MONROE CITY ROUTE J WATERSHED
ENVIRONMENTAL ANALYSIS

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D. Todd Farrand
Lynn King Heidenreich

College of Agriculture Food and Natural Resources

FAPRI At the University of Missouri
Food and Agricultural Policy Research Institute

Food & Agricultural Policy Research Institute (FAPRI)
University of Missouri

The Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI) is tasked to provide objective, quantitative analysis to decision makers. Since 1983, this service has been provided to Congress and national trade associations, and has focused on commodity policy issues.

In 1995, the unit was asked to expand its focus and begin the same level of effort to environmental issues, that of providing objective, analytical support. The unit spent considerable time examining the problems and determined the area most lacking analysis was at the local level; the farm, the watershed, the local community.

Similar to the extensive peer-review effort the unit goes through on national commodity policy issues, the environmental analysis effort recognizes the strong need for local involvement. If the local people who must live with the analysis have doubts about the way the analysis was developed, then the effort is wasted. Consequently, the process FAPRI brings to the table also incorporates extensive local input with respect to data sources and model calibration.

Our sincere thanks to those involved in helping to bring that detailed, local knowledge to the table.

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EXECUTIVE SUMMARY

Surface impoundments used for rural water supplies are at risk of contamination from agricultural non-point source pollution. Atrazine, an herbicide in the triazine family used to control broadleaf weeds and grasses in corn and a suspected carcinogen, has been detected in Monroe City's water supply. The Missouri Department of Natural Resources (MDNR) and the U.S. Environmental Protection Agency (EPA) have asked the Food and Agricultural Policy Research Institute (FAPRI) to evaluate alternative crop production practices that might reduce atrazine loadings without reducing farm income. This report focuses on the cumulative impacts on reservoir water quality of agricultural practices within the contributing watershed.

The Route J Reservoir is a secondary drinking water supply for Monroe City and also provides recreational benefits. In several public meetings, the local community listed atrazine and sedimentation among their concerns. On three dates in 1994, the quarterly sample of treated water exceeded the Maximum Contaminant Level (MCL) of 3.0 parts per billion (ppb) for atrazine set by EPA. Since compliance with state and federal law is based on a four-quarter running average, the treatment system was out of compliance. Monroe City applied to MDNR for an exemption from the violation to give the city time to develop a plan to reduce contaminant levels. Treated water samples have not exceeded the MCL since the violation, but concentrations in the Route J Reservoir have ranged from 1.5 ppb to 17.0 ppb. In 1998, Route J Reservoir was on Missouri's 303(d) list, a list of water bodies that do not meet water quality standards for their intended use.

FAPRI, in conjunction with United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) and other local sources, identified soils and production practices that are common in the watershed to assess the sources of atrazine in the reservoir, and determine the contribution of agriculture to sediment yield. A watershed-level environmental model was used to identify the relative contribution of atrazine and sediment from subbasins within the watershed. Alternatives modeled by FAPRI included a revised baseline to reflect changes in crop distribution related to low commodity prices for wheat, and three corn herbicide management regimes. Herbicide alternatives were taken from the Atrazine Management and Abatement Project, a cooperative effort between the local steering committee, NRCS, University of Missouri Outreach and Extension, MDNR, and chemical manufacturers. The goal of the project was to test herbicide regimes that reduced atrazine application by one-third.

Erosion and sediment yield values were low, even after removing wheat from most crop rotations. Low slopes and tillage practices that favor soil conservation reduce the risk of sheet and rill erosion. However, other factors not accounted for by the model, such as gully and road ditch erosion and livestock grazing in woodlots, also contribute sediment to the reservoir.

Atrazine loss ranged from an average of 15% under baseline conditions to 4% under the two-pass herbicide alternatives. The timing of application influenced atrazine

runoff more than reduced application rates. The two-pass alternatives, which applied atrazine post-emergence in June, showed the greatest reductions in loadings. This reduction is primarily due to the timing of application in relation to rainfall, but the two-pass systems also had higher decay rates because crop leaves intercepted atrazine before reaching the soil. Atrazine degrades 12 times faster applied to foliage than when applied to the soil. Although the herbicide alternatives were deemed effective in 1999, weed pressure was low and may not have been indicative of average conditions.

In general, increasing corn and soybean acres results in more erosion and more atrazine runoff, all else equal. Similarly, applying less atrazine per acre results in less atrazine runoff, all else equal. Recent acreage shifts in the Route J Watershed have resulted in more corn and soybeans being produced on steeper slopes. Model results suggest this shift has resulted in a larger increase in soil erosion than in atrazine runoff, because the steeper soils are more susceptible to erosion than flatter soils, but less susceptible to atrazine runoff. Reducing and postponing atrazine application will reduce atrazine loading in the reservoir significantly, but impacts on weed control effectiveness relative to baseline applications are uncertain.

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MONROE CITY ROUTE J WATERSHED
ENVIRONMENTAL ANALYSIS

INTRODUCTION

Agricultural practices can impair water quality through the contamination of run-off by sediment, pesticides, and nutrients. Such threats are of particular concern for rural communities that utilize surface impoundments for public water supplies. Atrazine, an herbicide in the triazine family used on corn and a suspected carcinogen, has been detected in Monroe City's water supply. The Missouri Department of Natural Resources (MDNR) and the U.S. Environmental Protection Agency (EPA) have asked the Food and Agricultural Policy Research Institute (FAPRI) to evaluate alternative crop production practices that might reduce atrazine loadings without reducing farm income. This report describes that part of the evaluation that deals with cumulative environmental effects at the watershed level. A separate FAPRI report covers the farm-level financial and environmental effects.

OBJECTIVES

The objectives of this analysis were to develop a baseline model of crop production practices in the Route J Reservoir watershed, and to evaluate the relative impacts of proposed alternative herbicide regimes on water quality in the reservoir.

STUDY AREA

Monroe City gets its water supplies from 2 reservoirs: South Lake, located 2.5 miles south of U.S. Highway 36 immediately east of U.S. Highway 24; and Route J Reservoir, located 4.5 miles south of U.S. Highway 36 and ¼ mile west of Ralls County Route J.

South Lake lies adjacent to the water treatment plant and at normal pool level contains 39 surface acres of water (Monroe City Water Resources and Steering Committee 1998). Its watershed encompasses approximately 657 acres of land under a mix of uses, including agricultural. South Lake is the primary source of municipal water for Monroe City, and also provides water to 3 rural supply districts.

Route J Lake contains 95 surface acres of water with a watershed encompassing 5017 acres. The reservoir is used for recreation and as a secondary drinking-water supply (Monroe City Water Resources and Steering Committee 1998). Water is moved to South Lake via an underground pipeline to replenish water levels during summer months. Since the Route J Watershed is the major land area providing water supplies for Monroe City and its rural water districts, it should have the largest impact on future water quality. Thus, Route J Watershed was chosen as the focus of research efforts.

The watershed is located in Monroe and Ralls counties in northeastern Missouri, southeast of Monroe City and north of Clarence Cannon Dam (Figure 1). The watershed lies within the 2920 square mile Salt River drainage area. Ely Creek, whose headwaters feed the Route J Reservoir, flows into the Salt River downstream of Clarence Cannon Dam. Elevation levels drop from 726 feet at the northwest end of the watershed to 642 feet at the dam. The dam was constructed in the 1960s and is in good condition. It is an earthen dam with a concrete drop spillway and an earthen emergency spillway.

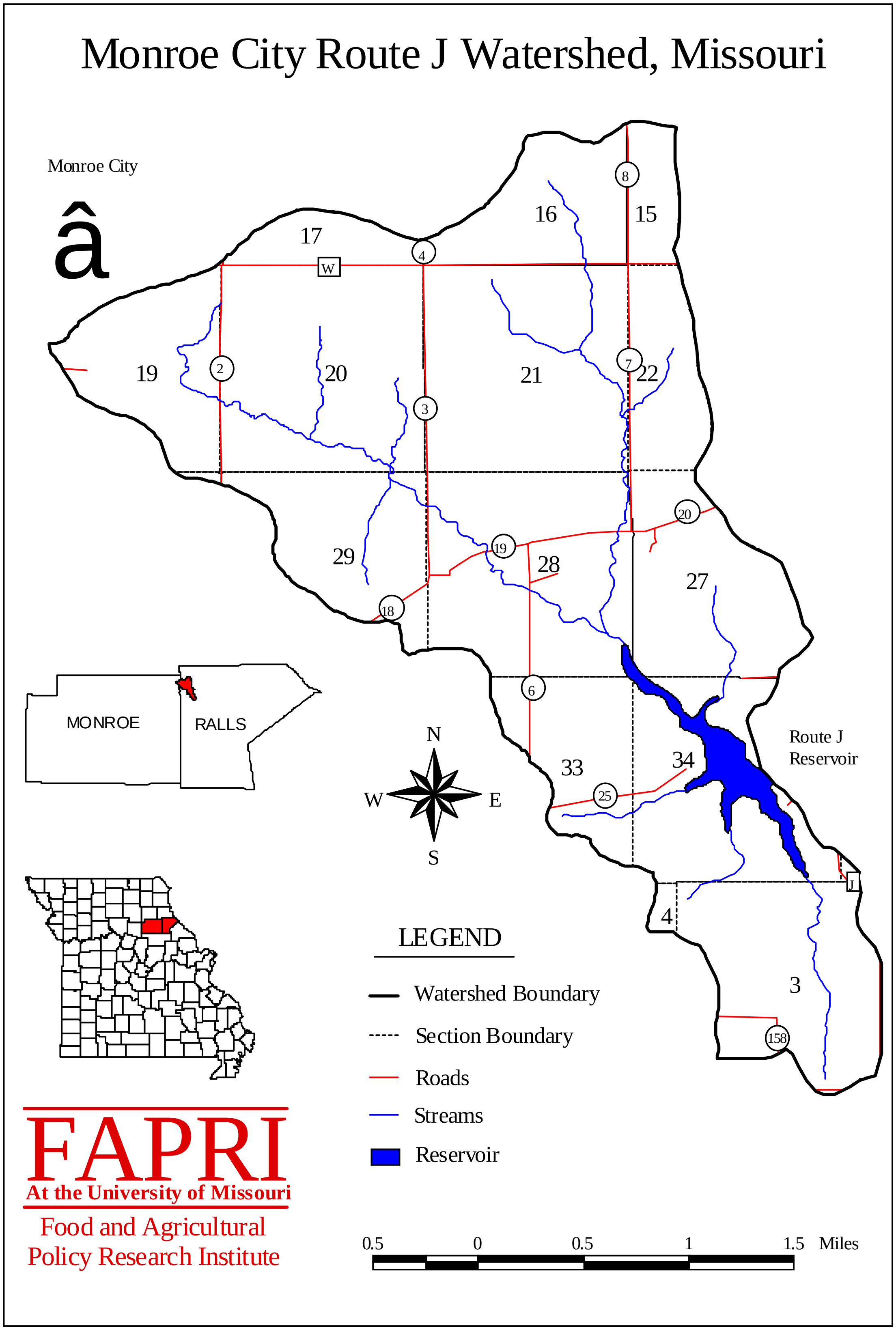

Figure 1. Location of the Monroe City Route J Watershed.

Water quality problems

During 1994, the quarterly average of treated water samples exceeded the Maximum Contaminant Level (MCL) of 3.0 parts per billion (ppb) for atrazine set by EPA. This resulted in Monroe City applying to MDNR for an exemption from the violation, giving the city time to develop a plan to reduce contaminant levels.

Quarterly water samples collected by MDNR from the Monroe City water treatment facility (post-treatment) between July 1996 and March 1998 did not exceed 0.35 ppb for atrazine. Treated water sampled through the CIBA Crop Protection Missouri Voluntary Atrazine Monitoring Program between January 1996 and November 1997 showed concentrations of less than 3.0 ppb. Raw water samples from the Route J Reservoir for the same time period showed concentrations ranging from 1.5 ppb to 17 ppb. Route J Reservoir was on Missouri's 303(d) list, a list of water bodies that do not meet water quality standards for their intended use, in 1998 because of atrazine.

Land Use

Analysis of 1992 satellite imagery shows that the Route J watershed is predominantly agricultural, with 65% of the land in rotation crops and 16% in various grass cover including pasture, hay, and Conservation Reserve Program lands (Table 1). Approximately 75% of the forested area within the watershed occurs in the area surrounding the reservoir, and forms a buffer between the reservoir and cropland (Figure 2).

Table 1. Land cover distribution in Monroe City Route J Watershed.

Land Cover	*Area (acres)*	*% of Watershed*
Cropland	3264	65
Grassland	801	16
Forest/Woodland	857	17
Water	95	2
Total	5017	100

Soils

The Monroe City Route J watershed is located within Major Land Resource Area 113, the Central Claypan Area. Wide, nearly level ridge tops and shallow streambeds with poorly to somewhat poorly drained soils characterize the northern two-thirds of the watershed. Steeper sloped soils of the southern one-third are generally wooded. The watershed soils' spatial distribution is shown in Figure 3, with distribution summarized in Table 2.

The majority of the cropland within the watershed is located on Putnam silt loam and Mexico silty clay loam. Typical of claypan soils, the high clay content and low permeability of these soils leads to increased potential for runoff from rainfall events, making the area vulnerable to loss of agricultural chemicals in surface runoff. Other soils underlying cropland include Leonard silt loam and Armstrong loam.

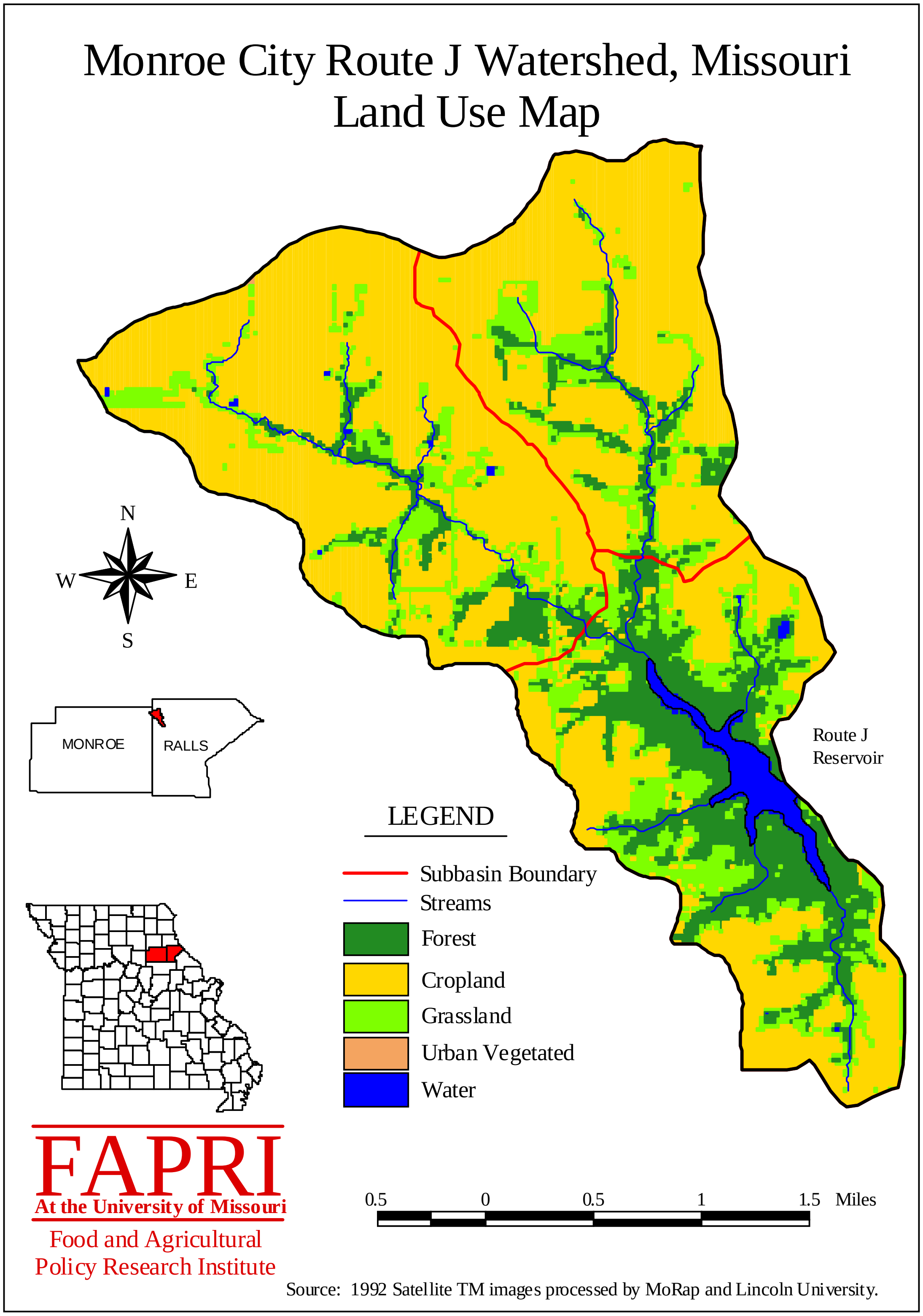

Figure 2. Land use distribution in the Monroe City Route J Watershed.

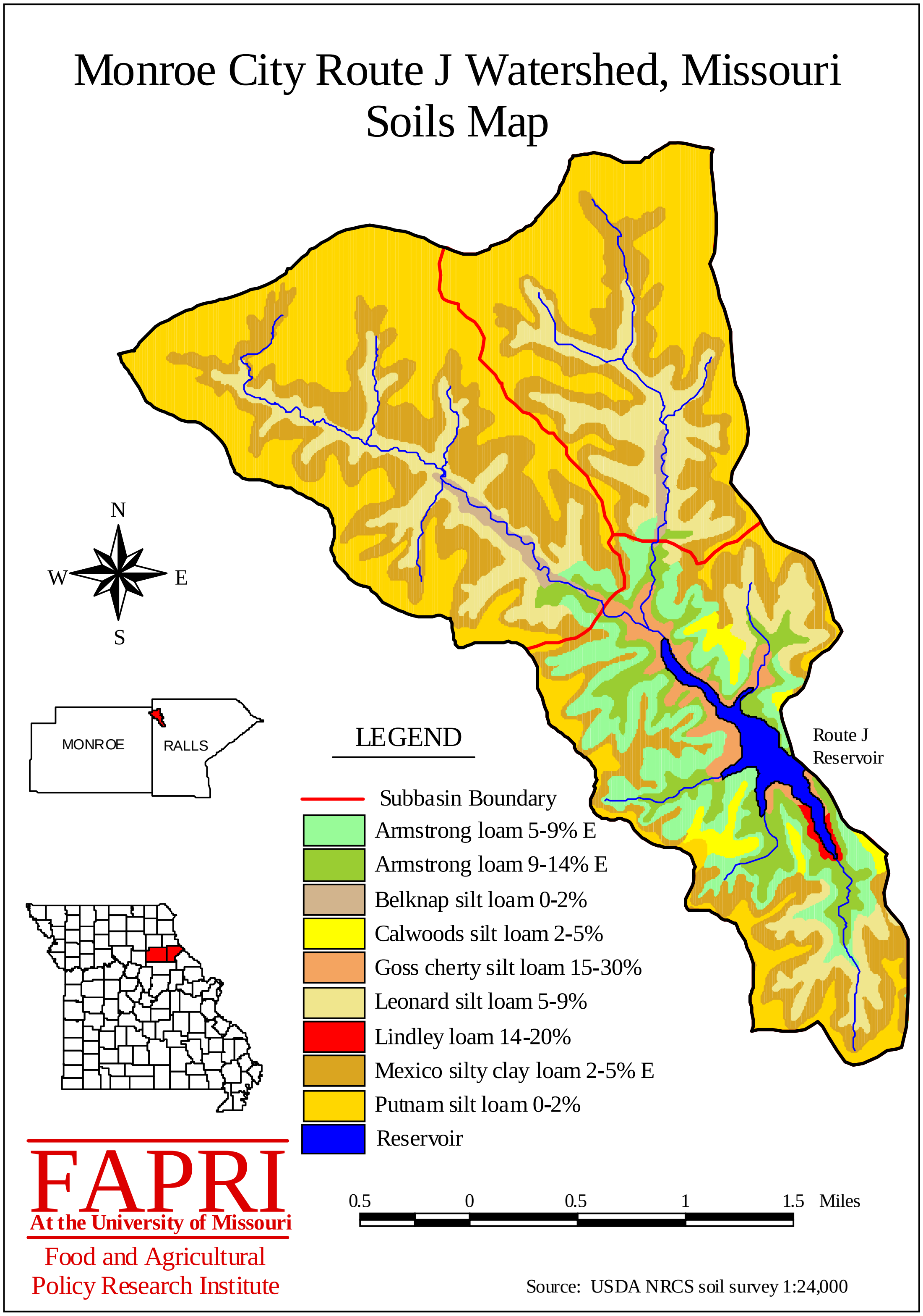

Figure 3. Soils distribution in the Monroe City Route J Watershed.

Table 2. Soil distribution in the Monroe City Route J Watershed.

Soil Map Unit	*% of Watershed*
Armstrong loam, 9-14% slopes, eroded	6
Armstrong loam, 5-9% slopes, eroded	9
Goss cherty silt loam, 15-30% slopes	2
Leonard silt loam, 5-9% slopes	14
Mexico silty clay loam, 2-5% slopes, eroded	28
Putnam silt loam, 0-2% slopes	37
Minor soil map units	4
Total	100

Crop History and Management

Crop history data was collected from Natural Resources Conservation Service (NRCS) Field Office records in New London for the years 1993 through 1997 to determine the acreage planted in each crop (Table 3), and the typical crop rotation patterns within the watershed. Five different crop rotations were determined to be the predominant rotation patterns in the area:

1. Corn-soybean (C-B)
2. Corn-soybean-soybean-wheat (C-B-B-W)
3. Corn-soybean-wheat-soybean (C-B-W-B)
4. Corn-soybean-wheat (C-B-W)
5. Corn-soybean-soybean-wheat-soybean (C-B-B-W-B)

Table 3. Major crop acreage and percentage of cropland in the Monroe City Route J Watershed.

Crop	*Acreage*	*% of Cropland*
Corn (including Milo)	1105	34
Soybeans	1520	46
Wheat	639	20
Total	3264	100

Rotation/soil associations and crop management information (e.g., application and planting dates) were obtained from NRCS personnel and the farm panel (Lansford et al. 1999). Virtually all of the corn is mulch-tilled (20-30% residue left after planting), while 100% of the wheat and 50% of the soybean acreage is no-till. The main herbicides used on the corn acreage during the crop history period were Extrazine™™, which contains atrazine and cyanazine, and Aatrex Nine-O™™, which contains atrazine. Application rates described by the farm panel indicate an average atrazine application of 1.54 lbs ai/ac. Appendix A details the crop management for each rotation used in the baseline model.

METHODOLOGY

Watershed Model

A baseline environmental simulation model depicting conditions as of 1997 was developed using the Soil and Water Assessment Tool (SWAT). SWAT is a physically based, watershed-scale, continuous daily time-step computer model developed by Arnold et al. (1998). The model simulates the water, chemical and sediment movement within a watershed that results from the interaction of weather, soil types, crop growth, and agricultural management. Simulations were run for 20 years, taking the last 10 years of output for analysis.

For modeling purposes, the Route J watershed was divided into 3 subbasins on the basis of streamflow patterns and similarities in soil types (Figure 4). This allows identification of potential "hot spots" for pesticide and/or sediment losses that can in turn be used to focus management efforts.

Data Collection

SWAT requires specific information about the weather, soil properties, topography, vegetative cover, and land management practices occurring within the watershed. Table 4 lists the input data gathered for the simulation and their respective sources.

Table 4. Sources of input data used in the Route J Watershed analysis.

Input Data	*Source*
Daily Temperature (maximum and minimum) and Precipitation values	Steffenville, MO station provided by the Missouri Climate Center, University of Missouri
Stream Channel (width, depth, and roughness coefficients)	Field survey by Lynn King Heidenreich, FAPRI
Land Use (type, spatial location, and extent)	1992 Landsat TM scenes processed by Missouri Resource Assessment Partnership (MoRAP) and Lincoln University
Soils (type, chemical properties, slope, spatial location, and extent)	USDA/NRCS 1:24,000 SSURGO digital soil surveys
	Pedon Database, USDA/NRCS Soil Survey Laboratory, Lincoln, NE
Crop Management	USDA/NRCS
	Farm Panel

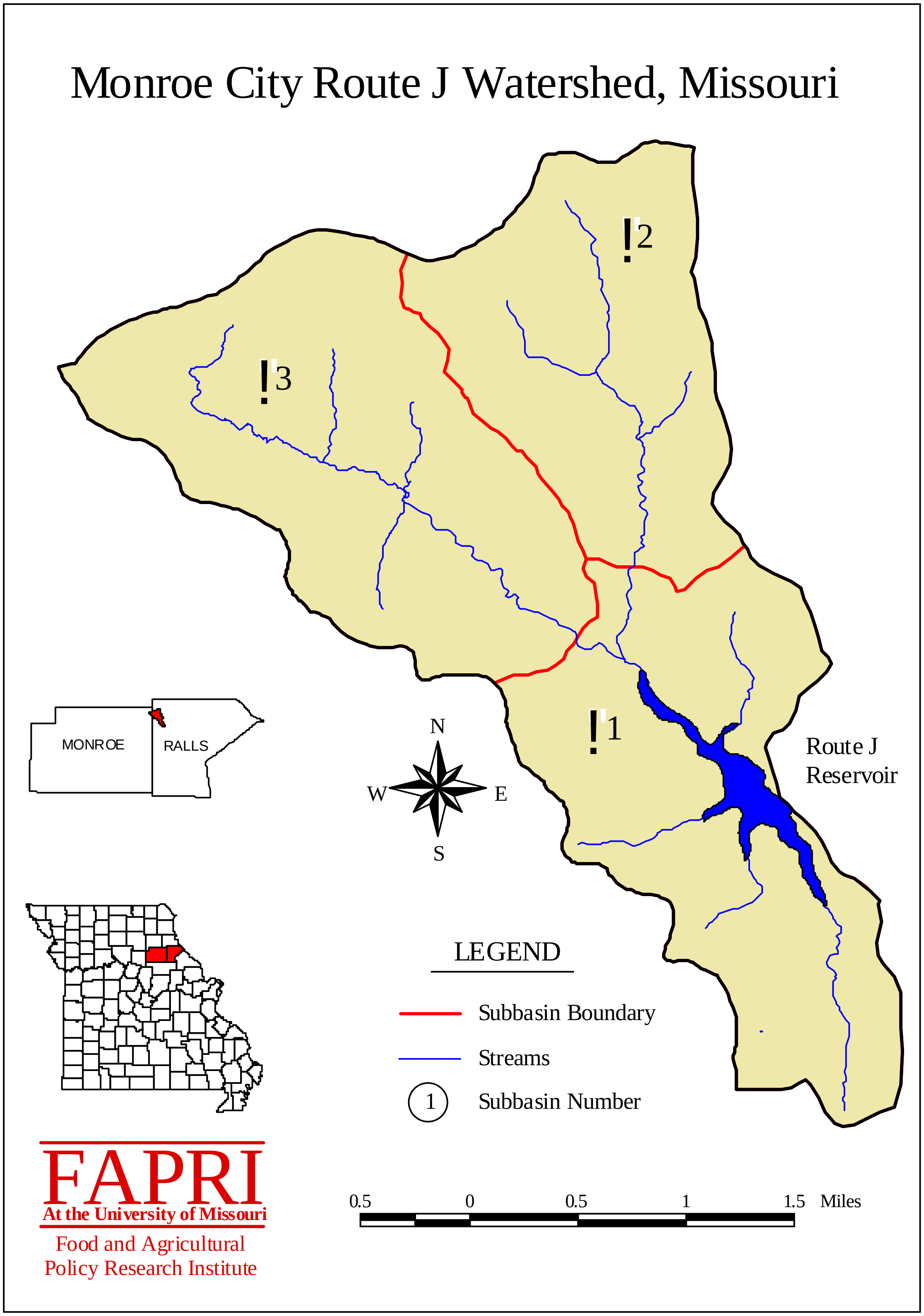

Figure 4. Subbasin delineation in the Monroe City Route J Watershed.

Model Assumptions

Several assumptions were made about the watershed in order to facilitate the modeling process. These assumptions, which have an impact on the outcome and interpretation of the model, are listed below.

1. Temperature and rainfall data from an official weather station in Steffenville, Missouri are representative of the daily weather in the watershed. Steffenville was the closest station at approximately 22 miles north-northwest of Monroe City.

2. Crop management operations (tillage, pesticide application, nutrient application, planting and harvest) are defined by fixed dates. The model does not modify these dates based on precipitation events or temperature.

3. Crop management operations are consistent across the watershed (i.e., they do not vary according to soil type, soil slope, or producer preference).

4. Baseline crop management operations are representative of the conditions in the watershed at the time of the MCL violation for atrazine.

Model Validation

For validation purposes, calculated outputs of the baseline model including surface runoff, crop yields, sediment yield, and chemical movement were compared to available measured values.

Surface Runoff

The Route J Watershed is not gauged and no U.S. Geological Survey gauges exist in nearby, comparably-sized watersheds. However, the Goodwater Creek watershed, a USDA Management Systems Evaluation Area (MSEA) study site, provides data to guide validation. Goodwater Creek's croplands lie on claypan soils, and estimates of surface runoff from croplands were approximately 30% of annual precipitation during the 2 years of the study (Smith et al. 1999). Depending on crop management and soil slope, calculated runoff values for cropland in the Route J Watershed ranged from 15 to 34% of annual precipitation with a 10-year average of 21%. Calculated runoff for all cover types in the Route J watershed was 7.1 inches per year, or 19% of average annual precipitation over the 10-year simulation.

Crop Yield

Crop yields calculated by the model were compared to those reported to the Missouri Agricultural Statistics Service for Ralls County. Table 5 lists the average yields calculated by SWAT and the average reported yields during the simulated period. SWAT does not capture pest damage or weed competition, which tend to depress yields.

Sediment Yield

Annual sediment deposit in the Route J Reservoir was estimated by NRCS at approximately 11 acre-feet/year (Monroe City Water Resources and Steering Committee

Table 5. Comparison of measured and calculated average crop yields (1989 – 1998).

Crop	*Average County Yield (bu/ac)*	*Average SWAT Yield (bu/ac)*	*Percent Difference*
Corn	104.4	104.6	0.2
Soybean	34.5	41.4	19.9
Wheat	44.7	47.3	5.7

1998). Sources of this sediment included sheet and rill erosion, ephemeral gullies, classical gullies, road ditches, and streambanks. Sheet and rill erosion on croplands was estimated by NRCS to account for approximately 4.5 acre-feet/year or 40% of the total (Rob Cheshier, NRCS Geologist, pers. comm.). Annual sediment deposit calculated by SWAT ranged from 0.4 to 2.4 acre-feet over the 10-year simulation period, with an average of 1.1 acre-feet/year (Figure 5). Because the NRCS and SWAT estimates account for different factors affecting erosion, this comparison should be viewed only as an indication of the validity of model results.

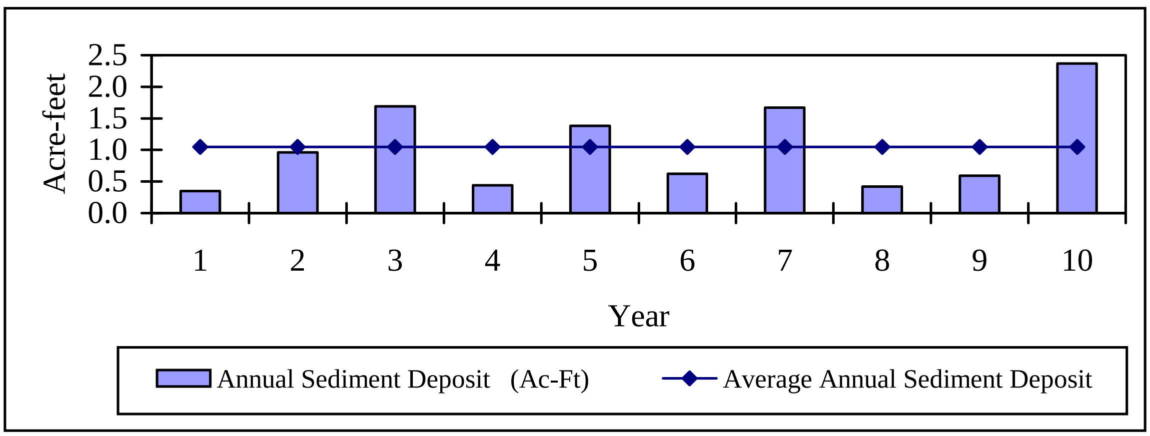

Figure 5. Calculated annual sediment deposit in Route J Reservoir

Atrazine Loss

Annual atrazine losses calculated by the model ranged from 2.3% to 24.7% of the total applied, with an average loss of 14.8% (Figure 6). In comparison, measured losses from the MSEA project in Goodwater Creek ranged from 0.3% to 19.5% (Smith et al. 1999). Timing of application with respect to precipitation affects the magnitude of losses. Approximately 98% of the reservoir loadings occurred in May, the month of application and the month of highest rainfall and runoff (Figure 7). Since the model does not adjust application dates to account for rain, calculated losses are expected to be higher in years with wet planting seasons. Still, the average annual loss for the 10-year simulation is within the range of measured values reported by Smith et al.

Atrazine loss rates calculated by SWAT give an estimate of the potential impairment of a water supply. However, the model does not account for lake processes such as stratification and turnover. These processes influence atrazine concentrations measured at the lake. Thus, concentrations reported by the model cannot be directly compared to data from water sampling programs.

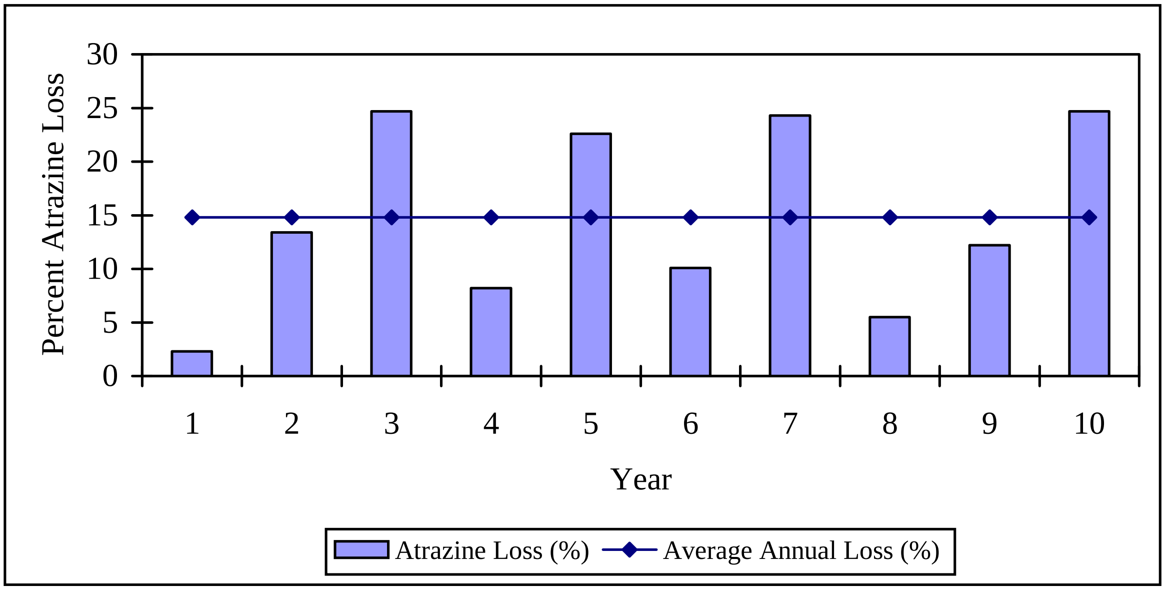

Figure 6. Calculated atrazine loss in the Route J watershed as a percentage of applied.

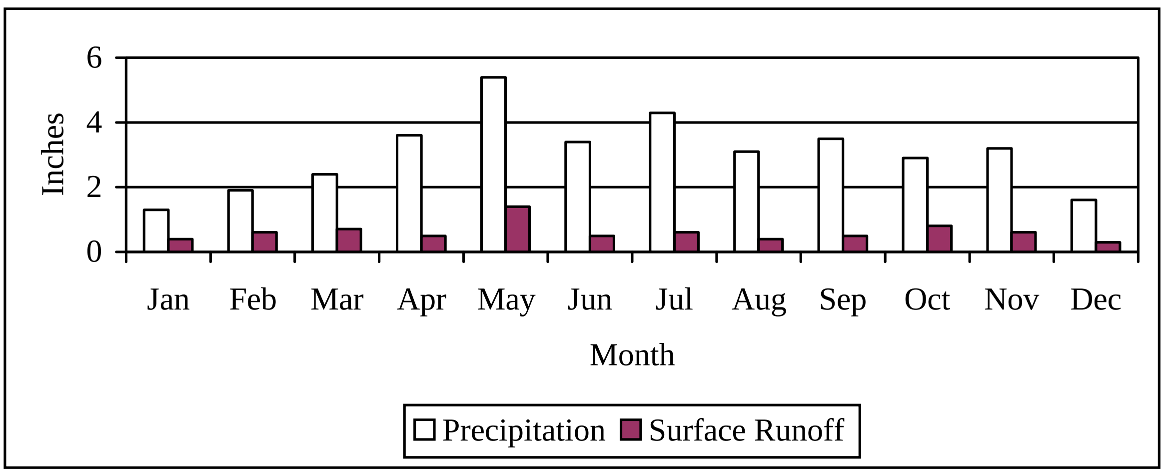

Figure 7. Average measured monthly precipitation and calculated runoff.

Crop Management Alternatives

Four alternative simulations were constructed for comparison to the Baseline: a baseline update and 3 alternative herbicide regimes. NRCS personnel supplied data for the alternatives. Like the Baseline, the alternative simulations were run for 20 years, taking the last 10 years of output for analysis. Thus, the relative impacts of the alternative managements on water, sediment, and chemical movements can be compared to baseline managements to evaluate their environmental effects.

Alternative 1 – Baseline Update

Between the 1997 and 1999 growing seasons, falling wheat prices induced a shift in crop acreages within the watershed (Table 6). Although crop managements (planting dates, application dates and rates, etc.) did not change relative to the Baseline, reduced wheat acres necessitated revisions to the crop rotations (Appendix B). Rotations used for alternative 1 were:

1. Corn-soybean (C-B)
2. Corn-soybean-soybean (C-B-B)
3. Corn-soybean-wheat-soybean (C-B-W-B)
4. Corn-soybean-wheat (C-B-W)

Table 6. Revised acreage and percentage of crops in the Monroe City Route J Watershed.

Crop Name	*Acreage*	*% of Cropland*	*% Change from Baseline*
Corn (including Milo)	1338	41	21
Soybeans	1730	53	14
Wheat	196	6	-69
Total	3264	100	--

Alternatives 2, 3 & 4 – Herbicide Alternatives

Alternative herbicide regimes were taken from the Atrazine Abatement and Management Project, a cooperative effort between the local steering committee, NRCS, University of Missouri Outreach and Extension, MDNR, and chemical manufacturers. The primary goal of the project was to reduce atrazine runoff without reducing the effectiveness of weed control. The project, which began with the 1999 growing season and will continue in 2000, limits atrazine applications within the watershed to approximately 1 lb ai/ac applied post-emergence as part of a planned two-pass system. Economic incentives offered by involved government agencies and chemical donations from manufacturers helped offset the increased costs and risks associated with a two-pass program.

A variety of chemical combinations were offered to producers within the watershed. The alternatives simulated here represent the three most common as judged by the total acres under each system in 1999 (Appendix C). Alternative 2 was planned as a two-pass system, but weed pressure in 1999 did not warrant a second pass. The alternative herbicide regimes were simulated using the rotations and crop proportions associated with Alternative 1 (i.e., the updated baseline).

RESULTS AND DISCUSSION

Alternative 1

Alternative 1 was constructed to reflect the change in crop proportions and rotations that occurred in the watershed over the course of the project. This shift resulted from falling wheat prices, which rendered the crop unprofitable. In the baseline model, wheat was planted on all cropland soils within each subbasin. Under Alternative 1, remaining wheat acreage was planted primarily on higher sloped soils (i.e., >1%) to maintain the benefits of reduced soil erosion that wheat provides (Figure 8). Removal of wheat from crop rotations resulted in increased corn and bean acreages on all soils. Thus, we expected to see corresponding increases in sediment yield and atrazine movement from baseline conditions.

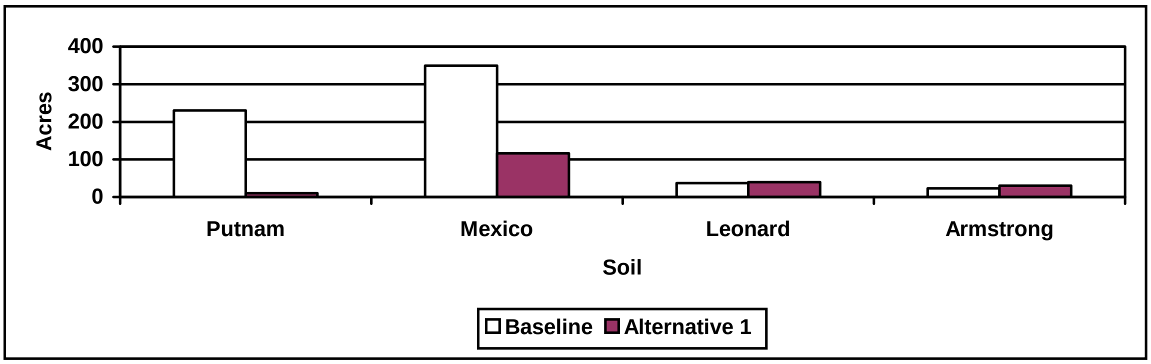

Figure 8. Wheat acreages in the Route J Watershed in the Baseline and Alternative 1.

Sediment

As expected, all measures of sediment movement increased in Alternative 1 relative to the Baseline. Calculated average cropland erosion (i.e., sediment movement in the field based on United Soil Loss Equations) increased from 1.8 to 2.4 tons/acre, an increase of 33%. Since crop rotations did not remain constant, direct comparisons cannot be made. However, the percentage of cropland acres in excess of the soil loss tolerance factor (T), as judged from Land Use and Treatment worksheets, increased from 31.4 % under the Baseline to 44.4% under Alternative 1, as most of the increase in corn and soybean acreage occurred on higher sloped soils. As with the watershed, each subbasin showed increases in calculated erosion rates proportional to the drop in wheat acreage within each subbasin (Figure 9).

Sediment yield (i.e., sediment which leaves the field and reaches the stream) also increased in Alternative 1, but to a lesser degree than erosion since the model allows some eroded sediments to settle in the field and streambed. Calculated sediment deposition in the reservoir increased from 1887 tons/year (approximately 1.1 acre-feet) in the Baseline to 2209 tons/year (approximately 1.2 acre-feet) in Alternative 1, an increase of 17%. These values represent sheet and rill erosion from all land uses in the watershed, and include deposition of sediment in the streams. Although Alternative 1 increased reservoir deposition in all months of the year, larger differences occurred in October through April, presumably due to the absence of wheat on the ground (Figure 10).

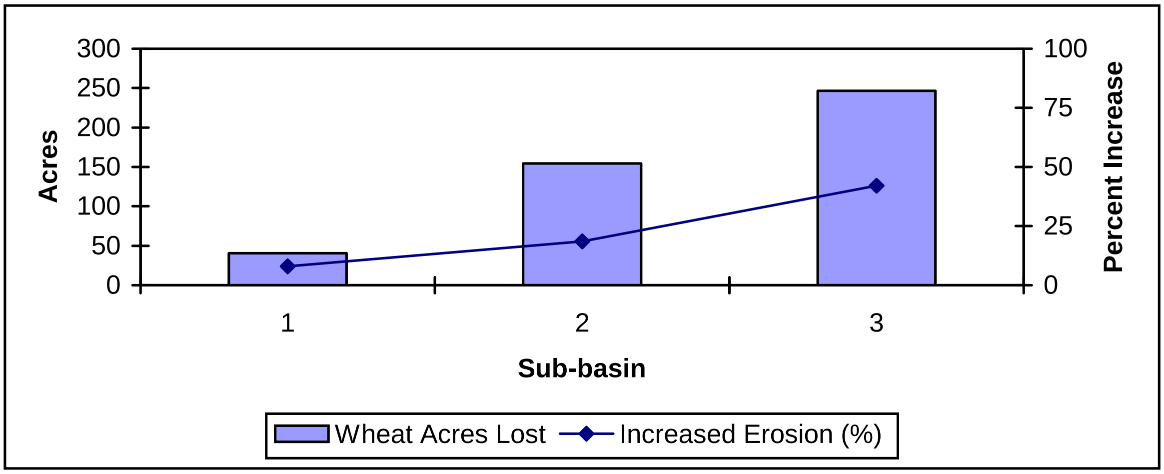

Figure 9. Changes in wheat acreages and calculated erosion rates for subbasins in the Route J Watershed.

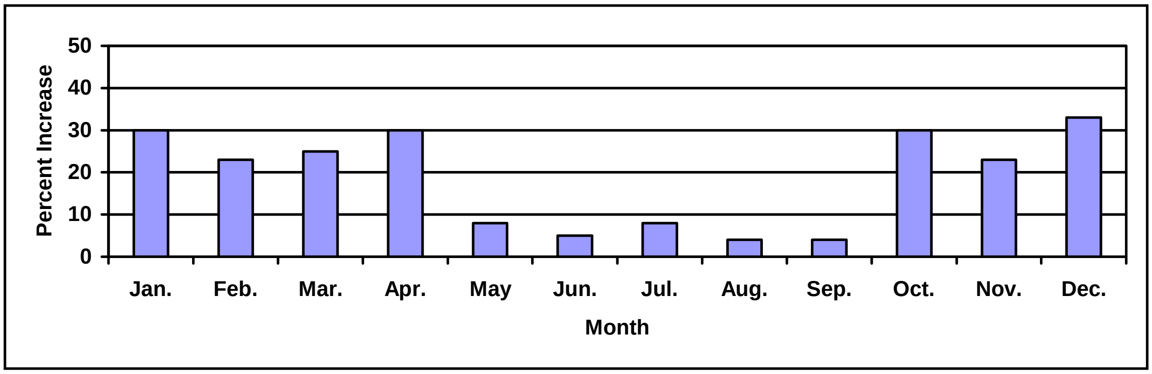

Figure 10. Change in average monthly sediment deposition in the Route J Reservoir from the Baseline to Alternative 1.

Atrazine Loss

An atrazine application rate of 1.54 lbs ai/acre was assumed for all corn acres in the watershed in both the Baseline and Alternative 1 simulations. Corn acreage varied across the subbasins in each simulation (Table 7), with Alternative 1 representing a 22% overall increase in both corn acreage and total atrazine application. Intuitively, these increases should yield equivalent increases in atrazine loading to the reservoir; however, a smaller than expected increase occurred in reservoir loading, with loss rates (percent of applied) actually falling below Baseline levels.

Table 7. Annual corn acreage and atrazine application in Route J Watershed subbasins.

Subbasin	*Baseline*		*Alternative 1*		*Percent Change*
	Corn Acres	*Total Atrazine Applied (lbs/yr)*	*Corn Acres*	*Total Atrazine Applied (lbs/yr)*	
1	226.7	349	288.1	444	27
2	346.5	534	506.4	780	46
3	531.6	819	548.0	844	3
Total	1104.8	1701	1342.5	2067	22

Although atrazine loading in the reservoir increased under Alternative 1, loadings did not increase in every subbasin (Table 8). Annual atrazine loss rates decreased under Alternative 1 in all subbasins and in the watershed as a whole. As a result, the 22% increase in atrazine application translated into only an 8% increase in reservoir loadings.

Table 8. Average annual atrazine loadings and loss rates in Route J Watershed subbasins.

Subbasin	*Annual Load (lbs)*			*Loss (% of applied)*		
	Baseline	*Alternative 1*	*Percent Change*	*Baseline*	*Alternative 1*	*Percent Change*
1	53	66	24	15.3	14.9	-3
2	80	105	31	15.0	13.4	-11
3	125	108	-13	15.2	12.8	-16
Reservoir	258	279	8	14.8	13.2	-11

Several confounding factors may be interacting to produce these results. First is the hydrology of the claypan soils (i.e., Putnam, Mexico, and Leonard), which underlie 97% of the cropland in the watershed. These soils have a restrictive layer that inhibits percolation. In the case of Putnam soils, the combination of low slope and a shallow, dense claypan may cause water to pool on the surface rather than moving through the soil profile. The Putnam soil map unit experiences more runoff and less lateral flow than the Mexico or Leonard soil map units (Figures 11 and 12), and investigations at the farm level suggested that Putnam soils had higher rates of atrazine runoff than Mexico or Leonard soils (Lansford et al. 1999). Lansford et al. reasoned that atrazine is very water soluble and might be concentrating at high levels in the pools before runoff occurs. Under Alternative 1 corn acreage increased disproportionately on higher sloped soils (Table 9), where infiltration is easier and atrazine runoff is lower (Lansford et al. 1999). Some of the increased atrazine application may have moved into the soil profile rather than with runoff, thereby reducing atrazine loss rates.

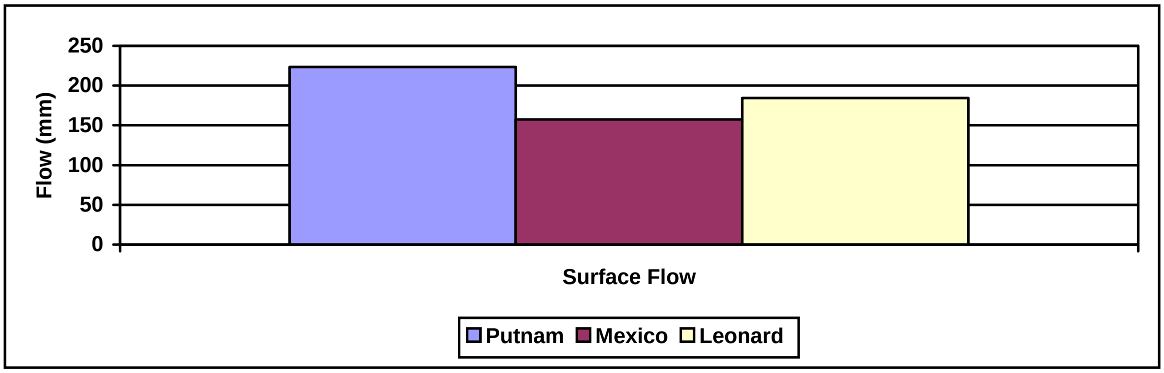

Figure 11. Runoff rates between cropped claypan soils in the Route J Watershed.

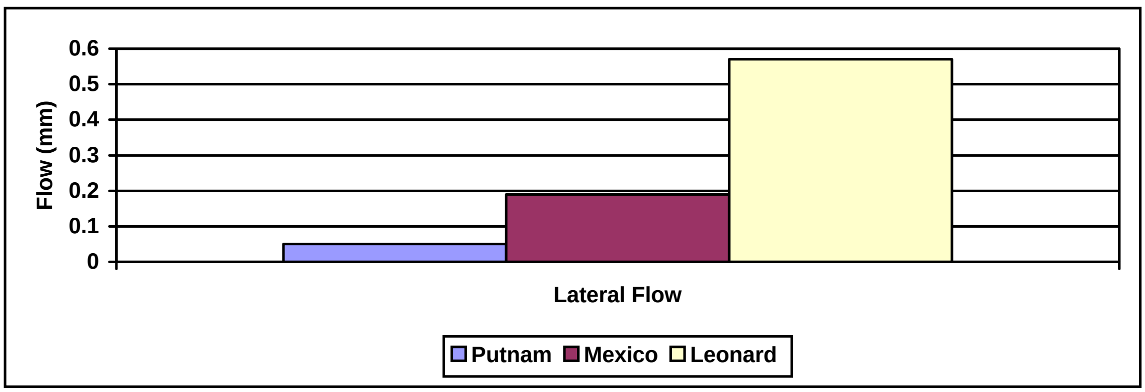

Figure 12. Lateral flow rates between cropped claypan soils in the Route J Watershed.

Table 9. Changes in corn acreage between the Baseline and Alternative 1 by soil map unit.

Soil Map Unit	*Modeled Slope (%)*	*Baseline (acres)*	*Alternative 1 (acres)*	*Percent Increase*
Putnam	1	695.9	792.0	14
Mexico, Leonard, and Armstrong	3, 5, & 7	409.2	550.5	35

The hydrology of the claypan soils can explain why the increase in reservoir loadings is less than the 22% increase in application. By itself, though, it cannot explain an increase in loadings of less than 14% (the increase on Putnam soils in Table 9). Another factor that may be affecting atrazine runoff is the distribution of the crops in the revised rotations. Removing wheat acreage from the mix of crops had the general effect of eliminating longer rotations, thereby increasing the frequency of corn plantings on a given field. This generalization holds true in subbasins 1 and 2; however, in subbasin 3 it holds only for rotations on Mexico soils. On Putnam soils, the only other cropped soil in subbasin 3, acreage also moved out of a corn-soybean rotation and into a corn-soybean-soybean rotation, reducing the frequency of corn acres planted (Table 10). Given that subbasin 3 saw only a slight increase in corn acreage under Alternative 1 (see Table 7), the shift to longer rotations on Putnam combined with the increased corn acreage on higher sloped soils may account for the drop in atrazine loadings from this subbasin (see Table 8).

Table 10. Annual average corn acreage by subbasin and soil type under the Baseline and Alternative 1 scenarios in the Route J Watershed.

Soils	*Baseline (acres)*			*Alternative 1 (acres)*		
	Sub 1	*Sub 2*	*Sub 3*	*Sub 1*	*Sub 2*	*Sub 3*
Putnam	80	249	367	89	343	359
Mexico	115	69	165	155	135	189
Leonard	10	28	0	13	28	0
Armstrong	23	0	0	31	0	0

Summary

The reduction of wheat acres planted within the watershed has negative environmental consequences with respect to sediment movement and atrazine runoff. Model results indicate that average rates of erosion (movement within the field) and sediment yield (movement to the stream) increase under Alternative 1. This results in more cropland being out of compliance with soil conservation goals and more sediment reaching the reservoir. The model only tracks sheet and rill erosion; other sources exist, including gullies, road ditches, and shorelines, whose impacts on the reservoir were not assessed. However, increased sedimentation from any source negatively impacts water quality in the reservoir.

Removing wheat from crop rotations increased corn and soybean acreages. The increase in corn acreage resulted in more atrazine applied in the watershed, which translated into increased reservoir loadings. However, this increase was not a 1:1 ratio as expected. Previous research has shown that atrazine loss is greater on clay soils than on fine textured or sandy soils (Baker and Laflen 1983; Donald et al. 1998). Model results suggest that variability exists within clay soils, with flatter soils (i.e., Putnam series) losing more atrazine than soils with higher slopes and less dense claypans. On soils with steeper slopes, where most of the wheat was lost, infiltration is easier and more atrazine may bind with soil particles, thus reducing atrazine loss rates. Average annual atrazine loadings in the reservoir increased less than expected under Alternative 1 primarily because they fell relative to the baseline in subbasin 3 due to its soil-crop combinations. Subbasin 3 contains 47% of the cropland within the watershed and so has the largest impact on the reservoir.

Herbicide Alternatives

Alternatives 2, 3, and 4 were constructed to model the effect of atrazine-reducing herbicide regimes on atrazine loadings in the Route J Reservoir. As noted previously, the alternative herbicide regimes were taken from the Atrazine Abatement and Management

Project and represent the 3 most commonly adopted managements as determined by the total acres treated in 1999 (Gary Noel, NRCS Resource Conservationist, pers. comm.). Though planned as a two-pass system, Alternative 2 had only one pass due to a lack of weed pressure in 1999, with 1 lb ai/ac of atrazine applied post-emergence in mid-May. Alternatives 3 and 4 were carried out as two-pass systems with atrazine applied post-emergence during the second pass in June at rates of 1.06 lbs ai/ac and 1 lb ai/ac, respectively. These 3 alternatives used the same crop configurations as Alternative 1.

Sediment

Apart from differences in pesticide applications on cornfields, the herbicide alternatives also differed from the Baseline and Alternative 1 in that the April fertilizer application was moved from the 1st to the 15th (Appendix C). This application was accompanied by a tillage operation to incorporate the fertilizer into the soil. A change in tillage timing relative to rainfall potentially can affect sediment movement. However, all measures of erosion and sediment yield calculated by the model for the herbicide alternatives were within 1% of the values resulting from Alternative 1.

Atrazine Loss

Alternatives 2, 3, and 4 reduced atrazine application rates from the Baseline by 35%, 32%, and 35%, respectively. However, reservoir loadings were reduced relative to the Baseline by 39%, 79% and 80%, respectively (Figure 13). The reason for the difference is primarily a function of timing.

Alternative 2 reduces application rates by 35%, but achieves a reduction of 39% in reservoir loadings by shifting the atrazine application from May 5 to May 15, which was slightly drier. Alternatives 3 and 4 reduce application rates by 32% and 35%, respectively, but achieve approximately an 80% reduction in reservoir loadings by delaying atrazine application until June, which averaged less rainfall and runoff than May.

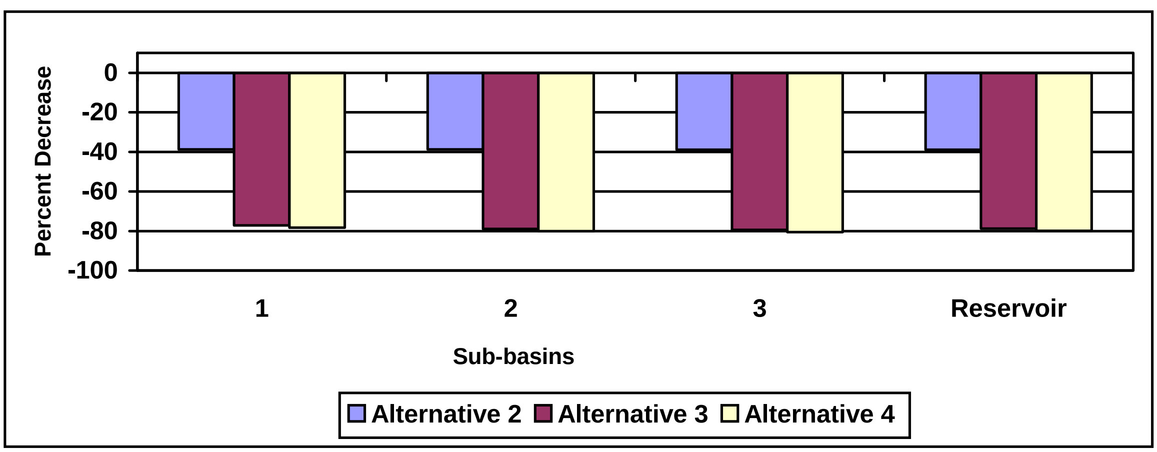

Figure 13. Changes in atrazine loading in the reservoir relative to the Baseline resulting from herbicide management alternatives in the Route J Watershed.

The reductions in reservoir loadings achieved by the alternatives result from less atrazine moving with runoff. However, atrazine, like any other pesticide, can suffer a number of different fates once it has been sprayed. Table 11 lists the fates tracked by SWAT and the percentage of applied atrazine meeting those fates under each management scenario. The timing of application impacted potential fates, with later applications experiencing less atrazine runoff, more degradation, and more atrazine remaining in the soil profile. These results are produced by the combination of rainfall timing and varying degradation rates for atrazine.

Table 11. The fate of atrazine (percent of applied) under each model scenario.

Fate		*Alternative*			
	Baseline	*1*	*2*	*3*	*4*
Moved with water	15	13	12	4	4
Moved with sediment	0	0	0	0	0
Remained in soil	3	3	4	6	6
Decayed	82	84	84	90	90
Total	100	100	100	100	100

Atrazine decays at varying rates depending on where it is in the environment. The half-life (i.e., the amount of time needed for half the chemical to breakdown) is only 5 days on the leaves of plants, but on the soil surface it is 60 days (Ribaudo and Bouzaher 1994). If oxygen is lacking in the soil profile, the half-life could be as long as 660 days. Atrazine tends to degrade slowest in the water column (e.g., reservoirs) where the half-life can be as long as 2 years.

The timing of application in relation to rainfall affects where atrazine ends up in the environment and, thus, the rate at which it decays. More atrazine moves with water in May (Baseline, Alternatives 1 and 2) than in June (Alternatives 3 and 4) due to a higher quantity of precipitation. Due to its water solubility, almost no atrazine moves with sediment (i.e., erosion). Less water means more atrazine persists in the soil profile, but SWAT does not indicate how the herbicide is distributed among the layers. This distribution could impact herbicide effectiveness and water quality.

May applications of atrazine had slower decay rates due to the longer half-life of atrazine on soil and higher quantities in runoff where SWAT does not calculate degradation. Higher decay rates for the June applications reflect less moving with runoff and more being applied to leaves. Further study will be needed to examine weed control effectiveness of reduced atrazine applications and two-pass systems.

Summary

Herbicide movements depend on a variety of factors, including tillage, soil moisture levels, timing of application relative to precipitation events, intensity and duration of rainfall, and total amount of precipitation (Smith et al. 1999). Rainfall quantity and intensity are typically highest in May. Model results suggest that by pushing application dates back, farmers in the watershed could avoid the worst of these events in most years. Also, increased plant growth leads to increased evapotranspiration, thereby reducing soil moisture levels and the potential for runoff. However, increased plant growth leads to increased leaf interception of spray-applied atrazine. Atrazine applied to foliage degrades 12 times faster than when applied to the soil. This degradation may decrease the effectiveness of the herbicide relative to the baseline, as well as reduce loading in the runoff. Although the herbicide alternatives were judged effective in 1999, weed pressure was low and may not have been indicative of average conditions.

APPENDIX A

Baseline Crop Management Practices

Corn – Soybean (CB1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean (CB2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean – Soybean – Wheat (CBBW1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Corn – Soybean – Soybean – Wheat – Soybean (CBBWB2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean – Wheat (CBW1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Corn – Soybean – Wheat (CBW2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Corn – Soybean – Wheat – Soybean (CBWB2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

APPENDIX B

Revised Crop Management Practices
(Alternatives 1-4)

Corn management practices listed in Appendix B are for Alternative 1 only. Corn managements for Alternatives 2-4 are listed in Appendix C. The rest of the rotations remain unchanged between the alternatives.

Corn – Soybean (CB1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean (CB2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean – Soybean (CBB1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Corn – Soybean – Wheat (CBW1)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Corn – Soybean – Wheat (CBW2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Corn – Soybean – Wheat – Soybean (CBWB2)

Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/01	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/01	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/05	Pesticide	Extrazine™ @ 3 lbs/ac
		Aatrex Nine-O™ @ 1 lb/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Soybean (no-till)

05/10	Fertilizer	Dry fertilizer 0 N, 40 P, and 60 K lbs/ac
05/10	Pesticide	Roundup Ultra™ @ 1 qt/ac
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

Wheat (no-till)

10/12	Fertilizer	Dry fertilizer 30 N, 30 P, and 15 K lbs/ac
10/12	Plant (drill)	Wheat
03/15	Fertilizer	Dry fertilizer 50 N, 0 P, and 0 K lbs/ac
06/25	Harvest	

Soybean (minimum till)

11/01	Tillage	Chisel-disk
05/11	Tillage	Field cultivate
05/12	Tillage	Field cultivate
05/12	Plant	Roundup Ready™ Soybeans
06/12	Pesticide	Roundup Ultra™ @ 1 qt/ac
10/01	Harvest	

APPENDIX C

Alternative Corn Herbicide Regimes
(Replaces corn managements in Alternative 1)

Alternative 2
Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/15	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/15	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/15	Pesticide	Axiom™ @ 19 oz/ac
		Atrazine @ 1 qt/ac
		Pounce™ @ 4 oz/ac
10/20	Harvest	

Alternative 3
Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/15	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/15	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Liberty Link™ Corn
05/08	Pesticide	Dual II Magnum™ @ 13 oz/ac
		Pounce™ @ 4 oz/ac
06/10	Pesticide	Liberty ATZ™ @ 32 oz/ac
		Atrazine @ 0.23 qt/ac
10/20	Harvest	

Alternative 4
Corn (minimum till)

03/25	Fertilizer	Anhydrous ammonia @ 150 lbs/ac
04/15	Fertilizer	Dry fertilizer 30 N, 80 P, and 80 K lbs/ac
04/15	Tillage	Field cultivate
05/01	Tillage	Field cultivate
05/01	Plant	Corn
05/08	Pesticide	Frontier™ @ 23.5 oz/ac
		Pounce™ @ 4 oz/ac
06/10	Pesticide	Atrazine @ 1 qt/ac
		Clarity™ @ 11 oz/ac
10/20	Harvest	

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