

A BMP Database for Nutrient Reduction

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ABSTRACT

A database was developed from published research for assessing the impact of BMP implementation on nutrient load and concentration. The objectives of this study were to develop a database of common fields of information from published research that could be used to assess nutrient measurements directly related to BMP implementation and, where available, measures of cost-effectiveness. This study, therefore, involved screening, identification, and review of appropriate articles, development of an ACCESS database, data extraction from appropriate articles, and development of a query interface to the database to facilitate use by a wider audience. A total of 596 articles were identified from titles, keywords, and abstracts for possible inclusion in the database. The main criteria for selecting articles for inclusion in the database was that the article report on primary research and include results from monitored field studies. Based on these criteria, 316 articles were excluded, data from 168 articles were incorporated in the database, and 112 articles remain to be reviewed.

KEYWORDS. Treatments, Queries, User interface, Measurements, Economics.

INTRODUCTION

The Chesapeake Bay Program (CBP) of the U. S. Environmental Protection Agency (EPA) originated out of a joint declaration signed by the states of Maryland, Pennsylvania, and Virginia, and the District of Columbia in 1983. The purpose of this new program was to coordinate the restoration of the declining health of the Chesapeake Bay. The pollutants that were identified as causing a myriad of problems in the Bay were the nutrients – nitrogen and phosphorus, and sediment. A large modeling effort has been ongoing as part of that program to look at the interactions of the various living systems and processes in an attempt to better understand how and where to most effectively control pollutant inputs, and to gauge the effect of control efforts made to date. The program includes a number of technical and scientific sub-committees to guide the research, modeling, policy, and implementation aspects of the program. One such committee – the Nutrient Sub-Committee – was charged with, among other tasks, that of developing a basis for accounting for implemented measures of NPS pollution control. At the present time, any given type of BMP is assumed to produce the same amount of pollutant reduction based on a literature review of pre-1980 nutrient export studies on single land use watersheds by Beaulac and Reckhow (1982). Since the initial model development in the 1980's, much more research has been conducted and their findings are available to improve the representation of BMP implementation within the Chesapeake Bay Watershed Model. In 1999, the Nutrient Sub-Committee contracted with the authors to conduct a comprehensive literature

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review of this most recent research and to organize the information collected from each article reviewed into a searchable electronic database.

The goal of this study was to develop a database from published research for assessing the impact of best management practice (BMP) implementation on nutrient load and concentration, and the cost-effectiveness of these BMPs. The objectives of this study were to develop a database of common fields of information from published research that could be used to assess nutrient measurements directly related to BMP implementation and, where available, measures of cost-effectiveness. This study, therefore, involved screening, identification, and review of appropriate articles, development of a database using Microsoft ACCESS software, data extraction from appropriate articles, and development of a user interface for standard queries to the database to facilitate use by a wider audience.

Over time, various literature reviews have been conducted and published regarding one or more BMPs and their effect on one or more pollutants. The list of publications included in each review varied from one review to the next, with a certain amount of overlap. These reviews tended to distill quantitative information into one or two tables comparing ranges of loading and concentration reported by the various studies. While these summaries certainly lend perspective to our understanding of BMP effectiveness, they do not always communicate the differences in management treatments, the context, or the limitations of the research results, and may result in misinterpretation of the data.

The chosen database framework in this project evolved over time, as many subtle, but important differences between studies were identified with successive reviews. This framework delineates a large number of study conditions and treatments that are important in assessing the applicability of research results to other areas, and are reflected in separate database fields. The reviews conducted in conjunction with the development of this database quantify, in a distilled, but encompassing format, the scope and range of pollutant measurements related specifically to definable BMPs and their measurable impact on nutrient loads and concentrations.

This database represents a dynamic source of information that can be updated with new articles, and/or new data fields judged to be useful by others. This database is not intended to replace the need for using primary sources of data, but to assist in the critical work of analysis of the published research. This study has undoubtedly missed some published work that has not been included. And, while the authors have exercised their best professional judgment in the identification, extraction and summarization of data for inclusion in this database, disagreement certainly is possible on how best to categorize and summarize the data included in this database. The intent, however, is for this database to serve as a base for others to build on and add to, and a resource that will reduce the redundancy of effort for future reviews and analysis as the list of relevant published research continues to expand.

STRUCTURE OF THE DATABASE

The database was created in ACCESS 2000 and consists of a wide variety of tables, forms and queries. The information from and about the reviewed articles is essentially contained in four linked tables with an ancillary fifth table. These tables and their relationships are illustrated in Figure 1.

The initial phase of the study entailed much trial-and-error in defining appropriate data fields and in categorizing the subtleties in difference from one research study to another. Each box in

Figure 1 represents one of the database tables, with the name of the table at the top, and the names of each data field listed underneath. The data are stored in a hierarchical fashion to minimize redundancy and to maintain the integrity of associated data. The field name in bold type is each table's primary key - a field whose numbers are unique within that table and is the field to which all other fields in a table are related.

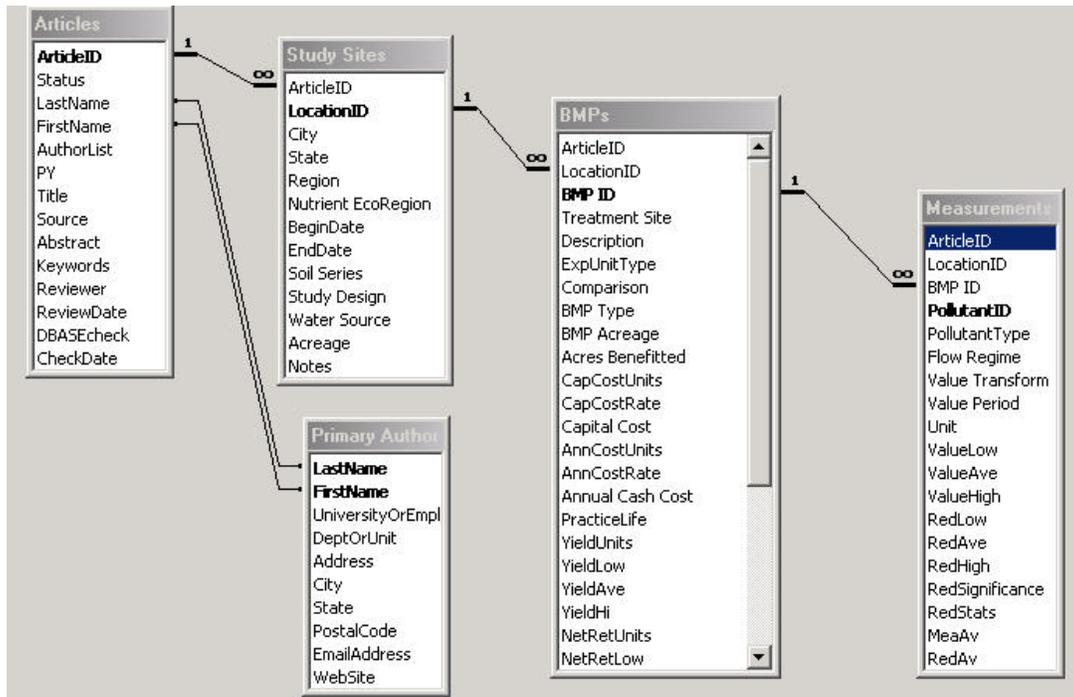


Figure 1. BMP Database Tables and their Relationships

CONTENTS OF THE DATABASE

The bibliographic citations for all articles screened were entered in the “Articles” table, whether or not their data was judged to be appropriate for the BMP analysis, and whether or not they had been reviewed. Data from articles that were consistent with study objectives were extracted and entered in the “Study Sites”, “BMPs”, and “Measurements” tables. The abstract, keywords, and contact information for the primary author of each article were extracted and entered into the “Articles” and “Primary Author” tables, where available from the article or an online database.

This study attempted to define common attributes among BMP research studies that would allow for comparisons between both the context of the studies, and between their water quality pollutant measurements. Many different experimental designs and approaches were used within the articles reviewed, along with a myriad of objectives, not all related to the objectives of this database. The objectives of these studies were not always to quantify the impact of a specific BMP. Indeed, many of the studies were involved with the design of a BMP, and so use a number of only slightly different treatments, trying to optimize one parameter for designing a BMP, e.g. filter strip width, or sediment pond detention time. For some studies, these various treatments were treated in aggregate as a single BMP with a range of responses cited. In others, where there was a clearly optimized or preferred design parameter, data for the best alternative was chosen as being most representative of the BMP. Some studies had combinations of objectives including

comparisons of landuses. In these situations, treatments related to a BMP were included, while non-related treatments were not entered in the database. Other studies simply presented the water quality impact related to a certain landuse or management practice without a control. The studies included in this database, however, are essentially those between a control, either in space or time, and a definable BMP.

For this review, many bibliographic databases were searched, and articles were identified, that described research on one or more BMPs and their impact on water quality, and included measured nutrient loads or concentrations for the specified study conditions. Since all of this information is not necessarily conveyed in the title, or even in the abstract, of any given publication, many publications were initially identified that did not contain sufficient information consistent with the design of this database. When reviewing each article, a set of criteria was used to screen articles with appropriate data.

The following types of articles were generally excluded from further review based on their abstracts:

- summary or review publications,
- modeling studies, except those related to economics, and
- pre-1980 studies.

During the actual review of articles, studies were also excluded which did not contain:

- nutrient measurements,
- an appropriate, identifiable control,
- an identifiable BMP, e.g. those comparing land uses or hydrologic conditions, and
- reported reductions.

After each article was screened or reviewed, the article references were further checked for other studies with potentially relevant data not previously identified for review. During this process, 596 articles were identified as potential contributors to the database. Of those 596 articles, 484 articles were screened during our project timeframe, and 168 articles met all of the review criteria. From those 168 articles, 644 entries of experimental controls and treatments were described for 201 study sites, along with 5081 entries of pollutant measurements. Because of the potential usefulness of the related articles, bibliographic information for all 596 articles were maintained in the database, along with abstracts for 293 of those articles.

After many attempts to retrieve the same kind of information from articles with economic information, it became obvious that economic articles were essentially a parallel data set, not always providing data that were useful for our database, e.g. they might report paired differences, with no way to calculate either load or percent reduction. While results from several economic studies have been included, these were primarily modeling studies using information about representative farms for an area. To retrieve the information on nutrient loss reductions from most economic articles would mean going back to the authors to collect information not presented in the articles – a much more complex task, not performed for this current project.

LIMITATIONS OF THE DATABASE

The studies reviewed ranged in scope from plot studies to basin studies and have come from all over the United States and abroad. The articles included studies of varying duration – some consisting of several rainfall simulator runs, others representing ten or more years of data.

Therefore, some articles incorporate the long-term effects of a BMP, while others do not. It was not possible to ascertain from the articles what, if any, long-term maintenance was needed or performed, with the longer-term studies.

In many research publications, much of the data are aggregated over some period of time for analysis and comparison. During the article reviews, professional judgment was used to identify and extract key measurements, usually aggregated at some time scale, to represent the overall findings from the research. Where data were summarized over the whole project or by project year, these data were generally extracted exactly as reported. In other cases, where data was reported in more detail, some aggregation or manipulation of the data was performed, in order to enable more direct comparison of the results with those from other studies. For this reason, the statistical significance of data in this database was difficult to quantify, and is understated. While significance of some weekly or monthly or seasonal values may have been reported in an article, the statistics no longer applied once these data were aggregated or cited as a range. When statistical tests were used, but statistical significance was not explicitly reported due to this aggregating effect, a notation was included in the “Notes” field of the “Study Sites” table.

A COMMON BASIS FOR COMPARISON

Different measurements can be made of the same pollutant, and different units can be used to describe the same measurement. Additionally, different names have been used in the literature to describe the same, or similar, forms of the same pollutant, particularly forms of nitrogen (N) and phosphorus (P). For the purpose of this database, pollutant measurements have been placed in the following measurement categories:

- concentration (load/volume)
- depth (over a watershed)
- load
- UAL, unit area load (load/area)
- UAV, unit area volume (volume/area)
- volume
- other, not in any of the above categories

Summarization can be performed within each of the first six measurement categories, and common units have been assigned to each of those categories, so that during summarization, all measurements within a given category are converted to the same units. The exceptions to the previous rule are all forms of bacteria concentrations, which are kept as cfu/100 mL.

A wide variety of N and P forms were reported in the reviewed articles. In order to condense the summaries, and to enable the broadest comparison possible, the user interface creates “pollutant categories” in an attempt to produce a reduced set of reported pollutants (although the primary target was various forms of N and P).

A final consideration in establishing a common basis is the type of flow being sampled. While groundwater measurements were not included in the database, measurements from shallow subsurface flow were included. The three types of flow regimes associated with the pollutant measurements in this database are surface, subsurface, and combined.

The common basis used for assessing ranges of reductions due to any given BMP, therefore, were that the BMP be reported for the same measurement category and for the same flow regime.

USER INTERFACE QUERIES

While experienced Microsoft ACCESS users can perform a wide variety of analyses directly with the various database tables, a user interface was developed to facilitate use of the database by a wider audience. While this interface is not comprehensive, it allows the novice user to perform several simple database queries for articles, a pollutant reduction analysis for user-specified study criteria, and average annual load reductions by pollutant category.

The user-specified criteria within the simple queries include options for combinations of subject, author, state, region, nutrient eco-region, soil type or great group, crop, study design, water source, and size.

The Pollutant Reduction analysis produces ranges and averages of pollutant measurements by BMP, flow regime, and measurement category for all reported pollutants, summarized further by control and BMP treatment, reported and calculated % reductions.

The Average Annual Load Reduction calculates average annual load reductions for a user-selected pollutant category reported in units of either load (e.g. kg) or UAL (e.g. kg/ha). A summary is then generated for all BMPs in the user-selected pollutant category with ranges and averages of reported and calculated % reductions. Since this load calculation is on an annual basis, data are not included from simulated rainfall studies (usually short-term plot studies) or studies with less than a year of data (so that aggregation on an annual basis will not be biased by short-term fluctuations in the data). Within the database, average measurements are calculated for each treatment (each line of data in the "Measurements" table). In both the Pollutant Reduction and the Average Annual Load Reduction summaries, average reported reductions are calculated for each treatment reporting some type of reduction. Average calculated reductions are calculated for each treatment as the difference between the average measurement of each treatment and its related control.

ECONOMIC DATA AND ANALYSIS

During the search for published articles, the primary focus was on nutrient measurements related to a specific BMP. When economic data was encountered in these articles, it was included in the database. While some cost-effectiveness figures are cited, most are based strictly on modeling studies. The economic data included in this database is relatively sparse, compared with the nutrient measurement data, for the reasons mentioned in the "Contents" section.

Five types of economic-related data were classified during the search and review of articles for this database – BMP costs, yields, net returns, risk impact, and cost-effectiveness. The "Economic Data and Analysis" page provides the user with options to look at a summary distribution of the types of economic data, to view data for individual types of economic data, and to view the bibliographic information for all articles with economic data.

SUMMARY

A structured database has been developed for comparison of nutrient reduction measures between BMPs and corresponding controls identified from published research. The database is intended to be a living, updatable resource, that can be added to as additional past and future relevant research is identified. Toward that end, the Chesapeake Bay Program will be maintaining the database and is currently in the process of conducting reviews of additional research and of converting the database into a web-based entity.