WATER ENVIRONMENT & REUSE FOUNDATION

Final **Report**

Agricultural Best Management Practices Database (AgBMPDB)

Version 2.0 Data Summary

INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org

Agricultural Best Management Practices Database (AgBMPDB)

VERSION 2.0 DATA SUMMARY

Prepared by:

Jane Clary and Jonathan Jones
Wright Water Engineers, Inc.

Marc Leisenring
Eric Strecker
Kevin Koryto
Geosyntec Consultants, Inc.

2017

INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org

NATIONAL CORN GROWERS ASSOCIATION

WATER ENVIRONMENT & REUSE FOUNDATION
WE&RF

USB
UNITED SOYBEAN BOARD
Progress Powered by U.S. Farmers

The Water Environment & Reuse Foundation (WE&RF) is a nonprofit (501c3) organization officially formed in July 2016 as the result of the merger of Water Environment Research Foundation and the WateReuse Research Foundation. The merged research foundation, with a combined research portfolio representing over $200 million, conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids.
The Foundation also plays an important role in the translation and dissemination of applied research, technology demonstration, and education, through creation of research-based educational tools and technology exchange opportunities. WE&RF materials can be used to inform policymakers and the public on the science, economic value, and environmental benefits of wastewater and recovering its resources, as well as the feasibility of new technologies.

For more information, contact:
The Water Environment & Reuse Foundation
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Tel: (571) 384-2100
www.werf.org
werf@werf.org

© Copyright 2017 by the Water Environment & Reuse Foundation. All rights reserved. Permission to copy must be obtained from the Water Environment & Reuse Foundation.
WE&RF ISBN: 978-1-94124-294-0
WE&RF Project: SIWM14T16/15T16

This report was prepared by the organization(s) named below as an account of work sponsored by the Water Environment & Reuse Foundation (WE&RF). Neither WE&RF, members of WE&RF, the organization(s) named below, nor any person acting on their behalf: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe on privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Wright Water Engineers, Inc., Geosyntec Consultants, Inc.

This document was reviewed by a panel of independent experts selected by WE&RF. Mention of trade names or commercial products or services does not constitute endorsement or recommendations for use. Similarly, omission of products or trade names indicates nothing concerning WE&RF's positions regarding product effectiveness or applicability.

About WE&RF

The Water Environment & Reuse Foundation (WE&RF) is a 501c3 charitable corporation which conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids while facilitating interaction among practitioners, educators, researchers, decision makers, and the public. Our research represents a portfolio of more than $200 million in water quality research.

WE&RF operates with funding from subscribers, donors, state agencies, and the federal government. Our supporters include wastewater treatment facilities, stormwater utilities, state and federal government agencies, technology vendors and equipment companies, engineers, and environmental consultants. WE&RF takes a progressive approach to research, stressing collaboration among teams of researchers, environmental professionals, scientists, and staff. All research is peer reviewed by leading experts.

WE&RF is driven by one overarching theme – To provide exceptional water research to advance science and technology. Our research, both relevant and impartial, and of the highest quality, forms a critical foundation for the adoption of sound policies and regulations to protect our natural resources and public health. We build that foundation through four core program elements:

- Applied research in water and the environment – Providing greater value to the industry by linking research with practical applications in the field.
- Accelerating innovation and adoption of technology – Through engagement, evaluation, and sharing of new technologies and solutions to complex problems to create impact.
- Transferring knowledge – The rapid and cohesive dissemination of research results to our subscribers and the water community to facilitate positive action.
- Setting an industry research agenda – As an accelerator for launching new research initiatives that will be needed to address future challenges for our industry.

WE&RF's mission is to catalyze innovation through actionable research in water and the environment. WE&RF accomplishes this mission by seeking to achieve four principal goals:

- Establish water research and innovation priorities to address current and future needs.
- Initiate transformative, integrated, and collaborative research and demonstrations.
- Fund and conduct independent and unbiased, actionable water research.
- Effectively communicate the results and progress of our research and innovation activities in a timely manner.

Interwoven in WE&RF's mission and goals is the need to provide industry leadership, to collaborate with interested parties and our partners, to uphold the integrity of the scientific process to ensure research is unbiased and is credible, and to do so in a transparent and accountable fashion that provides value to our subscribers and partners.

For the most current updates on WE&RF research, sign up to receive Laterals, our bi-weekly electronic newsletter.

Learn more about the benefits of becoming a WE&RF supporter by visiting www.werf.org.

Acknowledgments

This report was funded by the National Corn Growers Association and the United Soybean Board.

Research Team

Principal Investigators:
Jane Clary, M.S.
Wright Water Engineers, Inc.

Eric Strecker, P.E.
Geosyntec Consultants, Inc.

Project Team:
Marc Leisenring, P.E.
Kevin Koryto
Geosyntec Consultants, Inc.

Jonathan Jones, P.E.
Wright Water Engineers, Inc.

WE&RF Project Steering Committee

Julie Bowker
United Soybean Board/SmithBucklin

Rachel Orf
National Corn Growers Association

Max Starbuck, Director of Production
National Corn Growers Association

WE&RF Project Advisory Committee

Jerry Hatfield, Laboratory Director
National Laboratory for Agriculture and the Environment, U.S. Department of Agriculture, Ames, IA

Mike Plumer
Illinois Council on Best Management Practices

Sally Shaver
Shaver Consulting, Inc.

Amy Lynn Shober, Ph.D.
University of Delaware

Water Environment & Reuse Foundation Staff

Jeffrey J. Mosher
Chief Research Officer

Harry Zhang, Ph.D., P.E.
Program Director

Abstract and Benefits

Abstract:

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. As the AgBMPDB grows, it will also be useful for watershed assessments and planning efforts. This second release of the AgBMPDB continues to focus on row crops, particularly corn and soybeans. The complete database can be downloaded in Microsoft Access from http://www.bmpdatabase.org/agBMP.html.

This report provides a summary of agricultural BMP performance data available in the second release of the AgBMPDB and provides performance characterization updates, expanding on the initial data summary release. An inventory of key metadata and water quality data for individual studies is provided in appendices, which are available by request. Overviews of studies by geographic area and practice type are also described in this report. Based on the available data, characterizations of surface and subsurface pollutant loads and concentrations under various practice conditions are also provided. These 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.

Benefits:

- Provides consolidated data summary for Version 2.0 of the AgBMPDB.
- Provides comparisons illustrating the water quality benefits of agricultural BMPs for corn and soybean crops.
- Identifies additional research needs related to agricultural BMP performance.

Keywords: Agricultural BMPs, performance evaluation, best management practice, nutrients, sediment, water quality.

Contents

Acknowledgments iv
Abstract and Benefits v
Tables vii
Figures vii
Acronyms and Abbreviations viii
Executive Summary ES-1

Chapter 1: Introduction 1-1

Chapter 2: Overview of AgBMPDB Version 2.0 Analysis Data Set 2-1
2.1 Crops and Practices by HUC-10 Distribution 2-1
2.2 Conservation Practice Types included in Version 2.0 2-3
2.2.1 In-Field Practices 2-4
2.2.2 Edge-of-Field Practices 2-6
2.2.3 In-Field Land-Shaping Practices 2-6
2.2.4 Combinations of Practice Variables for Study Areas 2-7
2.2.5 Inventory of Practice Variables for Study Areas in AgBMPDB Version 2.0 2-7

Chapter 3: Analysis Methods and Practice Characterization Approach 3-1

Chapter 4: Data Summary 4-1
4.1 Characterization of Individual Studies 4-1
4.2 Summary of Results for Various Practice Combinations and Constituents 4-1
4.3 Characterization of Selected Practice Groups and Water Quality Analytes 4-5
4.3.1 Effect of Selected Management Practices on Subsurface Nitrogen Concentrations and Loads 4-6
4.3.1.1 Tillage 4-6
4.3.1.2 Cover Crops 4-9
4.3.1.3 Nutrient Management 4-11
4.3.2 Effect of Conservation Tillage on Sediment Surface Runoff Concentrations and Loads 4-14
4.3.3 Effect of Nutrient Management on Total Phosphorus in Surface Runoff Loads 4-16
4.3.4 Effect of Buffers on Sediment in Surface Runoff Concentrations and Loads 4-18
4.4 Other Analytes 4-19
4.5 Limitations of Version 2.0 Analysis 4-19

Chapter 5: Conclusions and Recommendations 5-1

References R-1

Tables

2-1 Number of Corn Study Areas by 10-Digit HUC and Study Focus 2-2
2-2 Number of Soybean Study Areas by 10-Digit HUC and Study Focus 2-3
4-1 Summary of Selected Pollutants and Practice Combinations 4-3
4-2 Average Annual Nitrate-N in Subsurface Drainage Under Various Tillage Practices 4-7
4-3 Average Annual Nitrate-N in Subsurface Drainage Under Various Cover Crop Practices 4-9
4-4 Average Annual Nitrate-N in Subsurface Drainage Under Various Nutrient Management Practices 4-12
4-5 Average Annual Sediment in Surface Runoff Under Various Tillage Conditions 4-14
4-6 Average Annual Total Phosphorus Under Various Nutrient Management Practices 4-16

Figures

1-1 General structure of AgBMPDB 1-1
2-1 Hydrologic unit code water resource region boundary map (2-digit HUC) 2-1
2-2 Representation of key variables potentially affecting pollutant loading from agricultural lands in row crop production in study areas in AgBMPDB version 2.0 2-8
3-1 Boxplot legend 3-1
4-1 Boxplots for average annual Nitrate-N in subsurface dainage under various tillage practices ... 4-7
4-2 Average annual nitrate-N concentrations in subsurface drainage under various tillage practices 4-8
4-3 Average annual nitrate-N loads in subsurface drainage under various tllage practices 4-8
4-4 Boxplots of average annual nitrate-N in subsurface drainage under various cover crop practices 4-9
4-5 Average annual nitrate-N concentrations in subsurface drainage under various cover crop practices 4-10
4-6 Average annual nitrate-N loads in subsurface drainage under various cover crop practices 4-10
4-7 Boxplots for average annual nitrate-N in subsurface drainage under various nutrient management practices 4-12
4-8 Average annual nitrate-N concentrations in subsurface drainage under various nutrient management practices 4-13
4-9 Average annual nitrate-N loads in subsurface drainage under various nutrient management practices 4-13
4-10 Boxplots of average annual sediment in surface runoff for various tillage conditions 4-14
4-11 Average annual sediment concentrations in surface runoff under various tillage conditions 4-15
4-12 Average annual sediment loads in surface runoff under various tillage conditions 4-15
4-13 Boxplots for average annual total phosphorus under various nutrient management practices .. 4-17
4-14 Average annual total phosphorus loads for various nutrient management practices 4-17
4-15 Average annual sediment concentrations in surface runoff under various buffer conditions 4-18
4-16 Average annual sediment loads in surface runoff under various buffer conditions 4-18

Acronyms and Abbreviations

AgBMPDB	Agricultural BMP Database
BMP	Best management practice
U.S. EPA	U.S. Environmental Protection Agency
HUC	Hydrologic unit code
kg/ha/yr	kilograms per hectare per year
mg/L	milligrams per liter
MLRA	Major land resource area
N	Nitrogen
NCGA	National Corn Growers Association
NOx	Nitrate+Nitrite and Nitrate
NRCS	Natural Resources Conservation Service
P	Phosphorus
SRP	Soluble reactive phosphorus
SSC	Suspended sediment concentration
TSS	Total suspended solids
µg/L	micrograms per liter
USB	United Soybean Board
WE&RF	Water Environment & Reuse Foundation

Executive Summary

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. As the AgBMPDB grows, it will also be useful for watershed assessments and planning efforts. This second release of the AgBMPDB continues to focus on row crops, particularly corn and soybeans. The complete database can be downloaded in Microsoft Access from http://www.bmpdatabase.org/agBMP.html.

This report provides a summary of agricultural BMP performance data available in the second release of the AgBMPDB and provides performance characterization updates, expanding on the initial data summary release. An inventory of key metadata and water quality data for individual studies is provided in appendices, that are available by request. Overviews of studies by geographic area and practice type are also described in this report. Based on the available data, characterizations of surface and subsurface pollutant loads and concentrations under various practice conditions are also provided. These 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.

The second release of the AgBMPDB expanded on the initial version by adding an additional 29 studies with over 150 study areas, bringing the number of study areas to 345. In-depth performance analysis and development of standardized analysis protocols remains limited by the number of entries; however, the following conclusions are evident from initial data analysis:

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 the AgBMPDB Version 2.0 align with expectations for BMP performance as presented in the literature:
    a. Nutrient management practices showed reductions in surface runoff phosphorus and subsurface nitrate loads.
    b. No-till and conservation tillage practices showed reductions in surface runoff sediment loads and subsurface nitrate concentrations compared to conventional tillage.
    c. Cover crops showed reductions in subsurface nitrate loads.
2. Because the AgBMPDB associates site metadata with individual performance study water quality data, the AgBMPDB provides a tool for researchers 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 and standardized reporting and access to study metadata can support decision making regarding which solutions have demonstrated performance, given various site and production characteristics.

3. Based on 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.

4. 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. In general, average annual concentrations are less variable than average annual loads, which reflect the variation in hydrology and potential challenges of accurate flow measurement.

5. The value of the AgBMPDB will grow as the database 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.

6. 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% 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% removal may be achievable. Conversely, if a producer has already implemented significant in-field BMPs and has a lower initial baseline, then a 60% 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.

This report also provides recommendations for future work related to the AgBMPDB project.

CHAPTER 1

Introduction

The second release of the AgBMPDB expands the data set by 29 studies from the initial Version 1.0. Seventy-three professional publications characterizing pollutant loading and/or concentrations in 345 fields and/or study plots are now included in Version 2.0. Many of these studies were identified from previous database efforts such as MANAGE (Harmel et al., 2008) and the Virginia Tech database (Dillaha et al., 2002). Because all data sets were obtained through publically available studies, data entry was limited to information available in the published version of these reports, with the vast majority being derived from peer-reviewed journal publications that provided data in summary form (e.g., annual loads per hectare). Full citations for published works by researchers are provided in the "Test Site" table of the AgBMPDB.

The AgBMPDB is a relational database in Microsoft Access (2013) including multiple tables linked together by unique numeric key fields. Figure 1-1 provides a simplified overview of the basic database structure. (Additional supporting tables are also included in the AgBMPDB, but are not identified in Figure 1-1.) 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.

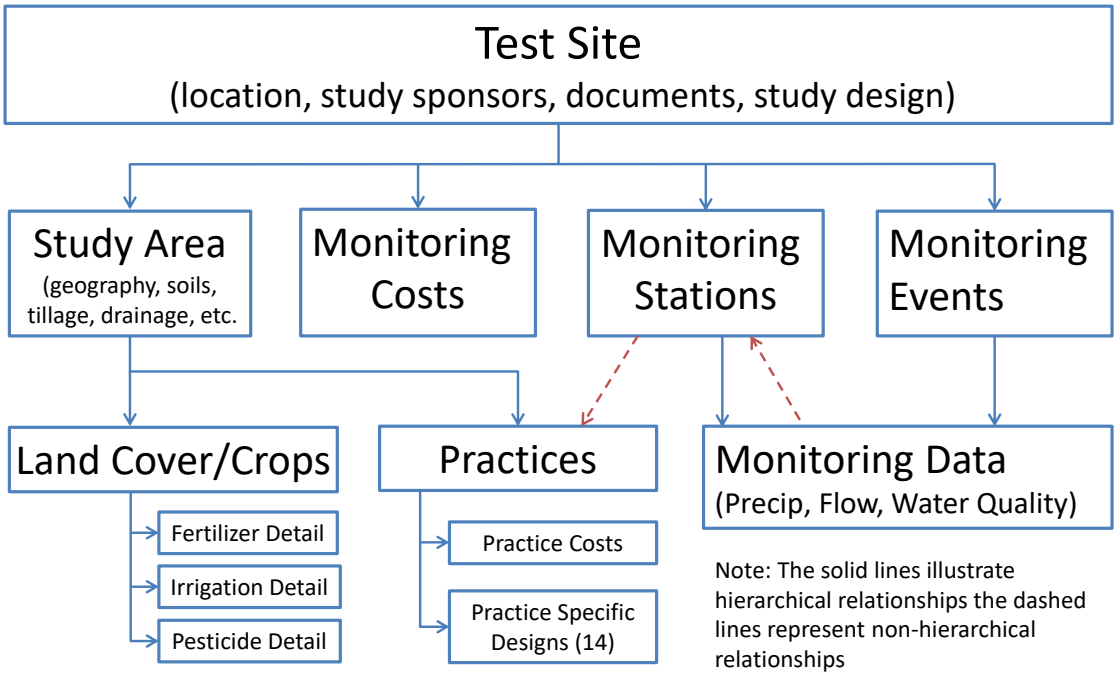


Figure 1-1. General structure of AgBMPDB.

CHAPTER 2

Overview of AgBMPDB Version 2.0 Analysis Data Set

Graphical and tabular summary statistics are provided in this chapter by pollutant category, with data summaries provided for each BMP category with sufficient data to generate statistical summaries.

2.1 Crops and Practices by HUC-10 Distribution

Tables 2-1 and 2-2 provide summaries of corn and soybean fields/study plots by 10-digit HUC associated with various study areas. Studies evaluating grass/hay/pasture and sorghum sites were also included in evaluated studies (typically as control sites) and are further described in Section 2.2.1. Each plot or field in a study is counted separately according to the practice or combination of practices in place at the particular plot. Because fields planted in corn-soybean rotations are counted in both the corn and soybean subtotals, the study areas in Tables 2-1 and 2-2 sum to more than the total number of study areas evaluated.[1] Of the 345 study areas, 82 were in some form of corn-soybean rotation. The majority of the studies for both corn and soybeans are located in the Upper Mississippi River Basin (Region 07). Figure 2-1 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) or where a HUC-10 could not be determined, 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/.

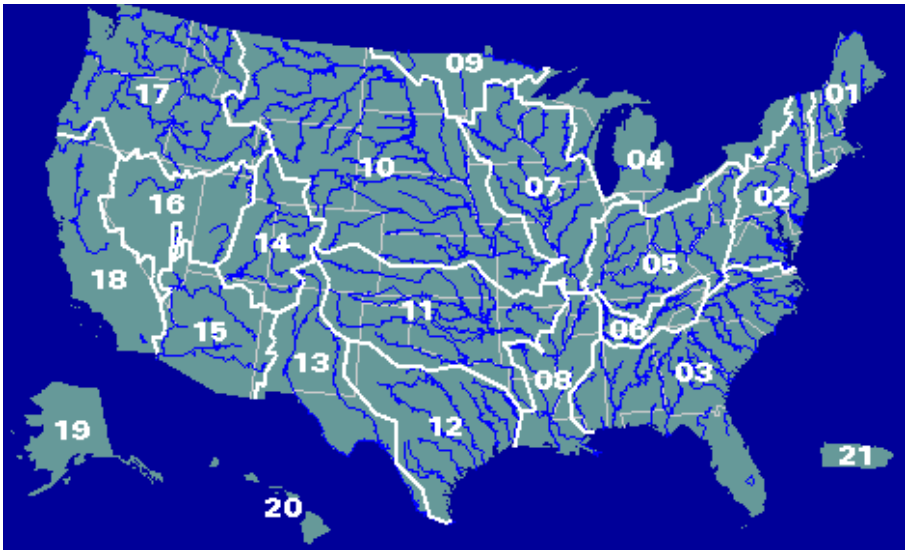


Figure 2-1. Hydrologic unit code water resource region boundary map (2-Digit HUC).
Source: U.S. Geological Survey http://water.usgs.gov/GIS/regions.html.

[1] Separate study area tallies for corn and soybeans are provided to meet study sponsor objectives.

Table 2-1. Number of Corn Study Areas by 10-Digit HUC and Study Focus

HUC Region	10-Digit HUC	Total	Bioreactor, Controlled Drainage	Buffer	Controlled Drainage	Cover Crop	Cover Crop, Controlled Drainage	Cover Crop, Fertilizer	Cover Crop, Fertilizer, Controlled Drainage, Crop Rotation	Cover Crop, Filter Strip	Crop Rotation	Crop Rotation, Fertilizer	Cropping Systems	CRP, Cropping Systems	Drainage, Cropping System	Fertilizer	Fertilizer, Crop Rotation	Fertilizer, Terrace	General, Contour Planting, Tillage, Grass Waterway	Grassed Waterway	Irrigation, Controlled Drainage, Fertilizer, Intercropping	Tillage	Tillage, Controlled Drainage	Tillage, Cover Crop	Tillage, Fertilizer	Tillage, Fertilizer, WASCOB	Other
New England	0110000202	3														3											
Mid-Atlantic	0201000102	2				2																					
Mid-Atlantic	0201000307	2														2											
Mid-Atlantic	0201000808	2																		2							
Mid-Atlantic	0201000811	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	0206000602	2																				2					
Mid-Atlantic	0207001108	1		1																							
Mid-Atlantic	0208010901	16				16																					
Mid-Atlantic	0208011004	1																									1
South Atlantic-Gulf	0311020401	3		3																							
Ohio	0504000119	14																				4		10			
Ohio	0510020507	3																				3					
Ohio	0512010810	4																				4					
Ohio	0512020703	9													9												
Tennessee	0603000207	3														3											
Upper Mississippi	0702000203	4																							4		
Upper Mississippi	0702000708	2														2											
Upper Mississippi	0702000804	13				4								3			2								4		
Upper Mississippi	0702000806	4											4														
Upper Mississippi	0702001101	8														8											
Upper Mississippi	0704000202	4																				4					
Upper Mississippi	0708010503	18	3			3				3	9																
Upper Mississippi	0708010504	3		3																							
Upper Mississippi	0708020112	27						7								8						12					
Upper Mississippi	0709000205	22														9									13		
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 U.S./Unknown	-999999	62		3	11		4		10			10				6					8	6			4		
Total Corn Study Areas		**284**	**3**	**17**	**19**	**25**	**4**	**13**	**10**	**3**	**9**	**10**	**4**	**3**	**9**	**57**	**2**	**2**	**3**	**2**	**8**	**41**	**0**	**10**	**26**	**3**	**1**

Table 2-2. Number of Soybean Study Areas by 10-Digit HUC and Study Focus

HUC Region	10-Digit HUC	Total	Bioreactor, Controlled Drainage	Buffer	Controlled Drainage	Cover Crop	Cover Crop, Controlled Drainage	Cover Crop, Fertilizer	Cover Crop, Fertilizer, Controlled Drainage, Crop Rotation	Cover Crop, Filter Strip	Crop Rotation	Crop Rotation, Fertilizer	Cropping Systems	CRP, Cropping Systems	Drainage, Cropping System	Fertilizer	Fertilizer, Crop Rotation	Fertilizer, Terrace	General, Contour Planting, Tillage, Grass Waterway	Grassed Waterway	Irrigation, Controlled Drainage, Fertilizer, Intercropping	Tillage	Tillage, Controlled Drainage	Tillage, Cover Crop	Tillage, Fertilizer	Tillage, Fertilizer, WASCOB	Other
Mid-Atlantic	0207001108	1		1																							
Mid-Atlantic	0208011004	1																									1
South Atlantic-Gulf	0316010603	6		6																							
Ohio	0504000119	14																				4		10			
Ohio	0512010810	4																				4					
Ohio	0512020703	3													3												
Upper Mississippi	0702000804	8				4								2			2										
Upper Mississippi	0702000806	3											3														
Upper Mississippi	0702001101	8														8											
Upper Mississippi	0702000708	2														2											
Upper Mississippi	0708010503	18	3			3				3	9																
Upper Mississippi	0708010504	3		3																							
Upper Mississippi	0708020112	25						5								8						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	10290101	3																							3		
Missouri	1029010104	9																							9		
Arkansas-White-Red	11070205	4																							4		
Outside U.S./Unknown	-999999	16		2	3		4									3							4				
Total Soybean Study Areas		**143**	**3**	**17**	**3**	**7**	**4**	**5**	**0**	**3**	**9**	**0**	**3**	**2**	**3**	**24**	**2**	**0**	**3**	**0**	**0**	**22**	**4**	**10**	**18**	**0**	**1**

2.2 Conservation Practice Types Included in Version 2.0

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. For example, conservation tillage and nutrient management are commonly used in tandem to minimize nutrient losses. 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 2.0.

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 (i.e., 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 2.0 of the AgBMPDB follow. The discussion focuses on practices that were reasonably well reported in the evaluated studies; 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 the data search 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 data summary the following crop rotations have been isolated for potential analysis:

- Corn (CO).
- Corn-Soybean Rotation (CS).
- Corn Extended Rotation (CEX) (without soybeans).
- Corn-Soybean Extended Rotation (CSX).
- Soybean (SB).
- 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 study area 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 which "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 others 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 this information is inconsistently reported. 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 analysis, a simple categorization approach is used:

- Nutrient Management (NM).
- Nutrient Conventional (NC).
- No Fertilizer Application (NF).

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 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). This is true regardless of the tillage equipment used; however, moldboard plowing is typically considered conventional tillage that inverts the soil and leaves the surface exposed to erosive forces (Janssen and Hill, 1994). Conservation tillage practices include 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 studies included in the database, many sites are expected to include tile drainage systems (even though most studies did not explicitly state whether tile drainage was in place); however, few study areas with tile drains 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 analysis, 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 the majority of the mid-western corn-soybean studies included in the current database 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 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 a 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 was not included as an explanatory variable in this analysis, but could be in the future.

2.2.2 Edge-of-Field Practices

The vast majority of studies in the current AgBMPDB focus on in-field practices instead of edge-of-field practices. Edge-of-field treatment practices in Version 2.0 of the AgBMPDB are characterized as:

- Edge of Field – Buffer (EB).
- Edge of Field – Drainage Water Management (ED).
- Edge of Field – Other (EO) (e.g., filter ditch, denitrification wall).
- Edge of Field-Water and Sediment Control Basins (EW).
- Edge of Field – None (EN).

The AgBMPDB is well suited for entry of edge-of-field practices; however, it is currently limited by the number of available studies. 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 2.0 includes only a few studies that focused on in-field land shaping practices such as terraces (Lietman et al., 1997) and grassed waterways (Udawatta et al., 2004, Braun et al., 2016), 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 these as a practice group; however, Appendices A and B (available by request), as well as the AgBMPDB itself, 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 345 study areas currently in 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, such as multiple regression, could likely be applied to better identify which of these variables (or variable strings) warrants isolating for further analysis. The data summary provided in Chapter 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 2.0

Figure 2-2 provides a graphical depiction of the types of practices and study characteristics represented in Version 2.0 of the AgBMPDB by relative percentage of the 345 fields/plots currently included in the database. Key observations related to these practices include the following:

- 44% of the study areas (151 fields/plots) had some type of nutrient management practice in place.
- 18% of the study areas (62 fields/plots) documented the use of a cover crop.
- 48% of the study areas (164 fields/plots) clearly stated that some form of tile drainage was present onsite.

A large portion of evaluated studies (49%, 169 fields/plots) did not explicitly state whether tile drains were present. Studies entered directly by researchers could improve the uncertainty of this field in future releases.

- Only 12% 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 2.0 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 95% of the study areas.
- Crop rotation practices were generally well documented for the study areas. There was 39% of the study areas planted in continuous corn, and 30% were in corn-soybean rotation (with some in corn-soybean-wheat rotation). The remaining 21% were divided relatively equally among other corn rotations, continuous soybean, grass-hay-pasture, sorghum or sorghum-soybean rotation. For purposes of the data analysis in Chapter 4, only the corn and soybean related crops have been characterized.
- Most study areas did not include edge-of-field treatment or in-field constructed erosion-control practices. The edge-of-field practices in Version 2.0 are limited primarily to riparian buffers and drainage water management sites. Other practices included in the database with a limited number

of characterized studies are terraces, grassed waterways, water and sediment control basins, and other practices such as a filter ditch.

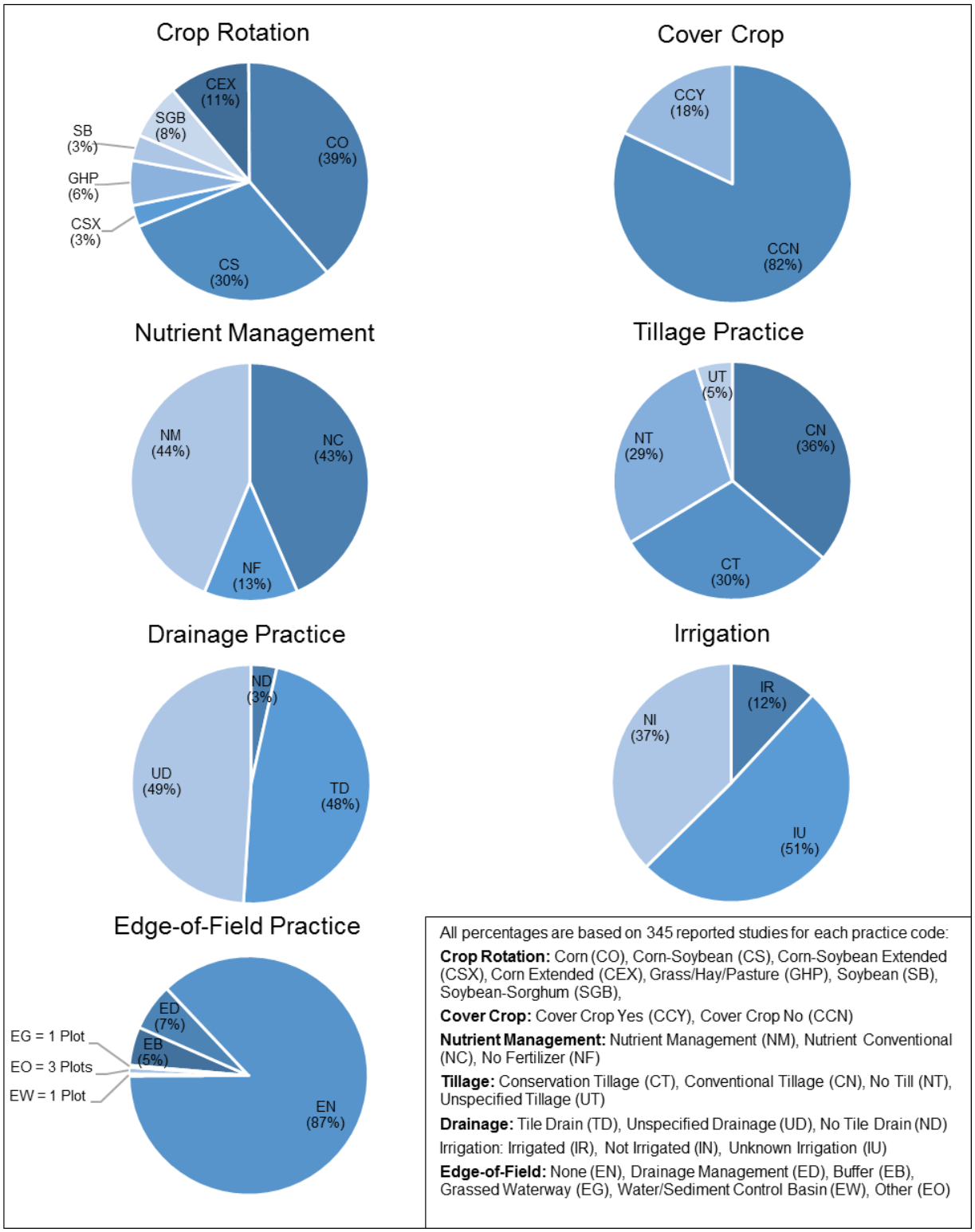


Figure 2-2. Representation of key variables potentially affecting pollutant loading from agricultural lands in row crop production in study areas in AgBMPDB Version 2.0.

CHAPTER 3

Analysis Methods and Practice Characterization Approach

As described in Chapter 1, this 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, and summary statistics provided.

For this data summary report, tabular statistical summaries are limited to subsets of interest for purposes of discussion in this report – the AgBMPDB should be downloaded for the complete data set. The number of data points reported is particularly important in terms of the robustness of the data set. The number of data points has improved in Version 2.0; however, limited data continue to be a constraint in data characterization due to the many variables potentially affecting water quality at agricultural sites. 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 average loads or concentrations; 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 report. Figure 3-1 provides a legend for interpreting each component of a boxplot.

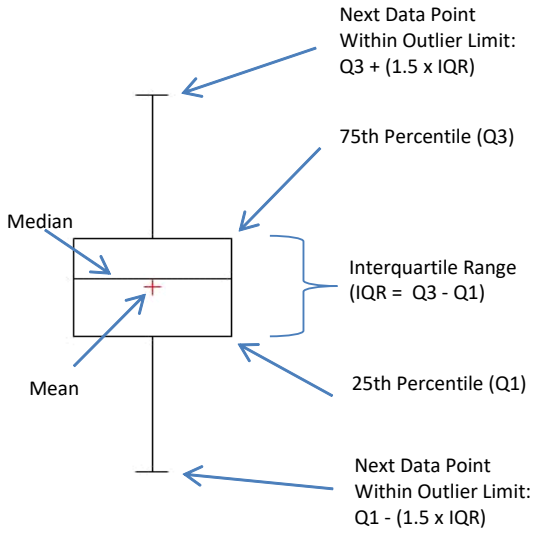
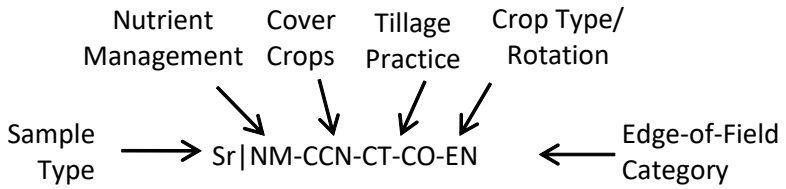


Figure 3-1. Boxplot legend.

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

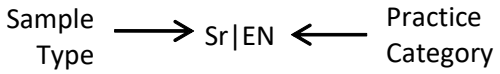
- For individual studies, two data summary appendices (available by request) have been developed and are available by request:
  - Appendix A provides a summary of key metadata associated with each study, primarily in narrative format.
  - Appendix B is a water quality concentration and load data summary 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.
- Soluble Reactive Phosphorus (for concentration data sets only).
- Total Phosphorus.
- Sediment.

Other nutrient forms and herbicides/pesticides 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 (available by request) for the individual studies, but are currently too limited among the studies to analyze categorically. Eight test sites contain reasonably detailed pesticide records; however, these records are not evaluated in this Data Summary.

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 and adherence to standardized protocols for sediment data collection and reporting is recommended to reduce this controllable source of potential variability.

CHAPTER 4

Data Summary

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

- Individual practice metadata and water quality data (Appendices A and B, available by request).
- General characterization of the range of practice combinations in Version 2.0.
- Characterization of concentrations and loads for specific practice groups and water quality analytes.

It is important to recognize that this data summary is not intended to serve as a robust "metadata analysis"; however, several practice-pollutant combinations have sufficient data to make some initial general observations. In Version 2.0, the most robust data sets are for subsurface nitrogen concentrations. The practice group that is least well represented is edge-of-field practices. For those interested in riparian buffer data sets, the WE&RF-sponsored Stream Restoration Database Version 1.0, developed as a companion product to the Urban Stormwater BMP Database and the AgBMPDB, may provide additional information, accessible at: http://www.bmpdatabase.org/stream.html.

4.1 Characterization of Individual Studies

Appendices A and B (available by request) provide information on individual studies in the AgBMPDB version 2.0. 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 BMP implementation. 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 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 http://www.bmpdatabase.org/retrieve_studies.html.)

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 spatially. 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 Chapter 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 more useful in characterizing the performance of practice combinations and for providing ranges of expected runoff and drainage concentrations and loads. This approach could also be further refined to include soil type, geographic area, study scale (e.g., field, plot, farm) and other characteristics.

Table 4-1 provides a basic summary of pollutant concentrations and loads for commonly reported pollutants that had at least three average annual results to display in the summary. Many pollutant-practice strings had only one or two results to display – these combinations are not shown in the table because they are not useful for estimating ranges. Practice combinations with higher numbers of results are considered to be more reliable. This table is provided for general reference and is not further interpreted in the report.

Table 4-1. Summary of Selected Pollutants and Practice Combinations
Note: Three-page table with key at end.

Pollutant-Sample Type-Practice Combination (subset of commonly reported pollutants with three or more average annual values)	**No.**	**Min**	**Max**	**Median**	**Mean**
Load Data (kg/ha/yr)					
Nitrate-N|Sb|NC-CCN-CN-CO-ED	3	7.4	21.9	8.3	12.5
Nitrate-N|Sb|NC-CCN-CN-CS-EN	4	21.9	47.1	30.3	32.4
Nitrate-N|Sb|NC-CCN-CT-CO-EN	4	24.9	46.6	31.2	33.5
Nitrate-N|Sb|NC-CCN-CT-CS-EN	11	14.0	65.0	25.8	32.3
Nitrate-N|Sb|NC-CCN-NT-CS-EN	7	22.6	63.9	26.0	34.3
Nitrate-N|Sb|NC-CCY-CN-CO-ED	3	4.5	10.5	4.6	6.5
Nitrate-N|Sb|NF-CCN-CN-CEX-EN	4	3.1	18.4	10.7	10.7
Nitrate-N|Sb|NM-CCN-CN-CEX-EN	4	7.2	29.5	15.8	17.1
Nitrate-N|Sb|NM-CCN-CN-CO-EN	6	2.6	182.5	23.6	48.9
Nitrate-N|Sb|NM-CCN-CT-CO-EN	5	17.0	54.8	31.3	33.6
Nitrate-N|Sb|NM-CCN-CT-CS-EN	7	17.0	35.5	23.7	24.5
Nitrate-N|Sb|NM-CCN-NT-CO-EN	3	15.0	190.1	41.1	82.1
Nitrate-N|Sb|NM-CCN-NT-CS-EN	5	12.0	53.0	13.9	27.6
Nitrate-N|Sb|NM-CCN-UT-CS-EN	6	13.0	16.0	14.8	14.5
Nitrate-N|Sb|NM-CCY-CN-CO-EN	4	15.0	138.6	21.8	49.3
Nitrate-N|Sb|NM-CCY-NT-CS-EN	5	15.2	27.9	24.2	22.4
Nitrate-N|Sr|NC-CCN-CT-CO-EN	3	0.5	1.8	1.2	1.2
Nitrate-N|Sr|NM-CCN-CT-CO-ED	3	1.4	5.7	2.4	3.2
Nitrate-N|Sr|NM-CCN-CT-CO-EN	5	0.9	8.6	2.3	3.3
Nitrate-N|Sr|NM-CCY-CT-CS-EN	3	1.9	6.6	3.8	4.1
Phosphorus, SRP|Sr|NC-CCN-CN-CO-EN	4	0.09	1.80	1.25	1.10
Phosphorus, SRP|Sr|NM-CCN-CN-CO-EN	5	0.09	1.70	0.50	0.71
Phosphorus, SRP|Sr|NM-CCN-NT-GHP-EN	3	0.10	0.80	0.25	0.38
Phosphorus, SRP|Sr|NM-CCY-CT-CS-EN	3	0.27	0.74	0.58	0.53
Phosphorus, Total|Sb|NM-CCN-CN-GHP-EN	4	0.38	0.46	0.42	0.42
Phosphorus, Total|Sr|NC-CCN-CN-CO-EN	5	0.38	4.80	4.48	3.45
Phosphorus, Total|Sr|NC-CCN-NT-CS-EG	3	0.13	0.18	0.13	0.14
Phosphorus, Total|Sr|NM-CCN-CN-CEX-EN	4	0.04	1.90	1.30	1.13
Phosphorus, Total|Sr|NM-CCN-CN-CO-EN	4	0.24	6.30	3.50	3.39
Phosphorus, Total|Sr|NM-CCN-CN-GHP-EN	4	0.01	0.05	0.02	0.02
Phosphorus, Total|Sr|NM-CCN-NT-CEX-EN	3	0.70	1.10	0.80	0.87
Phosphorus, Total|Sr|NM-CCN-NT-GHP-EN	3	0.15	1.10	0.90	0.72
Phosphorus, Total|Sr|NM-CCY-CT-CS-EN	3	1.34	2.33	1.35	1.67
Sediment|Sb|NC-CCN-CN-CEX-EN	4	144	247	234	215
Sediment|Sb|NF-CCN-CN-CEX-EN	4	164	353	260	259
Sediment|Sr|NC-CCN-CN-CO-EN	6	606	13114	4894	5354
Sediment|Sr|NC-CCN-NT-CS-EG	3	59	96	69	75
Sediment|Sr|NM-CCN-CN-CEX-EN	3	1035	2491	1350	1625

Pollutant-Sample Type-Practice Combination (subset of commonly reported pollutants with three or more average annual values)	No.	Min	Max	Median	Mean
Sediment|Sr|NM-CCN-CN-CO-EN	5	308	6722	2499	2921
Sediment|Sr|NM-CCN-NT-CEX-EN	3	111	236	143	163
Sediment|Sr|NM-CCN-NT-GHP-EN	3	29	817	60	302
Sediment|Sr|NM-CCY-CT-CS-EN	3	198	2600	734	1177
Concentration Data (mg/L)					
Ammonium-N|Sb|NC-CCY-CN-CS-EB	4	0.02	0.11	0.03	0.05
Ammonium-N|Sr|NC-CCN-CN-CEX-EB	3	1.26	1.29	1.28	1.28
Ammonium-N|Sr|NC-CCN-CN-CEX-EN	3	1.16	1.70	1.41	1.42
Ammonium-N|Sr|NC-CCN-CN-CO-EN	3	0.17	0.25	0.19	0.20
Ammonium-N|Sr|NC-CCY-CN-CS-EB	3	0.02	0.03	0.02	0.02
Ammonium-N|Sr|NM-CCN-CN-CO-EN	3	0.12	0.63	0.21	0.32
Ammonium-N|Sr|NM-CCN-NT-GHP-EN	3	0.05	0.06	0.05	0.05
Nitrate-N|Sb|NC-CCN-CN-CS-EN	4	17.2	38.0	20.5	24.1
Nitrate-N|Sb|NC-CCN-CT-CO-EN	5	19.8	26.9	25.2	23.5
Nitrate-N|Sb|NC-CCN-CT-CS-EN	12	10.2	32.0	16.5	17.5
Nitrate-N|Sb|NC-CCN-NT-CS-EN	8	7.6	23.0	12.8	14.2
Nitrate-N|Sb|NC-CCY-CN-CS-EB	4	2.5	6.7	3.9	4.2
Nitrate-N|Sb|NF-CCN-CN-CEX-EN	4	2.9	14.4	8.0	8.3
Nitrate-N|Sb|NM-CCN-CN-CEX-EN	4	5.8	18.3	10.0	11.1
Nitrate-N|Sb|NM-CCN-CN-CO-EN	4	9.9	19.2	14.4	14.5
Nitrate-N|Sb|NM-CCN-CT-CO-EN	5	11.4	24.0	22.0	18.8
Nitrate-N|Sb|NM-CCN-CT-CS-EN	7	7.4	15.3	11.3	11.1
Nitrate-N|Sb|NM-CCN-NT-CS-EN	5	6.8	22.1	11.4	12.3
Nitrate-N|Sb|NM-CCN-UT-CS-EN	6	9.7	11.2	10.8	10.6
Nitrate-N|Sb|NM-CCY-CN-CO-EN	3	5.1	9.8	7.2	7.3
Nitrate-N|Sb|NM-CCY-CT-CS-EN	3	7.4	9.3	8.0	8.3
Nitrate-N|Sb|NM-CCY-NT-CS-EN	6	6.2	11.2	9.9	9.5
Nitrate-N|Sr|NC-CCN-CN-CEX-EB	3	1.0	1.2	1.1	1.1
Nitrate-N|Sr|NC-CCN-CN-CEX-EN	3	1.2	1.7	1.6	1.5
Nitrate-N|Sr|NC-CCN-CN-CO-EN	4	3.3	18.8	12.0	11.5
Nitrate-N|Sr|NC-CCY-CN-CS-EB	3	2.7	6.2	5.2	4.7
Nitrate-N|Sr|NM-CCN-CN-CO-EN	6	2.8	18.7	6.9	8.9
Nitrate-N|Sr|NM-CCN-NT-GHP-EN	3	0.0	0.2	0.1	0.1
Phosphorus, SRP|Sb|NC-CCN-CN-CEX-EN	4	0.32	0.42	0.37	0.37
Phosphorus, SRP|Sb|NC-CCY-CN-CS-EB	4	0.00	0.01	0.00	0.00
Phosphorus, SRP|Sb|NF-CCN-CN-CEX-EN	4	0.02	0.03	0.02	0.02
Phosphorus, SRP|Sr|NC-CCN-CN-CEX-EB	3	0.44	0.75	0.50	0.56
Phosphorus, SRP|Sr|NC-CCN-CN-CEX-EN	3	0.67	0.70	0.69	0.69
Phosphorus, SRP|Sr|NC-CCN-CN-CO-EN	4	0.20	0.89	0.63	0.59
Phosphorus, SRP|Sr|NC-CCY-CN-CS-EB	3	0.02	0.02	0.02	0.02
Phosphorus, SRP|Sr|NM-CCN-CN-CO-EN	5	0.20	0.90	0.42	0.45

Pollutant-Sample Type-Practice Combination (subset of commonly reported pollutants with three or more average annual values)	**No.**	**Min**	**Max**	**Median**	**Mean**
Phosphorus, SRP|Sr|NM-CCN-NT-GHP-EN	3	0.19	0.88	0.49	0.52
Phosphorus, Total|Sb|NC-CCN-CN-CEX-EN	4	0.47	0.65	0.57	0.57
Phosphorus, Total|Sb|NF-CCN-CN-CEX-EN	4	0.11	0.16	0.14	0.14
Phosphorus, Total|Sr|NC-CCN-CN-CEX-EB	3	0.59	0.80	0.64	0.68
Phosphorus, Total|Sr|NC-CCN-CN-CEX-EN	3	0.79	0.87	0.84	0.83
Sediment|Sb|NC-CCN-CN-CEX-EN	4	55	111	97	90
Sediment|Sb|NF-CCN-CN-CEX-EN	4	59	135	120	108
Sediment|Sr|NC-CCY-NT-CS-EB	6	0	205	64	80

Practice String Notes for Table:

Flow Type: Subsurface Drainage (Sb) or Surface Runoff (Sr)
Nutrient Management: Nutrient Management (NM), Nutrient Conventional (NC), No Fertilizer (NF)
Cover Crop: Cover Crop Yes (CCY), Cover Crop No (CCN)
Tillage: Conservation Tillage (CT), Conventional Tillage (CN), No Till (NT), Unspecified Tillage (UT)
Crop Rotation: Corn (CO), Corn-Soybean (CS), Corn-Soybean Extended (CSX), Corn Extended (CEX), Grass/Hay/Pasture (GHP), Soybean (SB), Soybean-Sorghum (SGB),
Edge-of-Field/In-Field Practice: None (EN), Drainage Management (ED), Buffer (EB), Grassed Waterway (EG), Water/Sediment Control Basin (EW), Terrace (ET) Other (EO)

4.3 Characterization of Selected Practice Groups and Water Quality Analytes

For purposes of this data summary, the AgBMPDB was queried to identify practice groups and pollutants that had a reasonable number of study areas to make some simple comparisons regarding the effectiveness of various conservation practices for row crops, primarily corn and soybeans and associated crop rotations. To identify these data sets, the "study focus" description in the Test Site table was used to identify studies that evaluated certain practice groups, including both a control and treatment for the practice of interest for the most commonly reported pollutants. As a result of these queries, the following conservation practice groups and analytes are further characterized in this summary report:

- Conservation tillage effects on subsurface nitrate loads and concentrations.
- Cover crop effects on subsurface nitrate loads and concentrations.
- Nutrient management effects on subsurface nitrate loads and concentrations.
- Conservation tillage effects on surface runoff sediment loads and concentrations.
- Nutrient management effects on surface runoff total phosphorus loads.
- Buffer effects on surface runoff sediment loads for selected case studies.

Other comparisons may also be feasible, but were beyond the scope of this data summary. As indicated above, subsurface nitrate studies generally have the most robust data sets in the current version of the database. The sections below discuss the selected practice-pollutant combinations using a presence-absence ("binary") comparison approach that generally answers this question: Does the implementation of a particular practice (e.g., cover crops) indicate a water quality benefit (e.g., reduced nitrate loading)? This comparison does not hold other variables constant, so the question is answered without consideration of the influence of other variables. In some cases, the influence of other variables may

have greater effect on the practice being evaluated, which is a limitation of this simple comparison. The authors recognize that evaluation of agricultural systems is complicated by the many variables present in the physical watershed, production practices, and climate/weather variations present during a particular study. The AgBMPDB can be reviewed for more refined information on how other variables may confound the performance described in these simple comparisons. Additionally, in follow-up metadata analyses, it may be possible to conduct further analyses of the relationship between water quality and crop yields for various practices.

The format for this discussion includes tabulated based summary statistics for the conservation practice-pollutant combination followed by a "big picture" boxplot comparison, which is followed by more detailed bar charts of the annual average pollutant loads and concentrations reported by performance study. In the bar charts, the x-axis labels include study name, practice code of interest as previously defined in Chapter 3 (e.g., CCY or CCN for cover crops), and the monitoring station name from the AgBMPDB. Although both concentrations and loads are discussed below for each pollutant-practice combination, it is important to recognize that the studies providing pollutant concentration data may not be identical to those providing load data.

4.3.1 Effect of Selected Management Practices on Subsurface Nitrogen Concentrations and Loads

Conservation tillage, cover crops and nutrient management had reasonably strong data sets for subsurface nitrogen concentrations and loads. As discussed further below, performance data indicate that conservation tillage practices, nutrient management and cover crops reduce subsurface nitrate concentrations.

4.3.1.1. Tillage

Three types of tillage practices can be evaluated from the current data sets in the AgBMPDB, including conventional tillage (CN), conservation tillage (CT) and no-till (NT). Conventional tillage is most commonly described as using moldboard plow. Conservation tillage contains a wide range of practices with varying levels of crop residue remaining, depending on the tillage practice. Ideally, percent crop residue remaining would be reported to enable a more quantitative parsing of conservation tillage practices, but this information is often not described in the peer reviewed literature. This may help to explain why conventional and conservation tillage (excluding no-till) have comparable ranges of concentrations for some studies. Although both concentrations and loads of subsurface nitrate decrease with conservation tillage, particularly no-till practices, the variability is greater for load data, as would be expected given site-to-site variations in hydrology, along with the practical challenges of accurate flow monitoring, which can introduce significant uncertainty into load calculations.

Table 4-2 and Figure 4-1 provide nitrate concentrations and loads in subsurface drainage for tillage study results for fields/plots in various studies. For the bar charts in Figures 4-2 and 4-3, conventional tillage (CT) is generally plotted prior to the conservation tillage (CT) and no-till (NT) practices. As shown in the figures, for individual studies, conservation tillage and no-till practices generally reduce subsurface nitrate concentrations for most studies. Some of the studies are testing multiple treatments that combine various management methods such as the study area series with the prefix "Pede0" by Pederson et al. (2010), so the plot is also useful for illustrating the variability that is introduced as other practices such as various nutrient management strategies vary along with tillage practices. Nonetheless, even in the Pederson et al. (2010) example, the two plots with no-till have lower nitrate in subsurface drainage relative to the other five treatments in the study that do not utilize no-till practices. (Note: the alternating grey-shaded boxes can be used to visually group study practices that are intended to be compared to each other.) Load results in Figure 4-2 are more variable, but overall still indicate reductions in loads when comparing conventional tillage against conservation tillage and no till.

Table 4-2. Average Annual Nitrate-N in Subsurface Drainage Under Various Tillage Practices

	Nitrate-N Concentration (mg/L)			Nitrate-N Load (kg/ha/yr)		
Tillage Practice	**CN**	**CT**	**NT**	**CN**	**CT**	**NT**
Nbr. of observations	11	22	16	11	17	14
Minimum	6.0	7.0	4.8	13.6	11.6	1.4
Maximum	38.0	32.0	23.0	182.5	65.0	190.1
1st Quartile	9.3	11.2	8.8	20.4	17.0	14.2
Median	**13.4**	**12.6**	**11.3**	**28.0**	**18.4**	**24.1**
3rd Quartile	19.6	19.1	12.5	45.0	29.7	38.0
Mean	**15.3**	**14.8**	**11.4**	**51.5**	**25.9**	**43.7**
Variance	83.8	37.1	21.6	3111.4	217.3	2889.8
Standard deviation	9.2	6.1	4.6	55.8	14.7	53.8

Note: CN = Conventional Tillage, CT = Conservation Tillage and NT = No Till

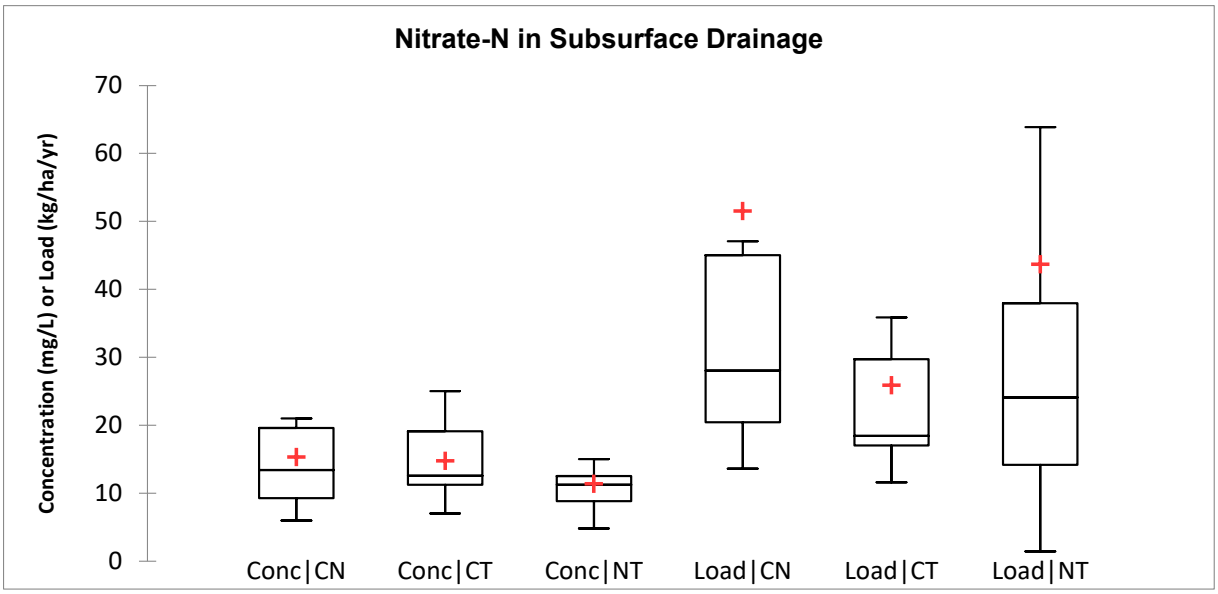


Figure 4-1. Boxplots for average annual nitrate-N in subsurface drainage under various tillage practices.

Note: The table and figure are based on a growing, but still limited, data set in the AgBMPDB v.2. Information presented is useful for general comparisons, but the limitations of the data set should be considered before findings are applied for more advanced purposes. This analysis does not differentiate between short-term and long-term no-till conditions. Subsurface nitrate losses may vary depending on the length of time the field has been in no-till.

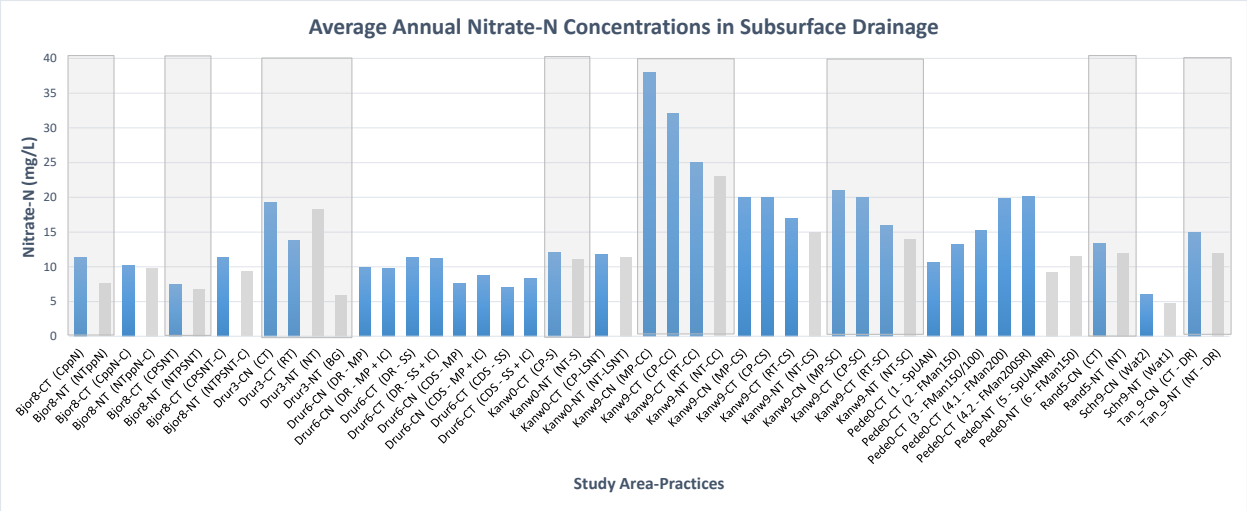


Figure 4-2. Average annual nitrate-N concentrations in subsurface drainage under various tillage practices.

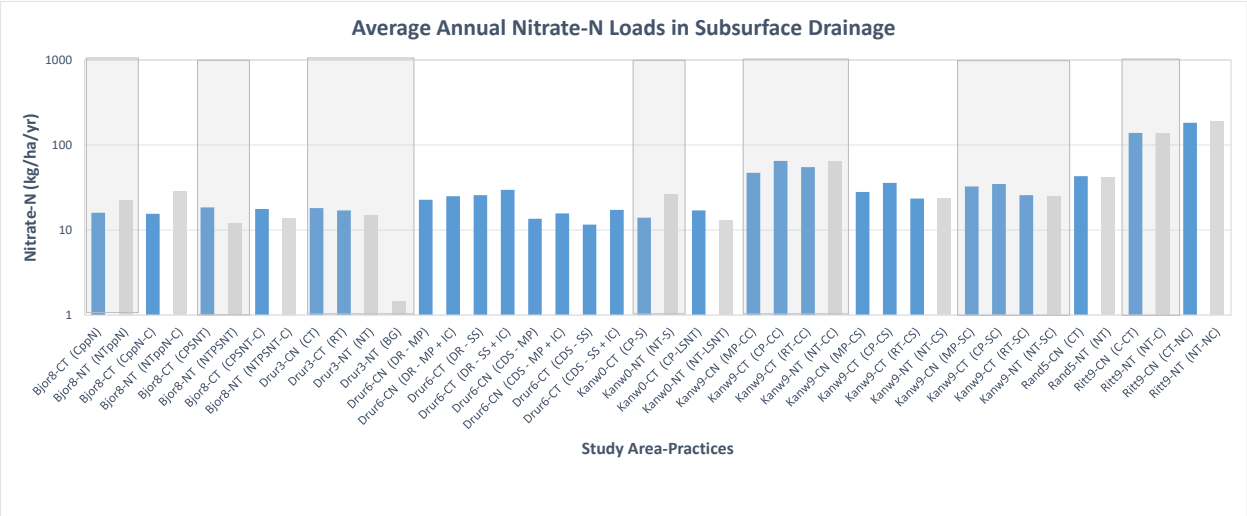


Figure 4-3. Average annual nitrate-N loads in subsurface drainage under various tillage practices.

Figure Notes: No-till bars are shaded in grey. Shaded box overlays are provided to separate studies. Practice string includes a short reference to study, tillage practice code (CN, CT or NT) and monitoring station name which can be used to obtain more information about the study area in the master database. Only studies that included tillage as a study focus are shown on the plot. Loads are shown on a log-scale in Figure 4-3.

4.3.1.2. Cover Crops

During 2016, several additional cover crop studies were added to the AgBMPDB based on input from Practical Farmers of Iowa (http://www.practicalfarmers.org/) related to Version 1.0 of this data summary. Study areas with cover crops are identified as CCY, and study areas without cover crops are identified as CCN. Relative to Version 1.0 of the AgBMPDB, this expanded data set provides clearer evidence of the benefits of cover crops in reducing subsurface nitrate loads, as shown in Table 4-3 and Figures 4-4 through 4-6. As was the case with conservation tillage, pollutant load data compiled among studies in multiple settings has higher variability than the concentration-based data. As was also the case with the tillage studies, studies that are also varying other treatments related to nutrients may confound interpretation of benefits of cover crops, but in most of the studies, subsurface nitrate reductions are evident for study areas that utilize cover crops. In addition to the subset of studies included in these tables and plots, many other studies in the AgBMPDB utilized cover crops, but may not have tested them as a variable (treatment-control) comparison. Those studies (where no testing was conducted) are not included in these tables and plots, representing a change in the analysis approach from the Version 1.0 analysis summary.

Table 4-3. Average Annual Nitrate-N in Subsurface Drainage Under Various Cover Crop Practices

	Nitrate-N Concentration (mg/L)		Nitrate-N Load (kg/ha/yr)	
Cover Crop Status	**CCN**	**CCY**	**CCN**	**CCY**
Nbr. of observations	17	12	16	14
Minimum	7.0	5.0	2.6	4.5
Maximum	21.3	11.2	190.1	138.6
1st Quartile	9.9	7.9	12.7	16.1
Median	**12.0**	**8.7**	**23.2**	**23.5**
3rd Quartile	15.3	9.3	39.8	27.2
Mean	**13.3**	**8.4**	**43.0**	**35.8**
Variance	22.5	2.7	3316.6	1912.0
Standard deviation	4.7	1.6	57.6	43.7

Note: CCN = Cover Crop No (absent); CCY = Cover Crop Yes (present).

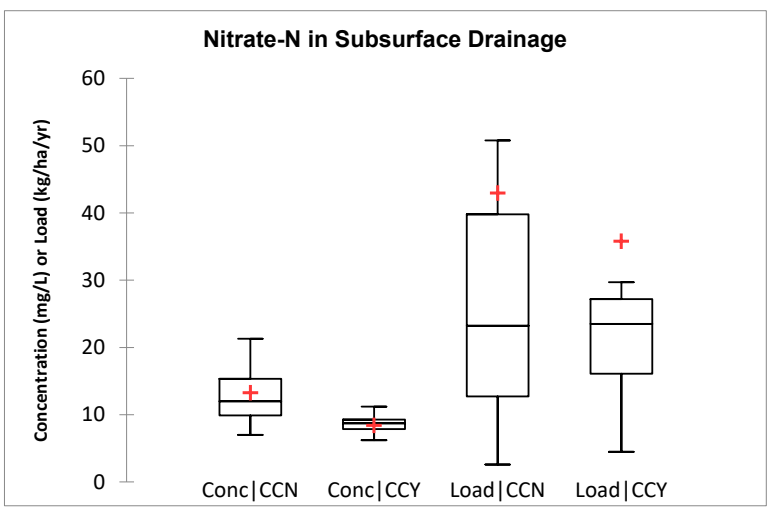


Figure 4-4. Boxplots of average annual nitrate-N in subsurface drainage under various cover crop practices.

Note: The table and figure are based on a growing, but still limited, data set in the AgBMPDB v.2. Information presented is useful for general comparisons, but the limitations of the data set should be considered before findings are applied for more advanced purposes.

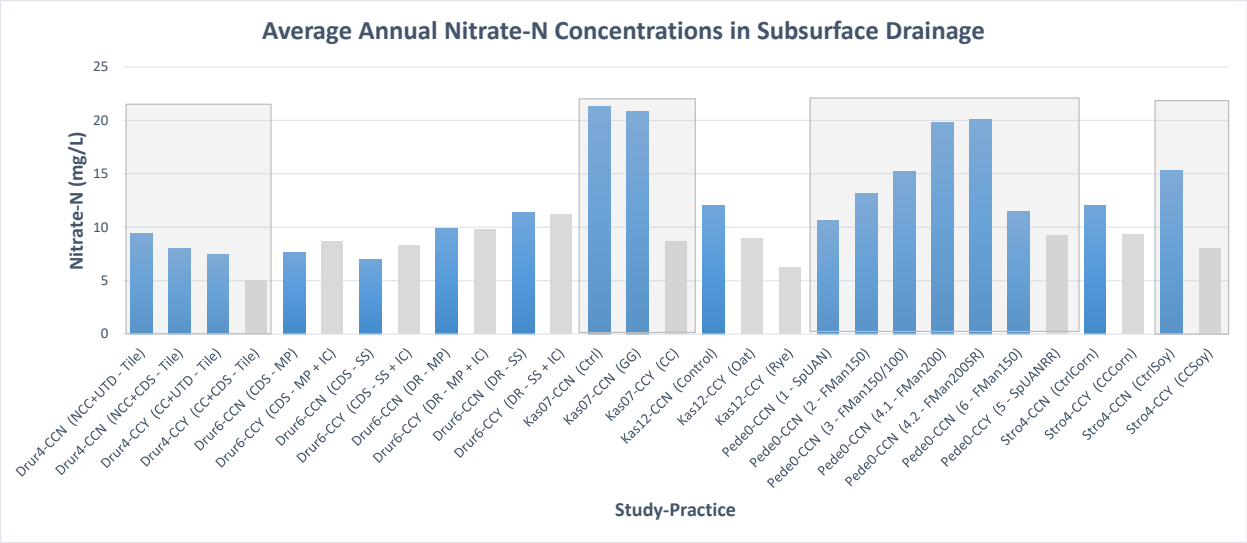


Figure 4-5. Average annual nitrate-N concentrations in subsurface drainage under various cover crop practices.

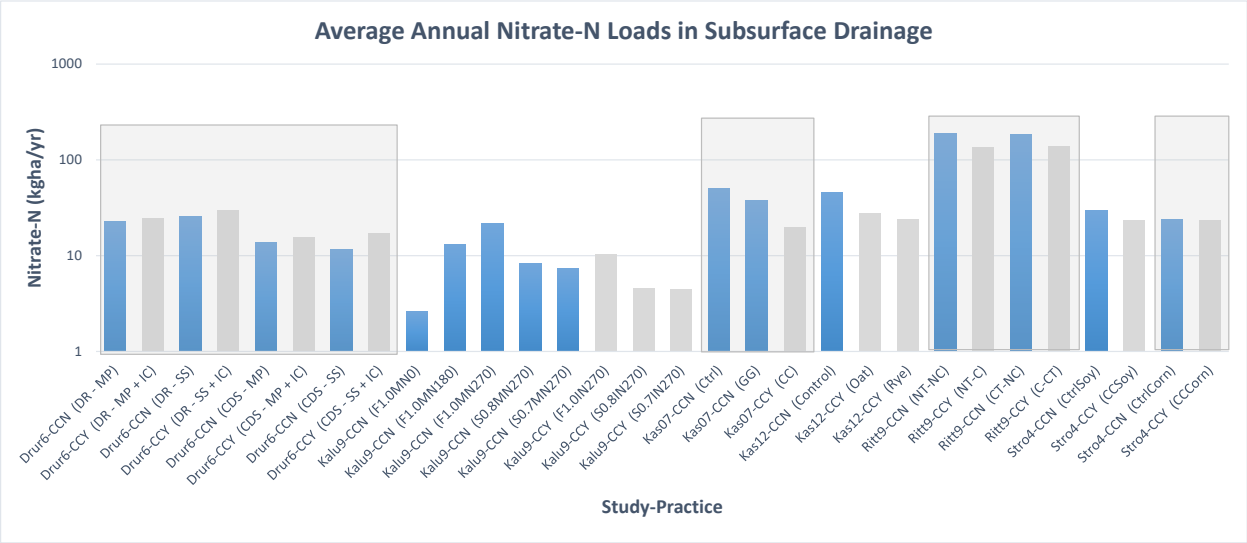


Figure 4-6. Average annual nitrate-N loads in subsurface drainage under various cover crop practices.
Note: CCY bars are shaded in grey. Shaded box overlays are provided to separate studies. Practice string includes a short reference to study, cover crop practice code (CCY or CCN) and monitoring station name which can be used to obtain more information about the study area in the master database. Only studies that included cover crops as a study focus are shown on the plots.

4.3.1.3. Nutrient Management

Nutrient management is the most complex management practice to characterize in the AgBMPDB because so many variables comprise effective nutrient management and site-based variables further complicate defining effective nutrient management practices that are transferable among multiple sites, particularly when reviewing literature as a third party. The AgBMPDB enables entry of metadata important to evaluating nutrient management, including variables related to nutrient sources, application rates, timing and method of application, cropping history, crop rotations, soil type and tests, crop yields and other factors. A thorough metadata analysis is beyond the scope of this report, so comparisons related to nutrient management are provided in a very simplistic manner in this section. If a study identified nutrient management or a fertilizer-related topic as the study focus and included various nutrient-related treatments and controls, then the study was included in the summary for nitrate in subsurface drainage. The extent of nutrient management may vary greatly among these studies. Despite these significant generalizations, the AgBMPDB shows that "nutrient management" appears to reduce nitrate concentrations in subsurface drainage (Table 4-4 and Figure 4-7). As was the case with other management practices, the load-related analysis is more variable; nonetheless, there is a downward shift in mean and median nitrate concentrations for both concentrations and loads and the variability (spread) of the data decreases for sites with nutrient management implemented.

In Figures 4-8 and 4-9, the blue bars represent conventional nutrient management (control) and the grey bars represent some form of nutrient management (treatment). As shown in these graphs, nutrient management practices implemented in individual studies generally demonstrate benefit in terms of nitrate reduction in subsurface drainage.

More detailed metadata analysis using information entered in the "Study Area" and "Fertilizer Detail" tables of the AgBMPDB would enable refinement of ranges of subsurface drainage concentrations achieved as the "4Rs" of nutrient management (i.e., right source, right rate, right time and right place) are varied and could also be related to crop yield responses corresponding to these variations.

Table 4-4. Average Annual Nitrate-N in Subsurface Drainage Under Various Nutrient Management Practices

	Nitrate-N Concentration (mg/L)		Nitrate-N Load (kg/ha/yr)	
Nutrient Management	**NC**	**NM**	**NC**	**NM**
Nbr. of observations	15	17	17	19
Minimum	7.6	5.1	4.5	2.6
Maximum	20.1	11.7	50.0	35.5
1st Quartile	11.2	8.2	10.5	13.0
Median	**12.0**	**10.0**	**20.0**	**15.0**
3rd Quartile	16.2	11.0	22.6	17.4
Mean	**13.7**	**9.5**	**20.1**	**15.8**
Variance	15.7	3.8	174.2	51.5
Standard deviation	4.0	1.9	13.2	7.2

Note: NC = Conventional Nutrient Management; NM = Nutrient Management

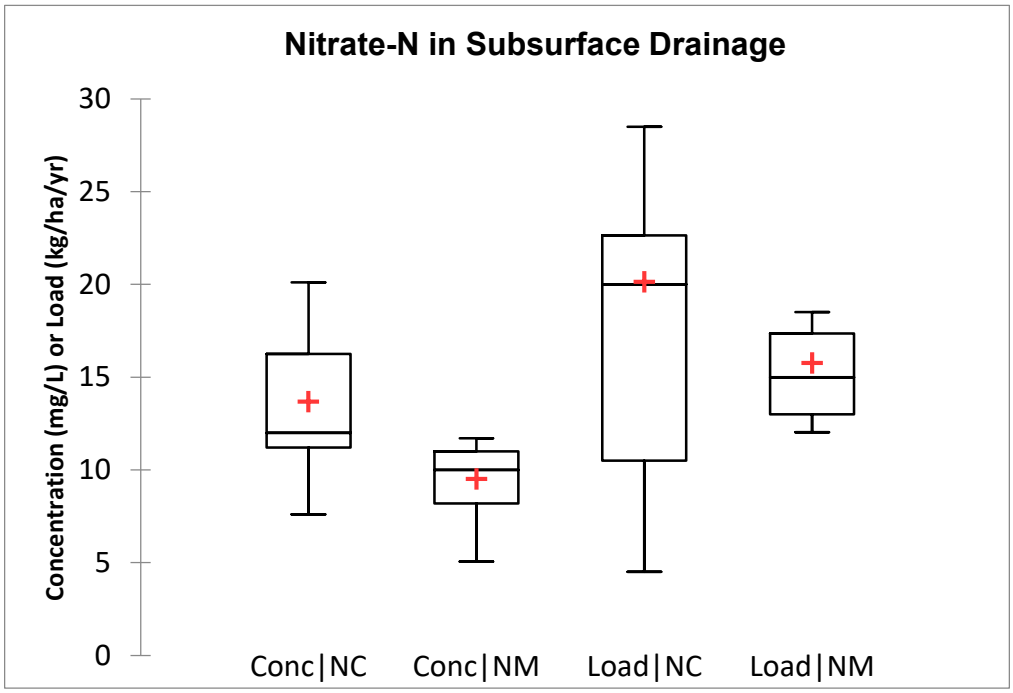


Figure 4-7. Boxplots for average annual nitrate-N in subsurface drainage under various nutrient management practices.
Note: The table and figure are based on a growing, but still limited, data set in the AgBMPDB version 2. Information presented is useful for general comparisons, but the limitations of the data set should be considered before findings are applied for more advanced purposes.

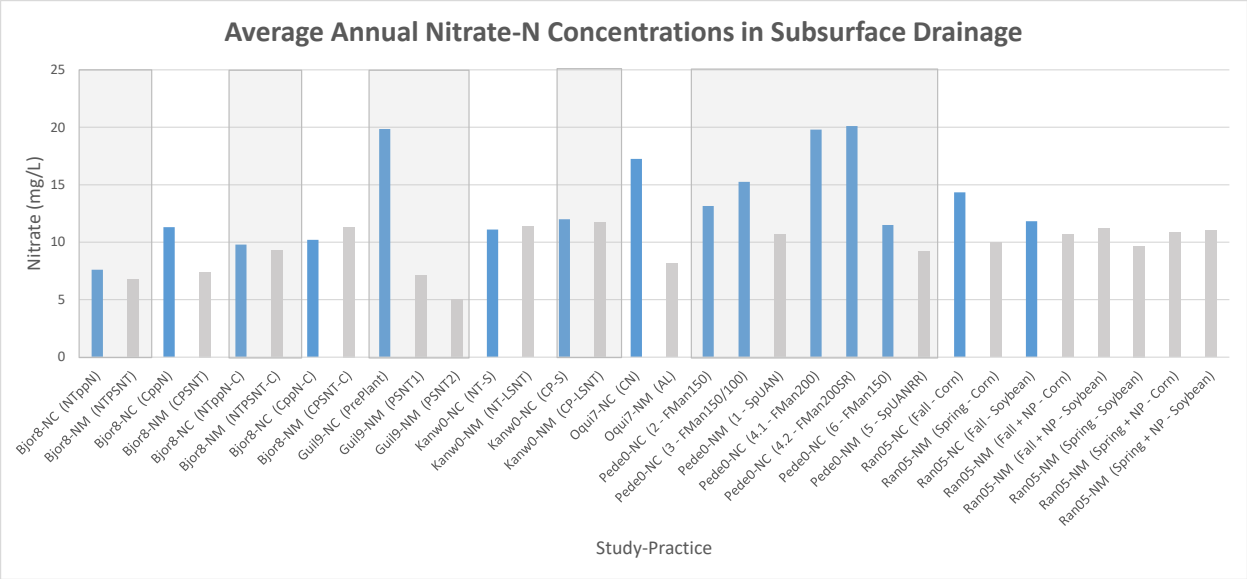


Figure 4-8. Average annual nitrate-N concentrations in subsurface drainage under various nutrient management practices.

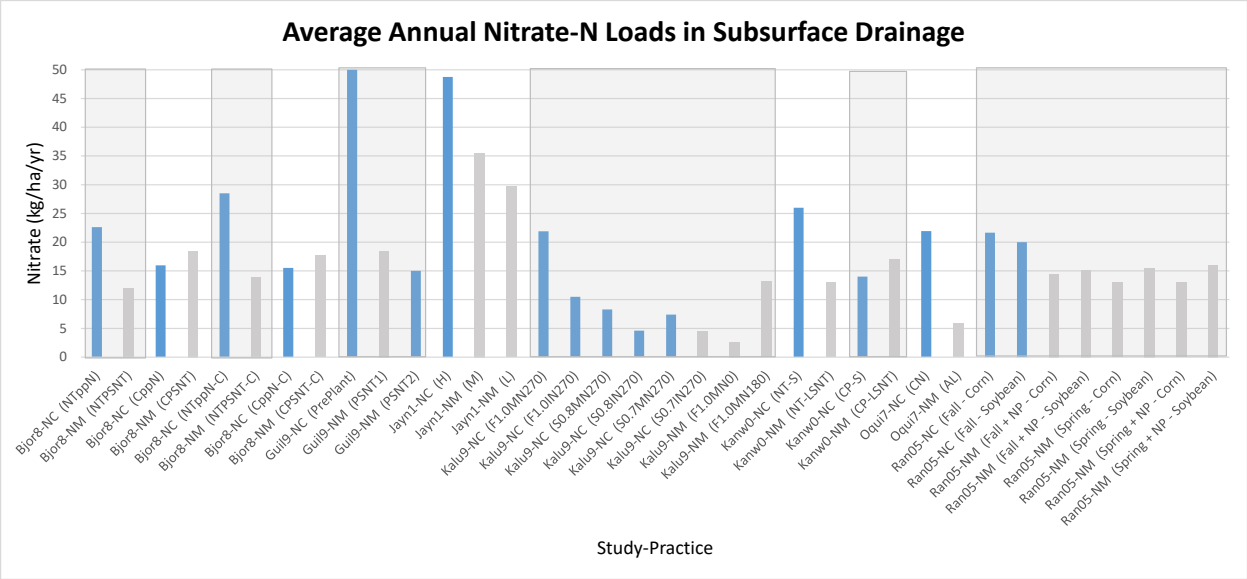


Figure 4-9. Average annual nitrate-N Loads in subsurface drainage under various nutrient management practices.
Note: Grey bars indicate nutrient management is in place. Shading is provided to separate studies. Practice string includes a short reference to study, nutrient management practice code (NC or NM) and monitoring station name which can be used to obtain more information about the study area in the master database. Only studies that included nutrient management (or fertilizer tests) as a study focus are shown on the plot.

4.3.2 Effect of Conservation Tillage on Sediment in Surface Runoff Concentrations and Loads

The majority of the studies in the current version of the AgBMPDB focus most heavily on nitrate, with less data available for sediment loads. Although the sediment concentration data in the studies included in the database is relatively limited for purposes at evaluating sediment concentrations in runoff for tillage studies, the sediment load comparisons contain a basic data set for purposes of general observations. As would be expected based on the physical understanding of conventional and conservation tillage practices, substantial reductions in sediment loading are evident in Table 4-5 and Figures 4-10 through 4-12 as producers shift from conventional tillage (e.g., moldboard plow) to various types of conservation tillage and no-till practices. Soil-associated nutrients such as phosphorus would also be expected to be reduced as less sediment is lost in surface runoff.

Table 4-5. Average Annual Sediment in Surface Runoff Under Various Tillage Conditions

	Sediment Concentration (mg/L)			Sediment Load (kg/ha/yr)		
Tillage Practice	CN	CT	NT	CN	CT	NT
Nbr. of observations	1	4	5	7	8	10
Minimum		149	169	311	190	111
Maximum		1435	395	6598	2600	719
1st Quartile		243	280	786	235	156
Median	**683**	**359**	**350**	**1350**	**310**	**244**
3rd Quartile		691	375	2050	937	534
Mean	**683**	**575**	**314**	**1990**	**767**	**335**
Variance		343046	8422	4646252	758639	51565
Standard deviation		586	92	2156	871	227

Note: CN = Conventional Tillage, CT = Conservation Tillage and NT = No Till.
Shaded columns indicated insufficient data for meaningful concentration-based comparison.

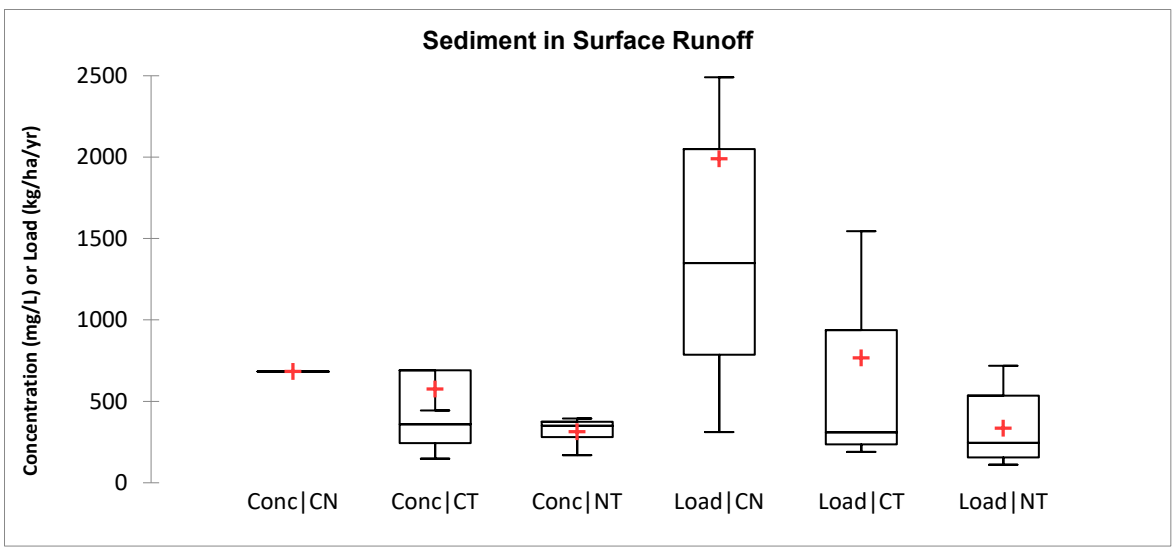


Figure 4-10. Boxplots of average annual sediment in surface runoff under various tillage conditions.
Note: The table and figure are based on a growing, but still limited, data set in the AgBMPDB version 2. Information presented is useful for general comparisons, but the limitations of the data set should be considered before findings are applied for more advanced purposes.

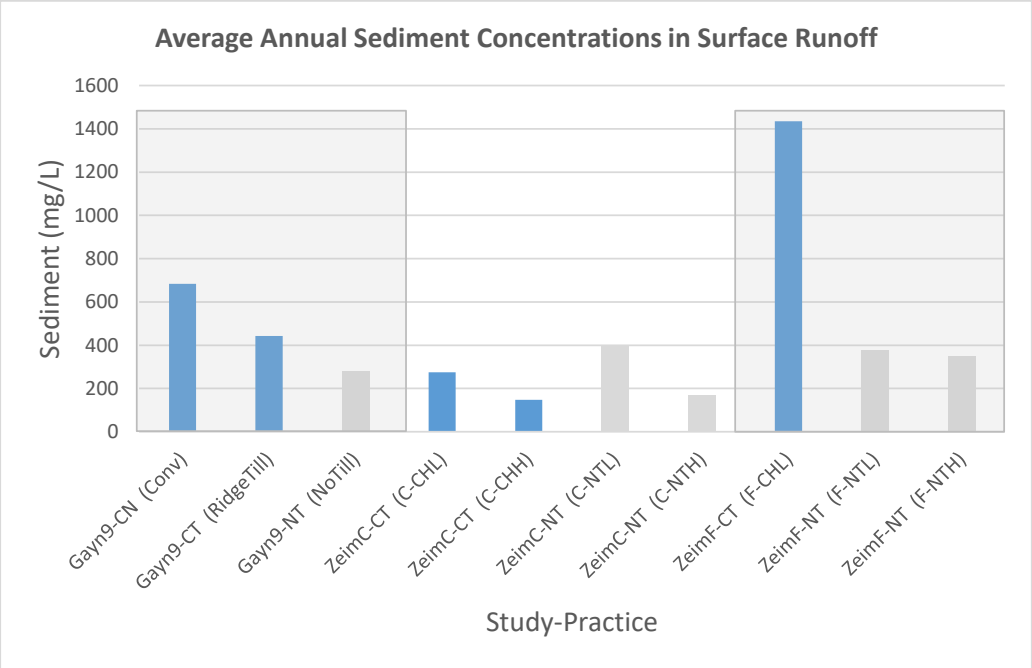


Figure 4-11. Average annual sediment concentrations in surface runoff under various tillage conditions.

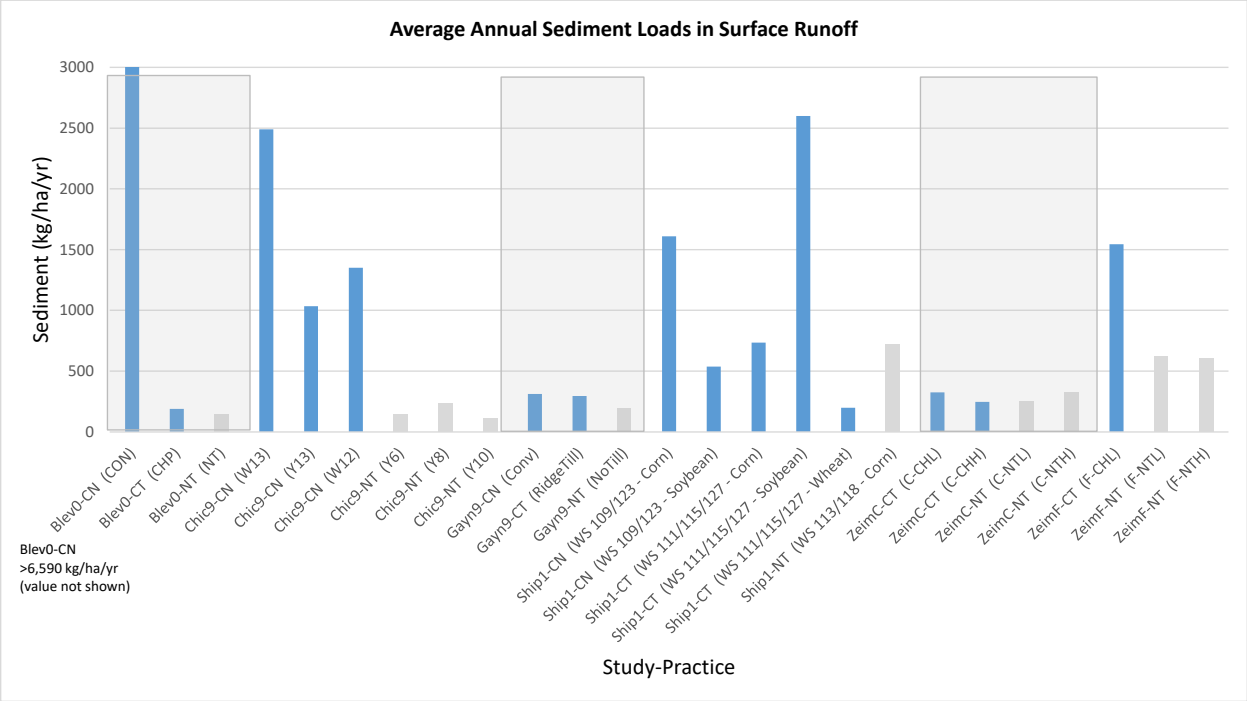


Figure 4-12. Average annual sediment loads in surface runoff under various tillage conditions.

Note: No-till bars are shaded in grey. Shaded box overlays are provided to separate studies. Practice string includes short reference to study, tillage practice code (CN, CT or NT) and monitoring station name which can be used to obtain more information about the study area in the master database. Only studies that included tillage as a study focus are shown on the plot.

4.3.3 Effect of Nutrient Management on Total Phosphorus in Surface Runoff Loads

Although phosphorus is frequently reported in studies included in the AgBMPDB, it is reported in many different forms (e.g., total phosphorus, soluble reactive phosphorus, particulate phosphorus) that are not consistent across studies. This reduces the number of studies that can be analyzed in an "apples-to-apples" comparison for any particular phosphorus-management practice combination. Despite this limitation, a basic comparison of total phosphorus loads for nutrient management practices demonstrates benefits of "nutrient management." As noted in Section 4.3.1.3, more detailed metadata analysis is needed to properly evaluate the specific types of nutrient management practices that result in the phosphorus load reductions shown in Table 4-6 and Figures 4-13 and 4-14. The concentration-based data for total phosphorus are provided in Table 4-6 but are not sufficient for comparison of nutrient management practices at this time.

Table 4-6. Average Annual Total Phosphorus Under Various Nutrient Management Practices

	Total Phosphorus Concentration (mg/L)		Total Phosphorus Load (kg/ha/yr)	
Nutrient Management	**NC**	**NM**	**NC**	**NM**
Nbr. of observations	1	2	7	6
Minimum		3.0	0.4	0.2
Maximum		6.7	21.2	9.3
1st Quartile		3.9	1.4	0.6
Median	**10.0**	**4.9**	**3.9**	**0.7**
3rd Quartile		5.8	8.4	1.0
Mean	**10.0**	**4.9**	**6.4**	**2.1**
Variance		7.0	58.4	12.5
Standard deviation		2.6	7.6	3.5

Note: NC = Conventional Nutrient Management; NM = Nutrient Management
Shaded columns indicated insufficient data for meaningful concentration-based comparison.

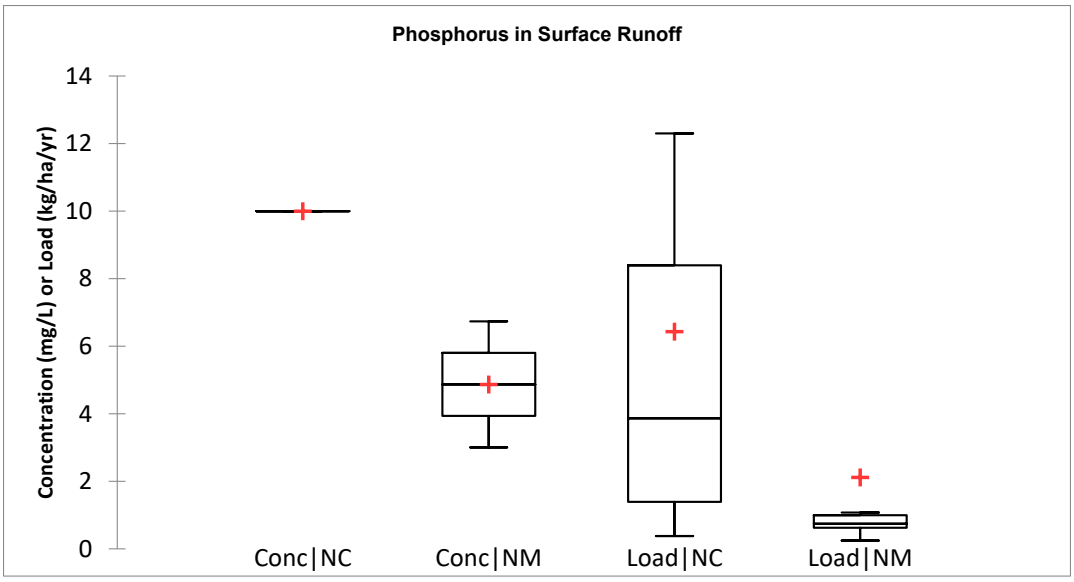


Figure 4-13. Boxplots for average annual total phosphorus under various nutrient management practices.

Note: The table and figures below are based on a growing, but still limited, data set in the AgBMPDB version 2. Information presented is useful for general comparisons, but the limitations of the data set should be considered before findings are applied for more advanced purposes.

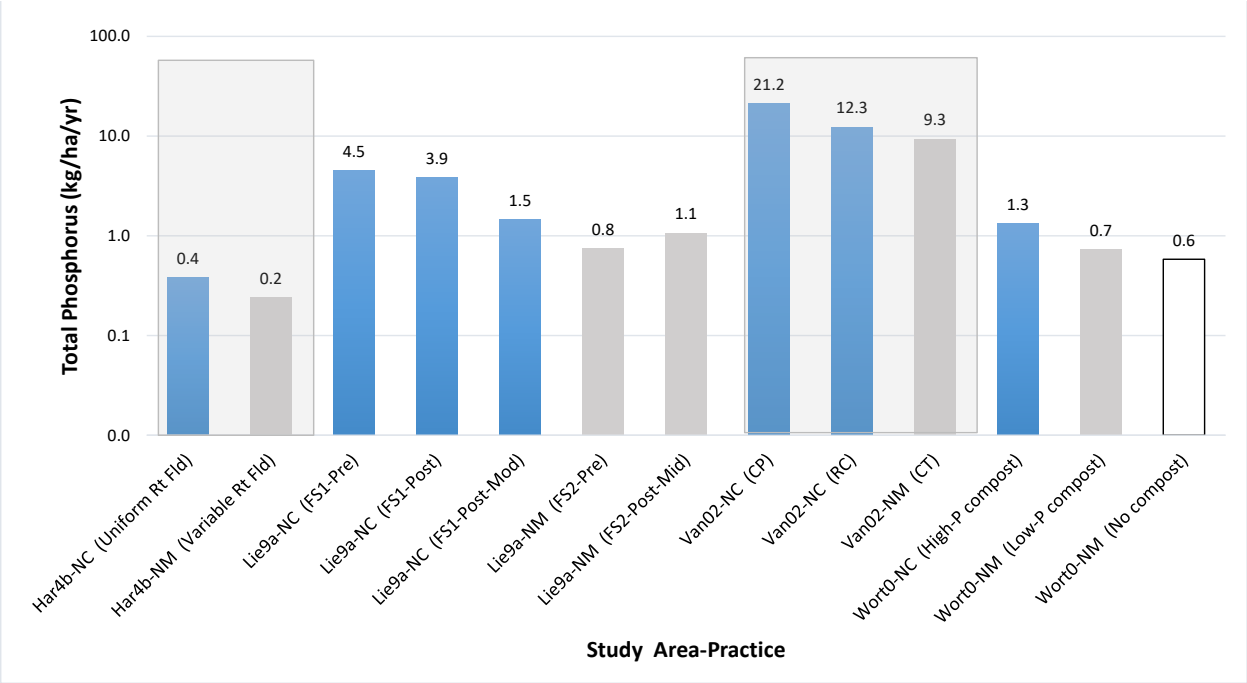


Figure 4-14. Average annual total phosphorus loads under various nutrient management practices.

Note: Shown on log scale with reported values for ease of comparison; blue bars represent conventional nutrient management and grey bars represent nutrient management; white bar indicates no fertilizer used. Shading is provided to separate studies. Practice string includes a short reference to study, nutrient management practice code (NC or NM) and monitoring station name which can be used to obtain more information about the study area in the master database. Only studies that included nutrient management (or fertilizer tests) as a study focus are shown on the plot.

4.3.4 Effect of Buffers on Sediment in Surface Runoff Concentrations and Loads

Edge-of-field vegetated buffers are a commonly used conservation practice that can help to reduce pollutant loading to waterbodies. Version 2.0 of the AgBMPDB contains relatively few edge-of-field studies; however, many buffer studies exist in the peer-reviewed literature. Because of the important role of these practices, sediment load reductions achieved at two individual studies in the AgBMPDB are shown in Figures 14-15 and 4-16, which can serve as a reminder that continued population of the AgBMPDB to enable continued quantification and synthesis of these benefits is needed. As noted previously, the Stream Restoration Database contains additional buffer-related performance data in various settings, including some agricultural locations.

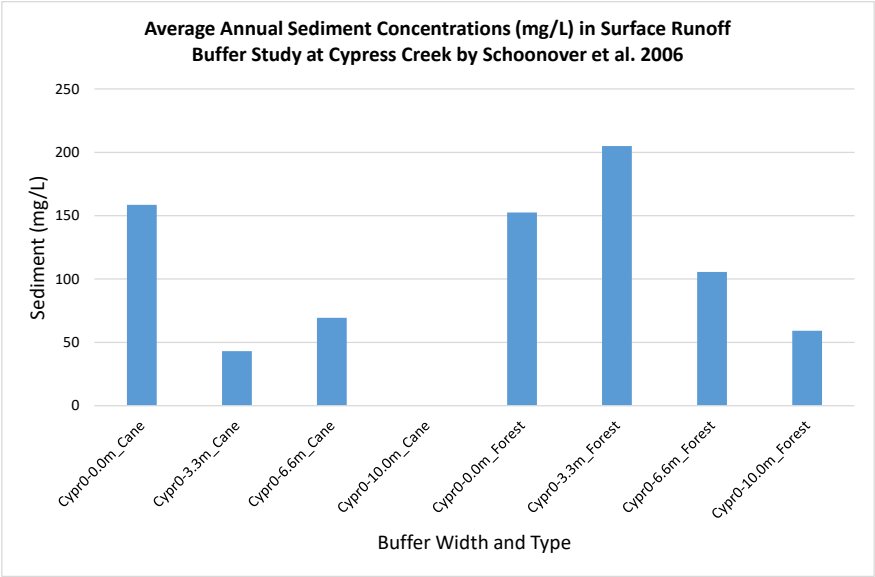


Figure 4-15. Average Annual Sediment Concentrations in Surface Runoff under Various Buffer Conditions.
Schoonover, et al., 2006.

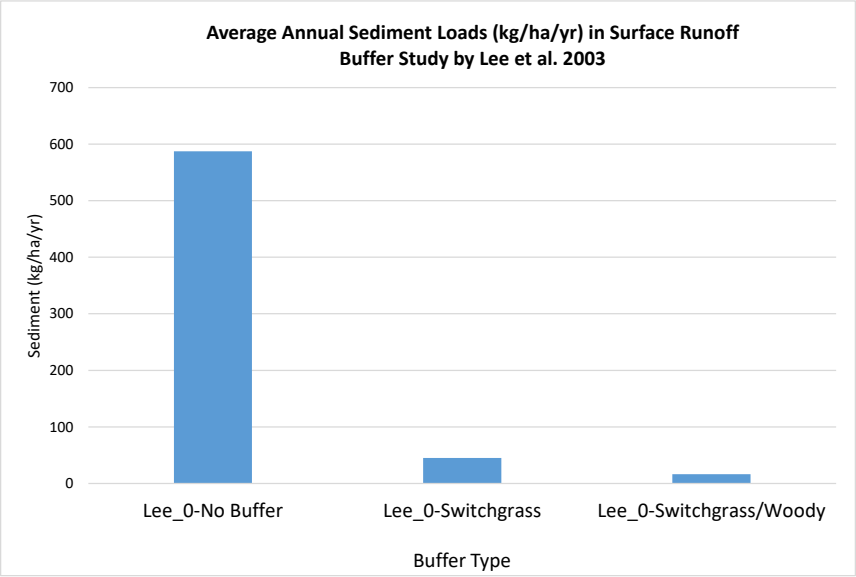


Figure 4-16. Average Annual Sediment Loads in Surface Runoff under Various Buffer Conditions.
Lee, et al., 2003.

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 2.0 Analysis

Version 2.0 of the AgBMPDB provides useful information for quantitatively evaluating agricultural BMP performance; however, it is still relatively limited in terms of the number of studies available for use in rigorous statistical comparisons. As the database continues to expand, it can be used to check the reasonableness of existing and on-going data collection compared to entered studies as well as recommendations provided by expert panels or agencies estimating agricultural BMP performance benefits. 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 2.0 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 understanding pollutant transport dynamics and 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 whether nitrogen or phosphorus (or both) is the focus of the management. This analysis did not attempt to differentiate among nutrient focus or other parameters such as timing, application method, rate, or frequency 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.” This Version 2.0 analysis, however, does show an overall benefit of nutrient management in reducing annual nutrient loads showing the importance of this practice in agricultural 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 expanded in future analyses.
- A moderate amount of crop yield data was included in Version 2.0. With additional data entries, it should be feasible to explore relationships between crop yield, fertilizer, and implemented practices on surface runoff and subsurface drainage water quality.
- Cost information was not analyzed in Version 2.0 due to general lack of reporting of this information in published literature sources used in the population of the database to date. Costs and yield data are critically important to agricultural producers and should be reported to the extent feasible in future database entries to support cost data analysis.

CHAPTER 5

Conclusions and Recommendations

The ultimate purpose of this AgBMPDB is to support science-based decisions in terms of cost-effectively and pragmatically managing pollutant loading from agricultural land while maintaining healthy soil and crop yields. The AgBMPDB provides a framework for identifying and storing both water quality and metadata needed to improve the understanding of agricultural BMP performance. The second release of the AgBMPDB expanded on the initial version by adding an additional 29 studies with over 150 study areas, bringing the number of study areas to 345. In-depth performance analysis and development of standardized analysis protocols remains limited by the number of entries; however, the following conclusions are evident from initial data analysis:

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 the AgBMPDB Version 2.0 align with expectations for BMP performance as presented in the literature:
    a. Nutrient management practices showed reductions in surface runoff phosphorus and subsurface nitrate loads.
    b. No-till and conservation tillage practices showed reductions in surface runoff sediment loads and subsurface nitrate concentrations compared to conventional tillage.
    c. Cover crops showed reductions in subsurface nitrate loads.
2. Because the AgBMPDB associates site metadata with individual performance study water quality data, the AgBMPDB provides a tool for researchers 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 and standardized reporting and access to study metadata can support decision-making regarding which solutions have demonstrated performance, given various site and production characteristics.
3. Based on 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.
4. 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. In general, average annual concentrations are less variable than average annual loads, which reflect the variation in hydrology and potential challenges of accurate flow measurement.
5. 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.

6. 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% 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% removal may be achievable. Conversely, if a producer has already implemented significant in-field BMPs and has a lower initial baseline, then a 60% 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.
7. Several recent literature reviews have been completed by others to develop pollutant 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 of 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.
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 refines 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. Nutrient and other pollutant trading frameworks that assign credits to agricultural non-point sources for pollutant load reductions require scientifically based quantitative estimates of the water quality benefits achieved by various agricultural BMPs. The AgBMPDB can be used to support this quantification, particularly as the database grows.

References

Note: See AgBMPDB version 2.0 for a list of studies included in the database.

Braun, D., Meals, D., Moore, J., and Macrellis, A. (2016.) Agricultural Practice Monitoring and Evaluation Year 4 Report. Stone Engineering Project ID 14-130. Prepared for Lake Champlain Basin Program. July 7.

Conservation Technology Information Center (CTIC) (2015). Conservation Tillage – Conservation Tillage Facts. Webpage visited 4/29/15. http://www.ctic.purdue.edu/resourcedisplay/281/

Dabney, S.M., Delgado, J.A., and Reeves, D.W. (2001). Using Winter Cover Crops to Improve Soil and Water Quality. *Communications in Soil Science and Plant Analysis.* 32:7-8, 1221-1250.

Dillaha, T., Yagow, G., Pease, J., Kibler, D., Bosch, D. (2002). The BMP Effectiveness Database. Prepared by Virginia Tech for the Nutrient Task Force Sub-Committee, U. S. EPA Chesapeake Bay Program, Nutrient Sub-Committee.

Drury, C.F., Tan, C.S., Gaynor, J.D., Oloya, T.O., and Welacky, T.W. (1996). Influence of controlled drainage-subirrigation on surface and tile drainage nitrate loss. *J. Environ. Qual*. 25:317-324.

Geosyntec and Wright Water Engineers (2014). International Stormwater Best Management Practices (BMP) Database Pollutant Category Statistical Summary Report: Solids, Bacteria, Nutrients, and Metals. Prepared under support from the Water Environment Research Foundation, Federal Highway Administration, Environment and Water Resources Institute of the American Society of Civil Engineers, December 2014. www.bmpdatabase.org

Harmel, R.D., Haney, R., McBroom, M., and Qian, S. (2008). MANAGE Database (v3): Nutrient Loss Database for Agricultural Fields in the US. http://www.ars.usda.gov/Research/docs.htm?docid=11079

Janssen, C. and Hill, P. (1994). Conservation Tillage Series. CT-1. Cooperative Extension Service, Purdue University. Webpage visited 5/12/17. https://www.extension.purdue.edu/extmedia/ct/ct-1.html

Lee, K.H., Isenhart, T.M., and Schultz, R.C. (2003). Sediment and nutrient removal in an established multi-species riparian buffer. J*. of Soil and Water Conservation*.

Lietman, P.L., Gustafson-Minnich, L.C., and Hall, D.W. (1997) Evaluation of agricultural best management practices in the Conestoga River Headwaters, Pennsylvania - Effects of pipe-outlet terracing on quantity and quality of surface runoff and ground water in a small carbonate-rock basin near Churchtown, Pennsylvania, 1983-1989. *U. S. Geological Survey. Water-Resources Investigation Report 95-4206*. Washington, D.C. 62 p.

Peterjohn, W.T. and Correll, D.L. (1986). Effect of riparian forest on the volume and chemical composition of baseflow in an agricultural watershed. Watershed Research Perspectives, 244-262.

Ritter, W.F., Scarborough, R.W., and Chirnside, A.E.M. (1998). Winter cover crops as a best management practice for reducing N leaching. *J. of Contaminant Hydrology*, 34: 1-15.

Schoonover, J.E., Willard, K.W.J., Zaczek, J.J., Mangun, J.C., and Carver, A.D. (2006). Agricultural sediment reduction by giant cane and forest riparian buffers. *Water, Air, and Soil Pollution* (2006) 169: 303-315.

Strock, J.S., Porter, P.M., and Russelle, M.P. (2004). Cover Cropping to Reduce Nitrate Loss through Subsurface Drainage in the Northern U.S. Corn Belt. *J. Environ. Qual*. 33:1010–1016.

van Vliet, L.J.P., Zebarth, B.J., and Derksen, G. (2002). Effect of fall-applied manure practices on runoff, sediment, and nutrient surface transport from silage corn in south coastal British Columbia. Can. *J. Soil. Sci*. 82(4): 445-456, 10.4141/S01-041.

Wesström, I. and Messing, I. (2007). Effects of controlled drainage on N and P losses and N dynamics in a loamy sand with spring crops. *Agric. Water Manage*. 87:229-240.

Udawatta, R.P., Motavalli, P.P., and Garrett, H.E. (2004). Phosphorus Loss and Runoff Characteristics in Three Adjacent Agricultural Watersheds with Claypan Soils. J*. Environ. Qual. 3*3:1709-1719.

U.S. Natural Resources Conservation Service (NRCS) (2006). Nutrient Management, Code 590. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_022228.pdf.

Water Environment & Reuse Foundation
1199 North Fairfax Street, Suite 900 ◆ Alexandria, VA 22314-1177
Phone: 571-384-2100 ◆ Email: werf@werf.org
www.werf.org
WE&RF Stock No. SIWM14T16/15T16
WE&RF ISBN: 978-1-94124-294-0

October 2017