

## **ASSESSMENT OF NONPOINT SOURCE DOMINATED WATERSHEDS IN MISSOURI**

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### **ABSTRACT**

The Watershed Research, Assessment, and Stewardship Project (WRASP) is specifically designed to facilitate fair implementation of the Total Maximum Daily Load (TMDL) program in agricultural watersheds in Missouri. At this time, the WRASP is targeting three watersheds on Missouri's 303(d) list. The WRASP is a unique partnership of government agencies, the private sector, and a not-for-profit organization. The technical approach for the project includes assessment of various scales of watershed monitoring (ranging from edge-of-field to large-scale watershed monitoring), reservoir water quality monitoring and watershed modeling. This approach will guide the planning process and facilitate the development of a voluntary and watershed scale Water Quality Management Plans (WQMP). The WQMP will then be voluntarily developed and implemented but will address the potential need for regulatory action should the effort not be successful. Demonstrating the economic impact of the WQMP to local landowners and producers and developing appropriate implementation plans will be critical to achieving local support.

### **INTRODUCTION**

The Missouri Corn Growers Association (MCGA) has embarked on the Watershed Research, Assessment, and Stewardship Project (WRASP). This project will focus on three priority watersheds that are listed on the 1998 Missouri Department of Natural Resources (MDNR) 303d list of impaired water bodies. The three, targeted watersheds include the watersheds of Smithville Reservoir, Monroe City South and Route J Reservoirs, and the Salt River tributary of Mark Twain Reservoir. Currently, the WRASP is planned to be a five-year study.

The primary impairment of these surface waters is previous elevated atrazine concentrations. Historic atrazine data has been collected by several sources including MDNR, the U.S. Army Corps of Engineers, the University of Missouri and Novartis. Unpublished data collected by Novartis show that atrazine concentrations (measured by ELISA methods) in the three targeted water supplies have periodically exceeded the maximum contaminant level of atrazine (3.0 µg/L) since 1995 (Figure 1). These data sets demonstrate water quality problems that have resulted in the 303d listing.

The MCGA, MDNR and Syngenta Crop Protection (formerly Novartis Crop Protection) developed a partnership to proactively approach the water quality problems discussed in the previous section, with the result being the development of the WRASP. The purpose of the WRASP is to collect data and information in order to lay the planning framework necessary to ultimately return these surface water supplies to unimpaired status. The goals of the five-year project are to:

- Assess the effects of land management practices on water quality,
- Accelerate implementation of cost-effective farming practices that improve water quality,
- Provide valuable information for future planning, and
- Facilitate development of Water Quality Management Plans (WQMP), which may serve as Total Maximum Daily Loads (TMDL).

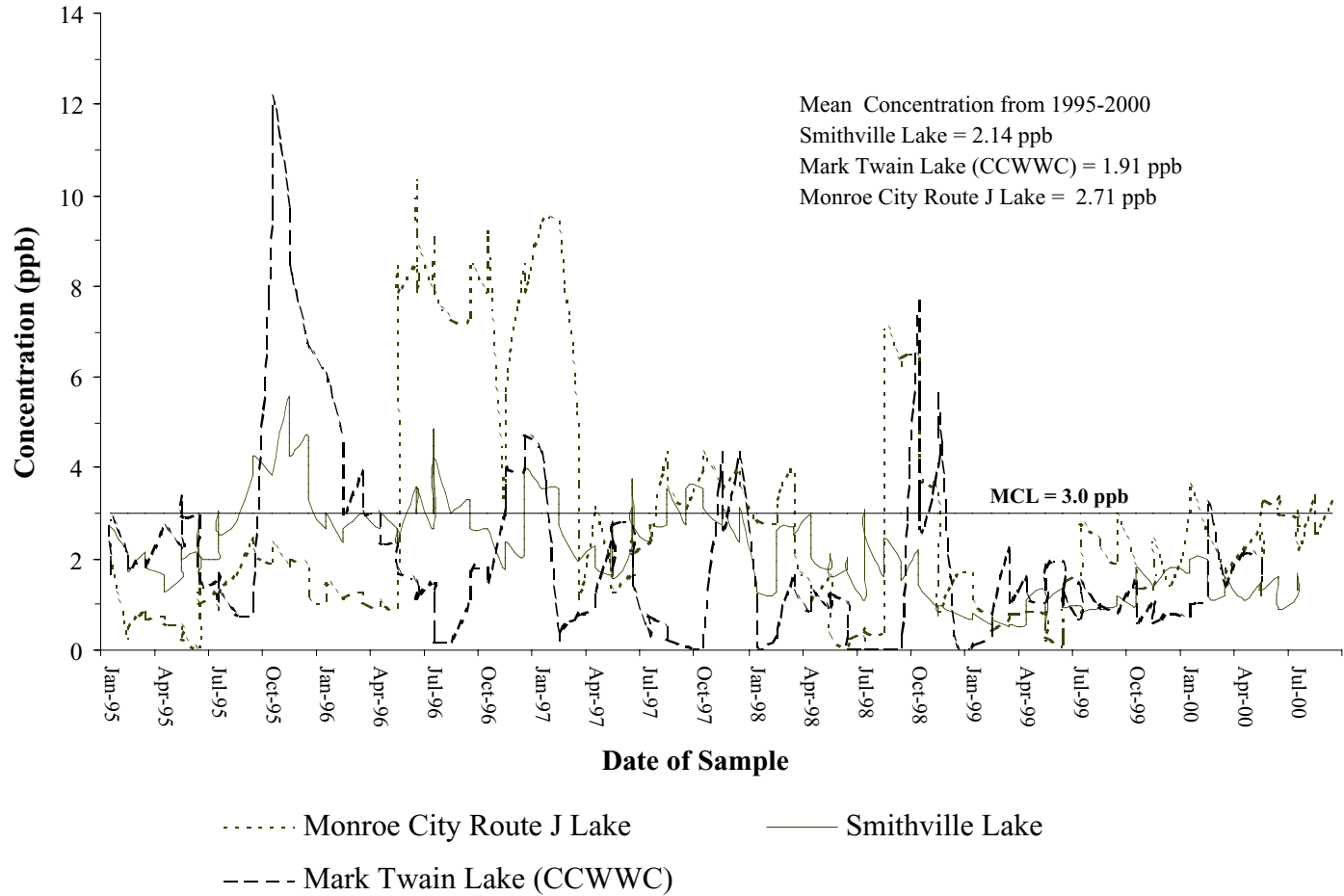
## **Study Watersheds**

Three watersheds are being evaluated in the comprehensive study. This includes two large watersheds (Smithville Reservoir and Salt River tributary of Mark Twain Reservoir) and one small watershed (Monroe City Route J Reservoir). Figure 2 illustrates the locations of the study watersheds. These areas are prone to high runoff, primarily because they have high clay content subsoils. Most of these soils are categorized into the C and D hydrologic groups meaning moderately high to high runoff potentials. In addition, erosion has caused significant loss of topsoil, which has exposed these subsoils and resulted in reduced water infiltration. The major land uses for these areas include terraced and unterraced cropland planted in corn, sorghum, and soybeans; pasture; and land enrolled in the Conservation Reserve Program (CRP). Other dominant land uses include forests and pasture ground.

### ***Smithville Watershed***

The Smithville Watershed is one of the large-scale watersheds that will be included in the WRASP. The watershed is approximately 135,600 acres in size. The majority of the watershed is located in Clinton County and parts of southern DeKalb County and northern Clay County. These counties are located in the Northwest portion of Missouri with Kansas City being the closest major city (located approximately 20 miles south).

**Figure 1: Atrazine Seasonal and Annual Concentration Pattern in Study Reservoirs 1995-2000**



**Figure 2: Locations of Study Watersheds**



### ***Mark Twain Watershed***

The North Fork of the Salt River (North Fork) of Mark Twain Watershed is the other large-scale watershed included in the WRASP. The entire Mark Twain watershed is located in the Northeast portion of the state of Missouri. It stretches as far north as Schuyler County (borders the State of Iowa) and south to Callaway County. It reaches west into Randolph County and east into Ralls County. Only the North Fork Watershed will be studied since this is the primary watershed that provides source water to the Clarence Cannon Wholesale Water Commission Water Treatment Plant. This watershed extends from Schuyler County to the mouth of Mark Twain Lake south of Shelbina in Monroe County. The North Fork Watershed is approximately 417,000 acres in area. Otter and Crooked Creek Watershed also drain into the North Fork arm of Mark Twain Lake; however, these watersheds will be studied by the University of Missouri and are outside of this study. The two separate studies may be used together in the future for planning purposes.

### ***Monroe City Route J Watershed***

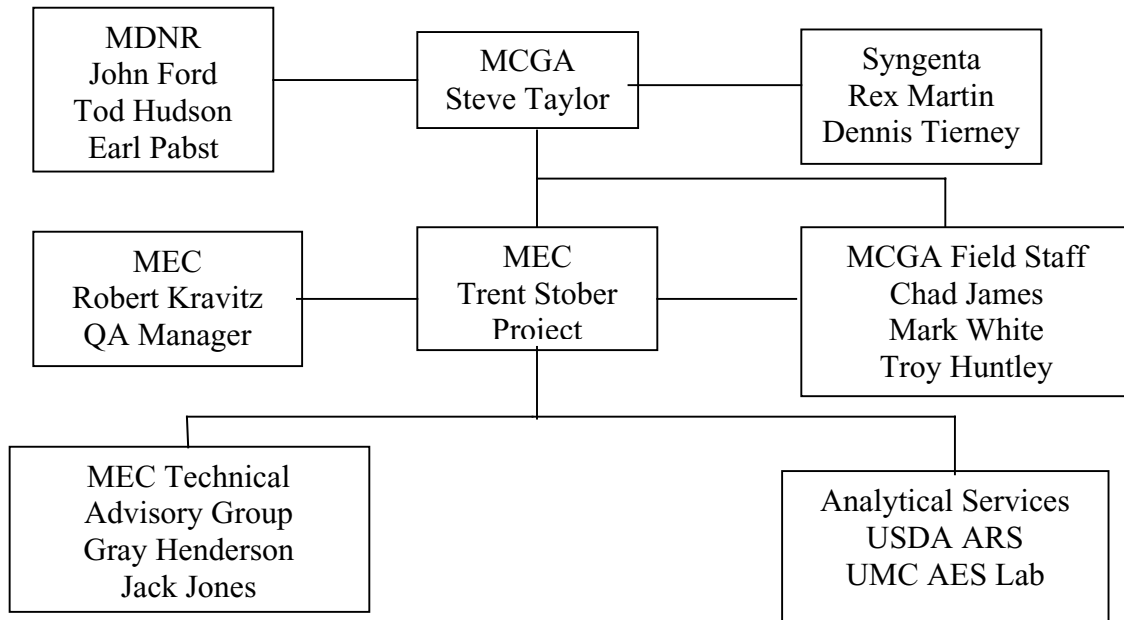
The Monroe City Route J Watershed will also be studied during this project and is much smaller in comparison to the two former watersheds. The Route J Watershed is located within Monroe County and is approximately 5200 acres in size. The Route J Lake is indirectly the main source of drinking water for Monroe City. Water is pumped from this reservoir into the much smaller South Lake. The South Lake watershed is only approximately 660 acres in size. The Monroe City Watersheds are located in the northwest corner of Ralls and the Northeast corner of Monroe Counties. The main focus will be directed at the Route J Watershed; however, a study of best management practices (BMP) effectiveness will be conducted in the South Lake Watershed.

## **Project Organization**

The sponsor of the project is the Missouri Corn Growers Association (MCGA), with relatively equal funding from MCGA, Syngenta Crop Protection and a Section 319 grant from the Missouri Department of Natural Resources (MDNR) and United States Environmental Protection Agency (USEPA). MCGA provides overall direction for the study, arranges access to agricultural fields, and provides field sampling. Midwest Environmental Consultants Co. (MEC) provides the study design, specifies sampling equipment and protocols, arranges for laboratory analysis, validates the data and presents and interprets the results of the study. In addition, MEC provides training to the MCGA sampling technicians regarding proper sample collection, preservation, packing and shipping, including proper field documentation. The U.S. Agricultural Research Service and the University of Missouri — Columbia, Agriculture Experiment Station Laboratory provide chemical analysis of atrazine and other parameters of interest.

Data from this study will be used to facilitate planning with the ultimate goal of improving water quality of the surface water supplies to unimpaired status. The principal data users therefore will be MCGA, Syngenta Crop Protection Inc., MDNR and MEC. The principal decision-makers will be MCGA and MDNR. Figure 3 presents an organizational chart for the project.

**Figure 3: WRASP Organizational Chart**



**METHODOLOGY**

A multi-faceted approach will be required to achieve water quality restoration in the targeted watersheds. The process involves the assessment of current water quality conditions and the use of several farm management strategies to reduce nutrient and herbicide inputs into the reservoirs. Based on interpretation of water quality data, a Water Quality Management Plan (WQMP) will be prepared to present the water quality restoration strategy. The WQMP will be shaped by evaluating the effects of farming practices and developing a watershed model to predict the scenarios that may result in water quality restoration. Public information and education efforts will be required throughout the process to achieve implementation of the WQMP. Demonstrating the economic impact of the WQMP and developing policy will be critical to achieve grower support and implementation. During implementation, water quality monitoring will be conducted to assess the effectiveness of the WQMP and reveal any required improvements of the plan.

The success of water quality restoration hinges on the technical assessments of existing and potential water quality since collection and interpretation of surface water quality data will drive WQMP development. The proposed technical approach of the WRASP, which will provide adequate information for the TMDL and WQMP processes, is broken into the following four evaluations:

- Watershed Assessment,
- Evaluation of Farming Systems and Best Management Practices (BMPs),
- Limnological Assessment, and
- Water Quality Modeling Evaluation.

## **Watershed Assessment**

The purposes of the Watershed Assessment are to: (1) determine the areas or sub-basins that account for the majority of the nutrient and herbicide annual loads; (2) estimate annual loading to the receiving water bodies; (3) provide insight into the impacts of land use and the effectiveness of BMPs on key water quality parameters; and (4) provide data useful for calibration of the water quality model.

The Watershed Assessment consists of monitoring stream water quality and flow at strategic locations within the targeted watersheds. Stream water quality is monitored for various herbicides (e.g., atrazine and its metabolites, cyanazine, metolachlor), inorganic nitrogen compounds, total nitrogen and phosphorus, and suspended solids. Automatic sampling equipment is utilized for flow weighted sample collection. Gaging stations are utilized to collect discharge data, with development of rating curves for each stream segment.

Interpretation of stream water quality data is complex and inherently involves uncertainty. This uncertainty is due to annual variation in several variables. Climatological parameters (particularly rainfall and runoff) greatly influence herbicide and nutrient runoff and vary significantly from year to year. This variability, coupled with crop rotation, makes comparison of historical data complex. Despite this complexity and inherent uncertainty, the assessment will yield quantitative data with which to evaluate the impacts of land use and BMPs.

The monitoring locations were selected based upon land use and watershed characteristics. Areas with varying soil types, slopes, and implemented BMPs may be monitored to observe the effects of these variables on water quality.

Two types of monitoring locations are being used. Large sub-basins, relative to the total watershed, area are monitored primarily to determine relative contribution of nutrients, suspended solids and herbicides and estimate annual input loading. This effort is referred to as the Large-Scale Watershed Assessment. Small watersheds (ranging from 300 to 1500 acres) consisting of almost exclusively row cropland use are also monitored. Similar watersheds with pasture or Crop Reserve Program (CRP) land use are also monitored, thus allowing quantification of differences in water quality associated with land use as related to nutrient runoff. Farming practices will be monitored or controlled in these watersheds during the study and thus this portion of the Watershed Assessment is related to the Evaluation of Farming Practices and Best Management Practices. These data will also be useful for calibration of the water quality model. The small watersheds

may serve as future sites for implementing BMPs evaluated in edge of field studies. The data collected during the initial years of the study would serve as baseline data against which the effectiveness of BMP implementation would be evaluated. This evaluation is referred to as the Small-Scale Watershed Assessment.

The number of sampling stations for the Large-Scale Watershed Assessment will vary significantly depending upon the size and morphology of the targeted watershed. One sampling station will be located at the nearest accessible stream segment to the water supply that will not be impacted by reservoir backup. Additional monitoring locations will be at the discharge of relatively large sub-basins that apparently contribute significant loadings based on land use. Suitability of the prospective monitoring locations for accurate flow measurement will be taken into account during the selection process. It is anticipated that five monitoring locations will be used for large watersheds (e.g. Smithville and Salt River Watersheds). Data collected by the University of Missouri-Columbia for a similar study at Monroe City will be utilized for the Monroe City Watershed data.

Sampling locations for the Small-Scale Watershed Assessment will be selected based on land use, representativeness of that land use to the remainder of the watershed, and suitability of location for sampling equipment installation. These small watersheds will range from 300 to 1500 acres in size and represent one predominant land use and farming practice. Both row-crop and pasture (CRP) land use will be monitored during this assessment. It is anticipated that 3 to 6 monitoring locations will be selected in the Mark Twain and Smithville watersheds.

The Watershed Assessment should provide excellent data for determining relative nutrient and herbicide contributions from sub-basins within the targeted watersheds and be useful in model development. Future funding and efforts may then be directed to the areas contributing disproportionately to annual loadings to each reservoir. In addition, the data produced by this evaluation will provide estimates of annual loadings since the major sub-basins are being monitored. The total annual nutrient and herbicide input load will be more than that determined by this effort because some small watersheds adjacent to the reservoirs will not be monitored. The contribution of these sources may be estimated based on the Small-Scale Watershed Assessment data, the Evaluation of Farming Practices and Best Management Practices studies, and/or watershed modeling.

### **Evaluation of Farming Systems and Best Management Practices**

The purposes of evaluating the impacts that farming systems and BMPs on water quality are to: (1) determine the most cost-effective practices to achieve watershed restoration; (2) produce data for calibration of the water quality model; and (3) provide data on the effectiveness of various farming practices that will be applicable to Missouri watersheds not targeted by the WRASP.

Alternative farming systems and/or BMPs may be essential for successful watershed restoration. Several farming practices, including various tillage practices and herbicide

programs, may result in water quality improvements. Some of these, particularly tillage practices, may result in environmental tradeoffs and must be weighed carefully. The effectiveness of these practices may vary significantly based on site-specific variables, such as soil type, slope, and hydrology.

Automatic sampling equipment is used in conjunction with flumes or weirs to determine nutrient, herbicide and suspended solids loads from terrace segments within fields (edge of field studies) managed with varying farm practices. Herbicide, nutrient, and suspended solid discharge are monitored. The results will be compared to determine the effectiveness of the studied practices.

The evaluation of these farming practices will be essential to determine the cost-effectiveness of possible solutions for watershed restoration. Each practice has varying implementation costs, impacts on crop yield, and effectiveness for load reduction. The WRASP will evaluate these practices on their costs relative to load reduction.

Several conventional and alternative farming practices are being evaluated, including tillage practices, herbicide programs, and BMPs. The data collected during this evaluation will be key for calibrating a water quality model. In addition, the comparison of the effectiveness of these practices in different regions of the State will provide greater insight to the most applicable practices in other Missouri watersheds. The following farm practices are being studied during the WRASP.

### ***Tillage Practices***

Conventional till, minimal till, and no-till are being compared. It is possible that conventional and minimum tillage will yield less herbicide runoff than no-till practices due to greater infiltration typically achieved during the initial rains after tilling but prior to soil reconsolidation. In addition, herbicides are commonly incorporated into the soil during tilling rather than the surface application for no-till systems. However, higher nutrient and sediment loads are typically associated with tilled versus no-till systems.

### ***Herbicide Programs***

Atrazine has historically been the most widely used corn herbicide due to its effectiveness and low cost. However, the water quality problems associated with the conventional application of this herbicide have resulted in the development of replacement or augmenting herbicides and the use of alternative herbicide programs. Lower application rates and two pass options are becoming more popular and may reduce atrazine runoff. The two pass programs show promise for reducing water quality problems. The use of augmenting herbicides, such as glyphosate (Roundup), has shown that adequate weed control may be achieved while reducing atrazine application. However, the health effects of many of the alternative herbicides have not been researched as extensively as atrazine and may prove to present health risks in the future.

### ***Best Management Practices***

Several BMPs are available that may reduce non-point source impacts. These include contour filter strips, terracing, grassed waterways, constructed wetlands, and riparian

corridors. Chemical characteristics and removal mechanisms must be evaluated to determine the effectiveness of BMPs. Since atrazine is soluble and thus typically transported in the liquid phase, management practices that increase infiltration (reduce runoff volume) are used to reduce surface water impacts. Secondly, atrazine may be adsorbed to soil particles and transported via sediment load. Therefore, BMPs that reduce sediment load may be moderately effective for atrazine reduction. Contour filter strips and grassed waterways are probably the most applicable and acceptable BMPs to many growers. Therefore, these will be most extensively studied during the WRASP. However, the extent of monitoring BMP efficacy may be limited due to budgetary limitations. Initial emphasis is being placed on alternative herbicide programs under the assumption they will yield the most cost-effective reductions in atrazine load. Other BMP systems, such as filter strips, will likely be evaluated in coming study years.

### **Limnological Assessment**

The purposes of the limnological assessment are to: (1) evaluate limnological processes that affect the fate and transport nutrients and herbicides; (2) estimate annual loading to the receiving water bodies; and (3) estimate the maximum annual atrazine loads that should result in achieving water quality standards, after accounting for safety factors.

Natural limnological processes can greatly influence the fate and transport of constituents within a surface water body. In addition, these processes affect different constituents, such as nutrients and herbicides, in different ways. Stratification may be the lake process that most significantly affects chemical transport. This becomes particularly important in determining the fate and transport of inflow constituents during stratification. During the summer, inflow may be significantly cooler than the epilimnion and initially plunge into the hypolimnion or an intermediate depth as a density current. The chemical(s) may then reside in the deeper zones until it disperses throughout the water column or until turnover. This may reduce the availability of nutrients for algae in the epilimnion or serve as a temporary sink for herbicides. This mechanism is of particular importance since drinking water intakes are typically in the epilimnion. Biological processes may also affect atrazine fate by microbial degradation.

The limnological assessment involves monitoring water quality at various locations in the reservoirs. Monitoring is conducted in major arms of the reservoirs, at one to two locations in the deeper areas, and at the reservoir outflows. Discrete samples will be obtained at various depths to determine the nutrient and herbicide distribution in the water column. The basic limnological parameters are monitored (i.e., total and soluble nutrients, chlorophyll *a*, solids), as well as herbicides. Atrazine degradation products will also be monitored to assess fate mechanisms.

Temperature and dissolved oxygen profiles are developed at each location for each sampling event. This data will be used to determine stratification, which is defined as greater than 1 °C temperature change per meter of depth. Samples are obtained from three depths of each monitoring location that exhibit stratification. Monitoring depths are located six inches below water surface, in the metalimnion, and in the hypolimnion.

Destratified monitoring locations are sampled obtained six inches below water surface and at a depth of one-half of the water column. Samples are obtained using a Van Dorn type sampler, with the exception of the shallow surface sampling. Sampling frequencies are once per three weeks from March through July and monthly for the remaining fall months.

Reservoir outflows will be monitored primarily to estimate load, which should account for the diffuse sources not monitored by the watershed assessment. The estimation of atrazine load using limnological data relies on the assumption that minor degradation of atrazine will occur in the water column. If this hypothesis is correct, the storage and outflow of atrazine will be equal to the inflow of atrazine. The concentrations of degradation compounds relative to atrazine concentrations will be compared between the stream flow monitoring and limnological monitoring to assess this assumption. Inflow will be estimated based on the total area of the watershed and the unit area runoff values established based on stream monitoring data. A water balance will be estimated based on outflow measurements and inflow estimates. These approaches will initially be attempted since the total inflow of atrazine may not be conclusively determined by the Watershed Assessment in some watersheds. This is due to diffuse sources located within small sub-basins around the reservoir. The contribution of these sources may also be estimated based on the Small-Scale Watershed Assessment data, the Evaluation of Farming Practices and Best Management Practices, and/or watershed modeling if land use and farming practices information is obtainable.

### **Water Quality Modeling Evaluation**

The main purpose of the proposed water quality efforts is to assess the various scenarios involving farm practices that may result in the desired watershed restoration. Thus, it may be very valuable for developing the WQMP. While water quality modeling may be extremely valuable, its accuracy relies heavily on the field data resulting from the other assessments of this study. Therefore, modeling will serve only as a tool rather than as a replacement for field data.

Several models may be utilized for nonpoint source modeling. The Hydrologic Simulation Program Fortran (HSPF) model may be utilized for this project; however, additional models will be evaluated prior to implementation due the complexity of HSPF. HSPF provides advanced simulation capability for nonpoint sources with mixed land uses and has been used for numerous watersheds since the early 1970s. The model includes watershed hydrology assessment, surface water quality analysis, nutrient and herbicide runoff processes, and decay and transformation components. The applications for HSPF include chemical fate and transport, watershed hydrology and water quality assessment, and evaluation of BMPs.

The main inputs include climatological data and numerous mathematical parameters used in erosion and overland flow concepts. The latter inputs require an extensive knowledge and experience with HSPF to produce accurate output. The model will be calibrated with the field data to greatly enhance the accuracy of the model. Ultimately, several scenarios may be evaluated to determine the land uses and farming practices that may be necessary

to achieve watershed restoration. This will then guide the WQMP and allow determination of the estimated cost of the restoration project.

## **RESULTS AND DISCUSSION**

Atrazine data in runoff are currently available for the May through July, 2000 period. This is a very limited time period and the winter and spring in 2000 were dry. Watershed conditions were such that soil moisture was not fully recharged and, correspondingly, surface water runoff was less than average during the period.

### **Smithville Watershed**

Atrazine runoff amounts from the small terrace segments (less than 5 acres) varied by a factor of over 100. This variation will be discussed in the section on application rates and methods. The atrazine discharge in runoff from small watersheds (ranging in size from 360 to 1180 acres) which were predominantly in cropland varied by a factor of 10 whereas the range for the two predominantly pasture or CRP watershed was a lesser factor of about 2. Likewise, the larger watersheds (4,600 - 25,000 acres) produced runoff with atrazine loads that varied by a factor of about 2.

Unlike on the terrace segments, atrazine application rates and methods were not under our control on the small or large watersheds. The results do indicate which areas within a larger watershed produce greater runoff amounts, at least for this year, and could be potentially targeted for implementation of improved management practices. They also show the dilution effect of less cropland on atrazine discharge as watershed size increases (sampling stations located further downstream).

### **Mark Twain Watershed**

Atrazine discharge at the various sampling locations in the Mark Twain watershed follow the same general trends as those at Smithville. Atrazine discharge amounts decrease as watershed size increases due to the dilute effect of runoff from land uses other than cropland. In this watershed the amounts from small watersheds (210 — 1170 acres) were less and their range was not as great as at Smithville. Both average and range of atrazine discharge from the managed terrace segments were very similar to those measured at Smithville.

### **Atrazine Application Method/Rate Effects**

The effects of atrazine application rate and method on the small terrace segments are summarized here. In general, atrazine applied prior to planting resulted in lower runoff amounts than when it was applied post planting. At Smithville, under conventional tillage, incorporation into the soil during pre-plant application resulted in lower discharge than when it was not incorporated. The reverse was true at the Mark Twain site. For no terrace segment was the total atrazine runoff more than 3% of the amount applied. Occurrence of precipitation that causes runoff relative to the time of application is

undoubtedly the most critical factor influencing discharge amounts. Because of the dry spring, there was little runoff at the time most pre-plant applications were made. On the other hand, precipitation occurred shortly after the post-plant applications and this led to elevated discharge associated with these treatments. As precipitation patterns vary from year to year we expect to see variations in these discharge patterns and would expect larger amounts to be associated with pre-plant applications in years where soil moisture conditions and spring runoff are closer to average.

## **ACKNOWLEDGMENTS**

This research is being funded by the Missouri Corn Growers Association, Syngenta Crop Protection, Inc., Missouri Department of Natural Resources, United States Environmental Protection Agency, United States Department of Agriculture, and the University of Missouri-Columbia.