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HOW GOOD IS GOOD ENOUGH

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WHAT DO WE NEED TO KNOW FOR WATER QUALITY PLANNING AND HOW DO WE GET IT?

Producers want to know the trade-offs before adopting different conservation management systems. Unfortunately, running simulation models is the only practical way to provide such information. This is a problem because conservationists don't have the time or interest to regularly perform such integrated modeling. A possible solution is the development of a suite of tools, so that modeling specialists could create a database of effects on typical fields to be used by conservationists and producers. Although the information would not be perfect, could it be good enough to provide water quality information for planning purposes?

Imagine a farmer in a watershed with agriculturally related water quality problems, willing to consider changing his or her management practices to help resolve the problems in the watershed. First, the farmer needs a rough understanding of the quantity of contaminants leaving his or her fields. Nonpoint source pollution is difficult to observe. The farmer's focus will be on the business of the farm, not offsite water quality issues. Before adopting a different management system, the farmer would want to understand the tradeoffs that he or she is being asked to make. Detailed, accurate information of these tradeoffs are difficult to find for the specific conditions of his or her farm. The available information rarely specifies the farmer's climate, slopes, soils, and existing management system. Further, most estimates of management effects are qualitative, or if quantitative, cover only a few resources and require integration and interpretation. Farmers will probably need specialized technical assistance to understand and implement a management system that addresses water quality as part of the farm's management plan. So, how can society provide those farmers facing water quality problems with adequate information needed for planning purposes at the lowest cost?

How good is good enough? How good does water quality information have to be for planning purposes? That depends on the problem and the farmer—the ultimate judge. Farmers want to know what management systems they'll have to adopt; how much income they'll have to give up; and what will the water quality benefits be. To provide this information at the field scale in a quantified way, will require new approaches. Should the approach be to use field scale simulation modeling for each field, or is it good enough to simulate the effects on representative fields to find the answers that can guide sound management choices?

Nonpoint source water quality problems are difficult to resolve because there is not one specific pollutant source to treat. In most cases, the solution is the widespread adoption of land management systems that pollute less or release runoff at rates similar to those of the natural vegetation. Understanding how land management over large areas affects water quality is the first challenge. The second is to encourage the adoption of practices to improve water quality. Thus, in agricultural watersheds a critical step is the incorporation of the watershed's water quality goals into the management plans of the farms and ranches within the watershed.

Incorporating knowledge about potential watershed effects into farm plans is difficult. The choice of crops, tillage systems, nutrient and pesticide application rates, methods and timing, and conservation practices such as filter strips, grassed waterways and

Table 1. **Probable minimum information requirements for a field.**

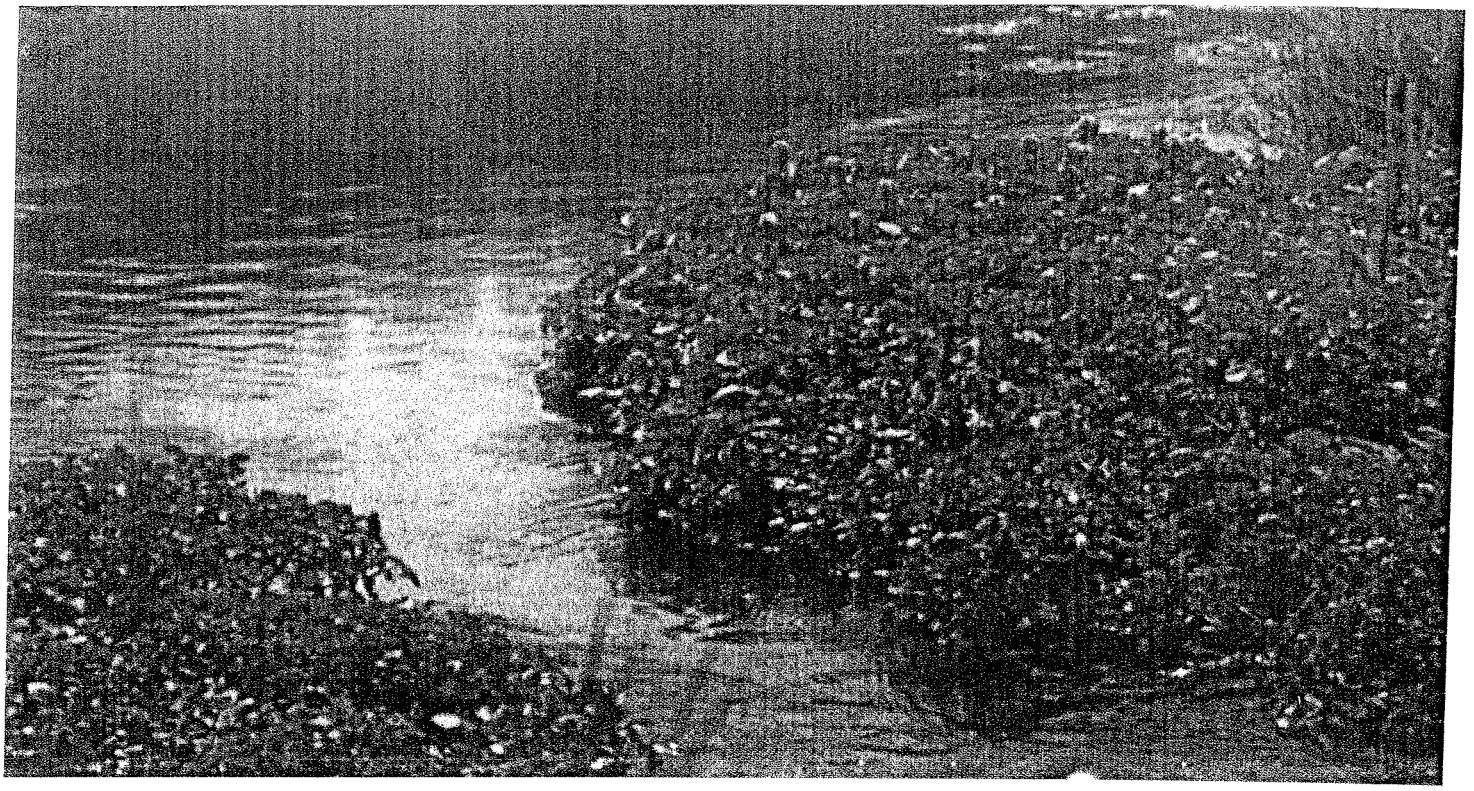
Variables of interest	Management systems			
	Current	Alternative 1	Alternative 2	Alternative 3
Net returns				
Other farm issues...				
Water quality variable(s)				
Other resource issues...				

Table 2. **An example of average results from a 20-year simulation of variables that would be of interest to farmers in the Deep Loess Hills of western Iowa.**

Concern	Mulch Till				No Till			
	Preplant N		Postplant N		Preplant N		Postplant N	
	Atrazine	Other	Atrazine	Other	Atrazine	Other	Atrazine	Other
1. Net returns $/ha	69	58	69	58	77	67	77	67
2. N in percolation ppm	13	13	12	12	13	13	11	11
2. N in runoff ppm	4	4	4	4	4	4	4	4
3. Sediment Yield Mg/ha	5	5	5	5	3	3	3	3
4. Atrazine – Runoff g/ha	4	0	4	0	1	0	1	0
4. Atrazine – Sediment g/ha	.2	.2	.2	.2	.1	.1	.1	.1
5. Soil Erosion Mg/ha	54	54	54	54	43	43	43	43
6. Other Pesticides	many	many	many	many	many	many	many	many

returns for the current management system and some alternatives would probably be of primary interest, although there could be other issues related to the farm business as well. Presumably there is at least one variable related to water quality, for which the alternatives do better than the current management system. If the information is to be provided by simulation models, the net returns from the current management system plays a critical role in building the farmer's confidence that the simulation model's results match the farmer's experience.

The quality of information required by farmers will probably vary widely. Table 2 shows a subset of simulation results for a field in the Deep Loess Hills of western Iowa as documented in Heilman (1995). A database that aids in decision-making would need to hold information such as this, but farmers would want a level of detail beyond annual average values to instill further confidence and to help understand the driving processes. For example, in a watershed with an excess nitrogen problem, if there are proposals that farmers should reduce the amount of nitrogen applied or split applications, farmers would be interested in seeing graphics that show how well the proposed alternatives



meet the plant's needs for nitrogen during critical periods to avoid stress. Farmers would probably also be very interested in information about the role of mineralization in allowing nitrogen to leave the field.

Ideally, one could point to long-term observed data on the existing management system and the alternatives for each field. However, such detailed measurements are extremely expensive and rarely available. The quantities of pollutants leaving a field are usually quite variable, so that even measured data must be interpreted with caution if taken over a relatively short time period. For example, observed data were collected at locations across the Midwest that related management systems to water quality as part of the Management System Evaluation Area, MSEA, program as described by Onstad et al. (1991). The MSEA program ran for about seven years. One MSEA location, the Deep Loess Research Station near Treynor in southeast Iowa, had been monitoring four watersheds since the early 1960s. Data from this location provides an indication of how well a seven-year monitoring window reflects longer term relationships. Watershed 3 is the field with the longest continuous crop rotation and tillage practice. The field was in pasture until 1972 and since then a continuous corn, ridge tillage system has been maintained. Ignoring years 1972 and 1973 as adjustment years, a 25-year record is available for 1974 to 1999 for some variables of interest to water quality.

Figure 1 illustrates what would have been the effect of beginning a monitoring program like MSEA in other years. Seven year moving averages for annual precipitation and runoff from 1980 to 1999, and from 1980 to 1996 for sediment yield were calculated, and compared to the 25 year mean. Precipitation varied little over that period, with the seven-year annual average varying at most 9 percent from the 25 year mean. Measurements of runoff varied between 68 and 155 percent of the 25 year mean. The sediment record varies much more than runoff because of very high sediment yields in years 1980 to 1982. A seven-year monitoring program in any of the early years would risk severely overestimating the amount of sediment to be expected from that management system. Other water quality variables of interest are not available, but their variability would probably fall between those of runoff to perhaps somewhat more than sediment, depending on how closely associated the pollutants are to the sediment particles.

There are inherent limits to the information that can be provided economically about nonpoint source pollution. Observed data should always be the foundation for both expert opinion and simulation modeling, but for quantitative estimates of the effect of management on key water quality issues, simulation models will have to be used to extrapolate over longer time periods and for other management systems, even in those places where observed data are available. Soil conservationists and extension agents with long experience tend to emphasize the need for information that can be used to "tell the story" about how management affects natural resources as being key in encouraging adoption, rather than the need for information that provides precise predictions.

The cost of providing nonpoint source pollution information

One of the key issues determining the cost of providing information is the scale of the simulation modeling work to be undertaken. For small efforts, the interactive modeling approach is clearly cost-effective. However, if large numbers of fields are to be simulated, then the database approach is more likely to be cost-effective. Because of the overhead in defining the representative fields, management system alternatives, and work necessary to create a database to both hold and make available the results, the database approach has high initial costs, but the costs drop rapidly on a per field basis.

Since the database approach assumes that representative fields are adequate, all or most of the simulations can be run simultaneously. Batch processing is more likely to result in consistent results, as the same modeler can run all simulations and the results compared to each other as a quality control measure. The

interactive modeling approach on the other hand, costs less to simulate only a few fields, but such efforts would require significant time for each field, and so would not provide the same economy of scale. The precise cost to run the model would depend on a number of factors including the simulation model(s) to be used, experience of the modeler, complexity of the landscapes, and the natural processes of interest. Realistically, however, the database approach is likely to cost more than current efforts, if it is undertaken as part of a more ambitious effort to provide quantitative information about water quality issues over large areas.

Implementation of the database approach

In 1998, the NRCS released a report that summarized a trial of a decision support system for water quality in Harrison County, Iowa (duVarney et al. 1998). The trial considered six soil/slope combinations with a total of 64 management systems.

A series of 20 management systems for a field on Ida soils was prepared by the NRCS county, area, and state offices to show influences on a number of water quality variables using modified versions of the GLEAMS model and CARE accounting program in the Iowa NRCS state office. With that information, presentations were made to a number of farmers by the soil conservationist to assess their response to a multiobjective tool that helps rank management systems. The farmers were comfortable considering information based on representative fields for water quality effects. Harrison County includes areas in the loess hills as well as along the Missouri river bottoms. To cover most of the situations in the county, perhaps 10 soil and slope groups with roughly 100 management system/soil slope combinations would be sufficient (Kurth, pers. comm., 2000). The executive summary of the report states:

> *The DSS Analysis Team recommends USDA invest in such a [Decision Support System], and form an interdisciplinary team of NRCS, ARS, and CSREES representatives to develop a plan identifying necessary resources and providing for development and release either on a gradual basis, accommodating the unique needs of State, watershed, or field offices, or by releasing components all across the Nation as they become available.*

A related project was the development of the MSEA research program, which revolved around the goal to "identify and evaluate agricultural management systems that can protect water quality for the Midwest." Two of the primary objectives were to measure the impact of prevailing and modified farming systems on the content of nutrients and pesticides in ground and surface waters, and to identify and increase understanding of the factors and processes that control the fate and transport of agricultural chemicals. These goals and objectives were addressed in five projects located in Iowa, Minnesota, Missouri, Nebraska, and Ohio. The overall structure of the MSEA program has been described by Hatfield et al. (1993) and an assessment of various components of best management practices evaluated within MSEA was described by Ward et al. (1994).

In 2000, a joint project between three Agricultural Research Service (ARS) locations and NRCS has been started to build the tools that are needed to implement such a decision support system using the database approach in Iowa. The project will start with the observed data relating management to the quantities of pollutants moved off agricultural fields from two of the MSEA sites in Iowa—centrally located Walnut Creek and Treynor in southwest Iowa. There are four simluation models that will be used. Depending on the field type, management system or resource problem, the Root Zone Water Quality Model (RZWQM) (Ahuja et al. 1999),

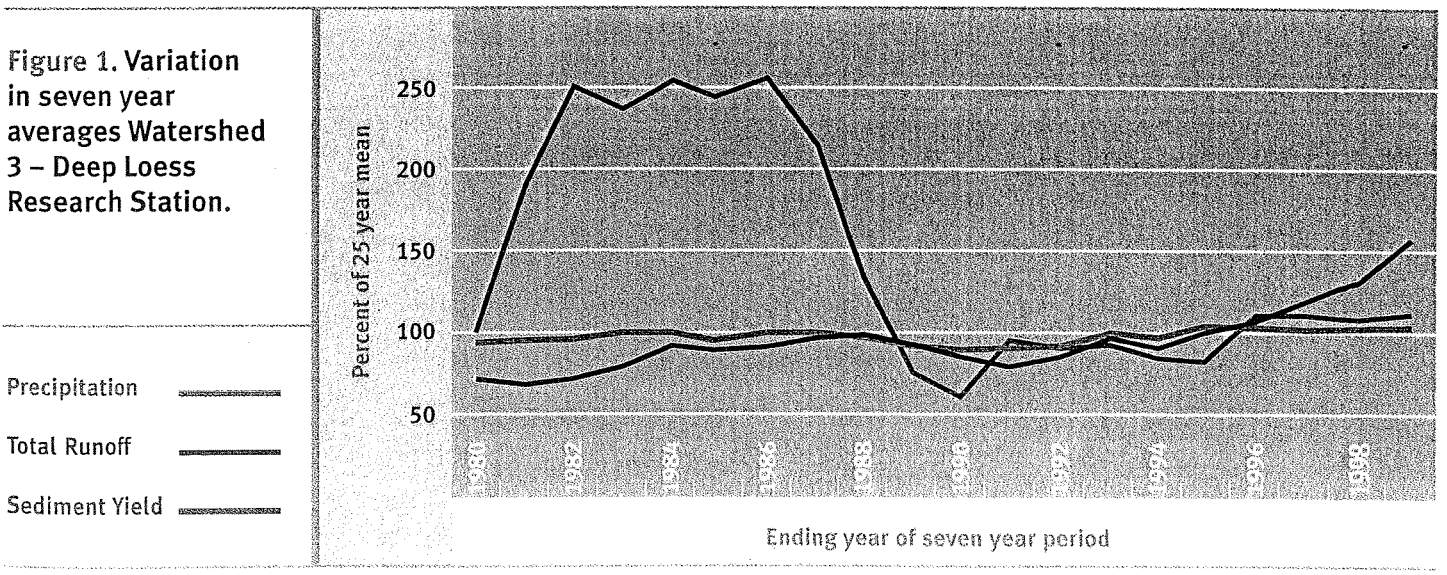


Figure 1. Variation in seven year averages Watershed 3 – Deep Loess Research Station.

Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1997), or GLEAMS models will be used to extrapolate the observed data from the MSEA sites to other areas of interest. Economic estimates of the difference in net income from alternative management systems will be made using the NRCS Procosts model. Those estimates will then be put into a database and made available for conservation planning by NRCS.

RZWQM is an integrated physical, chemical, and biological process model developed to simulate the effects of agricultural management (e.g., tillage, irrigation, fertilization, manure application, crop rotation, pesticide application, and tile drainage) on crop production and water quality. It was developed and tested in collaboration with the MSEA project. Since then, the model has been tested in a wide range of experimental and weather conditions and improved considerably. RZWQM has the capability of simulating macropore/preferential flow, water table fluctuation, chemical transport in runoff/percolation water, nitrogen/carbon dynamics, plant growth, and various agricultural management practices.

For erosion prediction, the RUSLE model will be used. For those situations where more detailed estimates of contaminant transport to a field's edge are needed, a modified version of the GLEAMS model will be used. Modifications to GLEAMS include the addition of the nitrogen leaching component from CREAMS (Knisel et al. 1980) and the crop growth component from the Erosion-Productivity Impact Calculator, EPIC (Williams et al. 1989). This version of GLEAMS is capable of estimating the sediment yield, nutrient and pesticide loading in runoff and adsorbed to sediment to the edge of the field and the nutrients and pesticides leached below the root zone, as well as crop yields for many management systems in Midwestern cropping systems.

The NRCS economic program Procosts will be used to calculate the net returns associated with management systems. Procosts implements the recommendations of the American Agricultural Economics Association (1998) for estimating commodity costs and returns. The NRCS has developed a number of databases to support this tool. Given an estimate of the crop yield, expected prices, and a list of operations, the program will calculate net returns and provide income statements or other reports for each crop or rotation. If prices change in the future, Procosts could be re-run to update the expected economic effects.

The database will contain descriptions of the climate, soils, field configuration, and management systems. It will also document how those descriptions were converted into model input to document model parameterization. Perhaps most importantly, the database will contain graphics to show producers how the processes being modeled are simulated. Lastly, the database will hold comments from specialists in the model components about the model results (hydrology, erosion, nutrients, pesticides, crop growth, and economics). Once the major management systems are simulated in a particular area and pass review, those results will be entered in the database and considered valid for planning purposes for a 5 to 10 year life, or until better observed data or simulation models become available.

The database will then be used inside a decision support tool based on the Prototype Water Quality Decision Support System developed at the Southwest Watershed Research Center (1994). The basic multiobjective approach was outlined by Wymore (1988), with Lane et al. (1991) demonstrating the utility of embedded simulation models. Improvements were made to the decision component to eliminate the need to specify a weight vector associated with all decision variables in Yakowitz et al. (1993a). This decision component allows a user to graphically compare management system alternatives that can have conflicting effects on a number of variables of interest. Given a table that quantifies the effects of a number of management systems on a number of objectives, like Table 1, and a ranking of the importance of those objectives, the algorithm will rank the alternative management systems and allow the user to assess the sensitivity of that ranking to the relative importance given to the objectives. Descriptions of this approach in the Midwest can be found in Yakowitz et al. (1993b). The same technology has been re-coded in the Java language for use in resource management in Queensland, Australia and called *The Facilitator*. The expected advantage of this effort will be that soil conservationists with NRCS will be able to include water quality issues into farm conservation plans with a rehearsed story to tell about the effects of management. There would be no delay or time-consuming effort to parameterize and check model results if the fields are similar to those in the database, allowing the conservationists to focus on conservation planning with farmers.

The benefits and impacts of this project will depend on the degree to which better information and decision support contributes to better management of agricultural land. Agriculture covers such large areas, that widely adopted small improvements could create large overall benefits. For example, in 2001, the area devoted to corn and soybeans in the state of Iowa contains over 8 million hectares planted in corn and soybeans and sales of corn and soybeans totaled over $5 billion. If the database approach is implemented and succeeds in improving net benefits in Iowa by even one-tenth of a percent of the value of the corn and soybeans produced, the annual benefits would be on the order of $5 million. It's too early to specify the costs of creating a database of management effects for Iowa. The major costs would be the investment of time by NRCS to define the scenarios, a modeling effort comprised of several modelers over several years, and a panel of experts to quality check the results. Depending on the power of the tools built to support the effort, level of detail desired, heterogeneity of the landscape, and potential to cooperate with neighboring states, creating a database for most of Iowa will take a number of man-years.

HYPOTHESIZED COSTS AND BENEFITS DEPENDING ON THE QUALITY OF INFORMATION PROVIDED

Until recently, a large-scale implementation of the database approach would have been highly expensive. Table 3 provides an overview of the tradeoffs facing society in determining the quality of information to be made widely available in agriculture. The best information in this context would be comprehensive, accurate, and specific to all farm fields in a region. In most areas currently available information would probably fall in the third category, expert opinion that is based on published information, some monitored data and limited simulation efforts. In general, increasing the quality of information available for decision-making provides additional benefits, but the benefits would begin to taper off once a general understanding of the situation is provided. Conversely, the cost of providing increased information would increase rapidly, especially as the amount of monitoring increases. Over time, the cost of providing information from the database approach (4 below) should decrease, so that there will be a period of time when the database approach can provide greater net benefits than either expert opinion (3) or the interactive modeling approach (5).

Table 3. Hypothesized costs and benefits depending on the quality of information provided.

	QUALITY OF INFORMATION USED FOR DECISION MAKING	LIKELY BENEFITS	LIKELY COSTS
1	Expert opinion based on scientific literature	Understand gross effects, but not specific to local conditions	Very low, requires trained personnel
2	Expert opinion based on literature and some locally monitored data	Understand major effects and provide some information on their relative magnitudes	Low, requires trained personnel and field experiments
3	Expert opinion based on literature, monitored data, and simulation efforts on limited projects	Understand major effects, relative magnitudes, and provide information on more management systems	Moderate, requires trained personnel, field experiments, and simulation efforts
4	Database of simulation results for representative fields using some monitored data	Understand major effects, relative magnitudes, cover large areas, can be quality checked, easy to explain	High, requires trained personnel, field experiments, simulation efforts and database development
5	Interactive simulation for individual fields using some monitored data	Understand major effects, relative magnitudes, cover many systems, customized to the individual field	Very high, requires trained personnel, field experiments, simulation efforts, and tools to automate parameterization
6	Widespread, detailed monitoring	Understand effects close to absolute magnitudes	Extremely high, most useful if future is like the past

Implications

There are many modeling and decision support efforts for water quality underway across the country. In considering whether those efforts should include the development of a systematic database containing quantitative estimates of management effects on representative fields, a number of negative factors should be taken into account. First of all, such an effort for an area as large as a state would require a significant investment to finance and organize. The use of representative fields is always open to criticism. Even with that simplification, there will be a number of fields or management systems that would be of interest to some farmers, but would not be contained in the database. The database would be of limited value in supporting decision making for very complex management systems such as that for precision agriculture. Furthermore, information based on representative fields would not be specific enough to individual fields to support regulatory efforts. In order to be credible, the simulations would have to do a very good job of estimating crop yields. This is much more difficult than simply simulating water quality effects because it requires the modeler to make good estimates of all parts of the water budget. Lastly, any problems with the observed data or the simulation models could result in inaccurate values in the database, unless these are caught during the expert review.

On the other hand, the advantages of pursuing a database approach will probably outweigh the disadvantages. Without a centralized effort to build a database, farmers are unlikely to be provided with information that is comprehensive across a number of concerns and presented in an integrated fashion. By reducing the number of people expected to run the simulation models, training is reduced and the results are made more consistent. The database approach would provide a mechanism to document and make available the best existing observed data, expert knowledge and simulation models. For all their disadvantages, simulation models will allow the comparison of alternatives over meaningfully long periods, and for new management systems on which there are no observed data. The most important contribution however, is that the information would be readily available.

If other areas adopt the database approach, there would be a number of other implications. First of all, there should also be a link to watershed scale modeling either as proposed by Lovejoy et al. (1997) or the Basins tool of the EPA. Every effort should be made to note needed improvements in interfaces, simulation models, and observed datasets. In another 5 to 10 years, a revised database should be built based on our improved tools and understanding. Also, future models would not have to be designed to be as "user friendly" as for the interactive modeling approach. There will be fewer modelers, and those specialists running particular models will have the time to become very familiar with those models. Instead of focusing on ease of use, model builders may want to build in support to make it easier to document and parameterize suites of scenarios, quality check the results, and load the results directly into a database to provide ease of access to model results, rather than ease of use for the models themselves.

There is a growing need for watershed management to address water quality issues across the United States. In addition to the watershed groups that have taken the initiative to improve management, many watersheds will be forced to implement TMDLs. Implementing watershed management plans implies an equally large need for field scale information, as fields are the unit on which land management decisions are made. Because of the greatly expanding demand for field scale information about water quality, watershed managers need to consider new approaches to providing that information to farmers. The approach presented in this paper proposes the creation of a database of management effects on representative fields using both simulation models and observed data.

Creating this database is a necessary step toward resolving water quality problems, but not sufficient by itself. Technical assistance to help farmers apply the information in the database will clearly be needed, and economic incentives as well. A database of field scale management effects serves many purposes, including helping NRCS encourage conservation planning, as an educational tool for producers, or to analyze the economic incentives needed to encourage the adoption of new management systems. An effort to build a database for a significant portion of a state will uncover gaps and problems with observed data, and the simulation models, but such knowledge could focus model improvement efforts and guide new experiments. The database approach just may be good enough.

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