

The water quality of any stream or lake depends upon how well its watershed is managed.

A watershed is the land area that drains to a given point in a river, stream or lake. Water that runs off each parcel of land within a watershed contributes water as well as the various constituents that are carried along with it, such as soil, nutrients, animal wastes, or decayed plant material. Even a native watershed, untouched by humans, can contribute numerous constituents that we might call "pollutants" to a stream. However, watersheds with more human activities tend to produce more pollutants.

Watershed groups in Kansas are in the process of setting limits to the total amount of pollutants that can be added to streams and lakes. These limits, called Total Maximum Daily Loads (TMDLs), help assure that pollutant loads to streams and lakes do not impair the public's ability to use these waters. As these limits are developed,

Assessing Tomorrow's Watersheds

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assess the overall conditions and relationships with stream and lake health, not only under current land-use conditions but also into the future. K-State researchers are at the leading edge in applying watershed assessment technologies.

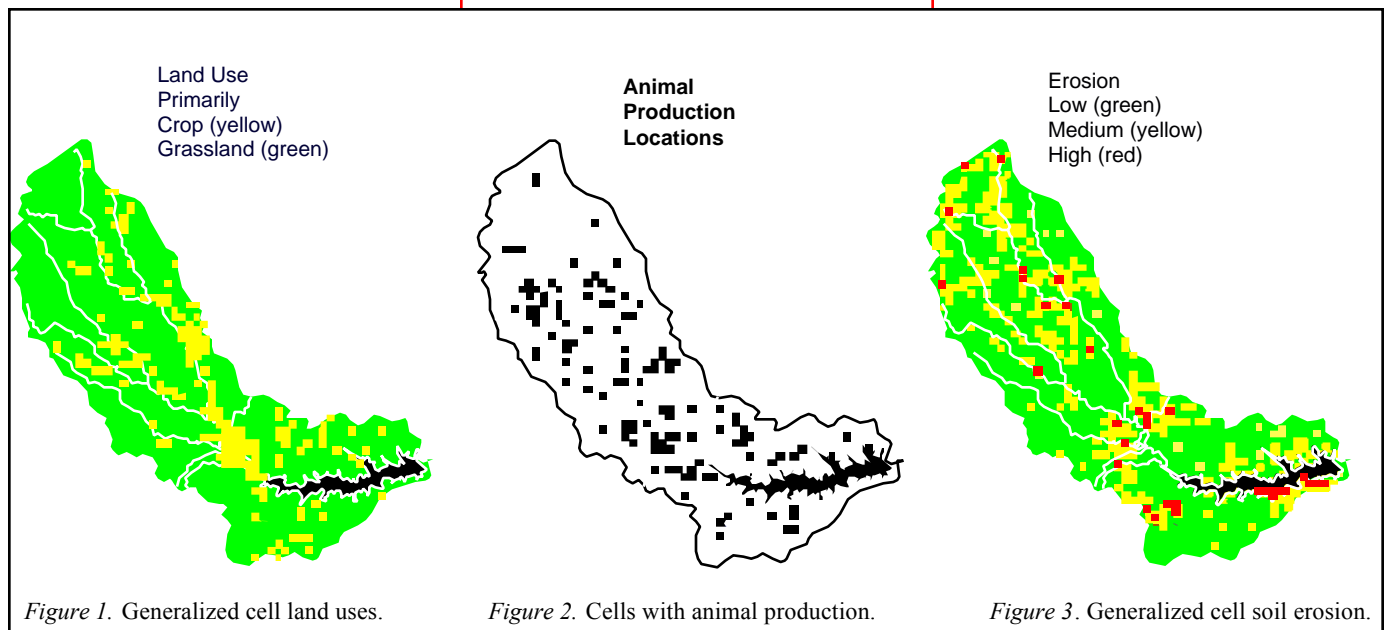
The overall goal of the modeling process is to help local watershed planners (such as watershed groups, county boards, or federal and state agencies) answer these questions for their watershed. This bulletin describes the basic modeling process, and demonstrates how watershed and lake models have been used to describe possible future directions for watershed development and help guide watershed management plans and TMDLs.

Selecting the Right Model

Many models are available to simulate how water quality is affected by changes in watershed management. This is handy, because a diversity of watersheds and pollutant sources exist,

many questions arise: Where are the major sources of pollution located? How should funding or education be targeted to help reduce pollutant discharges? How will proposed changes affect stream or lake health? What is a reasonable TMDL? Can a given TMDL be attained?

Recent developments in watershed computer-models can help planners



and most models have areas of specialty. A model is a tool that must be adjusted to solve the problems of specific types of watersheds or specific sources of pollutants. The adage that “you need the right tool for the right job” is true for modeling as well.

One such model, AGNPS (Agricultural Nonpoint Source), has been used successfully in Kansas. The AGNPS model was developed by the U.S. Department of Agriculture – Agricultural Research Service, from numerous equations and relationships that evolved from years of runoff and erosion research, in combination with a smaller model used to estimate pollutant loads from animal feedlots. In its current form, it can simulate water, sediment and nutrient yields from agricultural watersheds, and is well-suited to estimate the impacts of feedlots within these watersheds. It also allows point pollutant sources to be added anywhere in the watershed. Because the model was constructed to work within the agricultural landscape, it directly accounts for many types of common agricultural conservation practices, including terraces and small ponds; management practices, including fertilizer applications; and common landscape features, including grass waterways.

These features make AGNPS a good tool to assess the rural watersheds in Kansas. Three such watersheds, Melvern Lake, Clinton Lake and Horseshoe Creek, have been assessed to date.

Collecting the Right Data

No matter how good a model is, the results can be no better than the data used to run the model, so data collection is a critical step in developing a model. Data for each watershed can be collected from various sources, including soil survey maps, topographic maps, county assessor aerial photographs, the Natural Resources

Conservation Service (NRCS) National Resource Inventory and Kansas Department of Agriculture Farm Facts bulletins, as well as conversations with U.S. Army Corps of Engineers, Kansas Department of Health and Environment (KDHE), local NRCS and Kansas State University Extension personnel. Further detail is gathered by taking extensive field notes (while driving every public road within the watershed) about land uses, conservation practices, condition of ranges/pastures, feeding areas (e.g., size, condition, pollution control practices), farmsteads or residences and any other conditions that are judged to be of consequence to water quality. This is a slow process,

Lake (350 square miles). This cell size allowed land characteristics to be described in adequate detail but did not make the resulting model too complicated, time consuming, or expensive to create. Each individual cell is given 20 or more numerical values (for example, see generalized inputs for Melvern Lake Watershed in Figures 1 and 2) that describe characteristics of water movement, erosion, and sediment and nutrient transport. The results are AGNPS cells that respond to rainfall events in the same way as the real 160-acre plots in the field. The output from each cell is routed through the watershed in stream channels with chances for settling and transformations along the way.

Once the model contains all the pertinent data about a watershed, rainfall events can be applied and pollutant yields determined. (For example, see one output for Melvern Lake Watershed in Figure 3.) The AGNPS model can evaluate only individual storm events. So K-State researchers have developed a method to combine the results from a suite of large, medium and small storms that together would represent an average year of rainfall and erosion potential. For studies focused on the long-term impacts of watershed conditions or potential changes, this method works well.

Lake aging or eutrophication, the process by which lakes accumulate sediments and nutrients over time, were concerns for both Melvern Lake and Clinton Lake watersheds. The watershed pollutant yield results from AGNPS were used as inputs to a regionally calibrated lake eutrophication model, EUTROMOD. This provided a direct estimate of lake response to watershed changes. This is a good example of where it is necessary to focus on the long term: slowing lake eutrophication (aging) requires efforts to reduce sediment and nutrient loadings over the long term rather than from single-event spikes.

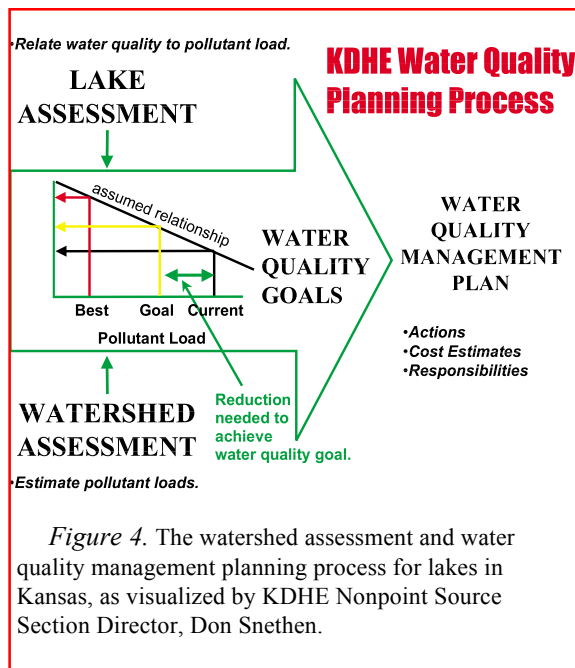


Figure 4. The watershed assessment and water quality management planning process for lakes in Kansas, as visualized by KDHE Nonpoint Source Section Director, Don Snethen.

averaging about one section of land (640 acres) per person-hour of field time, but it remains the best way to really see what is occurring in a watershed. These data are used to create an AGNPS model for the “current conditions.”

The backbone of the AGNPS watershed model is a grid of interconnected square cells. For example, a grid with 160-acre cells translated into a watershed model of 1400 cells for Melvern

Using the Model

The combination of lake and watershed models allows this watershed modeling approach to be responsive to the efforts of KDHE in assisting with watershed planning. In KDHE's "ideal" planning process (as shown in Figure 4), current-condition pollutant loads and resultant water-quality levels are determined. Models then are used to assess how water quality responds to specific changes in pollutant loads. Finally, a water-quality management plan is developed to achieve the pollutant-load reductions needed to meet the specific water-quality targets. The effectiveness of each possible action is assessed, in part, using water-quality models.

A good model with good data produces good results. To assure that good results are obtained, both data inputs and model outputs must be checked against watershed reality whenever possible. First, it is important to use actual, site-specific, rainfall data as well as land-use data, which can be verified using several public databases. Then the modeled runoff should be calibrated (by adjusting NRCS Curve Number inputs) to match measured streamflow for that watershed. It is also possible to verify that the modeled erosion is within expected regional

ranges for similarly sized watersheds using a published report of pond and lake sedimentation rates throughout Kansas. Finally, the resulting in-lake phosphorous concentration can be calibrated to average historical levels from lake samples by fine-tuning EUTROMOD's phosphorous availability factor. The model is typically calibrated using phosphorous, not nitrogen, because most lakes are phosphorous-limited for eutrophication. To the calibrated "current conditions" model, other watershed conditions and scenarios can be tested to determine potential water quality responses.

Using Model Results

Modeling results from the "current conditions" scenario helps watershed planners to determine regions or sites of high pollutant yield that need to be addressed (see Figure 3). Also, consideration of areas with low pollutant yields helps planners identify areas where things are being done right.

It is critical that watershed modelers work closely with local watershed groups and agency personnel to develop scenarios representing specific, benchmark conditions, or potential directions of future development, both good and bad. For the Melvern Lake assessment, K-State researchers and local personnel focused on the six

scenarios presented in Figures 5 and 6. The "current conditions" scenario is Scenario 1. The benchmark "best-case" condition for the watershed was considered to be a return to tall-grass prairie conditions (Scenario 4). Scenarios for possible improvements to water quality included converting all cropland to no-till management (Scenario 5), removing all feedlots (Scenario 2) or ponds (Scenario 3), terracing all cropland, or adding riparian buffer strips. Scenarios for potential water-quality degradation included returning all CRP and good-condition grass to cropland (Scenario 6), removing all cropland terraces, or converting the whole watershed to poorly managed cropland (considered a "worst-case" benchmark). Not all scenarios discussed above were important to the Melvern Lake watershed; only those that helped address local watershed concerns were tested.

Based on analysis of these scenarios, sound recommendations for action in each watershed, including establishment of TMDLs, can be made. The assessment process and key recommendations for one of the watersheds, Melvern Lake, are summarized on Page 4. Of course, recommendations are unique to local watershed conditions.

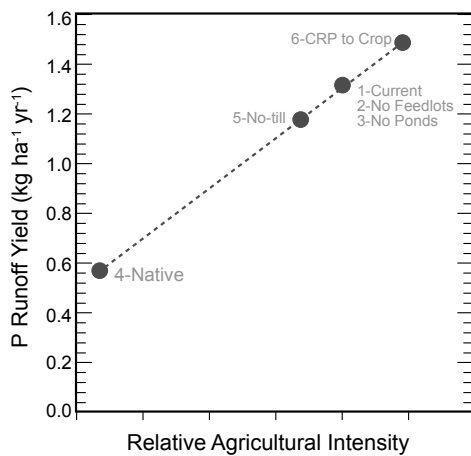


Figure 5. Modeled annual average phosphorus yields for six Melvern Lake watershed scenarios.

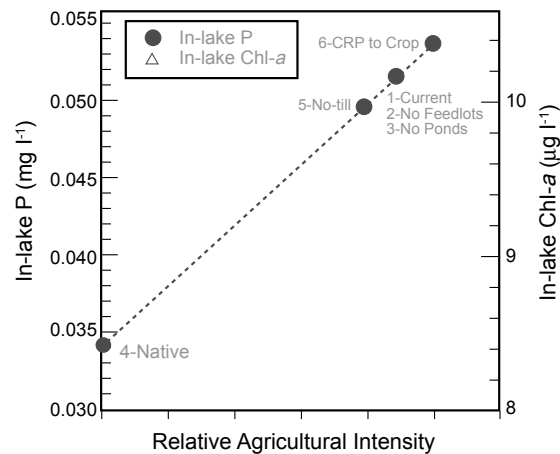


Figure 6. Modeled annual average lake phosphorus and chlorophyll *a* (an indicator of algae growth) responses for six Melvern Lake Watershed scenarios.

Melvern Lake Water Quality Assessment Summary

The following summary provides an indication of the types of results and recommendations that are produced by a watershed modeling and assessment process.

Pollutant sources. The water quality in Melvern Lake is among the best for Kansas reservoirs. This results from several factors: a) low-intensity land usage in the watershed – grassland predominates (80%), and the remainder is mostly cropland (20%); b) low population density – only about 1,500 people; and c) low-intensity livestock production – about 30,000 cattle scattered across hundreds of sites. We found no identifiable, dominant sources of pollution in the Melvern watershed.

Subwatershed assessment. The results of this project showed that sediment, phosphorus and nitrogen loadings were fairly low throughout the watershed. Because deposition and transformations in buffer areas, streams, wetlands and ponds reduce the impact of distant portions of a watershed on Melvern Lake, subwatersheds near the lake have a larger net effect on per-acre loading. This may increase the importance to the lake of areas such as the 3,800 acres of cropland managed by the Corps of Engineers. However, the higher delivery efficiency of zones nearer to the lake was offset by lower edge-of-field contributions. Thus, from a watershed management standpoint, we conclude that no one area of the watershed can be singled out as a prime contributor, and no one area should be targeted for education or financial assistance toward adoption of water-quality improvement measures.

Input to TMDL process. Guidelines were provided for determining the appropriate level for annual pollutant loading to Melvern Lake. A maintenance plan would keep average annual loadings of soil and nutrients no greater than current levels, estimated to be 0.48 tons/acre per year sediment, 1.2 lb/acre per year phosphorus, and 2.6 lb/acre per year nitrogen. Further analysis is necessary to refine these estimates from average annual levels to seasonal or monthly recommendations, particularly because runoff-producing rainfall events occurring randomly on the watershed in time and space produce nearly all of the loading to the lake.

BMP recommendations. For Kansas conditions, Melvern Lake is reasonably clean now. Though the modeling assessment shows that it can never become a clear, blue lake, its water quality can become better or worse depending on future watershed management. This is particularly true because nonpoint sources make up a large majority of the influent sediment, nutrient, and chemical loadings. For example, lake loading is estimated to be higher by 65,000 tons of sediment and 140,000 pounds of phosphorus per year than if the watershed were all in native grassland and woodland. Commonly used best management practices (BMPs) for small feedlots, cropland and grassland are recommended and their use would have an important impact.

Without models, it is difficult to assess how water quality within a watershed will respond to changes in programs and practices. Models provide this information, and help planners make decisions about the appropriateness of specific types of development in specific areas of a watershed. The results also help prioritize subwatersheds and land conditions that have the greatest potential benefits to water quality.

With careful planning and execution, models can help planners and agency personnel see into the future and make better-informed decisions about the direction of future watershed programs, practices and development.

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