Agricultural Best Management Practice Database (AgBMPDB)

Version 1.0 Data Summary

Prepared by

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Agricultural Best Management Practices (BMP) Database Version 1.0 Data Summary

1 INTRODUCTION

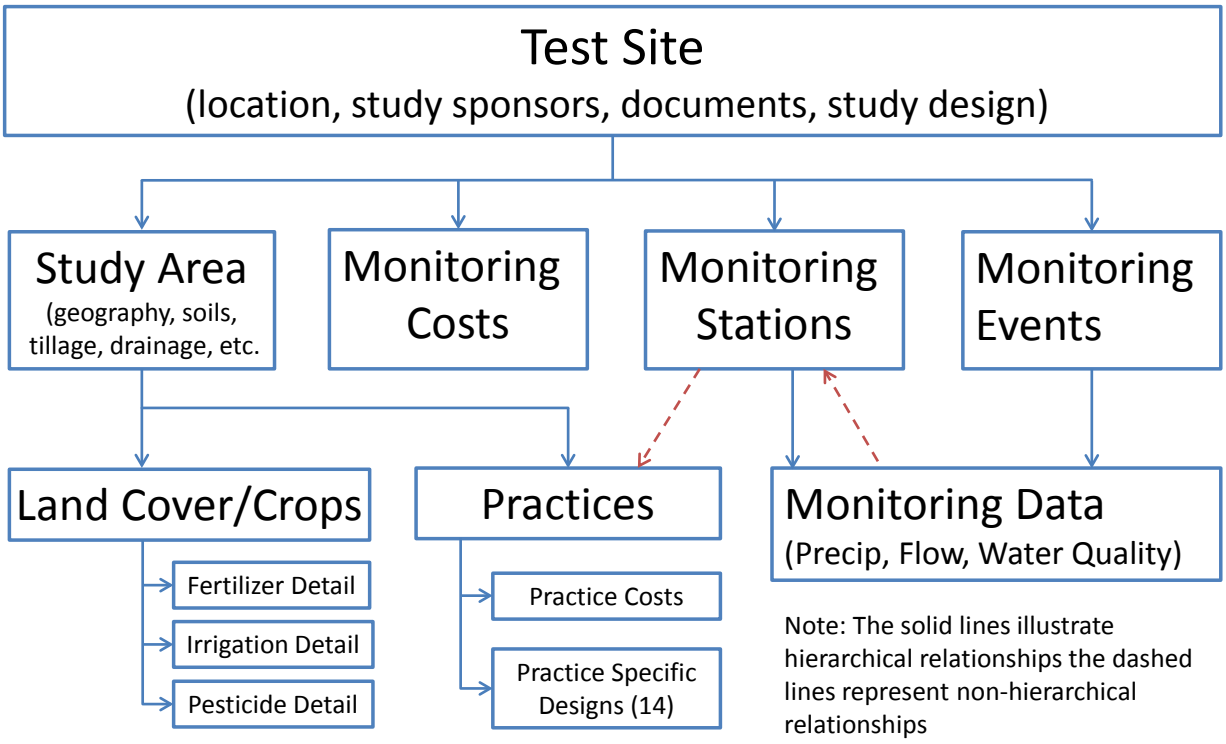
The purpose of the Agricultural Best Management Practice Database (AgBMPDB) is to develop a centralized repository of agricultural BMP performance studies to provide scientifically-based information on practices that reduce pollutant loading from agricultural sites. The AgBMPDB includes performance data and metadata that document the many field-based and practice-based variables that affect BMP performance. The long-term goal of the AgBMPDB is to provide agricultural advisors, planners, consultants and producers with information that enables them to better select systems of BMPs for their operations and to support improvements in agricultural BMP design and implementation. The AgBMPDB will also be useful for watershed assessments and planning efforts. The initial release of the AgBMPDB focuses on row crops, particularly corn and soybeans. The complete database can be downloaded in Microsoft Access (2007-2010) from http://www.bmpdatabase.org/agBMP.html.

This report provides an initial summary of agricultural BMP performance data available in the first public release of the Agricultural BMP Database and provides initial performance characterization that will continue to be updated in future releases of the AgBMPDB. An inventory of key metadata and water quality data for individual studies is provided in Appendices A and B. Overviews of studies by geographic area and practice type are also described in this report. Based on the available data, characterization of surface and subsurface pollutant loads and concentrations under various practice conditions is also provided. These initial characterizations should be considered preliminary, but are useful to illustrate how the AgBMPDB can be used to support evaluations of the expected benefits of conservation practices as the AgBMPDB grows.

Sources of data included in this initial release include 44 peer-reviewed professional publications that characterize pollutant loading and/or concentrations in 192 fields and/or study plots. Many of these studies have been included in some form in previous database efforts such as MANAGE (Harmel et al. 2008) and the Virginia Tech database (Dillaha et al., 2002). During 2014-2015, a significant effort was undertaken to extract additional metadata from studies compiled in a pre-release “starter” AgBMPDB completed in 2013. During 2014, these studies were further reviewed and prioritized to focus on enhanced metadata entry for corn and soybean crops. Although additional studies from the broader 2013 “starter database” may be included in future updates to the AgBMPDB, Version 1.0 only includes studies where enhanced metadata entry and checking against original published studies have been completed. Because all data sets were obtained through publically available studies, data entry was limited to information available in the published version of these reports. Full citations for published works by researchers are provided in the “Test Site” table of the AgBMPDB, as well as in the metadata summary provided in Appendix A to this data summary report.

The AgBMPDB is a relational database in Microsoft Access (2007-2010) including multiple tables linked together by unique numeric key fields. Figure 1 provides a simplified overview of the basic database structure. (Additional supporting tables are also included in the AgBMPDB, but are not identified in Figure 1.) The relational structure of the AgBMPDB allows data providers to define a Test Site (study location) that can then be linked to various information/data sets including Study Areas, Monitoring Stations, Monitoring Events, and Monitoring Costs. Each Study Area is linked to one or more Practices (conservation practice/BMP), as well as Crop information. Monitoring Stations can also be associated with the Practices being evaluated by the study. The Practices table links to 14 practice-specific design data tables (e.g., grassed waterway, conservation tillage) and Practice Costs (capital and operations/maintenance). Monitoring Events are linked to Monitoring Data, including Precipitation, Flow, and Water Quality. Data in these tables are also associated with the Monitoring Stations where the data were collected. The AgBMPDB structure is designed to enable users to retrieve metadata for conservation practice studies and their associated performance monitoring results.

Figure 1. General Structure of AgBMPDB



2 OVERVIEW OF AGBMPDB VERSION 1.0 ANALYSIS DATA SET

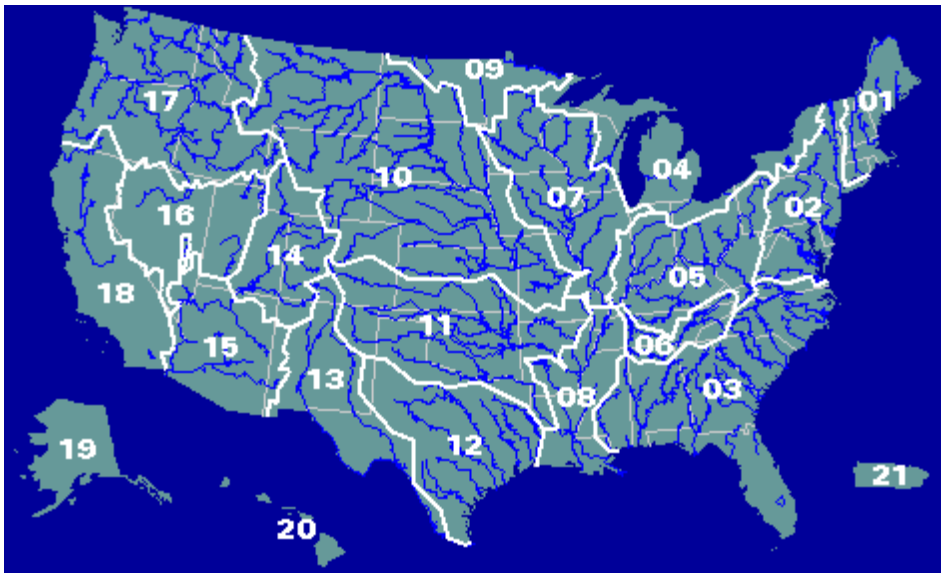
As noted in Section 1.0, Version 1.0 of the AgBMPDB focused on row crops, particularly corn and soybean crops, which were prioritized for data entry to support the objectives of project sponsors. Section 2.1 provides an overview of the geographic distribution of these studies by U.S. Geological Survey Hydrologic Unit Code (HUC) at the HUC-10 level. Section 2.2 provides a summary of the types of practices included in the initial release, which is dominated primarily by in-field practices.

2.1 Crops and Practices by HUC-10 Distribution

Table 1 provides a summary of corn and soybean fields/study plots by 10-digit HUC associated with various study areas. Additionally, several grass/hay/pasture sites are included in some studies (typically as control sites), and several sorghum field studies are also included. Each plot or field in a study is counted separately according to the practice or combination of practices in place at the particular plot. The majority of the studies for both corn and soybeans are located in the Upper Mississippi River Basin (Region 07). Figure 2 provides HUC-2 regional boundaries which represent the first two digits for each 10-digit HUC. For studies conducted outside of the U.S. (e.g., Canada, Italy), a -999999 is reported for the HUC.

In future analyses, as the AgBMPDB grows, analyses of performance results can be compared among geographic regions. Additional geographic characteristics documented in the AgBMPDB include EPA Nutrient Ecoregion, NRCS Major Land Resource Area (MLRA), and state. MLRA can be identified from http://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1045530.jpg or http://apps.cei.psu.edu/mlra/.

Figure 2. Water Resource Region Boundary Map (2-Digit HUC)



(Source: U.S. Geological Survey http://water.usgs.gov/GIS/regions.html)

Table 1. Number of Corn and Soybean Study Areas by 10-Digit HUC and Study Focus[1]

HUC Region	HUC_10	Total	Buffer	Controlled Drainage	Cover Crop	Cover Crop, Fertilizer	CRP, Cropping Systems	Drainage Management	Fertilizer	Fertilizer, Terrace	General, Contour Planting, Tillage, Grass Waterway	Irrigation, Controlled Drainage, Fertilizer, Cover Crop	Tillage	Tillage, Controlled Drainage	Tillage, Cover Crop	Tillage, Fertilizer	Other
Soybeans																	
Mid-Atlantic	0207001108	1	1														
Mid-Atlantic	0208011004	1															1
Ohio	0504000119	10													10		
Ohio	0512010810	4											4				
Upper Mississippi	0702000804	2					2										
Upper Mississippi	0708010504	3	3														
Upper Mississippi	0708020112	16							4				12				
Upper Mississippi	0711000303	6	3								3						
Upper Mississippi	0711000601	2														2	
Upper Mississippi	0714010801	2	2														
Lower Mississippi	0803020406	2											2				
Missouri	1020020308	3							3								
Missouri	1029010104	9														9	
Outside US	-999999	9	2					3						4			
No. of Soybean Fields/Plots (including control sites used in studies)		**70**	**11**	**0**	**0**	**0**	**2**	**3**	**7**	**0**	**3**	**0**	**18**	**4**	**10**	**11**	**1**
Corn	**HUC_10**	**Total**															
New England	0110000202	3							3								
Mid-Atlantic	0205030609	2							2								
Mid-Atlantic	0205030611	2								2							
Mid-Atlantic	0205030613	2							2								
Mid-Atlantic	0206000204	1	1														
Mid-Atlantic	0206000403	1	1														
Mid-Atlantic	0207001108	1	1														
Mid-Atlantic	0208010901	16			16												
Mid-Atlantic	0208011004	1															1
Ohio	0504000119	10													10		
Ohio	0512010810	4											4				
Tennessee	0603000207	3							3								
Upper Mississippi	0702000203	4														4	
Upper Mississippi	0702000804	3					3										
Upper Mississippi	0704000202	4											4				
Upper Mississippi	0708010504	3	3														
Upper Mississippi	0708020112	16							4				12				
Upper Mississippi	0711000303	6	3								3						
Upper Mississippi	0711000601	1														1	
Upper Mississippi	0714010801	2	2														
Lower Mississippi	0807020208	8		8													
Missouri	1020020308	3							3								
Missouri	1024000206	1							1								
Texas-Gulf	1207010101	12							6				6				
Texas-Gulf	1207020401	2							2								
Pacific Northwest	1709000905	6				6											
Outside US	-999999	35	3					11	3			8	6			4	
No. of Corn Fields/Plots (including control sites used in studies)		**152**	**14**	**8**	**16**	**6**	**3**	**11**	**29**	**2**	**3**	**8**	**32**	**0**	**10**	**9**	**1**

[1] Because many study areas include corn and soybean fields/plots in rotation, adding the number of soybean fields to corn fields will result in double counting if the grey-shaded lines in Table 1 are added together.

2.2 Conservation Practice Types included in Version 1.0

One of the challenges in evaluating agricultural conservation practices is that most study sites include a combination of multiple practices that often have overlapping or related effects; therefore, it is often challenging to isolate the effectiveness of an individual practice. Sections 2.2.1 through 2.2.3 provide additional information on the three overall practice types (groups) considered, including:

- In-field management practices (crop-related practices such as nutrient management, tillage, etc.)
- Edge-of-field treatment practices (treatment practices such as buffer strips, constructed wetlands)
- In-field constructed practices (land-shaping practices such as terraces, grassed waterways, and other relatively permanent features that help to minimize erosion)

Section 2.2.5 provides as overview of the extent to which various conservation practices were implemented in the studies included in Version 1.0.

2.2.1 In-Field Practices

The in-field practices considered in this report include crop rotations, cover crops, nutrient management, irrigation management, and tillage practices. Tile drainage is also considered an in-field practice (or field characteristic); however, if active water level management (drainage water management) is conducted, then this was considered an edge-of-field practice, as discussed below. General descriptions of each of these practices in the context of Version 1.0 of the AgBMPDB follow. The discussion focuses on practices that were reasonably well reported in the initial release; however, other in-field practice descriptions (e.g., pesticide management) can also be entered in the AgBMPDB, as described in the AgBMPDB User's Guide accessible at:
http://www.bmpdatabase.org/Docs/AgBMPDB%20UserGuideV1_Mar2014.pdf.

Crop Rotations. Crop rotation is a relatively common conservation practice used to maintain healthy soils and reduce the establishment of pests and disease. The studies in the database include a variety of crop types and rotation schedules. Since this initial database is focused on row crops, particularly corn and soybeans, most of the studies currently entered include one or both of these crops. However, there are other crop types, crop rotations and agricultural land uses represented in the database such as grass/hay/pasture, wheat, barley, rye, flax, oats, canola, tobacco, potato, and cotton. As the database grows, these other crops may be considered, but for this initial data summary the following crop rotations have been isolated for potential analysis:

- Corn (CO)
- Corn-Soybean Rotation (CS)
- Corn Extended Rotation (CEX)
- Soybean (SB)
- Corn-Soybean-Wheat Rotation (CSW)
- Grass/Hay/Pasture (GHP)
- Sorghum (SG)

- Soybean-Sorghum Rotation (SGB)

Cover Crops. Cover crops are generally used to reduce erosion and maintain soil health and fertility (Dabney et. al. 2001; Strock et al. 2004). While there are a variety of cover crop types and applications, for the purposes of this analysis a simplified approach is used to flag study areas according to whether a cover crop was used or not during the course of the study. Consequently, each test plot has one the following designations:

- Cover Crop-Yes (CCY)
- Cover Crop-No (CCN)

Nutrient Management. Nutrient management is broadly defined as managing the amount, source, placement, form and timing of the application of plant nutrients and soil amendments (NRCS 2006). The level of detail related to nutrient management varies from study to study, as does the extent to with "nutrient management" is implemented. For example, some studies provide detailed information on the type, timing, application method, rate, frequency and basis of fertilizer application, whereas some studies provide only limited information such as fertilizer type and application rate. In some cases, soil test results and crop yield objectives are clearly stated in descriptions of fertilizer practices, but not in all studies. As a result, the metadata for nutrient management is wide-ranging, inconsistent, and incomplete in some cases. Ideally, a detailed metadata analysis could be conducted on multiple subcategories of nutrient management practices, but for purposes of this initial release, a simple binomial categorization approach is used:

- Nutrient Management (NM)
- Nutrient Conventional (NC)

Studies where a "nutrient management" categorization has been included are those that "self-identify" as a nutrient management study or that explicitly identify practices such as split applications of fertilizer, side-dress applications, and other indicators of active nutrient management based on soil testing. This initial characterization of nutrient management is relatively subjective and may be refined in future analysis studies. For example, a more detailed evaluation relative to criteria in NRCS Practice Code 590 could be conducted. The "Fertilizer Detail" table of the database can be used to further refine and characterize nutrient management approaches.

Tillage Practices. Tillage practices are perhaps the most widely studied conservation practice in the literature reviewed to support the AgBMPDB. However, there are inconsistencies in how these practices are defined and described. Conservation tillage is generally described as a tillage practice that minimizes soil loss and helps retain soil moisture by leaving crop residue (typically greater than 30%) on the field (CTIC 2015). Conservation tillage practices included several different approaches such as mulch tillage, strip tillage, ridge tillage, or, simply, reduced tillage. No till is also a conservation tillage practice, but it is more clearly separated as a unique category relative to other "reduced" tillage practices. For the purposes of this categorical analysis, tillage practices have been classified as:

- Conventional Tillage (CN)
- Conservation Tillage (CT)
- No Till (NT)
- Unspecified Tillage (UT)

In future releases of the AgBMPDB, comparison of performance of subcategories of the broad-ranging category of “conservation tillage” may be appropriate.

Tile Drainage/Drainage Water Management. Tile drains are used to provide subsurface drainage in areas with high water tables or restrictive soil layers. Tile drains connected to a controlled outlet structure can be used for more active management of soil pore water to improve water quality by minimizing discharges to surface waters and providing opportunities for denitrification in the substrate (Drury et al. 1996; Wesström and Messing 2007). Due to the geographic location of the studies in the initial release, most of the sites are expected to include tile drainage systems (even though most studies did not explicitly state whether tile drainage was in place); however, few involved active drainage water management. Sites with tile drainage involving controlled drainage water management have also been identified as an edge-of-field practice (see Section 2.2.2.). In the future as the geographic distribution of the study areas grows, parsing study groups based on tile drainage characteristics would be beneficial. For purposes of this initial release, study plots are simply classified as:

- Tile Drain (TD)
- Unspecified Drainage (UD)
- No Tile Drain (ND)

Because tile drains are expected to be present in most of the mid-western corn-soybean studies included in Version 1.0 and because most of the studies do not include active drainage water management through regulation of water levels at control structures, tile drainage was not focused on as an explanatory in-field practice variable in this initial data summary.

Irrigation. While there is a host of irrigation management practices that farmers may use to minimize rates of water consumption and runoff, many of the studies in the database either did not irrigate or did not specify any particular practice. Therefore, given the limited data available irrigation has been classified as follows:

- Irrigated (IR)
- Not Irrigated (IN)
- Unknown Irrigation (IU)

Given the relatively few irrigated sites relative to the overall data set, irrigation has not been focused on for purposes of this initial report.

2.2.2 Edge-of-Field Practices

The vast majority of Version 1.0 of the AgBMPDB focuses on in-field practices instead of edge-of-field practices. Edge-of-field treatment practices are characterized as:

- Edge of Field –Buffer (EB)
- Edge of Field –Drainage Water Management (ED)
- Edge of Field – Other (EO) (Version 1.0 includes a filter ditch in this category)
- Edge of Field – None (EN)

The AgBMPDB is well suited or entry of edge-of-field practices. Riparian buffer and constructed wetland studies are two practices recommended for targeting in future data entry. See the User's Guide for additional edge-of-field practices.

Based on review of riparian buffers entered into the AgBMPDB, one challenge regarding use of these studies relates to variability in study design. Examples of study designs include:

- Groundwater monitoring wells were placed at the edge of field, upgradient of the riparian buffer to monitor subsurface nutrient, chloride, and hydronium ion concentrations. These groundwater concentrations were then compared to downgradient surface water concentrations from the gully stream draining the riparian area during baseflow conditions (Peterjohn and Correll 1986).
- Monitoring well network with multiple intermediate locations, focused exclusively on groundwater (Schoonover et al. 2006).
- Surface monitoring of runoff into and out of the buffer (Lee et al. 2003). This study design is useful for characterizing effect of the buffer on particulates such as sediment and total phosphorus, but does not capture movement of subsurface nitrate.

2.2.3 In-Field Land-Shaping Practices

A third category of practices includes relatively permanent landforms shaped or constructed in-field-to minimize erosion such as terraces or grassed waterways. Because Version 1.0 includes only one study each that focused on terraces (Lietman et al. 1997) and grassed waterways (Udawatta et al 2004), these studies have been grouped using nomenclature similar to the Edge-of-Field studies with the following codes:

- Terraces (ET)
- Grassed Waterway (EG)

Terraces and grassed waterways are not discussed further in this report due to insufficient numbers of studies available to evaluate terraces as a practice group; however, Appendices A and B (as well as the AgBMPDB) can be reviewed for more information on sites with these practices in place.

2.2.4 Combinations of Practice Variables for Study Areas

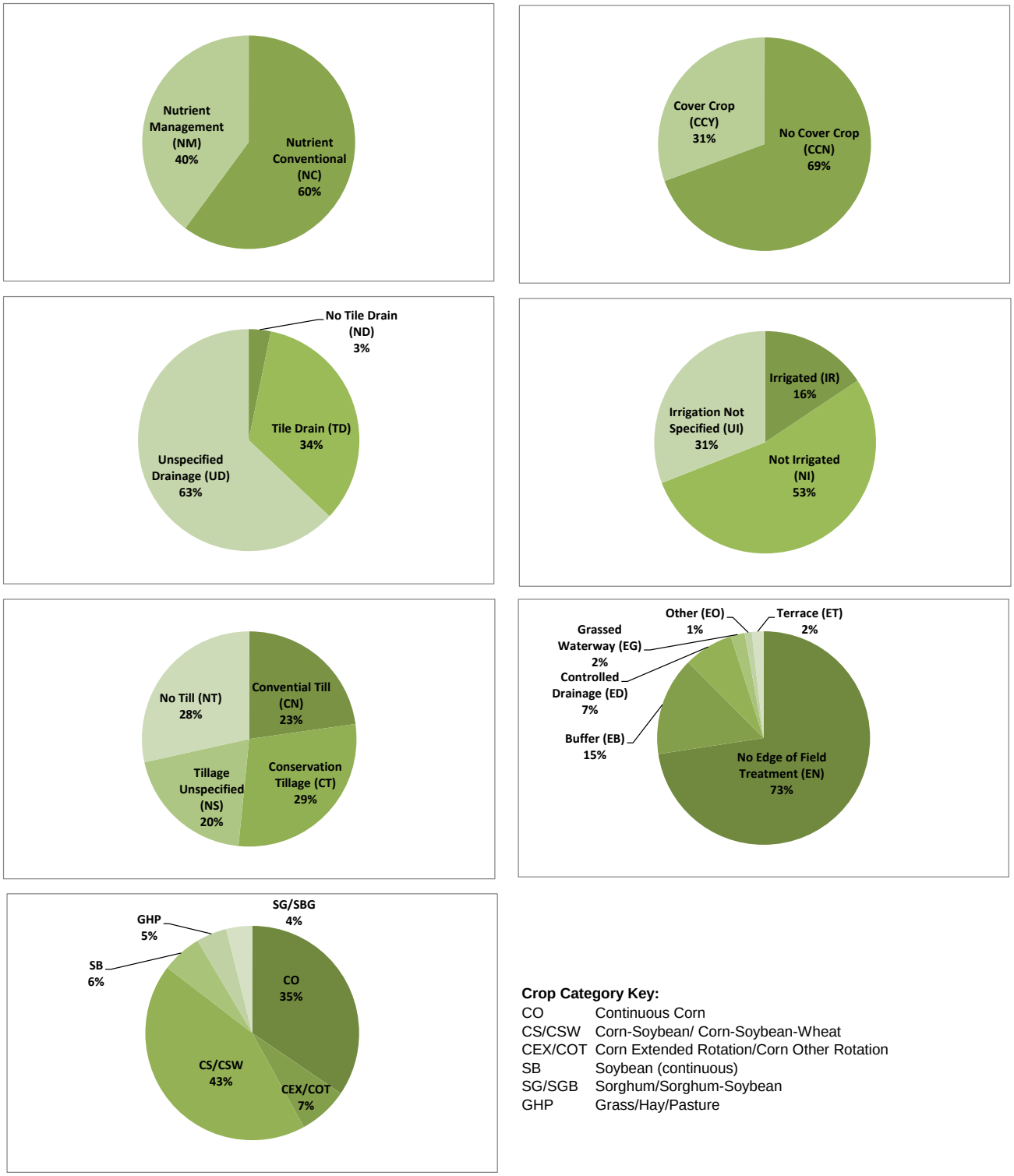
Ideally, evaluation of conservation practice performance would be conducted based on development of "bins" (or groups) of practices that combine multiple practices for each crop type and geographic area. Initial exploration of this "binned" approach for the 192 study areas in the initial release of the database resulted in over 100 combinations with only one to a few studies per grouping, even without considering important variables such as soil, slope, climate and weather conditions (e.g., wet year, drought). As the AgBMPDB grows, advanced statistical methods could likely be applied to better identify which of these variables (or variable strings) warrants isolating for further analysis. The initial data summary provided in Section 4 identifies some of the more effective conservation practices, but additional data are needed to better characterize individual practices and the synergistic effects of multiple practices.

2.2.5 Inventory of Practice Variables for Study Areas in AgBMPDB Version 1.0

Figure 3 provides a graphical depiction of the types of practices and study characteristics represented in Version 1.0 of the AgBMPDB by relative percentage of fields/plots included in the studies entered. Some key observations related to these practices include:

- Approximately 40 percent of the study areas had some type of nutrient management practice in place.
- Approximately 30 percent of the study areas documented the use of a cover crop.
- Approximately 35 percent of the study areas clearly stated that some form of tile drainage was present, with the remainder not explicitly indicating whether tile drains were present. Most study areas did not document that active drainage water management was being used for tile drains systems.
- Only 15 percent of the study areas clearly documented irrigation use; the remainder did not explicitly comment on irrigation. Characterization of irrigation practices may be a more significant issue in arid and semi-arid states since irrigation practices with return flows constitute a major delivery mechanism for pollutants. Currently, the geographic distribution of the study areas is weighted less heavily to locations where irrigation is a key issue; instead, drainage (removal of water from fields) is a more significant focus for the Version 1.0 data sets.
- Tillage practices were divided relatively evenly among no-till, conventional tillage and some form of conservation tillage. Type of tillage practice was reported for more than 80 percent of the study areas.
- Crop rotation practices were generally well documented in the study areas. Approximately 35 percent of the study areas were planted in continuous corn, and nearly 45 percent were in corn-soybean rotation (with some in corn-soybean-wheat rotation). The remaining 20 percent were divided relatively equally among other corn rotations, continuous soybean, grass-hay-pasture, and sorghum or sorghum-soybean rotation. For purposes of the initial data analysis in Section 4 of this report, only the corn and soybean related crops have been characterized. Most of the grass-hay-pasture sites in these studies were used as control sites relative to treatments applied fields growing row crops.
- Most study areas did not include edge-of-field treatment or in-field constructed erosion-control practices. The edge-of-field practices in Version 1.0 are limited primarily to riparian buffers and drainage water management sites. Only a few studies included terraces, grassed waterways and other practices such as a filter ditch. Better representation of edge-of-field practices in the next release of the AgBMPDB would be beneficial and allow for more robust analyses of the benefits of edge-of-field practices.

Figure 3. Representation of Key Variables Potentially Affecting Pollutant Loading from Agricultural Lands in Row Crop Production in Study Areas in AgBMPDB Version 1.0



Crop Category Key:

CO	Continuous Corn
CS/CSW	Corn-Soybean/ Corn-Soybean-Wheat
CEX/COT	Corn Extended Rotation/Corn Other Rotation
SB	Soybean (continuous)
SG/SGB	Sorghum/Sorghum-Soybean
GHP	Grass/Hay/Pasture

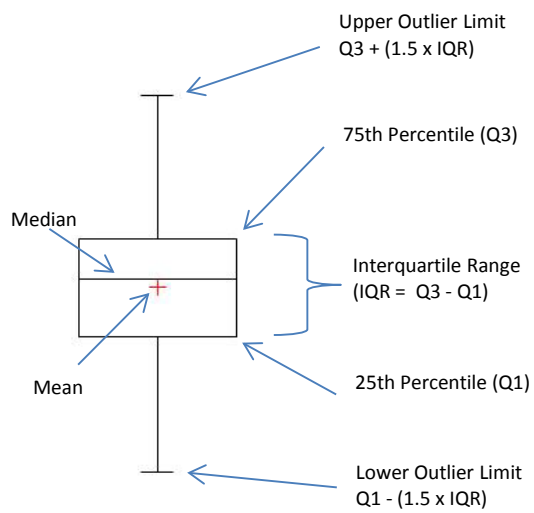
3 ANALYSIS METHODS AND PRACTICE CHARACTERIZATION APPROACH

As described in Section 1, this initial version of the AgBMPDB is a compilation of data reported from previously developed databases and published literature, as opposed to direct communication with the original researcher. Due to the variety of data collection and reporting methods used by the various researchers, the type of information reported varies considerably across studies in terms of metadata, water quality analytes reported and in terms of summary statistics associated with water quality data.

For this initial release, tabular statistical summaries are limited to the number of data points, minimum, mean, and maximum. The number of data points reported is particularly important in terms of the robustness of the data set. As expected, the number of data points is a significant limiting factor for the data characterization provided in this initial release. When more data become available, future summaries should also include additional parametric and non-parametric statistics that further describe of the central tendency and variability (or spread) of the data set.

Graphical representations of the data are useful for quickly assessing potential differences between practice groups, along with general data trends. In the Urban Stormwater BMP Database, individual monitoring events are typically reported, as opposed to annual load or averages; therefore, several different types of graphical presentation are used such as time series plots, boxplots and probability plots (Geosyntec and Wright Water Engineers 2014). At this time, the AgBMPDB has very little event-based data; therefore, an individual study might report one or a few annual average concentrations or loads, making graphical time-series representations less useful or inappropriate for many studies. Thus, graphical representations of the data have been limited to boxplots and simple bar charts for purposes of this initial report. Figure 4 provides a legend for interpreting each component of a boxplot.

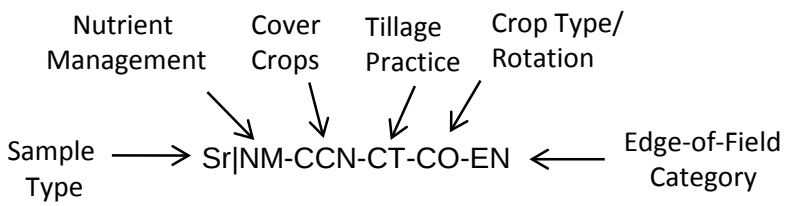
Figure 4. Boxplot Legend



Using the tabular and graphical techniques described above, two simplified approaches to summarizing data have been included for purposes of this initial report.

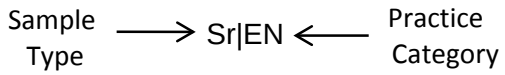
- For individual studies, two data summary appendices have been developed:
    - Appendix A provides a summary of key metadata associated with each study, primarily in narrative format.
    - Appendix B is a water quality concentration and load data summary for each study, as extracted from the literature for key water quality constituents. The water quality statistic(s) reported is based on the metrics selected by the original data provider.
- For practices groups (e.g., tillage practices), data summaries are limited to average annual concentrations (mg/L) and average annual loads (kg/ha/yr) for a subset of commonly reported water quality constituents.

In the data analysis in Section 4.2, study types are characterized by a practice "string", which includes the following combination of variables presented in the same order for each study area according to surface runoff (Sr) or subsurface (Sb) sample types:



The abbreviations for each practice code were defined in Section 2.2 and are repeated for convenience throughout the remainder of the document. Using the example above, the sample for this a study described by this string of codes would represent surface runoff (Sr) at a field where some type of nutrient management (NM) is in place, without a cover crop (CCN), with conservation tillage (CT) for a continuous corn (CO) crop and no edge-of-field (EN) treatment.

A simplified practice string may also be used to indicate the condition of one sample type-characteristic combination, as is used in Section 4.3.



In this case, data sets are grouped and compared based on only two factors: whether the sample represents surface or subsurface flows and the presence or absence of a key practice condition. In this example above, the sample would represent a surface sample with no edge-of-field practice (EN) that could be compared to another surface sample with an edge-of-field practice. An obvious limitation of this simplified approach is that it masks other variables that could be controlling observed water quality related effects. Nonetheless, this "binary" approach is considered a reasonable tool for purposes of identifying general qualitative trends and practices that warrant further investigation in the future as the database grows.

Water quality analytes considered in the remainder of this report have been selected based on the most commonly reported analytes representing both soluble and particulate sample fractions, including:

- Ammonium as N
- Nitrate as N
- Dissolved Phosphorus
- Soluble Reactive Phosphorus (for concentration data sets only)
- Total Phosphorus
- Sediment

Other nutrient forms and herbicides/pesticides[2] are also included in the AgBMPDB, but are less consistently reported among the studies. Examples of other nutrient forms reported include total nitrogen, total particulate phosphorus, dissolved nitrogen, total organic nitrogen, total inorganic nitrogen, total Kjeldahl nitrogen, etc. Several of these additional nutrient forms are summarized in Appendix B for the individual studies, but are currently too limited among the studies to analyze categorically.

For sediment-related constituents, there is significant inconsistency (and lack of information) with reporting sampling and analysis methods. Some researchers specifically indicate that total suspended solids (TSS) or suspended sediment concentrations (SSC) were measured, while others generally refer to “sediment.” The analysis method can influence the quantification of sediment concentrations and loads; however, for the purposes of this analysis, it has been assumed that the reported sediment-related parameters are approximately equivalent among the studies. This assumption is considered reasonable given the number of variables at play influencing these metrics, but the development of standardized protocols for sediment data collection and reporting is recommended to reduce this potential source of variability.

4 DATA SUMMARY

The data summary provided in this report consists of three components:

- Individual practice metadata and water quality data.
- General characterization of the range of practice combinations in Version 1.0.
- Characterization of concentrations and loads for specific practice groups and water quality analytes.

[2] There is only one study currently in the database with herbicide data entered (IDRA Farm in Quebec, Canada). This study includes detailed storm event concentrations for atrazine, metolachlor, and desethylatrazine (DEA). As more data on pesticide and herbicide use and runoff loading and concentration data become available, the effects of various in-field and edge-of-field conservation practices may be evaluated.

4.1 Characterization of Individual Studies

Appendices A and B provide information on individual studies in the AgBMPDBv1.0. Individual studies typically focus on just a few potential explanatory variables and the methods for BMP performance analysis are typically either control vs. treatment or before vs. after BMPs have been implemented. The characterization of individual studies can be relatively straightforward and involves comparing water quality monitoring results (loads and concentrations) from the various test plots/fields. It is recommended that a standardized format for characterizing data for individual studies be included in future analyses; however, for purposes of this initial release, the tabular Excel summary in Appendix B can be used to extract data for studies of interest or data can be queried from the Access database itself. One of the challenges associated with developing a standardized characterization format for individual studies is that researchers summarize data using a variety of different metrics and statistical approaches, which are not necessarily directly comparable to each other.

Future enhancements to the individual study analyses will be primarily dictated by the quantity of study data available including both measurements and metadata and the consistency in the reported parameters. Studies with many individual storm event samples or several seasonal or annual load estimates could be summarized with additional data plots, such as time series and boxplots, and hypothesis tests. For example, hypothesis tests could be conducted to evaluate whether statistically significant differences are observed between control and test plots using the Mann-Whitney, Wilcoxon and/or Kruskal-Wallis tests. Boxplots could be used to visualize those differences. (For an example of a standardized analysis summary, see the Google Earth map for urban stormwater BMPs at www.bmpdatabase.org.)

4.2 Summary of Results for Various Practice Combinations and Constituents

One of the challenges of evaluating agricultural BMP performance is the fact that real-world agricultural operations include multiple management and production practices (with or without treatment BMPs) that vary temporally and physically. Management of pollutants discharged from agricultural sites is a function of complex interactions among physical site conditions, cultivation practices, applications of fertilizer and pesticides/herbicides, irrigation practices, crops (and crop rotations), weather and climate, and other factors. As an initial strategy to recognize these interactions, a categorization scheme was developed to apply “strings” of practice codes to studies in the initial release of the AgBMPDB using the method described in Section 3. As a result, both surface (Sr) and subsurface (Sb) samples are characterized according to a practice string. Although there are some notable limitations to this approach when working with a relatively small data set, as the AgBMPDB grows, this type of combined practice approach is expected to be useful in characterizing the performance of practice combinations. This approach could also be further refined to include soil type, geographic area, study scale (e.g., field, plot, farm) and other characteristics.

Table 2 provides an initial summary of the annual average nutrient and sediment loads by unique practice combination for surface runoff and subsurface samples in the AgBMPDB Version 1.0. Similarly, Table 3 provides annual average concentrations. As indicated in these tables, there are relatively few studies in each practice “bin”, so conclusions drawn for a particular practice combination are severely limited because a particular observation may be controlled by other characteristics at an individual study site, such as sandy vs. clay soils, karst topography, etc., rather than the group of practices being implemented. For this reason, Figure 5 through Figure 9 also include the study name (defined by the first few letters of the author’s last name and a numeral related to publication year), so that unusual or extreme conditions in a particular study can be identified through additional metadata review. For example, several studies in the initial data set appear to have unusually high loading and concentration rates, including Lietman et al. (1997), van Vliet et al. (2002) and Ritter et al. (1998), as illustrated in Figures 5, 7 and 8.

While the number of test plots and associated data points are severely limited when the data are parsed to unique practice combination strings, some qualitative insights of the synergistic effects (or lack thereof) of multiple practices are still possible, particularly when the practice strings are grouped according to the individual study as is the case in Figures 5 through 9. In these figures, the study group can be identified by the author code (e.g., Chic9) and then the string of practices can be reviewed to identify which variable was modified (tested) in the study. (Note: in some cases such as nutrient management, an NM code may be applied to more than one field/plot in a study area; the coarse “NM” code does not capture levels/degrees of nutrient management, but could be refined in future AgBMPDB reports.)

For example, the lowest average annual surface loadings and concentrations for sediment and phosphorus are the study areas with some type of edge-of-field practice, regardless of the type or number of in-field practices implemented. For the test plots without edge-of-field practices, those with no-till tend to have the lowest sediment loads (< 200 kg/ha/yr except one test plot at 719 kg/ha/yr) and concentrations (all test plots < 280 mg/L). Surface sediment loads and concentrations are generally higher and more variable for test plots with conventional or conservation tillage (198 to 13,114 kg/ha/yr and 245 to 1,520 mg/L). In general, loading rates are expected to be significantly more variable than concentrations due to differences in

precipitation rates and the complexities associated with accurately measuring flow and computing annual loads.

As with sediment, phosphorus loadings are highly variable. Total and dissolved phosphorus loadings for no-till range from 0.70 to 1.10 kg/ha/yr and 0.60 to 0.34 kg/ha/yr, respectively. For conventional and conservation till they range from 0.001 to 21.20 kg/ha/yr total phosphorus and 0.001 to 1.45 kg/ha/yr dissolved phosphorus. Phosphorus loadings may be affected by a combination of crop type/rotation and nutrient management practices. Continuous corn (CO) without nutrient management (NM) tends to produce higher loadings (0.38 to 21.20 kg/ha total phosphorus) than corn-soybean (CS) and corn extended rotation (CEX) with NM (0.04 to 2.33 kg/ha). While the number studies reporting phosphorus concentrations is too limited to corroborate this observation from data currently in the AgBMPDB, the five highest phosphorus loadings are from studies with continuous corn crop and without nutrient management practices. In general, the range of observed phosphorus loadings indicate that study areas with characteristics comparable to conditions represented in the AgBMPDB should be able to achieve an annual average surface loading less than 2 kg/ha of total phosphorus by implementing conservation practices.

Nitrogen loadings and concentrations are even more variable and difficult to relate to specific practices or groups of practices. While the number of data points for ammonium is currently too limited to make any general observations, the nitrate data set is relatively robust. In general, subsurface nitrate loads and concentrations are significantly higher than surface loads and concentrations regardless of the practices implemented. Nutrient management practices appear to have some effect on subsurface concentrations, but the data are highly variable and are confounded by the Ritter et al. (1998) study where nutrient management and no-till have some of the highest subsurface nitrate loads. Cover crops do not indicate a general improvement in surface or subsurface nitrate loads, but studies that implement drainage water management (ED) indicate average annual subsurface nitrate loads and concentrations can be reduced to less than approximately 20 kg/ha/yr and 9 mg/L, respectively.

While the discussion above attempts to identify the practices that may cause differences between observed loads and concentrations, there are numerous confounding variables that should be considered before drawing conclusions. Differences in soil type, slope, climate, hydrology, study design, monitoring and computational methods, and others may mask the effects of a particular practice or combination of practices. Unfortunately, too few studies are available in this first version of the database (particularly those that report this type of metadata) to assess the influence of these variables. This first data summary provides a preliminary range of loads and concentrations observed for a variety of studies that can be used to compare results from future studies. As more studies are entered and standardized approaches are utilized, these types of data summaries may eventually be useful for defining “typical” loading rates and concentrations from agricultural fields with and without conservation practices in various settings.

Table 2. Summary of Annual Mean Loads (kg/ha/yr)

		Average Annual Load (kg/ha)		
Analyte-Sample Type-Practices	No.	Mean	Minimum	Maximum
Ammonium-N|Sb|NC-CCN-CT-CO-EN	1	0.17	0.17	0.17
Ammonium-N|Sb|NM-CCN-CN-CO-EN	1	0.30	0.30	0.30
Ammonium-N|Sb|NM-CCN-CT-CO-EN	1	0.30	0.30	0.30
Ammonium-N|Sb|NM-CCN-NT-CO-EN	1	0.30	0.30	0.30
Ammonium-N|Sr|NC-CCN-CN-SB-EN	1	0.86	0.86	0.86
Ammonium-N|Sr|NC-CCN-CT-CO-EN	1	0.36	0.36	0.36
Ammonium-N|Sr|NC-CCN-CT-CS-EN	1	0.86	0.86	0.86
Ammonium-N|Sr|NC-CCN-NT-SB-EN	1	0.98	0.98	0.98
Ammonium-N|Sr|NC-CCN-NT-SBG-EN	1	0.64	0.64	0.64
Ammonium-N|Sr|NC-CCY-CN-CS-EN	2	0.65	0.50	0.80
Ammonium-N|Sr|NC-CCY-NT-CS-EN	1	0.80	0.80	0.80
Ammonium-N|Sr|NM-CCN-CN-CO-EN	1	0.02	0.02	0.02
Ammonium-N|Sr|NM-CCN-CT-CO-EN	1	0.18	0.18	0.18
Ammonium-N|Sr|NM-CCN-NT-CO-EN	1	0.08	0.08	0.08
Ammonium-N|Sr|NM-CCY-CT-CS-EN	3	0.37	0.30	0.50
Nitrate-N|Sb|NC-CCN-CN-CC-EN	1	46.70	46.70	46.70
Nitrate-N|Sb|NC-CCN-CN-CO-ED	3	12.53	7.40	21.90
Nitrate-N|Sb|NC-CCN-CN-CS-EN	2	30.08	28.02	32.13
Nitrate-N|Sb|NC-CCN-CT-CC-EN	2	58.84	52.68	65.01
Nitrate-N|Sb|NC-CCN-CT-CO-EN	1	28.42	28.42	28.42
Nitrate-N|Sb|NC-CCN-CT-CS-EN	5	26.72	13.67	35.49
Nitrate-N|Sb|NC-CCN-NT-CC-EN	1	63.51	63.51	63.51
Nitrate-N|Sb|NC-CCN-NT-CS-EN	3	24.86	23.91	26.00
Nitrate-N|Sb|NC-CCY-CN-CO-ED	3	6.53	4.50	10.50
Nitrate-N|Sb|NC-CCY-CN-CO-EN	1	50.00	50.00	50.00
Nitrate-N|Sb|NM-CCN-CN-CO-ED	2	13.35	13.10	13.60
Nitrate-N|Sb|NM-CCN-CN-CO-EN	5	53.78	2.60	182.50
Nitrate-N|Sb|NM-CCN-CT-CO-ED	3	12.93	9.20	18.00
Nitrate-N|Sb|NM-CCN-CT-CO-EN	2	21.35	17.00	25.70
Nitrate-N|Sb|NM-CCN-CT-CS-EN	1	17.00	17.00	17.00
Nitrate-N|Sb|NM-CCN-NT-CO-EN	3	82.06	15.03	190.10
Nitrate-N|Sb|NM-CCN-NT-CS-EN	1	12.50	12.50	12.50
Nitrate-N|Sb|NM-CCY-CN-CO-ED	1	15.70	15.70	15.70
Nitrate-N|Sb|NM-CCY-CN-CO-EN	4	49.28	15.00	138.60
Nitrate-N|Sb|NM-CCY-CT-CO-ED	1	17.30	17.30	17.30
Nitrate-N|Sb|NM-CCY-CT-CO-EN	1	29.70	29.70	29.70
Nitrate-N|Sb|NM-CCY-NT-CO-EN	1	136.00	136.00	136.00

(continued on next two pages, notes at end of table)

Table 2. Summary of Annual Mean Loads (kg/ha/yr) (cont.)

		Average Annual Load (kg/ha)		
Analyte-Sample Type-Practices	No.	Mean	Minimum	Maximum
Nitrate-N|Sr|NC-CCN-CN-CO-EN	1	0.63	0.63	0.63
Nitrate-N|Sr|NC-CCN-CN-CO-ET	2	1.78	0.84	2.72
Nitrate-N|Sr|NC-CCN-CN-CS-EB	2	0.03	0.02	0.03
Nitrate-N|Sr|NC-CCN-CN-CS-EN	1	0.09	0.09	0.09
Nitrate-N|Sr|NC-CCN-CN-SB-EN	1	2.61	2.61	2.61
Nitrate-N|Sr|NC-CCN-CT-CO-EN	2	1.49	1.21	1.78
Nitrate-N|Sr|NC-CCN-CT-CS-EN	1	6.22	6.22	6.22
Nitrate-N|Sr|NC-CCN-NT-CO-ET	1	0.83	0.83	0.83
Nitrate-N|Sr|NC-CCN-NT-SB-EN	1	2.35	2.35	2.35
Nitrate-N|Sr|NC-CCN-NT-SBG-EN	1	4.24	4.24	4.24
Nitrate-N|Sr|NC-CCY-CN-CS-EN	2	5.50	2.00	9.00
Nitrate-N|Sr|NC-CCY-CT-CO-EN	1	0.47	0.47	0.47
Nitrate-N|Sr|NC-CCY-NT-CS-EN	1	5.80	5.80	5.80
Nitrate-N|Sr|NM-CCN-CN-CO-ED	1	2.15	2.15	2.15
Nitrate-N|Sr|NM-CCN-CN-CO-EN	2	1.58	1.56	1.60
Nitrate-N|Sr|NM-CCN-CT-CO-ED	3	3.15	1.40	5.70
Nitrate-N|Sr|NM-CCN-CT-CO-EN	5	3.28	0.91	8.60
Nitrate-N|Sr|NM-CCN-NT-CO-EN	1	2.94	2.94	2.94
Nitrate-N|Sr|NM-CCN-NT-CO-ET	1	0.76	0.76	0.76
Nitrate-N|Sr|NM-CCY-CN-CO-ED	1	1.48	1.48	1.48
Nitrate-N|Sr|NM-CCY-CN-CO-EN	1	1.40	1.40	1.40
Nitrate-N|Sr|NM-CCY-CT-CO-ED	1	1.48	1.48	1.48
Nitrate-N|Sr|NM-CCY-CT-CO-EN	1	1.20	1.20	1.20
Nitrate-N|Sr|NM-CCY-CT-CS-EN	3	4.10	1.90	6.60
Phosphorus, Diss|Sb|NC-CCN-CT-CEX-EN	2	0.080	0.060	0.100
Phosphorus, Diss|Sb|NC-CCN-CT-CS-EN	3	0.166	0.113	0.226
Phosphorus, Diss|Sb|NC-CCN-NT-CS-EN	1	0.137	0.137	0.137
Phosphorus, Diss|Sb|NM-CCN-CN-CEX-EN	1	0.060	0.060	0.060
Phosphorus, Diss|Sr|NC-CCN-CN-CO-EN	3	1.125	0.900	1.313
Phosphorus, Diss|Sr|NC-CCN-CT-CEX-EN	2	0.002	0.001	0.002
Phosphorus, Diss|Sr|NC-CCN-CT-CS-EN	3	0.077	0.046	0.123
Phosphorus, Diss|Sr|NC-CCN-NT-CS-EN	1	0.125	0.125	0.125
Phosphorus, Diss|Sr|NC-CCY-CN-CS-EN	2	0.210	0.190	0.230
Phosphorus, Diss|Sr|NC-CCY-NT-CS-EN	1	0.340	0.340	0.340
Phosphorus, Diss|Sr|NM-CCN-CN-CEX-EN	4	0.501	0.004	1.200
Phosphorus, Diss|Sr|NM-CCN-CN-CO-EN	3	0.871	0.275	1.450
Phosphorus, Diss|Sr|NM-CCN-NT-CEX-EN	3	0.767	0.600	1.000
Phosphorus, Diss|Sr|NM-CCY-CT-CS-EN	3	0.843	0.350	1.340
Phosphorus, Total|Sb|NC-CCN-CN-CO-EN	1	0.49	0.49	0.49
Phosphorus, Total|Sb|NC-CCN-CT-CEX-EN	2	0.89	0.65	1.13
Phosphorus, Total|Sb|NC-CCN-NT-CO-ET	1	0.16	0.16	0.16
Phosphorus, Total|Sb|NM-CCN-CN-CEX-EN	1	0.75	0.75	0.75

Table 2. Summary of Annual Mean Loads (kg/ha/yr) (cont.)

		Average Annual Load (kg/ha)		
Analyte-Sample Type-Practices	No.	Mean	Minimum	Maximum
Phosphorus, Total|Sr|NC-CCN-CN-CO-EN	7	2.11	0.38	4.48
Phosphorus, Total|Sr|NC-CCN-CN-CO-ET	2	2.66	1.46	3.87
Phosphorus, Total|Sr|NC-CCN-CN-CS-EB	2	0.03	0.02	0.04
Phosphorus, Total|Sr|NC-CCN-CN-CS-EN	1	0.20	0.20	0.20
Phosphorus, Total|Sr|NC-CCN-CT-CEX-EN	2	0.04	0.00	0.07
Phosphorus, Total|Sr|NC-CCN-CT-CO-EN	1	21.20	21.20	21.20
Phosphorus, Total|Sr|NC-CCN-CT-CS-EN	1	1.32	1.32	1.32
Phosphorus, Total|Sr|NC-CCN-NT-CO-ET	1	0.75	0.75	0.75
Phosphorus, Total|Sr|NC-CCY-CN-CS-EN	2	0.84	0.44	1.24
Phosphorus, Total|Sr|NC-CCY-CT-CO-EN	1	12.30	12.30	12.30
Phosphorus, Total|Sr|NC-CCY-NT-CS-EN	1	0.86	0.86	0.86
Phosphorus, Total|Sr|NM-CCN-CN-CEX-EN	4	1.13	0.04	1.90
Phosphorus, Total|Sr|NM-CCN-CN-CO-EN	4	1.71	0.24	2.89
Phosphorus, Total|Sr|NM-CCN-CT-CO-EN	1	9.30	9.30	9.30
Phosphorus, Total|Sr|NM-CCN-CT-CS-EN	2	0.66	0.58	0.73
Phosphorus, Total|Sr|NM-CCN-NT-CEX-EN	3	0.87	0.70	1.10
Phosphorus, Total|Sr|NM-CCN-NT-CO-ET	1	1.07	1.07	1.07
Phosphorus, Total|Sr|NM-CCY-CT-CS-EN	3	1.67	1.34	2.33
Sediment|Sb|NM-CCN-CN-CO-EN	1	588	588	588
Sediment|Sb|NM-CCN-CT-CO-EN	1	236	236	236
Sediment|Sb|NM-CCN-NT-CO-EN	1	198	198	198
Sediment|Sr|NC-CCN-CN-CO-EN	2	6860	606	13114
Sediment|Sr|NC-CCN-CN-CO-ET	2	1931	628	3234
Sediment|Sr|NC-CCN-CN-CS-EB	2	31	16	45
Sediment|Sr|NC-CCN-CN-CS-EN	1	587	587	587
Sediment|Sr|NC-CCN-CT-CO-EN	1	9000	9000	9000
Sediment|Sr|NC-CCY-CN-CS-EN	2	1073	537	1609
Sediment|Sr|NC-CCY-CT-CO-EN	1	2300	2300	2300
Sediment|Sr|NC-CCY-NT-CS-EN	1	719	719	719
Sediment|Sr|NM-CCN-CN-CEX-EN	3	1625	1035	2491
Sediment|Sr|NM-CCN-CN-CO-EN	2	310	308	311
Sediment|Sr|NM-CCN-CT-CO-EN	2	5648	296	11000
Sediment|Sr|NM-CCN-NT-CEX-EN	3	163	111	236
Sediment|Sr|NM-CCN-NT-CO-EN	1	193	193	193
Sediment|Sr|NM-CCY-CT-CS-EN	3	1177	198	2600

Notes:
Sample Type Code: Subsurface (Sb) or Surface (Sr). (Sr samples are also shaded grey.)
Practice Codes: Nutrient Management: Nutrient Management (NM) or Nutrient Conventional (NC)
Cover Crop: Cover Crop Yes (CCY) or Cover Crop No (CCN)
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), or No Till (NT)
Edge-of-Field: Terrace (ET), Buffer (EB), Grassed Waterway (EG), Edge of Field Treatment No (EN)
Crop Codes: Corn (CO), Corn-Soybean (CS), Soybean (SB), Corn Ext. Rotation (CEX)

Table 3. Summary of Annual Mean Concentrations (mg/L)

	Average Annual Concentrations (mg/L)			
Analyte-Sample Type-Practices	No.	Mean	Minimum	Maximum
Ammonium-N|Sb|NC-CCN-CN-SB-EN	1	0.10	0.10	0.10
Ammonium-N|Sb|NC-CCN-NT-CO-EB	1	0.07	0.07	0.07
Ammonium-N|Sb|NC-CCN-NT-CO-EN	1	0.01	0.01	0.01
Ammonium-N|Sb|NC-CCN-NT-SB-EN	1	0.11	0.11	0.11
Ammonium-N|Sb|NC-CCY-CN-CS-EB	4	0.05	0.02	0.11
Ammonium-N|Sb|NC-CCY-CN-CS-EN	2	0.03	0.02	0.04
Ammonium-N|Sr|NC-CCN-CN-CS-EB	1	1.09	1.09	1.09
Ammonium-N|Sr|NC-CCN-CN-CS-EN	1	0.81	0.81	0.81
Ammonium-N|Sr|NC-CCN-CN-SB-EN	1	0.16	0.16	0.16
Ammonium-N|Sr|NC-CCN-NT-SB-EN	1	0.26	0.26	0.26
Ammonium-N|Sr|NC-CCY-CN-CS-EB	3	0.02	0.02	0.03
Nitrate-N|Sb|NC-CCN-CN-CS-EN	3	26.4	20.0	38.0
Nitrate-N|Sb|NC-CCN-CN-SB-EN	2	10.5	6.0	15.0
Nitrate-N|Sb|NC-CCN-CT-CS-EN	7	20.3	12.3	32.3
Nitrate-N|Sb|NC-CCN-NT-CO-EB	1	0.4	0.4	0.4
Nitrate-N|Sb|NC-CCN-NT-CO-EN	1	8.0	8.0	8.0
Nitrate-N|Sb|NC-CCN-NT-CS-EN	4	16.0	11.1	23.0
Nitrate-N|Sb|NC-CCN-NT-SB-EN	1	4.8	4.8	4.8
Nitrate-N|Sb|NC-CCY-CN-CO-EN	1	19.9	19.9	19.9
Nitrate-N|Sb|NC-CCY-CN-CS-EB	4	4.2	2.5	6.7
Nitrate-N|Sb|NC-CCY-CN-CS-EN	2	8.0	7.1	9.0
Nitrate-N|Sb|NM-CCN-CN-CO-ED	1	7.6	7.6	7.6
Nitrate-N|Sb|NM-CCN-CN-CO-EN	3	14.2	9.9	19.2
Nitrate-N|Sb|NM-CCN-CT-CO-ED	1	7.0	7.0	7.0
Nitrate-N|Sb|NM-CCN-CT-CO-EN	2	12.6	11.4	13.8
Nitrate-N|Sb|NM-CCN-CT-CS-EN	1	11.4	11.4	11.4
Nitrate-N|Sb|NM-CCN-NT-CO-EN	2	15.2	12.0	18.3
Nitrate-N|Sb|NM-CCN-NT-CS-EN	1	11.6	11.6	11.6
Nitrate-N|Sb|NM-CCN-NT-SB-EN	1	12.0	12.0	12.0
Nitrate-N|Sb|NM-CCY-CN-CO-ED	1	8.7	8.7	8.7
Nitrate-N|Sb|NM-CCY-CN-CO-EN	3	7.3	5.1	9.8
Nitrate-N|Sb|NM-CCY-CT-CO-ED	1	8.3	8.3	8.3
Nitrate-N|Sb|NM-CCY-CT-CO-EN	1	11.2	11.2	11.2
Nitrate-N|Sr|NC-CCN-CN-CO-EN	1	4.0	4.0	4.0
Nitrate-N|Sr|NC-CCN-CN-CS-EB	1	2.8	2.8	2.8
Nitrate-N|Sr|NC-CCN-CN-CS-EN	1	2.0	2.0	2.0
Nitrate-N|Sr|NC-CCN-CN-SB-EN	1	0.5	0.5	0.5
Nitrate-N|Sr|NC-CCN-NT-SB-EN	1	0.6	0.6	0.6
Nitrate-N|Sr|NC-CCY-CN-CS-EB	3	4.7	2.7	6.2
Nitrate-N|Sr|NM-CCN-CN-CO-ED	1	2.4	2.4	2.4
Nitrate-N|Sr|NM-CCN-CN-CO-EN	3	3.9	2.8	4.8
Nitrate-N|Sr|NM-CCN-CT-CO-ED	1	1.8	1.8	1.8
Nitrate-N|Sr|NM-CCN-CT-CO-EN	2	5.2	1.9	8.4
Nitrate-N|Sr|NM-CCN-NT-CO-EN	1	13.7	13.7	13.7
Nitrate-N|Sr|NM-CCY-CN-CO-ED	1	1.6	1.6	1.6
Nitrate-N|Sr|NM-CCY-CN-CO-EN	1	3.1	3.1	3.1
Nitrate-N|Sr|NM-CCY-CT-CO-ED	1	1.6	1.6	1.6
Nitrate-N|Sr|NM-CCY-CT-CO-EN	1	2.8	2.8	2.8

Table 3. Summary of Annual Mean Concentrations (mg/L) (cont.)

	Average Annual Concentrations (mg/L)			
Analyte-Sample Type-Practices	No.	Mean	Minimum	Maximum
Phosphorus, Diss|Sb|NC-CCN-CT-CS-EN	3	0.11	0.07	0.15
Phosphorus, Diss|Sb|NC-CCN-NT-CS-EN	1	0.08	0.08	0.08
Phosphorus, Diss|Sr|NC-CCN-CT-CS-EN	3	0.45	0.34	0.61
Phosphorus, Diss|Sr|NC-CCN-NT-CS-EN	1	0.78	0.78	0.78
Phosphorus, Diss|Sr|NM-CCY-NT-CS-EN	1	1.03	1.03	1.03
Phosphorus, Diss|Sr|NM-CCY-NT-CS-EO	1	0.28	0.28	0.28
Phosphorus, Total|Sr|NC-CCN-CN-CS-EB	1	0.7	0.7	0.7
Phosphorus, Total|Sr|NC-CCN-CN-CS-EN	1	1.0	1.0	1.0
Phosphorus, Total|Sr|NC-CCN-CT-CS-EN	1	10.0	10.0	10.0
Phosphorus, Total|Sr|NM-CCN-CT-CS-EN	2	4.9	3.0	6.7
Sediment|Sb|NM-CCN-CN-CO-EN	1	337	337	337
Sediment|Sb|NM-CCN-CT-CO-EN	1	190	190	190
Sediment|Sb|NM-CCN-NT-CO-EN	1	137	137	137
Sediment|Sr|NC-CCN-CN-CS-EB	1	245	245	245
Sediment|Sr|NC-CCN-CN-CS-EN	1	688	688	688
Sediment|Sr|NC-CCN-CT-CS-EN	1	1520	1520	1520
Sediment|Sr|NC-CCY-NT-CS-EB	6	80	0	205
Sediment|Sr|NC-CCY-NT-CS-EN	2	156	153	159
Sediment|Sr|NM-CCN-CN-CO-EN	1	683	683	683
Sediment|Sr|NM-CCN-CT-CO-EN	1	443	443	443
Sediment|Sr|NM-CCN-CT-CS-EN	2	1273	1250	1297
Sediment|Sr|NM-CCN-NT-CO-EN	1	280	280	280

Sample Type Code: Subsurface (Sb) or Surface (Sr). (Sr samples are also shaded grey.)
Practice Codes: Nutrient Management: Nutrient Management (NM) or Nutrient Conventional (NC).
Cover Crop: Cover Crop Yes (CCY) or Cover Crop No (CCN).
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), or No Till (NT).
Edge-of-field: Terrace (ET), Buffer (EB), Grassed Waterway (EG), Edge of Field Treatment No (EN).
Crop Codes: Corn (CO), Corn-Soybean (CS), Soybean (SB).

Figure 5. Bar Chart of Average Annual Sediment Loads in Surface Runoff for Combinations of Conservation Practices and Crop Rotations

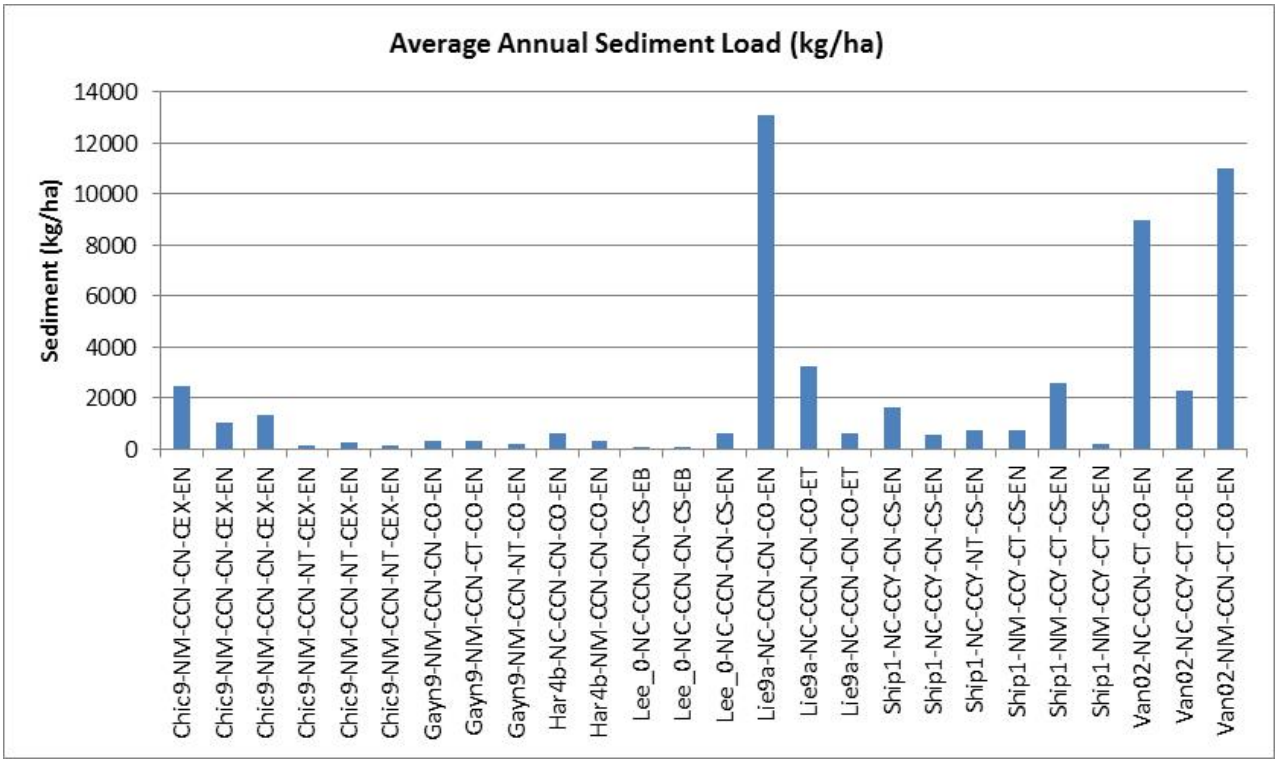


Figure 6. Bar Chart of Average Annual Sediment Concentrations in Surface Runoff for Combinations of Conservation Practices and Crop Rotations

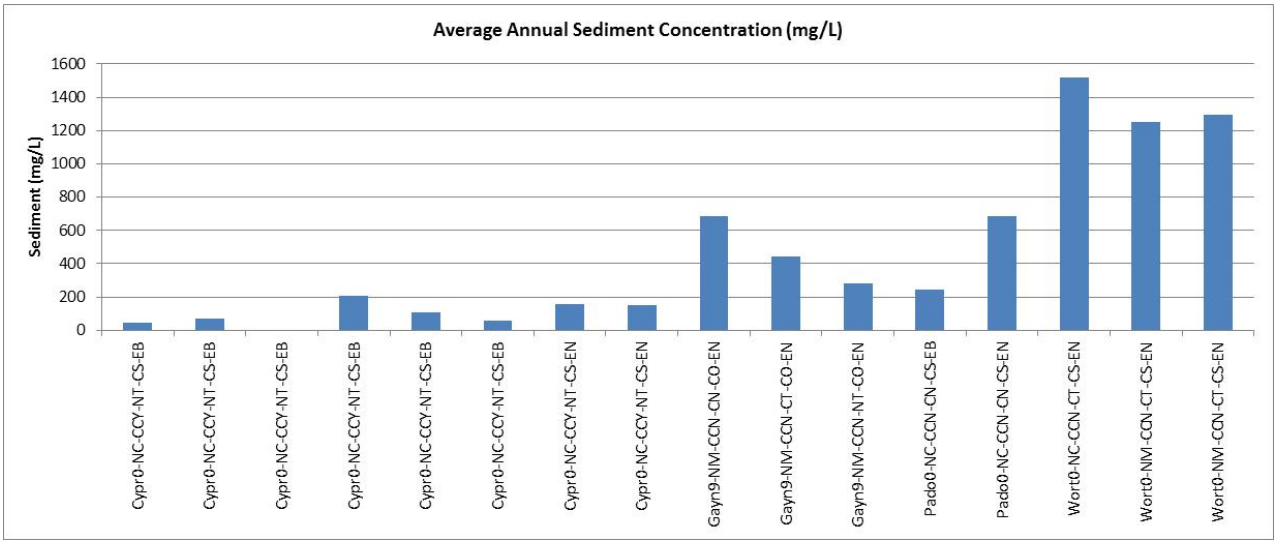


Figure 7. Bar Chart of Average Annual Total Phosphorus Loads in Surface Runoff for Combinations of Conservation Practices and Crop Rotations

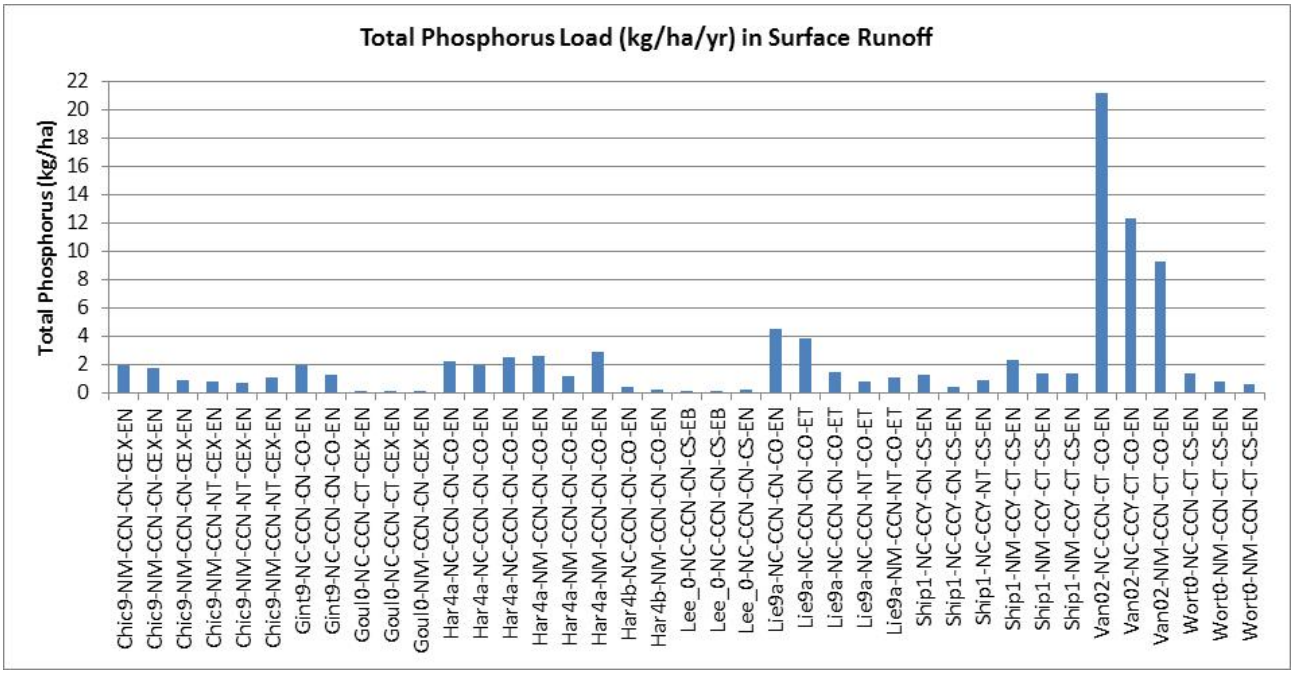


Figure 8. Bar Chart of Average Annual Nitrate-N Loads in Subsurface Drainage for Combinations of Conservation Practices, Crop Rotations and Study Sources

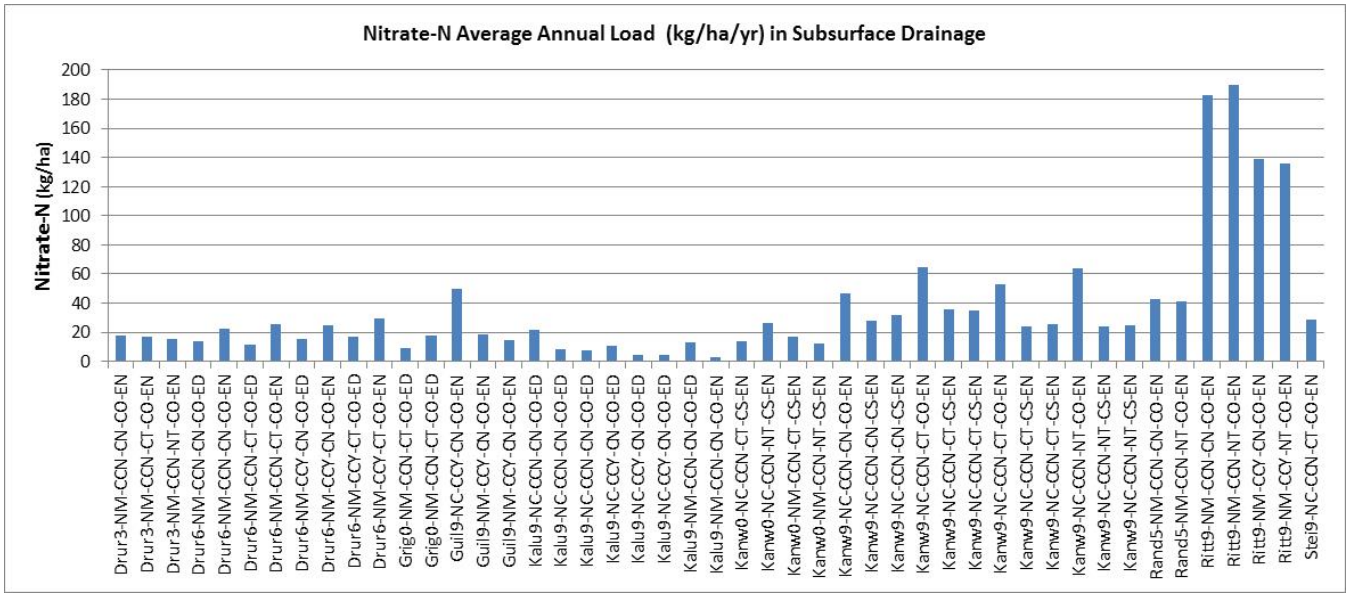
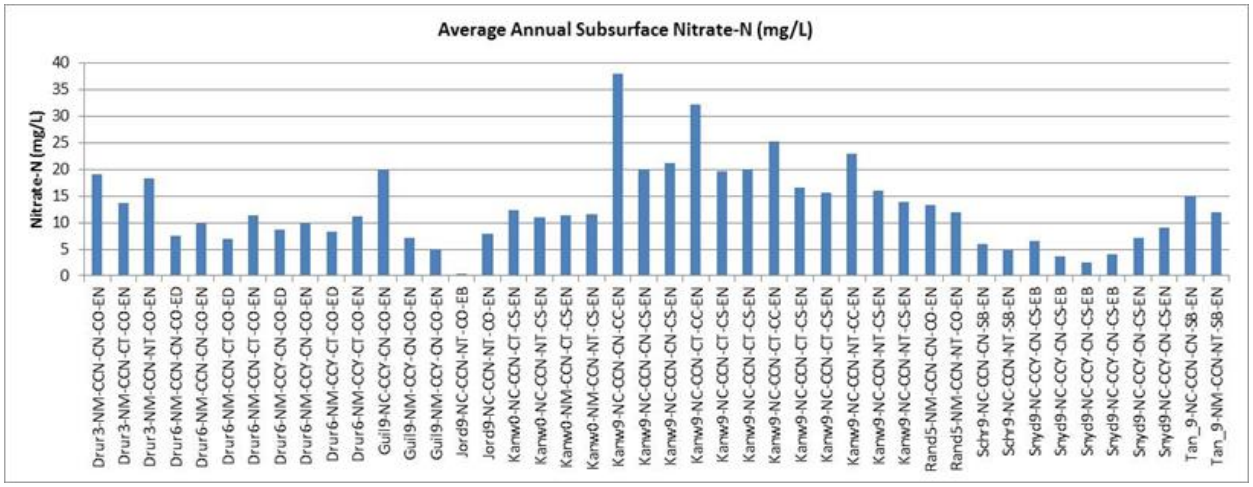


Figure 9. Bar Chart of Average Annual Nitrate-N Concentrations in Subsurface Runoff for Combinations of Conservation Practices, Crop Rotations and Study Sources



4.3 BMP Performance Data Summary for Selected Water Quality Analytes

Sections 4.3.1 through 4.3.3 provide insight into how surface and subsurface pollutant loads and concentrations vary based on the presence or absence of certain individual practice types. When reviewing these tables and plots, it is important to be aware that other variables are not held constant. For example, plots are provided comparing sites with and without cover crops; however, other variable conditions such as nutrient management (or lack thereof) are not considered in this particular presentation. The following analysis is useful for informing the answers to big picture questions such as:

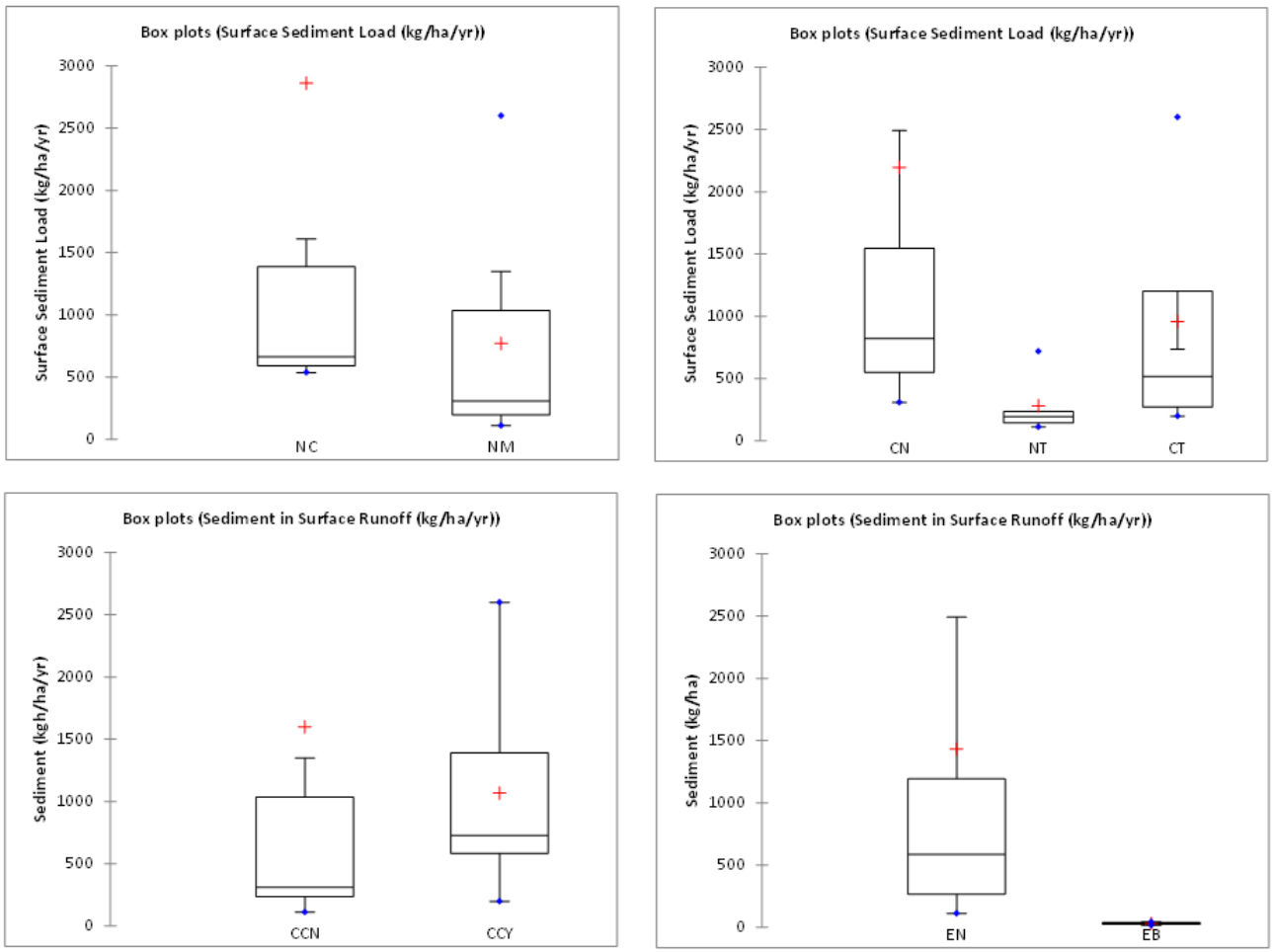
- What are the ranges of concentrations and loads at sites that are achievable with and without certain practices?
- Do sites with a certain practices tend to result in lower loads and/or concentrations than sites without this practice in place?

The data included in the discussion below have been restricted to corn and soybean crops (or rotations) and three studies with significantly elevated nutrient and sediment loads have been excluded (Lietman et al. 1997, van Vliet et al. 2002, and Ritter et al. 1998); however, the results of these three studies can be reviewed in the plots in Section 4.2. Additionally, after the edge-of-field comparisons were conducted in the sections below, sites with edge-of-field practices were removed from the remaining “in-field” practice data set so that in-field practice results would not be confounded by edge-of-field treatment benefits, which are quite substantial in most of the edge-of-field studies.

4.3.1 Sediment Loading in Surface Runoff

Figure 10 provides characterization of sediment loads in surface runoff under four sets of "binary" comparisons of the effects of various conservation practices. As indicated below, no-till (NT) and riparian buffers (EB) have the most profound effect on sediment loads among the practices summarized. Cover crops interestingly do not show a net reduction in annual average sediment loads for this particular data set, but there is wide variability among the studies indicating that the effects of cover crops on soil loss are confounded by other variables.

Figure 10. Boxplots of Sediment Loads (kg/ha/yr) for Surface Runoff under Various Practice Conditions

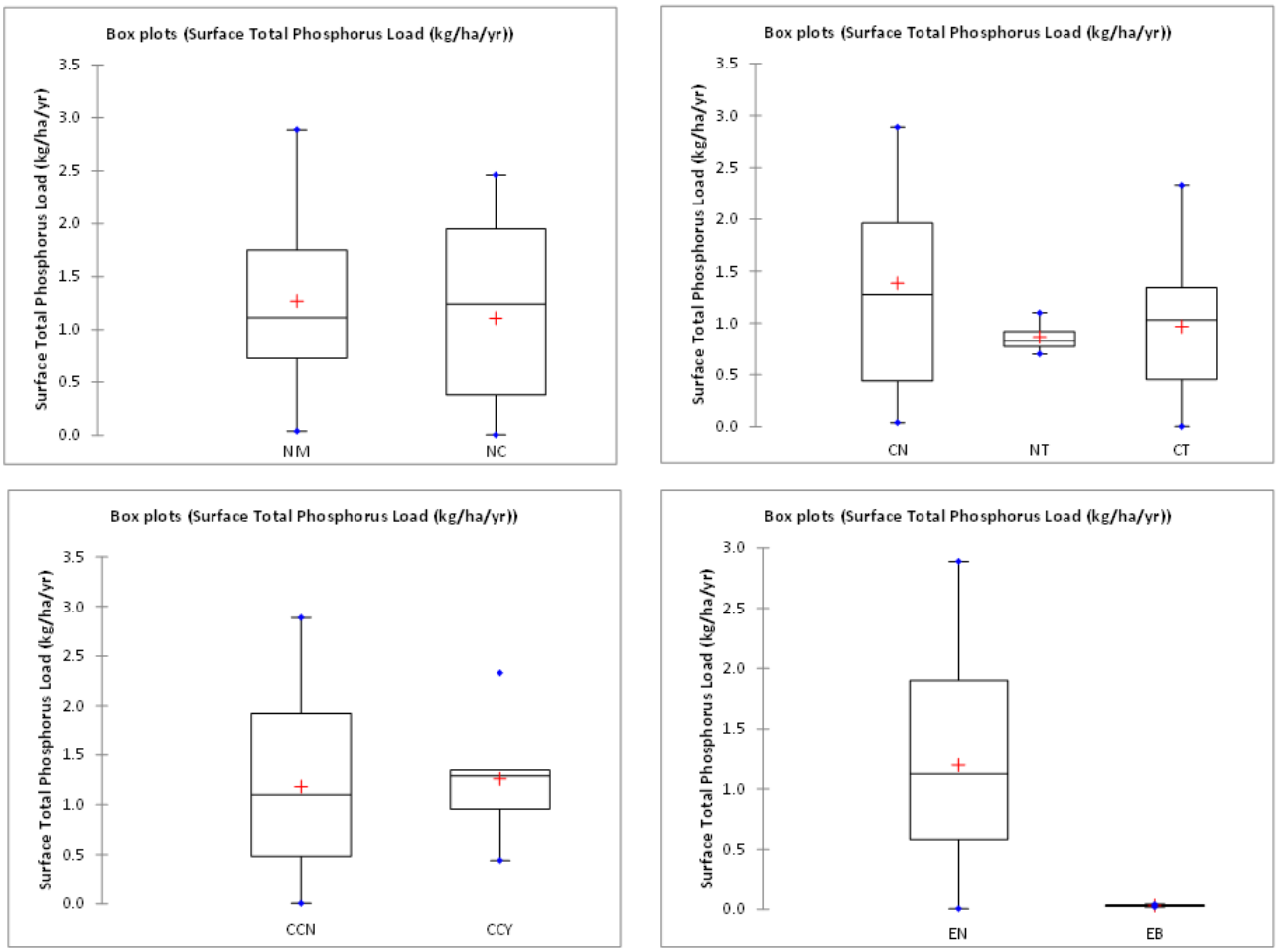


Boxplot Legend:
Practice Codes: Nutrient Management: Nutrient Management (NM) or Nutrient Conventional (NC)
Cover Crop: Cover Crop Yes (CCY) or Cover Crop No (CCN)
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), or No Till (NT)
Edge-of-field: Buffer (EB), Edge of Field Treatment No (EN)

4.3.2 Total Phosphorus Loading in Surface Runoff

Box plots for surface loads of total phosphorus are shown in Figure 11. As would be expected, these plots generally follow the same patterns as sediment with the highest reductions found for no-till (NT) and riparian buffers (EB). This observation is consistent with the tendency for phosphorus to be closely associated with soil particles.

Figure 11. Boxplots of Total Phosphorus Loads (kg/ha/yr) for Surface Runoff under Various Practice Conditions

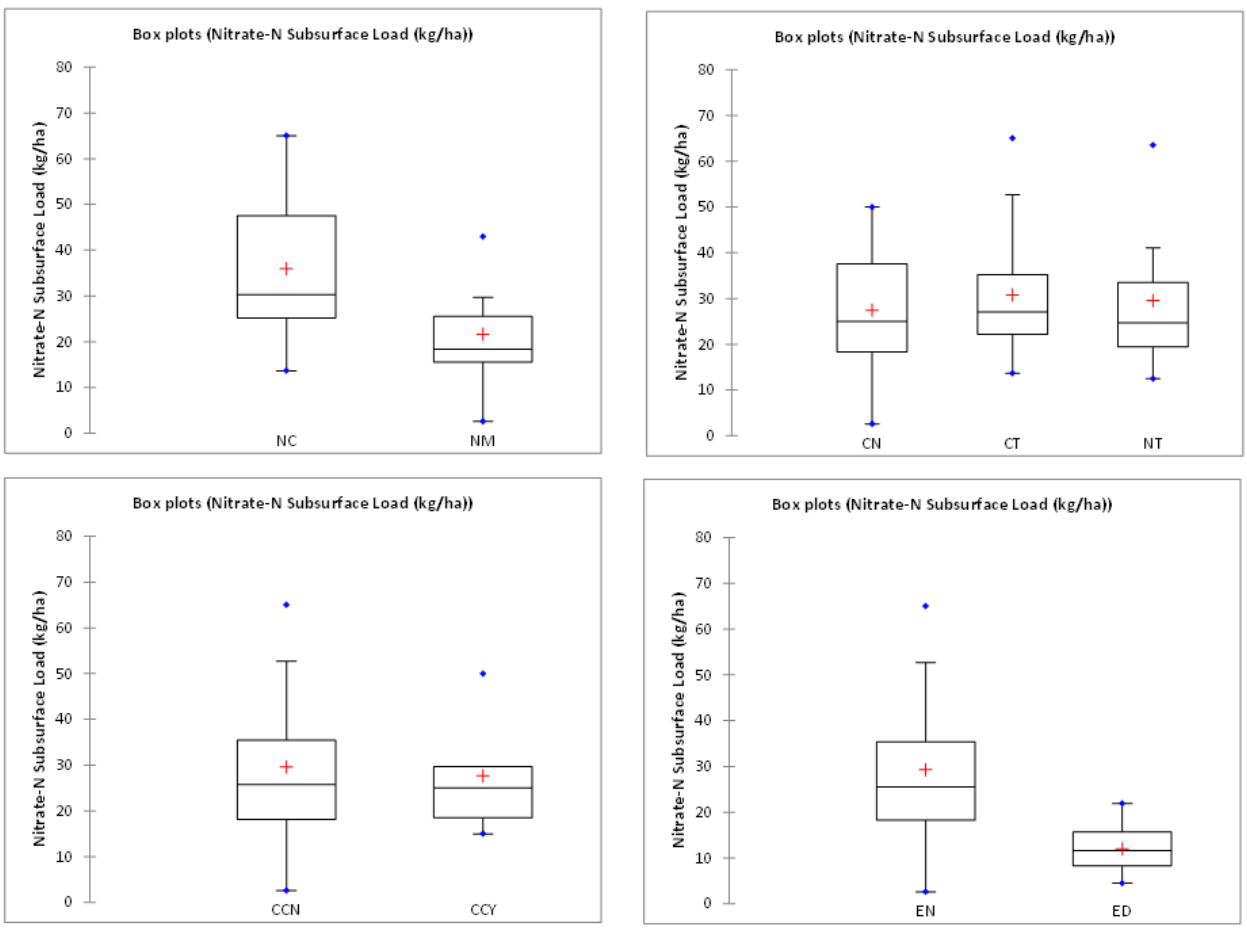


Boxplot Legend:
Practice Codes: Nutrient Management: Nutrient Management (NM) or Nutrient Conventional (NC)
Cover Crop: Cover Crop Yes (CCY) or Cover Crop No (CCN)
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), or No Till (NT)
Edge-of-field: Buffer (EB), Edge of Field Treatment No (EN)

4.3.3 Nitrate Loading in Subsurface Drainage

Box plots of subsurface nitrate loads are shown below in Figure 12 for various conservation practices. As indicated in the figures, nutrient management (NM) and controlled drainage (ED), when evaluated independently, show significant reductions in subsurface nitrate loads whereas tillage practices (CT and NT) and cover crops (CCY) do not. These results are consistent with other published literature and practice. Nutrient management practices are specifically intended to reduce the leaching of nitrogen. For example, applying nitrogen in the spring rather than the fall and/or applying as a sidedress has been shown to reduce nitrate losses (Randall et al. 2003). Cover crops would be expected to capture excess nitrogen during the non-growing seasons (Brandi-Dohrn, 1997); therefore, the use of cover crops would be expected to reduce annual loads and concentrations. Figure 12 does not show a subsurface nitrate load reduction from cover crops; however, the effects of cover crops may be masked by other variables influencing subsurface nitrate loads for the studies summarized.

Figure 12. Nitrate-N (kg/ha/yr) Subsurface Loads under Various Conservation Practice Conditions



Boxplot Legend:
Practice Codes: Nutrient Management: Nutrient Management (NM) or Nutrient Conventional (NC)
Cover Crop: Cover Crop Yes (CCY) or Cover Crop No (CCN)
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), or No Till (NT)
Edge-of-field: Drainage Water Management (ED), Edge of Field Treatment No (EN)

Based on the studies summarized from the database, nutrient management and drainage water management appear to be the most effective types of practices affecting subsurface nitrate loads. Nutrient management is a very broad category that encompasses the type, timing, method, rate, and frequency of fertilizer application. Future studies should provide sufficient metadata regarding nutrient management practices to support identification of the most important factors influencing subsurface nitrate loads and concentrations. Given the relatively small number of drainage water management studies in the database, addition of more studies with adequate metadata regarding design and operation of drainage water management approaches in various settings would also be beneficial.

4.4 Other Analytes

Sections 4.1 through 4.3 are provided largely for illustrative purposes regarding the types of characterizations and analyses that can be conducted in future analyses as the AgBMPDB grows. Although data for other analytes such as other forms of nitrogen and phosphorus and some pesticides are included in the AgBMPDB, they have been excluded from this analysis due to the limited number of data points. These other analytes will be considered in future database summaries as additional data are added.

4.5 Limitations of Version 1.0 Analysis

This initial characterization of data included in Version 1.0 of the AgBMPDB provides a starting point for characterizations of pollutant loads and concentrations for key water quality constituents and conservation practice combinations, as well as for estimating baseline conditions for sites without conservation practices in place. The following limitations of the data set and analysis should be kept in mind as future studies are entered into the database:

- The AgBMPDB is structured to accept event-based data; however, data available for Version 1.0 focused primarily on annual or seasonal total loads and average concentrations. While aggregated data are useful for many purposes, they do not capture important temporal variations that may be useful for improving agricultural BMP practices. For example, reporting of individual events is useful for characterizing the portion of the overall pollutant loading that occurred as a result of major storm events, or timing of storm events relative to planting and associated nutrient and irrigation applications.

- “Nutrient management” has a broad range of implementation levels and varies depending on the whether nitrogen or phosphorus is the focus of the management. This initial analysis does not attempt to differentiate among these due to the lack of sufficient metadata. Incorporation of data from the NCGA’s Soil Health Project and additional peer review by soil scientists is recommended for future analyses related to “nutrient management.” Nonetheless, even this initial database release shows the potential benefits of nutrient management.

- Although the AgBMPDB requests several soil-related parameters, more consistent reporting of soil characteristics and soil test results are key areas where improved reporting would be beneficial. Analysis of soil-related influences on surface and subsurface loadings should be further integrated into future analyses.

- A moderate amount of crop yield data was included in Version 1.0. In future analyses, it should be feasible to explore relationships between crop yields, fertilizer and other practices with water quality in surface and subsurface runoff.

- No cost data were incorporated during 2014 due to general lack of reporting of this information in published literature sources used in this initial AgBMPDB release. Both costs and yield data are critically important to agricultural producers and should be reported as part of conservation practice performance studies.

5 CONCLUSIONS AND RECOMMENDATIONS

The ultimate purpose of this AgBMPDB is to support science-based decisions in terms of managing pollutant loading from agricultural land while maintaining healthy soil and crop yields. The initial release of the AgBMPDB provides a framework for identifying and storing both water quality and metadata needed to improve the understanding of agricultural BMP performance. Although in-depth performance analysis and development of standardized analysis protocols for the AgBMPDB is beyond the scope of this initial Data Summary, the following conclusions are noteworthy:

1. Water quality data for individual studies, groups of practice combinations, and comparisons of sites with or without certain practices in place clearly show that agricultural BMPs can provide significant reductions in pollutant loading from agricultural lands used for row crops. For the most part, the initial findings of AgBMPDB Version 1.0 align with expectations for BMP performance as presented in the literature.

2. Because metadata associated with individual performance studies is now associated with water quality data in an accessible master database, researchers will have the basis to further explore the potential underlying causes of strong or weak performance of agricultural BMPs, which can be used to improve BMP selection and implementation in the future. Even limited initial data analysis provided in this report demonstrate that a “one size fits all” solution to agricultural water quality challenges is not realistic; therefore, more systematic reporting and access to study metadata can support decision-making regarding which solutions have demonstrated performance, given various site and production characteristics.

3. Summarized runoff quality data from various agricultural sites can inform watershed modeling and planning efforts by providing valuable information on the potential range of concentrations and loads that could be expected with and without implementing conservation practices.

4. The value of the AgBMPDB will grow as the AgBMPDB is further populated. There is a significant amount of published, peer-reviewed literature suitable for entry into the AgBMPDB that has not yet been entered. Continued support of the AgBMPDB effort by multiple producers beyond corn and soybean producers is needed to enable continued growth of the AgBMPDB and more refined data analysis. It may be beneficial to target certain practices of interest to producers and/or certain geographic areas and prioritize entries of those studies. This effort will also help to identify areas where additional research is needed so that research dollars are maximized.

5. One of the key benefits of the AgBMPDB is that both metadata and edge-of-field water quality data are compiled and accessible for future use in consistent formats. Because

commonly used percent removal metrics for BMP performance do not provide reliable information on the edge-of-field concentrations and loads that are being achieved on farms, the AgBMPDB can be used to further refine expectations for practically achievable water quality goals. For example, a 60 percent sediment removal estimate for buffers is expected to be affected by the initial (baseline) conditions. If a field has high sediment loads as a baseline, then 60 percent removal may be achievable. Conversely, if a producer has already implemented significant in-field BMPs and has a lower initial baseline, then a 60 percent removal rate may not be realistic. The AgBMPDB will help to place load reduction estimates in context relative to baseline conditions and desired water quality endpoints.

6. Several recent literature reviews have been completed by others to develop percent reduction estimates to support nutrient reduction strategies for agricultural producers (e.g., Iowa Nutrient Reduction Strategy). Data from the already compiled literature supporting these load reduction estimates could be added to the AgBMPDB. This effort would extend the value to the work already conducted and enhance consistency between future metadata analysis efforts using the AgBMPDB and existing nutrient reduction strategies. Partnering with agricultural research universities to conduct this effort is recommended.

7. Based on initial data analysis provided in this summary report, the challenges of effectively analyzing agricultural research data are evident due to the number of variables that combine to determine pollutant loading and BMP performance at a given site. Examples of these variables include study-specific conditions such as soil, slope, climate and weather conditions (e.g., wet year, drought), cultivation and drainage practices, edge-of-field practices implemented, in-field erosion control practices (e.g., grassed waterways, terraces), crop yield goals, and others.

8. A future task for the AgBMPDB project should include development of a standardized analysis protocol at the individual BMP and combined BMP levels that further refine the initial data characterization in this report. The analysis protocols should be peer reviewed by soil scientists and other agricultural experts before application of these methods to future releases of the AgBMPDB.

9. Given the resources needed to enter extensive amounts of metadata from already published studies, a short-list of the highest priority data entry elements should be developed to facilitate continued population of the AgBMPDB in order to increase the number of studies with a reasonable amount of metadata to support meaningful analyses in the future.

6 REFERENCES

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APPENDIX A. AGBMPDB VERSION 1.0 INDIVIDUAL PRACTICE METADATA SUMMARY (2015)

APPENDIX B. AGBMPDB VERSION 1.0 INDIVIDUAL PRACTICE WATER QUALITY DATA SUMMARY (2015)