doesn't have slope information. So I would agree with dividing it between coastal plain and upland areas.
- Issues to consider moving forward with literature searches:
    - Criteria for distinguishing "low disturbance"? We'll have to be consistent with the Conservation Tillage Panel as well.
    - For the literature, we should divide manure into liquids and solids; 2 categories. But what about the semi-solid category? Where would that fit? And maybe for "low disturbance", then liquid or solid isn't much of a consideration.
        - Could use % of solids in order to distinguish between them.
    - Should a credit be given for P reduction with high disturbance incorporation?
- Don Meals: Moving forward with literature searches, note that many papers are going to report changes in runoff or sediment losses on the basis of one or two (predominantly simulated) storms, so be careful to pay attention to what annualized effectiveness results might be.
- Moving forward with the searches, we need to look at ammonia losses. Emma added a column in the literature summary spreadsheet that has ammonia, but we need to start populating those fields.
    - Curt: Should we go back through the more classic literature to look at this factor for the tillage side of things?
- Rory, Robb, and Curt will start digging into the literature and report back later.
- Don Meals will spend some time reviewing the conventional literature, pulling out references and abstracts to forward to panel members. This should free up the panel members' time to look in the unpublished data/grey literature.
- Curt: Is the ammonia reduction alone what we can use? May have to convert that for our efficiency to a reduction in application rate. Should to talk to Jeff Sweeney.

Participants:

Chris Brosch	VT
Curt Dell	USDA ARS
Dan Dostie	USDA NRCS
Don Meals	Tetra Tech
Rory Maguire	VT
Robb Meinen	Penn State
Lindsey Gordon	CRC

10/14/2015

Actions & Decision:

ACTION: Dan to compile list of non-peer-reviewed sources and reports for the panel to research further.
ACTION: Panel members to quickly search for other sources that have not already been included in the summary table.
ACTION: Panel to look at existing entries in the literature summary table to check whether ammonia losses were reported, and to note down those values in the appropriate table columns.
ACTION: Curt to finish adding sources to the table and modify columns in summary table (completed by the end of this week 10/16):

- Panel can include non-peer reviewed sources. A column will be added to the summary table indicating the type of literature (extension/grey, peer-reviewed, non-peer-reviewed).
- Add a column next to P loss indicating form of loss: subsurface v. surface, soluble v. particulate.
- Curt will then send the revised summary table to Rory for further edits.

Meeting Notes:

- Curt asked for suggestions for other columns to include in the literature review table
- Rory asked about adding columns to break up timing into spring and fall
  - Curt said that this information may not be available in every source, but it should still be recorded if that information is available.
  - Mark noted that in the colder seasons, the volatilization processes will slow down. Suggested adjusting the window based on seasonality. This may be something for the panel to consider moving forward, and to collect any seasonality information in the literature.
- Arthur asked if we will be clarifying whether P loss is through runoff, or some other means.
  - Curt suggested adding a column to specify whether the P loss is through soluble or particulate P, or a combination of both.
  - Add a column next to P loss as to what the form of loss is: subsurface v. surface, soluble v. particulate.
    - Don noted that this information is partially captured in the notes column, but agreed with adding a column for the loss pathway.
- Panel members should send suggestions for column categories to Curt.
- Timeline:
  - Complete filling out summary table and start digging into the literature review in November to assess the usable data.
  - In the short term, panel will work to complete the review of peer reviewed literature and grey/extension literature that we are currently aware of.
- Mark suggested sharing information with Jack Meisinger for assistance on ammonia values.
- Future meeting: Inviting chair of Conservation Tillage Panel (Wade Thomason) to participate and coordinate across panels.

Participants:

Dan Dostie	USDA NRCS
Don Meals	Tetra Tech
Robb Meinen	Penn State University
Rory Maguire	Virginia Tech
Curtis Dell	USDA ARS

Lindsey Gordon	CRC Staff
Arthur Allen	UMD Eastern Shore
Mark Dubin	UMD
Chris Brosch	Virginia Tech

2/12/2016

- Mark Dubin has located additional funding to support someone that the panel identifies in order to assist in the panel work and literature reviews.
    - Panel members should help in this process, identifying contacts who would be appropriate to fill this position.
    - This would be a 20-30 hour time commitment, and this person would be collecting more sources, and extracting information (including ammonia volatilization) into the spreadsheets developed by the panel.

Participants:

Lindsey Gordon	CRC
Curt Dell	USDA
Dan Dostie	NRCS
Don Meals	Tetra Tech
Mark Dubin	UMD
Chris Brosch	DDA
Rory Maguire	VT

9/14/2016

Actions & Decisions:

ACTION: Curt Dell and Robb Meinen will develop a more specific approach for ammonia loss crediting based on time since incorporation.

DECISION: The panel agreed to move forward with using 85% for ammonia losses for manure injection (liquid and poultry litter), and to not have a separate category for poultry litter.

ACTION: The panel agreed to determine how to account for N and P leaching on the coastal plain, but not to consider leaching for the upland regions of the Bay watershed.

DECISION: The panel agreed that high-disturbance incorporation should not receive any credit for P reduction.

ACTION: The panel agreed to review their table of references, and identify any additional literature sources that would help inform effectiveness estimates.

Meeting Notes:

- Curt reviewed the progress of the panel thus far. Tasks for the panel to accomplish include determining the allowable lapsed time between manure application and incorporation, estimating reduction efficiencies for N and P for each of the three categories of injection/incorporation, and determining if separate factors are needed for solid and liquid manures.
    - The proposed approach is to determine a typical (median) value for each loss pathway in each category. Then, multiply that reduction factor for each loss pathway by a typical

fraction of total loss of N or P accounted for by that pathway, and then sum the weighted factors in t

- Mark Dubin offered the option to split out these factors by physiographic regions of the watershed.
- Rory Maguire noted that according to VA's recommendations, the longer the time before injection, the lower the effectiveness.
- Dan Dostie: Is there a place in the report to put some context when it comes to ammonia – for the model purposes, we want to keep this simple.
    - Curt Dell: There will be a section in the report where we write in how we came up with these numbers, and where we have to rely on our judgement. We will document that.
- Dell: I'm going to propose that incorporation must be within 24 hours, but we wouldn't discount the ammonia losses from the literature.
    - Maguire: What do you mean by discounting the factors?
    - Dell: What was in the literature was very prompt incorporation – so if we allow incorporation up to 4 days, then we would have to cut back the literature numbers proportionally, because we're allowing that longer timeframe.
    - Mark Dubin: One option is to lay out the different values for each time period. If one state program is more restrictive than another, then they can still report it and get the value out of it. We can also create a default – where if the state doesn't know, then there would be a standard value that is reported.
    - Dell: Hearing that, maybe we can revise to say that if it's within 24 hours, ammonia reduction would receive the full credit indicated by the literature, with a proportional reduction based on time since incorporation.
- Panel members agreed that 75% and 50% were appropriate numbers to use for ammonia losses for high-disturbance incorporation and low-disturbance incorporation, respectively.
- Panel agreed to continue searching the literature to refine the range of values for runoff and leaching for Nitrogen.
- Mark Dubin will facilitate collaboration between the Manure Incorporation/Injection Panel and the Conservation Tillage Panel.
- Panel supported splitting leaching estimates based on physiogeographic region (piedmont/karst vs. coastal plain), and expressed concern on the information informing the leaching estimates, due to reliance on rainfall studies.
    - Dell: So I'm hearing that for upland areas of the watershed, we could just have a factor for ammonia reduction, but for the coastal plain where there is leaching potential, should we develop a method for reducing our reduction factor in those areas? And how would we do that?
    - Mark Dubin agreed to ask Ken Staver for additional information on leaching.
- Curt noted that the panel will have to consider the variability of effectiveness estimates derived from the P studies, but that there is likely some P benefit that the panel would want to capture. Mark Dubin asked if certain studies used different tools that could produce widely varying results.

Participants:

Lindsey Gordon	CRC
Jeff Sweeney	EPA
Dan Dostie	USDA NRCS
Rory Maguire	VT

Curt Dell	USDA
Arthur Allen	UMD Eastern Shore
Mark Dubin	UMD
Don Meals	Tetra Tech
Robb Meinen	Penn State University

9/27/2016

Actions & Decisions:
DECISION: The panel reached agreement to revise ammonia crediting to two timing categories (<24 hours, 1-3 days) for low and high disturbance incorporation: Low disturbance: =24 hr= 50%, 1-3 days= 34%; High disturbance: =24 hr= 75%, 1-3 days= 50%
DECISION: Panel members agreed not to consider N losses in runoff, but to acknowledge in the report that runoff N can be significant following manure application.
DECISION: Panel members agreed not to consider N losses in runoff, but to acknowledge in the report that runoff N can be significant following manure application.
DECISION: Panel members agreed to use a 45% reduction credit for total runoff P in injection.
DECISION: Panel members agreed to move forward with 30% as the reduction credit for total runoff P with low disturbance incorporation.
DECISION: Panel members agreed to a 30% reduction credit for total runoff P from high disturbance incorporation in the coastal plain, and no reduction credit for upland areas.
ACTION: The panel will work to acquire values on the proportion of the coastal plain that is sloping and covering ditch drainage areas in order to inform estimates of the fraction of total P losses with runoff in coastal plain areas.
ACTION: Curt Dell will distribute a revised table of efficiency values that will be used in the upcoming Beta 4 version of the Phase 6 Watershed Model.
DECISION: Panel members agreed to give full credit for incorporation within 3 days, and to not credit incorporation after 3 days.

Meeting Notes:

- Curt Dell gave an overview of the outcomes from the Agriculture Workgroup meeting. The AgWG approved the use of the panel's placeholder efficiency values for use in the Beta 4 run of the Phase 6 model.
- Curt proposed deleting the 'Fraction of total loss' column for ammonia in the reduction factors table.
- Chris Brosch noted that incorporation did not have a significant impact on P load based on studies using a rainfall simulator. Based on that, keeping the runoff P reduction at 0% for high-disturbance incorporation seems reasonable.
- Robb Meinen: If <1 day, and 1-3 days are two categories for time since incorporation, will another category be anything longer than 3 days?
    - Dell: The AgWG feedback was that having so many time-frames was a bit excessive, and that having 2 categories would be sufficient for reporting purposes.
    - Meinen: So if it's 4 days, would that be entered as 0, or would it not be entered at all?
    - Dell: If that was the case, you wouldn't receive any credit. So it would not be entered.
- Panel discussed whether to address practice impacts on N losses in runoff. Data is very limited, but an AgWG member suggested that runoff N could be significant after manure application and suggested the panel reconsider.

    - Rory agreed that the data was very thin, and would feel uncomfortable with relying entirely on best professional ju
- Robb noted that there were a couple of studies that indicated N reductions, but that they were simulated studies.
- Curt asked the panel if they felt there was enough data to suggest a credit.
- Curt proposed the panel use a 45% reduction credit for total runoff P in injection. Panel members expressed support for the value.
    - Mark Dubin suggested fleshing out the justification section for this efficiency value.
- Curt proposed using a 40% reduction credit for total runoff P in low disturbance incorporation.
    - Rory expressed concern, and suggested that this number should be lower based on the angle of incorporation.
- Curt noted that to be consistent with the categories of the CTP, there would have to be <40% disturbance, and farmers would have to demonstrate that their aerators were significantly angled.
- Chris suggested using a similar ranged methodology like that for injection, and removing the outliers in the range of values from the literature summary. Curt replied that the range would still be very spread out.
- Curt suggested 30-35%; Rory and Robb agreed that 30% would be a reasonable number.
- Curt proposed using a 20% reduction credit for total runoff P from high disturbance incorporation. The panel had originally decided not to give a credit for P in this category because sediment bound P losses offset reduction in soluble P losses in a majority of cited studies, however the AgWG asked the panel to reconsider this decision based on the long-term benefit of mixing manure and the resultant P binding. Curt also recommended that the report state this practice is not advisable where erosion potential is high.
- Mark reminded the panel to consider how their recommendations fit within the Conservation Tillage Panel framework, especially as it relates to the base condition.
- Rory noted that he thinks 0% is appropriate, given that the base condition would assume that tillage is happening. He also noted that he could support a reduction on the coastal plain, but not in the upland areas.
    - Robb noted that he had found two studies in the MD coastal plain that provide values for this category.
- Curt suggested somewhere between 30-40% reduction in the coastal plain. Panel members suggested 30%.
- Curt proposed that for upland regions, the panel use 80% as the fraction of total P losses with runoff (soluble and particulate). Panel members agreed that this number was reasonable.
    - Curt also noted that the panel still needs to determine a representative value for the eastern shore.
    - Mark suggested the panel ask Wade Thomason and Pete Kleinman for additional data to inform this estimate.
- Curt suggested the panel get values on the proportion of the coastal plain that is sloping and covering ditch drainage areas to estimate the fraction. Panel members agreed.
- Curt proposed giving full credit for incorporation within 3 days, and to not credit incorporation after 3 days.
- Curt and Robb will begin working to draft the panel's report, and will reach out to panel members for input as necessary.

Participants:

Lindsey Gordon	CRC
Don Meals	Tetra Tech
Curt Dell	USDA
Rory Maguire	VT
Arthur Allen	UMES
Mark Dubin	UMD
Chris Brosch	DDA
Robb Meinen	Penn State University

Appendix E: Consolidated Response to Comments

Appendix F: Conformity with WQGIT BMP Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT 2014) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where the panel addressed the requested protocol criteria.

1. **Identity and expertise of panel members:** *See Table 1in Section*1.

2. **Practice name or title:**
   - Manure Injection
   - Manure Incorporation High Disturbance
   - Manure Incorporation Low Disturbance

3. **Detailed definition of the practice:** *See Section 2 for detailed definitions of MII BMPs.*

4. **Recommended N, P and sediment effectiveness estimates:** *See Tables 2 and 3 (Section 3) for recommended N and P effectiveness estimates for Upland and Coastal Plain regions, respectively.*

5. **Justification of selected effectiveness estimates:** *See Section 4 for justification of effectiveness estimates, based on literature and best judgment of Panel members.*

6. **List of references used:** *See Section 7 for the full list of references.*

7. **Detailed discussion on how each reference was considered:** *See Section 4 for discussion of how literature data and best judgment were considered.*

8. **Land uses to which BMP is applied:** *See Section 5.1 for table of CBW land uses to which the MII BMPs apply.*

9. **Load sources that the BMP will address and potential interactions with other practices:** *See Section 5.1 for applicable land sources*

10. **Description of pre-BMP and post-BMP circumstances and individual practice baseline:** *See Sections 5.2.*

11. **Conditions under which the BMP works, including conditions where the BMP will not work, or will be less effective:** *See Sections 5.6 – 5.8*
    a. **Variations in BMP effectiveness across the watershed due to climate, hydrogeomorphic region, or other measureable factors.** *See Sections 5.6 – 5.8 and Tables 2 and 3.*

12. **Temporal performance of BMP including lag times between establishment and full functioning:** *See Section 5.7; there is no lag time anticipated between establishment and full function of the BMPs*

13. **Unit of measure:** *Acres or percentage of acres implementing practice.*

14. **Locations in Chesapeake Bay watershed where the practice applies:** *All acres of the applicable land uses in in the Bay watershed (Section 5.1). Note regional difference in proposed P reduction efficiency.*

15. **Useful life of the BMP:** *MII is intended to be represented as an annual practice, so for the purposes of this report the useful life of the practice is 1 year.*

16. **Cumulative or annual practice:** *Annual.*

17. **Description of how BMP will be tracked, reported, and verified:** *See Section 6.1 for a discussion of how manure injection & incorporation should be tracked and reported to the Bay Program. More details are also available in the Scenario Builder Technical Appendix (Appendix A).*

18. **Ancillary benefits, unintended consequences:** *See Section 5.10.*

19. **Timeline for a re-evaluation of the panel recommendations:** *The Panel recommends review in 5 years (or standard timeline) to address availability of new technologies and incorporate results of ongoing research. Information from long-term studies with natural rainfall will be especially desirable.*

20. **Outstanding issues that need to be resolved in the future and list of ongoing studies, if any:** *See Section 5.10*

21. **Documentation of dissenting opinion(s):** *While no dissenting opinions were expressed or recorded, significant notes related to recommendations were recorded in Appendix D (Approved Manure Injection & Incorporation Expert Panel Meeting Minutes).*

22. **Operation and maintenance requirements and how neglect alters performance:** *The Panel did not document operation and maintenance issues except to note that equipment selection and operation influences the effectiveness of manure injection and incorporation.*