Oklahoma Water Research Institute
Annual Technical Report
FY 2002

Introduction

The Environmental Institute at Oklahoma State University has as its mission to serve as a center for stimulation and promotion of interdisciplinary research, graduate education and public education relating to understanding, protecting, utilizing and sustaining the natural environment. The University Center for Water Research (UCWR) is an integral part of the Institutes research efforts and is responsible for developing and coordinating water research funded through two programs: Oklahoma Water Resources Research Institute (OWRRI) funded by the Department of the Interior through the U.S. Geological Survey and the Water Research Center, (WRC) funded by the State of Oklahoma. The primary objective of the UCWR is the promotion of research of water related issues that are not only of national and regional concern, but also address the needs of Oklahoma.

The federally supported Oklahoma Water Resources Research Institute is one of 54 Water Institutes created under Section 104 of the Water Resources Research Act. In Fiscal Year 2002, the $84,785 grant to the OWRRI was used to support four research projects and water research administration and development activities as well as the information transfer program. The three research projects supported by the OWRRI program are as follows:

Project 2002OK2B Springs in Peril: Have Changes in Groundwater Input Affected Oklahoma Springs? assessed the status of Oklahoma springs with respect to groundwater input, and the effects of altered groundwater flow rates on spring biota.

Project 2002OK3B Enhanced Life Cycle Assessment: Analysis to Guide Environmental Technology Implementation develops an enhanced life cycle assessment (ECLA) framework for the integrated assessment of the implementation of environmental technologies.

Project 2002OK4B Resistance Tomographic Imaging, Digital Mapping and Immersion Visualization of Evaporite Karst in Western Oklahoma investigates a novel and innovative procedure that combines electrical resistivity tomography (ERT), digital mapping and immersion visualization hardware and software to provide a digital image of subsurface conduit networks in a karst environment.

Project 2002OK6B Evaluating Cost Effective Technologies to Reduce Phosphorous Loading to Surface Waters in the Ozark Region develops methods that will aid watershed managers in the Ozark and similar regions to set and implement TMDLs in a cost effective manner.

Research Program

Springs in Peril: Have Changes in Groundwater Input Affected Oklahoma Springs?

Basic Information

Title:	Springs in Peril: Have Changes in Groundwater Input Affected Oklahoma Springs?
Project Number:	2002OK2B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Oklahoma 4th
Research Category:	Ground-water Flow and Transport
Focus Category:	, None, None
Descriptors:	invertabrate fauna, biomonitoring, temporal change, dewatering, springs, groundwater-surface water interactions,spring discharge, spring fauna, Oklahoma crayfish
Principal Investigators:	Elizabeth A. Bergey

Publication

Problem and Research Objectives

Problem. Groundwater is an extremely important commodity to Oklahoma, with heavy use by agriculture, industry, municipalities, and private landowners. Groundwater is also critical for wildlife and for maintaining the high-quality outdoors environment of Oklahoma, especially through the influence of groundwater on springs and on stream flows.

Springs, by definition, are the locations where groundwater emerges and becomes surface water. As a habitat, springs share the characteristics of both underground waters (nearly constant temperatures and water flow, and low oxygen concentration) and surface waters (light and algal growth, inputs of dead plant material, and the water-air interface which allows gas exchange and colonization by flying insects). Typically, springs have a characteristic fauna that may include certain fishes and a predominance of non-flying invertebrates, such as snails and flatworms.

The extensive use of groundwater in Oklahoma and surrounding states may reduce water levels in some Oklahoma aquifers, with consequent partial or complete dewatering of the associated springs. In fact, springs provide an excellent point to monitor quantitative and qualitative changes in groundwater resources. Such reduction in spring flows may adversely affect the plants and animals living in spring, especially those species that are spring specialists. The flow of streams associated with springs may also be adversely affected by groundwater use.

Recently, there have been two proposed large-scale water sales projects in Oklahoma. Although neither sale has gone through, both are still possible and these potential sales highlight the growing value of Oklahoma water. The first sale would involve water extracted from southeastern Oklahoma and sold to Texas. Although the sale would involve only surface stream flow, the interaction between streams and groundwater could also affect alluvial aquifers (= aquifers associated with streams and rivers).

The second proposed water sale would involve the direct extraction of groundwater from the Arbuckle-Simpson aquifer, a process that would almost certainly affect the springs and spring-fed streams in this area. These streams and springs are used by local municipalities and have very high recreational value.

Original objectives: This research will addresses (1) the flow status of springs in Oklahoma, and (2) the effects of altered flow rates on spring biota. Discharge data and invertebrate surveys from 50 springs collected in 1981-1982 (existing data from a previous OWRRI project; Matthews et al.1983) and in 2001-2002 (this project) are being used to assess changes in groundwater discharge into springs and indicate how any changes may affect the invertebrate fauna of springs.

Specific objectives of the project are:

A. Estimate the extent of groundwater flow changes into springs throughout Oklahoma.

B. Determine if changes in spring conditions over the past 20 years have affected spring invertebrate communities.
C. Determine whether some types or locations of springs are more susceptible to flow reduction than other springs.
D. Identify possible indicator species that either appear or disappear in flow-impacted springs.
E. Increase the knowledge base of the biodiversity and distribution of spring-dwelling invertebrates.
F. Train one graduate student to work on the springs of Oklahoma.
G. 'Re-use' data from the project by adding data to the OBS database, to be used, for example, in future research projects by external researchers.
H. Disseminate information and results in a final report, by developing a project website, presenting results at one or more meetings, and writing one manuscript.

Added objectives. In addition to sampling invertebrates at each spring, fish were collected, when present. Fish were collected in the 1981-1982 study and their inclusion in this study adds to the information gained about changes in the biota over the 20-year period. Fish were not included in the original proposal because there was insufficient time to obtain the required approval for research involving vertebrates by the University of Oklahoma. Approval has since been obtained.

Additionally, the study was expanded to include about 20 additional springs, with emphasis on sampling springs that were in areas underrepresented in the original 50 springs study. Also, because spring-owner questionnaires were found to be a good method of indicating possible flow changes over time, questionnaires were sent to a large number of spring owners.

Methodology

The study hinges on the comparison of two datasets of spring surveys, one collected in 1981-1982 and the other collected in 2001. In order to have comparable surveys, the methods used in the 2001 springs survey closely followed those of the previous survey. Descriptions of the methods used in the 1981-1982 surveys are found in the final project report (Matthews et al. 1983), manuscripts (Matthew et al. 1985), and in the field notes from the project.

Field sites. The 50 spring sites were originally selected because they had enough flow to be used as a water supply (with a few exceptions), were good sites for monitoring particular aquifers, and had landowner permission for privately owned sites. The 50 sites are located in 29 Oklahoma counties (Figure 1) and in 8 aquifers.

As in the earlier survey, springs were surveyed during the summer. Data and samples collected at each spring included:

- A description of the spring site. This description included a diagram of the spring, directions to re-locate the site, GPS readings, and information on local land use, alterations to the spring, and the vegetation in and near the spring.
- Measurement of several physical and chemical parameters: including, pH; water temperature; conductivity; water widths, depths, and velocities. Discharge (the quantity of water flow per time, as liters per second) was calculated from the last three variables.
- Sampling for aquatic invertebrates. Qualitative sampling followed the 1981-1982 sampling protocol and included dip-netting, picking organisms off stones, and collecting leaf packs, which were preserved and later searched for invertebrates in the laboratory. Additionally, 3 to 6 core samples (diameter = 10.2 cm) were collected at each site. Invertebrate samples were preserved in 70% ethyl alcohol.
- Sampling for fish. Springs were seined with a fine-meshed (3 mm openings) seine and representatives of each species caught were preserved in 10% formaldehyde. The majority of captured fish were released.

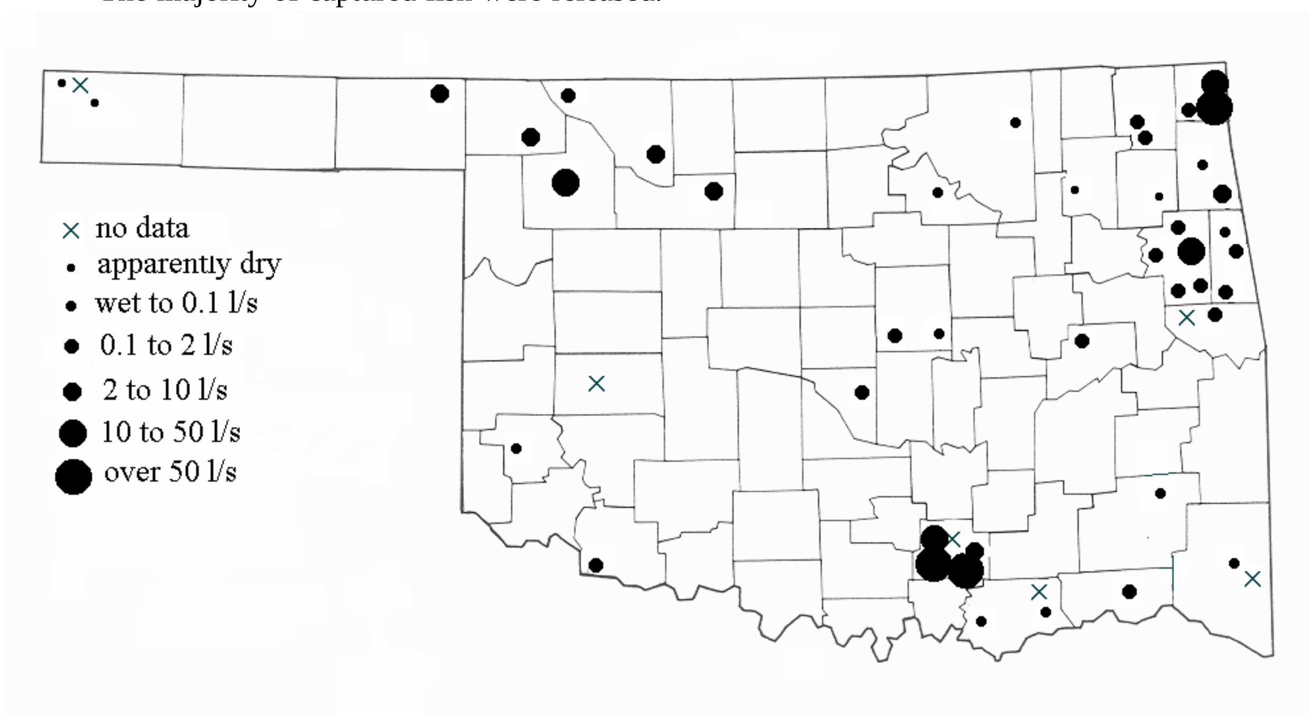

Figure 1. Location of the 50 springs sampled in 1981-82 and in 2001. The calculated discharge of each spring during the 2001 sampling is indicated by the symbol marking each spring (see legend).

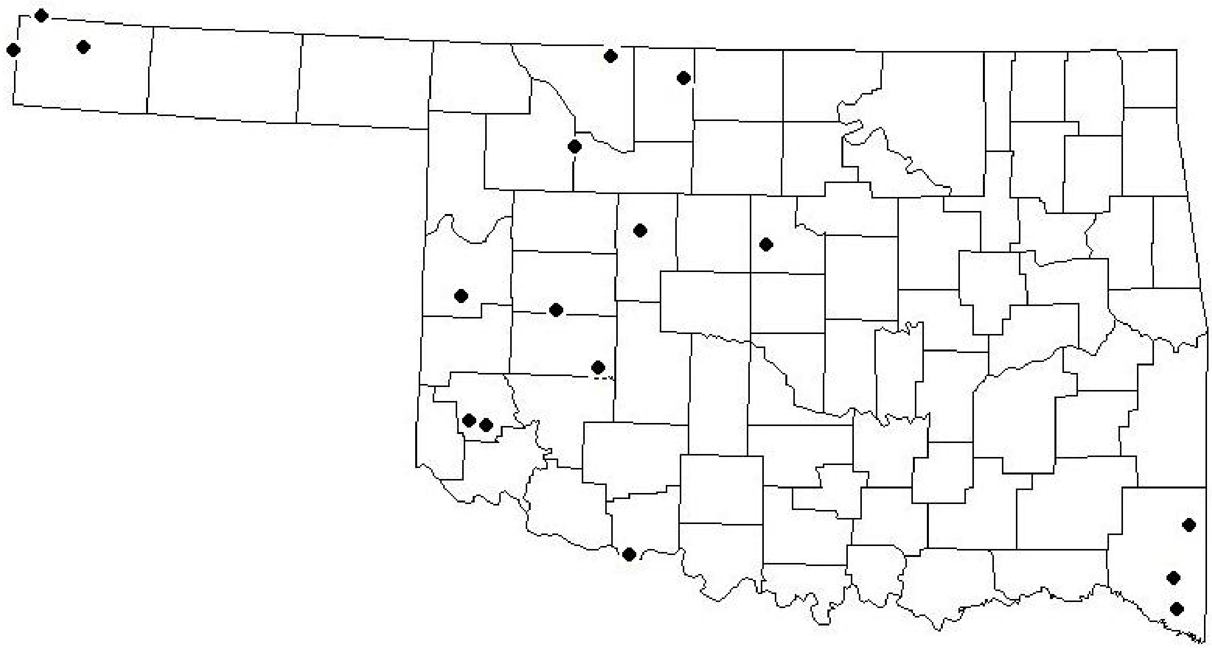

Figure 2. Location of 24 springs sampled in 2002-3. Some of the indicated locations are pairs of nearby springs.

Laboratory processing of biological samples. Fish samples were rinsed of formaldehyde, identified by Dr William Matthews (Curator of Fishes, Sam Noble Oklahoma Museum of Natural History, University of Oklahoma), and transferred to 70% ethyl alcohol. The fish samples will be deposited in the fish collection at the SNOMNH.

Invertebrates in the invertebrate samples have been sorted from the substrates and divided into broad taxonomic categories. Chironomids and crayfish are mostly identified and identification of other invertebrates is on going.

Questionnaires. Owner questionnaires were used to identify springs whose flow patterns had altered over time. Questionnaires were not completed for all sites, especially sites on public lands. Some questionnaires were of little value because owners had recently purchased the property or were not very familiar with their spring.

Principal Findings and Significance

1. Data on spring flows and changes in flow between 1981 and 2001 were reported in the 2001-2 annual report and are not repeated here.

2. Changes in spring flow over time were accessed for an additional 35 spring locations using questionnaires (no previous flow data were available for these locations). Of these springs, owners reported reductions in flow at 4 locations; no change was reported at 25 locations and owners did not know at 6 locations. Reductions in flow were associated

with increased groundwater use for irrigation (2 spring locations) and siltation of the spring (2 spring locations) by their owners.

3. The four springs with reduced flow were primarily alluvial springs (in Cimarron, Custer, Greer and Woods Counties), although the Greer and Woods County sites may have been associated with bedrock aquifers (Dog Creek Shale & Blaine Gypsum Aquifer and Cedar Hills Sandstone Aquifer, respectively). This supports last year's finding that alluvial aquifers sometimes have flow-impacted springs.

4. The 2001 results indicated reduced flows in springs associated with the Ogallala Aquifer in Cimarron County. A second map series (Johnson 1983) indicates that the sampled Cimarron County sites are alluvial springs and are independent of the Ogallala Aquifer and, hence, no Ogallala springs in the Oklahoma panhandle were sampled. In contrast, 2 Ogallala-source springs were sampled in Roger Mills County and no evidence of reduced spring flow was found. Hence, this study showed no evidence of impacted flow of Ogallala aquifers in Oklahoma (although only 2 Ogallala-associated springs were sampled).

5. Of the 50 springs sampled in 1981 and 2001, 20 contained fish, 36 contained crayfish, and 10 contained neither fish nor crayfish. Of the additional 24 springs sampled in 2002-3, only three contained fish and eight contained crayfish. The additional 24 springs tended to have lower flow and be more western that the original set of 50 springs.

6. The occurrences of fish and crayfish were associated with flow. In the 50-springs dataset, mean flow of fish-containing springs was 34.6 L/s, mean flow of crayfish-containing springs was 14.4 L/s, and mean flow of springs with neither fish nor crayfish was 1.0 L/s.

7. Fish composition in springs was associated with the particular aquifer (the source of water) and with the contained watershed (the conduit of fish travel).

8. Eleven species of crayfish were collected in springs in 2001-3. This amounts to 41% of the known non-cave-dwelling crayfish species in the state. Crayfish were not identified in the 1981-2 study, so comparisons with the earlier dataset are limited.

9. Although the fish faunas in most springs changed little over between 1981 and 2001, a few springs had large changes. These changes were either (1) a reduction in diversity (or apparent loss of fish) that resulted from erosion/siltation, spring drying, or flow diversion or, less commonly, (2) an increase in diversity because of impoundment of the spring and fish stocking and colonization of the resultant pond.

Significance.
No evidence of recent reduced flow was found for the majority of the approximately 70 springs included in the 2-year study. Most springs with apparent reduced flows were associated with various alluvial aquifers, the Trinity Aquifer, or the Vamoosa Aquifer.

Possible reasons for reductions in spring flows include local increases in groundwater-based irrigation, direct modifications to the spring (e.g., construction of a forestry road over the spring), and land-use effects (e.g., farming and livestock operations resulting in siltation of the spring).

Springs in Oklahoma support a diverse group of organisms, including several species of fish, crayfish, and salamanders, and a variety of crustaceans and insects.

Based on the relationship between spring flows and fish presence, reduced flows in springs would likely result in reduced fish diversity and, if flow is sufficiently reduced, the loss of fish from affected springs.

References

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Enhanced Life Cycle Assessment Demonstration at the Tar Creek Superfund Site

Basic Information

Title:	Enhanced Life Cycle Assessment Demonstration at the Tar Creek Superfund Site
Project Number:	2002OK3B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Oklahoma 1st,3rd,4th
Research Category:	Social Sciences
Focus Category:	Law, Institutions, and Policy, Economics, None
Descriptors:	Integrated environmental decision-making, risk assessment, benefit-cost analysis, life-cycle assessment, stakeholder processes
Principal Investigators:	Robert P Anex, Will J Focht, Chad Settle

Publication

<u>Problem and Research Objectives</u>:

The proposed research will develop an Enhanced Life-Cycle Assessment (ELCA) framework for the assessment of environmental technologies that will be demonstrated by assessing the life-cycle costs and benefits, risks, and stakeholder acceptability of using treatment wetlands for cleanup and restoration at the Tar Creek Superfund site.

Our overall objective is to develop a systematic process for environmental technology assessment that accounts explicitly for the interdependence among changes in releases of pollutants, human health risks, and economic impacts throughout the technology life cycle, and that is guided by stakeholder concerns and preferences regarding environmental management and pollution control. **Specific goals of the proposed research** include: i) development of methods of assessing stakeholder concerns and preferences suitable for guiding policy-relevant analyses; ii) to integrate risk assessment and benefit-cost analysis methods with life-cycle assessment techniques; iii) to demonstrate the ELCA framework by producing policy-relevant data regarding the costs, benefits, risks, and stakeholder acceptability of using treatment wetlands at the Tar Creek Superfund site; and iv) to identify priority information needs of the decision-making process to help guide future scientific research.

<u>Methodology</u>:

The process of making environmental decisions involving health, societal, and economic issues is most commonly supported by three types of analysis: benefit-cost analysis (BCA), life-cycle assessment (LCA), and human health risk assessment. This project is advancing these analytic methods by integrating them into a coherent ELCA framework. The ELCA framework is both an integrated set of analysis tools that support the policymaking process as well as a procedure that involves stakeholders in defining the analysis process and therefore involves them in a critical part of policymaking. Involving stakeholders in the analysis process is important because stakeholders will not support a policy decision that they do not feel is fully legitimate.

The ELCA framework is being used to assess the technical effectiveness of the enhanced wetland technology in reducing human health risk through an integrated LCA and risk assessment process. The risk assessment process is guided by input from stakeholders gathered through survey and interviews. Benefit-Cost Analysis (BCA) is being used to assess the net benefit of the proposed use of treatment wetlands at the Tar Creek site. Incorporating BCA within the ELCA framework assures that the market and non-market site characteristics that are evaluated and included in the analysis are those that are important to the stakeholders and not simply those that an analyst thinks should be important. The BCA is also guided by the results of stakeholder interviews, Q sorts, and surveys. Stakeholder acceptability is being assessed from interviews with stakeholders residing or working near the proposed project site. Statements from these interviews are being Q sorted by stakeholders in a subsequent interview, and these Q sorts are being factor analyzed to reveal general perspectives on the technologies and to determine whether a conflict exists among these perspectives. Finally, the information regarding stakeholder concerns and preferences regarding the proposed remediation technology being developed from narrative analysis of the open-ended interview transcripts, Q methodology, and preference ranking are being used to develop a survey instrument.

Survey responses are being analyzed using descriptive statistics and regression to determine stakeholders' concerns and judgments of the acceptability of the proposed remediation technology as well as their willingness to tradeoff benefits and costs to implement the technology. The information regarding stakeholder preferences and concerns is being fed back to guide and inform the three assessment processes (LCA, BCA and risk assessment).

Principal Findings and Significance:

Of the three assessment exercises in this project (social impact assessment; economic impact assessment; environmental risk assessment), the social impact assessment effort needed to be completed first, since it is used to help frame the conduct of the other components. This assessment was conducted by interviewing selected stakeholders who are nearby residents, regulatory officials having responsibility for site remediation, experts who have or are conducting studies of the site, and representatives of various interest groups who perceive that they have a stake in site remediation. The social impact assessment was conducted via two rounds of face-to-face stakeholder interviews conducted in the Picher-Cardin-North Miami area surrounding the Tar Creek site.

Careful analysis of the cognitive maps from the first round of interviews resulted in the construction of an aggregate map which incorporates features of all ten maps. Aggregate maps provide a unique perspective by summarizing the schema of a whole social system into one map. Therefore they are characteristic of the social system and not attributable to any individual participant. This map serves to inform our understanding of the stakeholders' perspectives and the preparation of the interviews regarding the wetland treatment systems.

The remaining task under the social impact assessment activity is eliciting the stakeholders' reactions to the new wetlands technology and assessing their health concerns through a knowledge assessment. An influence diagram has been prepared for use as the standard for assessing participant knowledge. The results of social impact assessment have been used to frame the economic and technological effectiveness assessments that are now underway.

The economic assessment task has developed an economic valuation method based on the benefit transfer approach. The model for Tar Creek has been completed but has not yet been populated with data representing treatment wetland performance. This is the remaining task.

The risk assessment task was begun by developed in expert mental model of the Meyer Ranch site at Tar Creek. Influence diagrams were created to represent the movement of contaminants from mine drainage and the possible exposure pathways of those contaminants to humans. In addition, influence diagrams included socioeconomic factors, future sediment removal of wetlands, and future development as probable sources of risk to humans. Three influence diagrams were created. The first one represents the movement of contaminants from mine drainage without implementation of an alkaline wetland treatment system. The second represents movement of contaminants through an alkaline wetland treatment system until reaching humans, and the third diagram represents the interactions among elements within an alkaline wetland system. The arrows symbolize direct pathways of contaminants to different medias (air, soil, and water), and receptors (animals, plants, microorganisms, and humans) which are represented by squares. The oval boxes are some of the transport and exposure mechanisms of contaminants. The three diagrams provided a general overview of the elements affecting the water quality of Mayer Ranch, North Miami, Oklahoma, and therefore, affecting human health.

Several experts on different areas, such as toxicology, wetland science, and water quality among others, were identified and interviewed. Dr. Mary Jane Calvey, a toxicologist, wetland specialists: Dr. Robert Nairn and Dr. Aisling O'Sullivan, Dr. Dennis Datin and Mr. David Cates, environmental engineers, and Ms. Denae Athay, an environmental scientist were interviewed. Their input, suggestions, and comments helped improve influence diagrams.

All available information from interviews and influence diagrams were collected and reviewed to complete the final expert mental model of Mayer Ranch, North Miami Oklahoma. In addition, influence diagrams representing the existing risk and new risks created by wetland treatment systems were incorporated in the final expert mental model.

Without a doubt, the Mayer Ranch system has a high level of complexity, and so does its expert mental model. It is evident that gaps of knowledge exist when trying to explain both transport mechanisms of metals in different media, and the mechanisms of action within wetlands. The resulting expert mental model takes into account exposure pathways of metals until they find their way to humans, but it does not comprise the magnitude of each pathway. Although pathways of metal exposure to humans may always exist regardless of the presence of a wetland treatment system, the difference lies in the degree of exposure. For instance, metal concentration moving from a wetland treatment system to humans may be lower in comparison with metal concentrations getting to humans without passing through wetland treatment systems. In addition, human health risks due to creation of wetlands, future development and socioeconomic factors influence human exposure pathways. This expert mental model tries to incorporate all elements affecting the system in question. It also provides an image of the interactions of humans within the Mayer Ranch ecosystem, which become highly important when assessing human health and environmental impacts.

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Resistance Tomographic Imaging, Digital Mapping, and Immersion Visualization of Evaporite Karst in Western Oklahoma

Basic Information

Title:	Resistance Tomographic Imaging, Digital Mapping, and Immersion Visualization of Evaporite Karst in Western Oklahoma
Project Number:	2002OK4B
Start Date:	3/1/2001
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Oklahoma 4th
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrogeochemistry, Methods
Descriptors:	Resisitivity imaging, digital mapping, visualization, evaporite karst, Oklahoma, contaminant transport, groundwater pollution
Principal Investigators:	Aondover Tarhule, Thomas Dewers, Rozemarijin Tarhule

Publication

Problem and Research Objective

Karst aquifers are susceptible to contamination because surface waters are introduced directly into the aquifer system through voids, sinkholes, and sinking streams. Once in the system, the contaminants move rapidly through a network of solution conduits that are difficult, expensive and time consuming to detect using conventional methods such as well sampling or core drilling. Moreover, these discrete sampling methods have a very high probability of missing conduits or contaminant flow paths; the drill core has to be located directly above, or in very close proximity to, the contaminant in order to locate it. Similarly, monitoring wells frequently fail to detect contaminants in kart systems because the flow is concentrated preferentially in the solution conduits. The failure to detect the pathways of contaminant movement may pose a serious health hazard to the people using the aquifer system. At the same time the physical collapse of subsurface voids may undermine surface structures, causing economic damage, insurance claims, litigation, expensive engineering remediation works and, in some cases, even loss of lives (Johnson and Quinlan, 1995; Smith, 1997; Johnson, 2001). These considerations, as well as the fact that soluble rocks (gypsum and dolomite) occur within 30 meters below ground surface (m.b.g.s.) in about 10% of the state of Oklahoma, motivated the present study.

The goal of the study therefore is to investigate the feasibility of detecting and mapping subsurface karts voids using electrical resistivity tomography and to use a combined GPS/laser range survey technique to evaluate the positional accuracy of detected voids. The advantage of the resistivity method is that it is non-invasive, rapid and inexpensive relative to a conventional well drilling program. The method also generates very fine resolution (nearly continuous) resistivity image of the subsurface in two or three dimensions.

Study Area and Geologic Setting

Three cave systems, Nescatunga, Corn, and Jester; all located in the gypsum deposits of western Oklahoma, were investigated (Fig. 1). The geology of the Nescatunga area consists of Permian age soluble gypsum and red shale beds of the Blaine Formation, which is in conformable contact with the underlying Flowerpot Shale and the overlying Dog Creek Shale (Miller et al., 2003; Stanley, 2002). Four gypsum beds, two dolomites and intervening clay shales comprise the Blaine Formation at this site. Medicine Logde, the lower most gypsum layer is overlain by dolomite, followed by the Nescatunga gypsum layer, which contains the cavern system. Red shales overlie the Nescatunga gypsum and then, topping the red shales, another layer of dolomite.

Several cavern systems located in the Permian Cloud Chief Formation including Endless Cave, collectively make up the Corn Caves in Wasita County (Looney and Bozeman, 1984). In the study area the Cloud Chief Formation is approximately 300 feet thick and consists of (oldest to youngest) Weatherford Dolomite, unnamed shale, a gypsum-anhydrate unit and capped with alternating sandstone and shale units. The type locality for the Cloud Chief Formation near Endless/Corn Cave reports the gypsum/anhydrite unit as being 100 feet thick (Fay, 1962). The Cloud Chief Formation is conformable with the underlying Rush Springs Sandstone and the overlying Doxey Shale (Miller et al., 2003).

The third cavern system studied was Jester cave in Greer County. According to Johnson (1987, p.47), Jester cave "developed mainly in a 16-foot-thick gypsum bed in the lower part of the Van Vacter member of the Blaine Formation. In this area, the Blaine consists of about 150 feet of interbedded gypsum, dolomite, and red bed shale." The total thickness of the Van Vacter member in the Jester cave area is 80 feet. Six principal gypsum beds, numbered sequentially from 1 through 6, make up the Van Vacter member. A thin dolomite underlies each gypsum layer and, in most places, thin, unnamed shale overlies each of the gypsums.

Methodology

The single channel Sting R1-IP-Swift™ resistivity meter with programmable electrodes was utilized for this study. Advanced Geosciences Inc. in Austin, Texas, produces the system. The idea is to pass a current of known voltage into the subsurface to be imaged through two current electrodes, and then using a second pair of potential electrodes, measure the potential drop induced by the differential response of earth materials to the penetrating current. The method is effective for detecting voids because air-filled voids show up as anomalously high resistivity regions on the resisitivity field since air has infinite resitivity. On the other hand, water-filled voids show up as anomalously low conductivity spots owing to the high conductivity of water. To carry out a survey, a CREATOR® software is first used to program the desired sequence of electrode switching, corresponding to the array type chosen. Four array types, Wenner,Wenner-Schlumberger, dipole-dipole and pole-dipole, were investigated. These array types probe the subsurface in different ways even though they utilize stakes in the same position. For example, the Wenner array takes measurements along several parallel profiles at fixed depths below the ground surface (e.g. 2 m, 4 m, 6 m). In contrast, the dipole-dipole array makes a much larger density of sample measurements, which, in principle, improves the resolution of target features. Survey transects were laid out roughly perpendicular to the orientation of known cave passages and the resisitvity profile of the subsurface recorded automatically according to the array type(s) specified. GPS coordinates and elevations of selected points along each transect were obtained using a Trimble ProXRS® GPS system. The raw data collected is first used to calculate apparent resistivity, which is the weighted average of the resistivity under the four electrodes. The exact formula used depends on the array type. Owing to inhomogeneities in the subsurface, the apparent resistivity is different from the true resistivity. The modeling software RES2DINV™ (Loke and Barker, 1996) was used to obtain the true resistivity from which anomalously high (low) features were interpreted against the known resistivity range of common earth materials.

Ground truth was achieved using a novel method. Internal cave morphology was first mapped in 3 dimensions using Trimble's new 4600LS with RTK (real-time kinetic) option, part of a GPS package recently purchased by the University of Oklahoma School of Geology and Geophysics (SG&G). Our particular package permitted real-time cm-scale accuracy in both the horizontal and vertical dimensions. The ProXRS GPS system was mounted on a tripod near an entrance to the cavern system being surveyed, along with the reflectorless laser rangefinder and digital compass (Fig. 2). A DGPS carrier phase location was sited at this initial position. Differential corrections were obtained onsite using the OmniStar system and later via internet resources. A series of control points or stations were then located within the cavern itself spatially referenced to the GPS position by a series of offsets using mounted reflectors. Beginning at the entrance to the cave, the laser configuration occupied each of these control stations successively, permitting a survey of the surrounding cavern walls (consisting of locations referenced to the control points) to be conducted. Although positioning error invariably increases with each successive control point occupied within the cavern, we achieved sub-decimeter accuracy in distance and inclination from each control point, and confirmed the accuracy by reoccupying control stations. Positioning data was then stored and analyzed using GIS (e.g. ESRI ARCVIEW) and CAD. In summary, the steps used in acquiring and utilizing the data are as follows (more details on the procedure may be found in Galen et al (2003):

1. Acquire Carrier Phase DGPS position outside cave entrance.

2. Survey a series of offset stations from this position into and through the cave using laser positioning (in filter mode) and reflectors.

3. Survey cavern wall morphology at sites of interest from surveyed offset stations with filter mode off.

4. Export positions to CAD or GIS software for visualization.

Superimposing the transect of the internal cave passage on a profile of the surface resistivity survey allowed us to determine both the position and elevation of the cave along the surface transect. Finally, the true position of the cave passage is compared to the resistivity signature of the passage to assess positional accuracy. The assessment consisted of measuring the horizontal and vertical departure of the resistivity anomaly from the true position of the cave passage.

Principal Findings and Significance

Internal Cave Mapping

We mapped a small portion of Endless Cave in September of 2002. Detailed map of this cave may be found in Looney and Bozeman (1984, p.39). In Figure 2, we show the traverse of the resistivity survey, the initial DGPS position outside the cave, the surveyed stations, and the data points collected to record cavern morphology, at two scales and in two and three dimensions. These are included with various sources of geographical information systems (GIS), including digital orthophoto quadrangles (DOQ's), a digital raster graph (DRG) of the USGS 7.5' Corn, Oklahoma Quadrangle, and a ten meter resolution digital elevation model (DEM), and assembled using ESRI's ARCView™ software.

Figure 3a shows the location of the Endless Cave study site located on Gyp Creek near the boundary between Washita and Custer Counties. A base map of surface topography is produced by draping a 1meter DOQ over the DEM. In Figure 3b, the horizontal locations of the resistivity survey and the cave survey station transect are given by intersecting white lines. A cluster of points at this intersection denote more than 50 locations of cave wall, ceiling, and floor morphology that are used as ground truth for the surface geophysical imaging of the cavern in this locality. A three-dimensional portrayal of this data set is shown in Figure 3c, with the DOQ drape rendered transparent. This image is oriented as north-looking; north-south running section-line roads are visible on the underlying digital raster graph going from the bottom of the image to the horizon at the middle of the image.

The internal morphology of Nescatunga caves were mapped in July, 2002. In Figure 4 we show the two- and three-dimensional GIS of a portion of Nescatunga Cave. Figure 4a shows the location of the Window study site located south of Highway 15 approximately 20 miles east of Woodward in Major Co., Oklahoma. In Figure 3b, the horizontal locations of the resistivity survey and the cave survey station transect are given by intersecting white lines connecting the survey points. A cluster of points at this intersection denote approximately 100 locations of cave wall, ceiling, and floor morphology that are used as ground truth for the surface geophysical imaging of the cavern. A three-dimensional portrayal of this data set is shown in Figure 4c, with the DOQ drape rendered transparent. The DRG beneath is the 7.5' USGS Belva, Oklahoma quadrangle. The view is nearly due east-looking.

Jester cave was mapped in June 2003. The data are still being analyzed. In any case the results generated so far demonstrate the feasibility of using the GPS laser range finder to map the internal morphology of caves. There are two downsides to this mapping procedure. First, the equipment is costly although it is rugged and reasonably mud-proof. Second, the method can only be used to map caves large enough to be entered by humans. On the positive side, the method offers a fast, accurate, and relatively non-intrusive means to map cave position and morphology. It provides "(under)ground truth" for geophysical methods used for cavern detection.

Significance and Contribution of the Internal Cave Mapping

One potential application of our results is that millimeter-to-cm-scale accuracy achieved with this mapping approach could be used to ascertain the degree to which such cavern systems evolve over time scales of decades.

The following poster based on the results was presented at the annual meeting of the Geological Society of America.

Galen, M., T. Dewers, and A. Tarhule (2002). Laser positioning and 3-d mapping of Western Oklahoma karst. Poster Presented at the Annual meeting of the Geological Society of America, Denver, October 26-30.

Subsequently, the result was elaborated and a the following paper has been accepted for publication in Circular 109 of the Oklahoma Geological Survey Bulletin.Association

Miller, Galen, T. Dewers, and A. Tarhule (accepted). Laser Positioning and 3-Dimensional Digital Mapping of Gypsum Karst, Western Oklahoma, USA. Oklahoma Geological Survey.

Additional data presently being generated will be incorporated and another paper submitted for publication possibly in *Cave and Karst Science* or in the *Journal of Applied Geophysics.*

Following the poster presentation at the GSA, we have received inquiries from the USGS office in Florida about how to use the same approach to map the caves in Florida. A second inquiry came from a Petroluem Geochemist in Ireland who also wanted to know how to use the approach to map their chemical plant. These inquiries testify to the success of our research and the dissemination outreach we have achieved.

Resistivity Tomography

ERT: Figure 5a shows the resistivity cross-section near the highway. The plot is based on a dipole-dipole array utilizing 7 m electrode spacing. Electrode 14 was located next to an ODOT drill hole (95 m from start of survey transect, labeled C by the ODOT drill team). The depth to the bottom of the cave (measured in the drill hole) is 21 m. The cavern is approximately 5 m high by 10 m wide. This information is used to locate the cave on the resistivity profile. The cave coincides in position with an area of anomalously high resistivity (> 22 000 Ohm m), providing definitive proof of this anomaly as a void. However, the resistivity anomaly is slightly offset to the right of the true position of the cave. An examination of the measured resistivity data points revealed two missing measurements at this depth. Missing measurements occur during surveys either due to a faulty electrode or an inability of the Sting to obtain useable data at that measurement point. Hence, interpolation over the missing points could have resulted in a shift of the anomaly. Even so, the result is consistent with other investigators (see www.agiusa.com/stingcave.shtml) that have also reported marginal positional offsets in the true location of caves detected from resistivity profiles. No other resistivity anomalies are detected on this profile.

Figure 5b is a plot of the resistivity cross section near the window entrance. The survey utilized a Wenner array with 5 m electrode spacing (equipment failure precluded the use of a dipole-dipole array at this site). The plot revealed two anomalies, one in the center of the plot with resistivity > 24 000 Ohm m and a second to the left of the profile, but at the same depth as the first anomaly, with resistivity > 11 000 Ohm m. From the results of the GPS/laser range mapping, it was established that the centroid of the cave passage is at electrode 14 (65 m) and the depth to the bottom of the cave is 10-11 m. The cave itself measured 3 m high by 12 m at this point. Superimposing this information on the resistivity profile confirmed that the anomaly in the center of image is the target cave passage. Such excellent agreement suggests strongly that the second anomaly is also most likely a cavern passage. Although not mapped, local cavers we spoke to mentioned a second cave passage parallel to the main one we surveyed and in the general location of the anomaly identified.

These results suggest that ERT is a viable method for detecting subsurface features in the gypsum karst of Oklahoma. Major findings from the studies described above can be summarized as follows:

1. The dipole-dipole array produces high-resolution resistivity profiles that are good for imaging cavities. However, the method is prone to “current decay” with a concomitant loss of measurement points. This array type appears to be useful for relatively shallow voids but it is not possible (nor perhaps even desirable) to determine the maximum depth for which dipole-dipole is ideal because of the influence of other factors such as geology and the resistivity contrast between the target feature and the host medium.

2. The Wenner and Wenner-Schlumberger arrays appear to give rather coarse (poorly resolved) resistivity signal of the target voids. For example, void signatures in the resistivity profile typically extended over 2-3 times the actual size of the cavity. As a result, the likelihood of missing a void is high if one were to drill to the target cave or feature based on the image detected with these arrays. Finally, the depth penetration of these arrays is also more limited than the other methods used.

3. The pole-dipole array yielded the best results in terms of depth penetration, detection consistency and image resolution. We have, therefore, adopted and recommend this array type for detecting cavities in the gypsum karst of Western Oklahoma. The downside to this method is that the "infinity" electrode has to be separated from the survey transect by about 5-8 times the length of the survey transect. In closed quarters or small plots this requirement can be a challenge to meet as it increases the number of landowners from whom one has to request permission.

Based on the experience and confidence gained from the above studies, we proceeded to map one passage in the Jester Cave system that is too small to be entered by humans. The data, however, are still being analyzed. We have also carried out a 3-D resistivity survey of a part of the Nescatunga cave system and the data are still being analyzed.

In terms of dissemination, the results of resistivity tomography generated to date have been presented at the Annual Meeting of the Geological Society of America:

Tarhule, A., T. Halihan, T. Dewers, R. Young, A. Witten (2002). Integrated subsurface imaging techniques for detecting cavities in Oklahoma evaporite karst. Annual meeting of the Geological Society of America, Denver, October 26-30.

A paper has also been accepted for publication in circular 109 of the Oklahoma Geological Survey Bulletin.

Tarhule, Aondover, T. Dewers,R. Young, A. Witten, T. Halihan (accepted) Integrated Subsurface Imaging Techniques for Detecting Cavities in the Gypsum Karst of Oklahoma. Oklahoma Geological Survey.

The results achieved to date are encouraging and have satisfied several cardinal objectives of the study. Even so, it is becoming increasingly clear that some of the original objectives will not be met. These include the following:

a. It may not be possible to establish definitively the smallest size of cavity that can be detected with resistivity tomography. The reason is that detectability depends is a function of the interactions of several factors, which defer from one site to another. Proposing a numerical value even based on successful empirical findings at one or a few sites may therefore neither justified nor helpful.

b. We have also not found suitable site for testing the feasibility of detecting vertically stacked voids.

c. Finally, we have not evaluated the effect of conduit geometry in amplifying or moderating the resistivity signal. In our experience to date this objective probably is not justified by the resolution achievable with resistivity tomography.

Clearly, therefore, the approach has several strengths but some drawbacks. The best possible use of our results therefore is to complement traditional aquifer characterization and monitoring techniques. For example, resistivity tomography would be especially useful and cost effective for determining suitable locations for drilling monitoring wells in karst aquifers.

Conclusions

This study described an innovative approach for mapping caverns in gypsum karst with resistivity tomography and then using a three-dimensional digital mapping of the caverns to ground truth the anomalies detected. The approach is much more rapid and cost effective than the traditional approach of drilling to confirm target features. Insights gained from the study are useful for investigating buried karstic features for which prior ground truth is not feasible. The study demonstrated the feasibility of detecting cave passages with resitivity tomography and identified the most effective array type for the gypsum karst of Western Oklahoma. The results of the 3-D mapping of internal cave morphologies have begun to attract attention within the cave mapping community as reflected in the requests we have received so far. Analysis of data already collected to map cave passages that are too small for humans, as well as three-dimensional resistivity mapping are continuing.

Acknowledgement

We acknowledge with gratitude financial support provided by the Oklahoma Water Resources Research Institute (OWRRI), which provided funding for the resistivity equipment. Additional support by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma allowed us to involve several graduate and undergraduate students in the research. The Oklahoma Transportation Center (OTC), also provided funding that enabled us to investigate the different though related aspect of karst geohazards. We thank especially Drs. Gorman Gilbert and Thomas Landers (OTC) and Donald Barrett (ODEQ) for coordinating the research initiatives. We acknowledge with gratitude the assistance and cooperation received from the landowners including Gary and Cinda Innman, Mr. Richard Harris, and Mr. L. Harms. Sue and John Bozeman introduced us to these caves and the owners and provided valuable background information. We thank Scott Chistenson (USGS), Curt Hayes (Consulting Geologist for ODOT) and Jim Nevels (Chief soil scientist, Materials Division at ODOT) for their cooperation and assistance on various aspects. We are grateful to Gaylen Miller for field assistance and support provided by the Oklahoma Geological Survey. Finally, we are pleased to acknowledge the contribution of our field assistants (Mark Jaeger, Zakari Saley-Bana, Julie Turrentine, Brent Wilson, and Joseph Zume).

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FIGURES

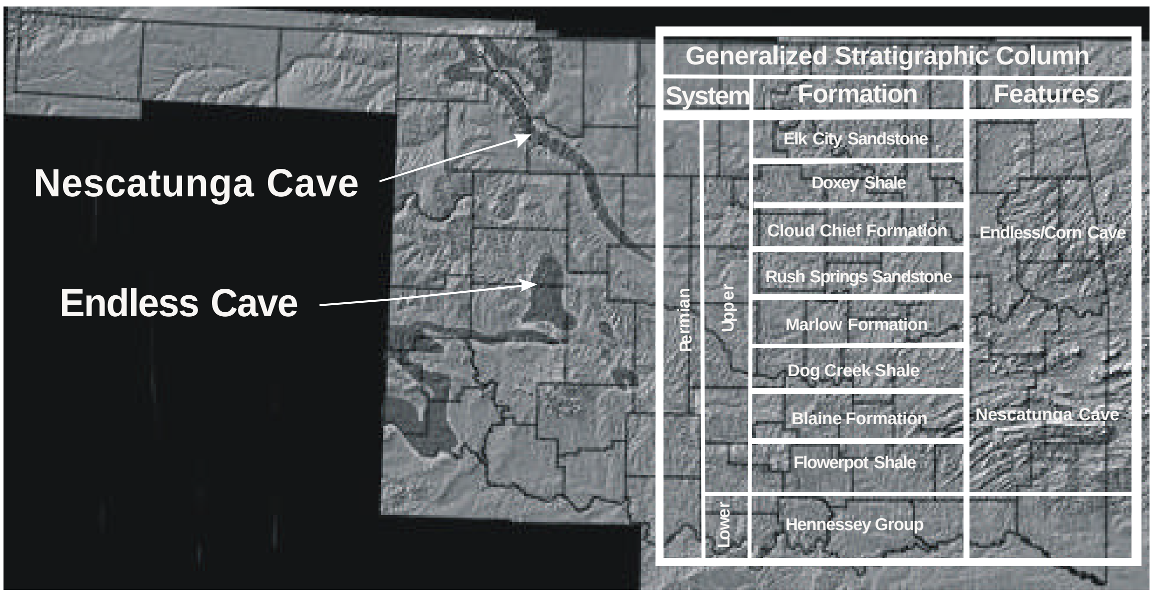

Figure 1

Figure 1. Locations of the study areas on the Oklahoma state digital elevation model, and a generalized stratigraphic section of the gypsum members housing the surveyed caves. The grey shaded regions outline regions of Oklahoma underlain by gypsum and susceptible to karst-related collapse and other hazards (after Johnson and Quinlan, 1995).

Figure 2a Figure 2b

Figure 2A. A co-author (GM) showing the digital mapping method in action, taking a laser position of horizontal distance, vertical distance, and azimuth to a reflector shot point. The reflectorless laser rangefinder, a digital compass, and handheld computer are all mounted on a monopod/tripod assembly Cave graffiti seen in the background unfortunately is a common occurrence close to the entrance. B. The other end of the survey: reflection of camera flash is seen from abicycle reflector used in laser positioning of cave transects.

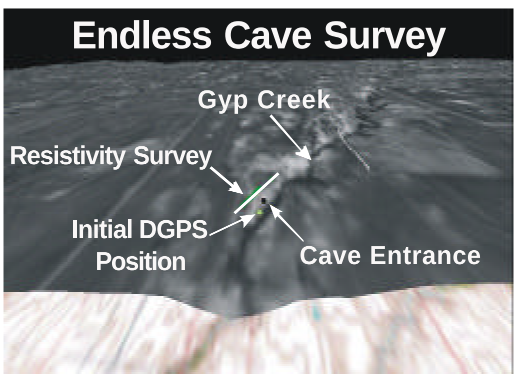

Figure 3a

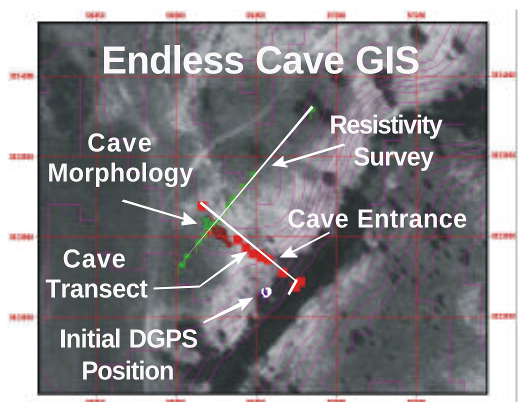

Figure 3b

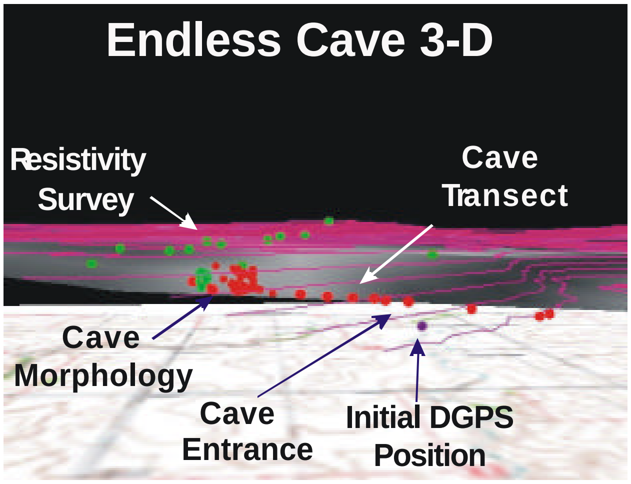

Figure 3c

Figure 3. Results of survey at Endless Cave, part of the Corn Caves in Washita Co., Oklahoma in September, 2002. A. Location of study area viewed from the south on draped DOQ/DEM. B. Two-D GIS of cave locations, cave morphology, and surface resistivity survey line discussed by Tarhule et al. (2003, this issue). C. Three-D GIS depiction of cavern location beneath ground surface. Contour interval is 2m, and UTM grid shows 50m spacing for scale.

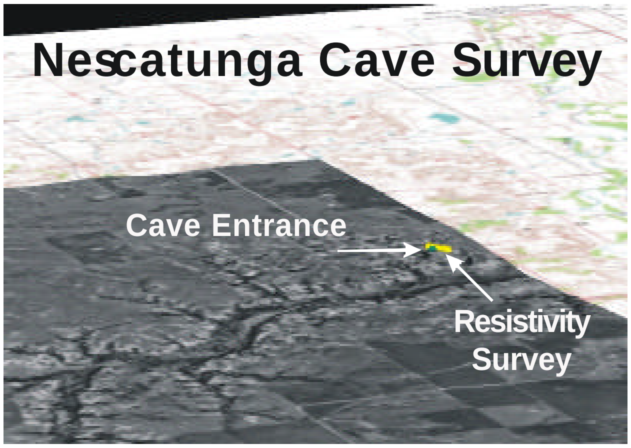

Figure 4a

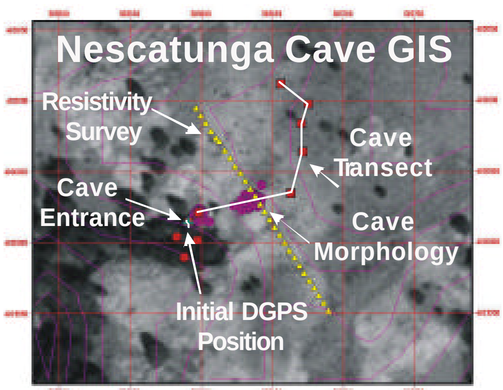

Figure 4b

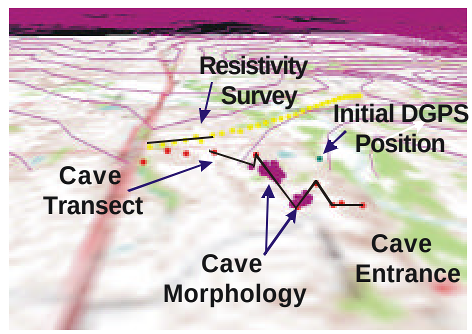

Figure 4c

Figure 4. Results of survey at the Window area, Nescatunga Caverns, in Major Co. Oklahoma, in July, 2002. A. Location of study area viewed from the southwest on draped DOQ/DEM. B. Two-D GIS of cave locations, cave morphology, and surface resistivity survey line discussed by Tarhule et al. (2003, this issue). C. Three-D GIS depiction of cavern location beneath ground surface. Contour interval is 2m, and UTM grid shows 50m spacing.

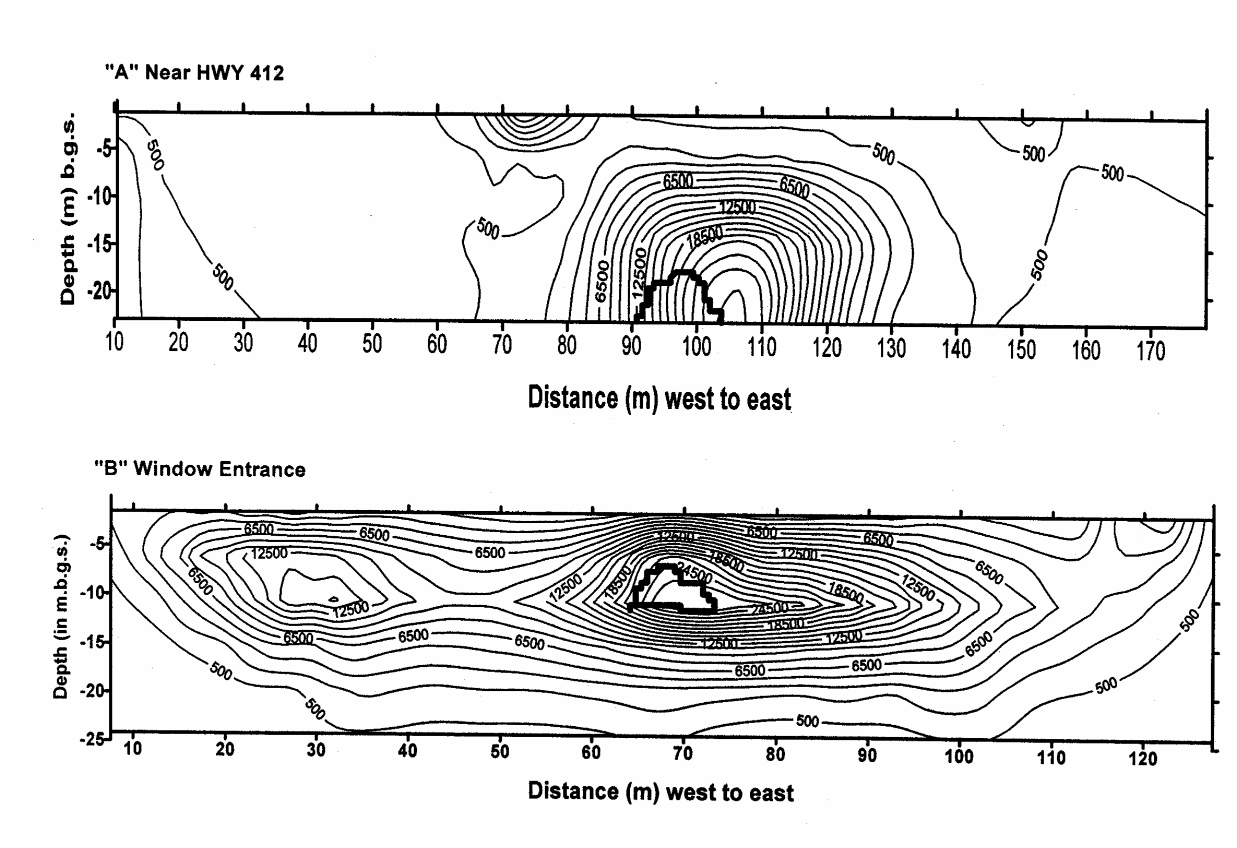

Figure 5. 2-Dimensional resistivity cross-sections of the subsurface (a) near HWY 412 based on a dipole-dipole array and 7 m electrode spacing, and (b) near the window entrance based on a Wenner array and 5 m electrode spacing. The true locations of the cavern is shown on both plots and contours represent resistivity values in Ohm m.

Evaluating Cost Effective Technologies to Reduce Phosphorus Loading to Surface Waters in the Ozark Region

Basic Information

Title:	Evaluating Cost Effective Technologies to Reduce Phosphorus Loading to Surface Waters in the Ozark Region
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Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	Oklahoma 3rd
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Focus Category:	Non Point Pollution, Economics, Water Quality
Descriptors:	Poultry litter, Phosphorus, pollution, economics, agriculture, watershed modeling
Principal Investigators:	Daniel E. Storm, Arthur Louis Stoecker

Publication

1. Ancev, Tihmoir, 2003, "Optimal Allocation of Waste Management Practices with Economic Implications for Policies to Regulate Phosphorus Pollution in the Eucha-Spavinaw Watershed", PhD Dissertation, Dept. of Agricultural Economics, College of Agricultural and Natural Resource Sciences, Oklahoma State University, Stillwater, OK, 204pp.

Evaluating Cost Effective Technologies to Reduce Phosphorus Loading to Surface Waters for the Ozark Region

Final Report

Submitted to:

Oklahoma State University Environmental Institute
United States Geological Survey

Authored by:
Daniel E. Storm, Professor
Arthur L. Stoecker, Associate Professor
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Oklahoma State University
Biosystems and Agricultural Engineering Department
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Stillwater, Oklahoma

June 24, 2003

SYNOPSIS

Title: Evaluating Cost Effective Technologies to Reduce Phosphorus Loading to Surface Waters for the Ozark Region

Investigators: Principal Investigators:
Dr. Daniel E. Storm, Professor
Dr. Arthur L. Stoecker, Associate Professor

Investigators:
Tihomir Ancev, Graduate Research Assistant
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Oklahoma State University, Stillwater, OK

Congressional District: Oklahoma, Third.

Descriptors: poultry litter, phosphorus, pollution, economics, agriculture, watershed modeling

Problem and Research Objectives: Hydrological and nutrient dynamics analysis shows that reduction of external phosphorus loading to lakes Eucha and Spavinaw in the Ozark region is necessary to mitigate the problem of lakes eutrophication. The sources of external phosphorus loading in the watershed are point sources (municipalities), non-point sources (agriculture) and background loading (natural). Reduction of external phosphorus loading could be achieved at both point sources and non-point sources. The main problem treated in the study was to determine how to achieve the desired phosphorus reduction in a manner that would be least costly to the society as a whole. The research objectives were:

- Estimate phosphorus loading in the Eucha/Spavinaw watershed using the SWAT model and determine the sources and their relative contributions.

- Evaluate cost effective technologies of phosphorus abatement for both point and non-point sources of phosphorus loading.

- Determine the level of phosphorus abatement that would be socially least expensive.

- Determine the most cost effective poultry litter and land management practices on a site-specific basis using high-level spatial detail.

Methodology: The Lake Eucha/Spavinaw Basin was modeled using Soil and Water Assessment Tool (SWAT) to evaluate the non-point source nutrient loading to the lakes and its origins. State-of-the-art Geographic Information System (GIS) and weather data were used in the model. Land cover data were developed from satellite imagery and ground truth data. In addition, high detail daily rainfall estimates were derived from Next Generation Weather Radar (NEXRAD) data and incorporated in the model.

Nutrient loads for the basin were estimated using the US Geologic Survey (USGS) program LOADEST2 using observed water quality measurements and stream flow data provided by the City of Tulsa (COT) and the USGS. The hydrologic portion of the model was calibrated using three USGS stream flow stations, and the phosphorus portion was calibrated using data from eight COT water quality stations.

The economic modeling was based on minimizing total abatement and environmental damage costs related to phosphorus loading in the Eucha/Spavinaw Basin. Abatement costs were estimated at the point source (City of Decatur, Arkansas) as the costs of chemical treatment to precipitate phosphorus in the municipal wastewater. The estimation was conducted by enumerating engineering cost data. Abatement costs were also estimated for the non-point (agricultural) sources of phosphorus pollution in the basin, as a reduction of net agricultural income under the alternative poultry litter and land management practices. The estimation was conducted using agricultural statistics data and agricultural enterprise budgets. The total and marginal phosphorus abatement costs were derived within a linear programming optimization framework.

Environmental damage costs treated in the study were the cost of additional drinking water treatment at the City of Tulsa and cost of recreational values of the area lakes. Other environmental damages were not considered because of the lack of data and technical limitations. The costs of additional water treatment for the City of Tulsa were estimated by regression analysis using cost and phosphorus loading data. The costs of lost recreational values for the area lakes were estimated using the travel cost method. The demand for recreation was estimated as a function of phosphorus loading in the watershed using maximum likelihood method. Cost of lost recreational values was approximated by the change in consumer surplus under various phosphorus loading levels. Total and marginal environmental damage costs were estimated as a function of phosphorus loading using regression analysis.

The level of phosphorus abatement that is least costly to the society as a whole was determined by equating the marginal abatement and damage costs. At this determined level of abatement, optimal poultry litter and land management practices were assigned to each distinct agricultural land area in the watershed. Optimal level of abatement was also assigned to the point source.

Principal Findings and Significance: The calibrated SWAT model estimated the average annual total phosphorus loading to Lake Eucha to be 49,400 kg/yr, which includes 11,400 kg/yr from the City of Decatur point source for the period 8-1-1998 to 3-15-2002, and about 38,000 kg/year from the non-point sources. The principal findings are:

- Optimal levels of phosphorus loading under the various policies and technologies analyzed suggest that a reasonable economic target for phosphorus loading from the point and non-point sources could be set in a range of 23,000 to 26,000 kg/year. It is difficult to set an exact optimal level of phosphorus loading in the watershed because of inherent uncertainties with both SWAT and the economic modeling.

- The use of uniform restriction policies alone (represented by the Soil Test Phosphorus criterion) to regulate litter application and phosphorus loading in the watershed is not an efficient policy. A more efficient outcome is likely if site-specific (i.e. field level) criterion is used.

- Changing the land use patterns and existing land management practices is an effective and efficient way to achieve phosphorus-loading reduction. In particular, changing the existing management practices (stocking rates and fertilization) on the overgrazed pastureland is very important for phosphorus reduction. A significant portion of the row crop (40%) was also found optimally converted to other land use (hay) with less potential for phosphorus runoff.

- Litter management technologies, such as treating poultry litter with alum, were found to efficiently reduce phosphorus loading.

- Transportation of poultry litter within and outside the watershed was found to be an important part of the optimal solution for reduction of phosphorus loading.

- Abatement of the point source is required to achieve least cost reduction of external phosphorus loading in the watershed.

- Results are presented at a high level of spatial detail enabling the use of site-specific policies and targeting to achieve the most effective and efficient reduction of phosphorus loading in the watershed.

PUBLICATIONS

Dissertations

Ancev, Tihomir, 2003, “Optimal Allocation of Waste Management Practices with economic Implications for Policies to Regulate Phosphorus Pollution in the Eucha-Spavinaw Watershed “, Ph.D. Dissertation,” Department of Agricultural economics, College of Agricultural and Natural Resource Sciences, Oklahoma State University Stillwater, OK, Number of Pages: 204

Conference Proceedings

Ancev, T., Arthur.L. Stoecker and Daniel E. Storm. “Optimal Spatial Allocation of Waste Management Practices to Reduce Phosphorus Pollution in a Watershed”, Selected Paper, Annual Meeting of the American Agricultural Economics Association, Montreal, Canada, 2003.

White, Michael J., Daniel E Storm, Scott Stoodley, Michael D. Smolen. “Modeling the Lake Eucha Basin with SWAT 2000.”, Selected Poster, TMDL Conference, 2003.

Ancev, T., Arthur L. Stoecker, and Daniel E. Storm. "Least-Cost Watershed Management Solutions: Using GIS Data in the Economic Modeling of Phosphorus Loading in a Watershed.", Selected Paper, Annual Meeting of the Southern Agricultural Economics Association, Mobile, AL, 2003.

Ancev, T., Arthur L. Stoecker and Daniel E. Storm. " Evaluating Cost Effective Technologies to Reduce Phosphorus Loading to the Surface Waters in the Eucha-Spavinaw Watershed", Annual Research Symposium, Oklahoma State University Stillwater, OK, 2003.

Students Supported By Project

Type	**Number**	**Discipline**
Undergraduate	2	Biosystems Engineering
Masters		
Ph.D.	2	Agricultural Economics Biosystems Engineering
Post Doc		
Total	4	

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART I

SWAT MODEL SETUP

INTRODUCTION

Lakes Eucha and Spavinaw water quality is being degraded from excess algal growth. This excess growth is the result of an overabundance of nutrients in the lake, assumed to be primarily phosphorus. Phosphorus loads originate from either point sources, such as the City of Decatur municipal waste water treatment plant, or from nonpoint sources like pastures. The majority of the phosphorus loading has been attributed to nonpoint sources (Wagner and Woodruff, 1997; Storm et al., 2001). Fields in the Lake Eucha basin have received phosphorus from poultry litter application for many years. Poultry litter is often applied to meet the crop's nitrogen requirements. When phosphorus in excess of what the crop can use is applied, phosphorus builds up in the soil. Runoff extracts soluble phosphorus from the soil and litter, and carries sediments containing phosphorus to the lakes. The SWAT (Soil and Water Assessment Tool) model was used to predict how external loads are affected by management changes.

SWAT INPUT DATA

GIS data for topography, soils, land cover, and streams were used in the SWAT model. These data used were the most current at the time of compilation. Observed daily rainfall and temperature data were used in all modeling.

An ArcView GIS interface is available to generate model inputs from commonly available GIS data. These GIS data are summarized by the interface and converted to a form usable by the model. GIS data layers of elevation, soils, and land use are used to generate the input files. Observed temperature and precipitation can be incorporated. If no observed weather data are available, weather can be stochastically simulated.

Topography

Topography was defined by a Digital Elevation Model (DEM). DEMs for the United States are available for downloading via the Internet. The DEM was used to calculate subbasin parameters such as slope, slope length, and to define the stream network. The resulting stream network was used to define the layout and number of subbasins. Characteristics of the stream network, such as channel slope, length, and width, were all derived from the DEM.

Individual 1:24,000 thirty meter DEMs were stitched together to construct a DEM for the entire basin. When tiled, 1:24,000 DEMs often have missing data at the seams. These missing data must be replaced. A 3x3 convolution filter was applied to the DEM to produce a seamless filtered DEM. Any missing data at the seams of the original DEM were replaced with data from the filtered DEM. The resulting seamless DEM retains as much non-filtered data as possible (Figure 1.1). Filtering tends to remove both peaks and valleys from a DEM thereby reducing the perceived slope. For this reason the use of filtered data were kept to a minimum.

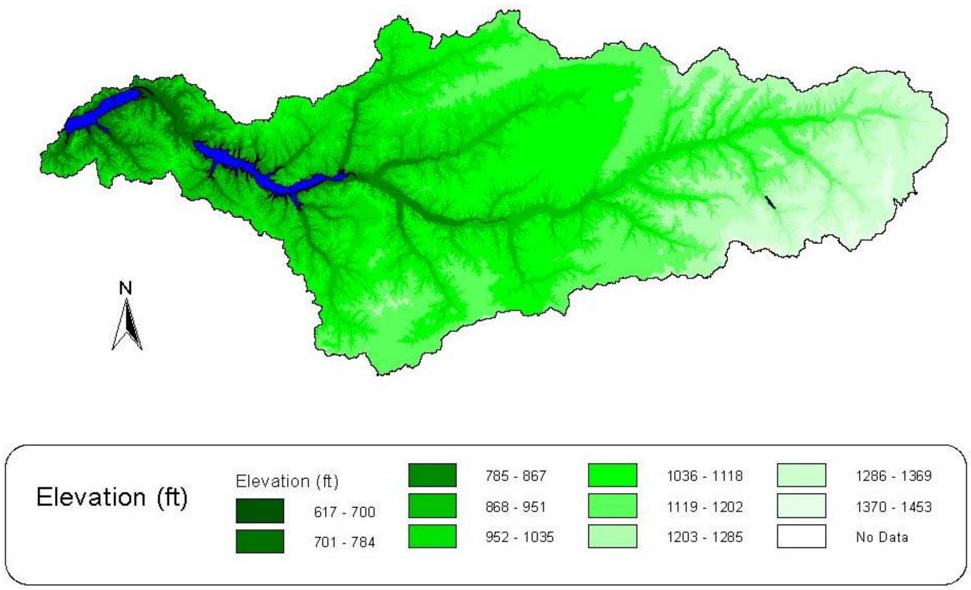


Figure 1.1 Seamless Digital Elevation Model (DEM) for the Lake Eucha/Spavinaw Basin constructed from U.S. Geographic Survey 1:24,000 DEMs.

Soils

Soil GIS data are required by SWAT to define soil characteristics. SWAT uses STATSGO (State Soil Geographic Database) data to define soil attributes for any given soil. The GIS data must contain the S5ID (Soils5id number for USDA soil series), or STMUID (State STATSGO polygon number) to link an area to the STATSGO database.

The soils layer was derived from two separate GIS coverages (Figure 1.2). The Oklahoma portion is 200-meter resolution MIADS (Map Information Assembly and Display System) data from the Oklahoma Natural Resource Conservation Service (NRCS). The Arkansas portion is a 1:20,000 order II soil survey digitized by the University of Arkansas.

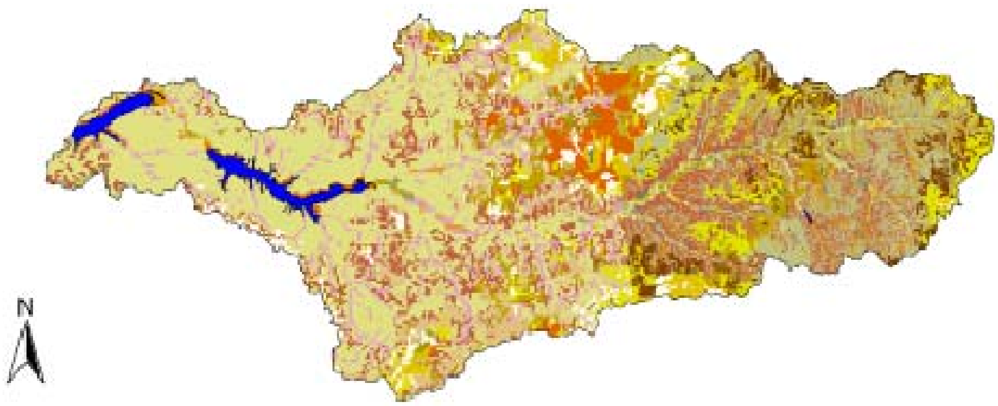


Figure 1.2 Soil distribution in the Lake Eucha/Spavinaw basin.

Land Cover

Land cover is perhaps the most important GIS data used in the model. The land cover theme affects the amount and distribution of pasture, row crop, and forest in the basin. These land covers are radically different. Forested areas contribute little to the nutrient loading, while pastures and row crops are thought to be the primary source of nutrients entering the lakes. Row crop in this basin is assumed to be green beans followed by winter wheat, based on the observations of Delaware County Cooperative Extension agent Jason Hallenbeck.

It is important that land cover data be based on the most current data available, since land cover changes over time. Land cover was derived from 30 meter Landsat 7 ETM+ imagery, digital aerial photos, and 45 ground truth data points provided by Oklahoma State University (OSU) (1.4).

Imagery for June 12, 2001 was obtained and classified by Applied Analysis Inc. (AAI). An unsupervised iterative self-organizing data analysis (ISODATA) clustering algorithm was applied by AAI to define spectral categories. After several iterations these categories combined into individual land covers. The report of the AAI classification is located in Appendix 1.1.

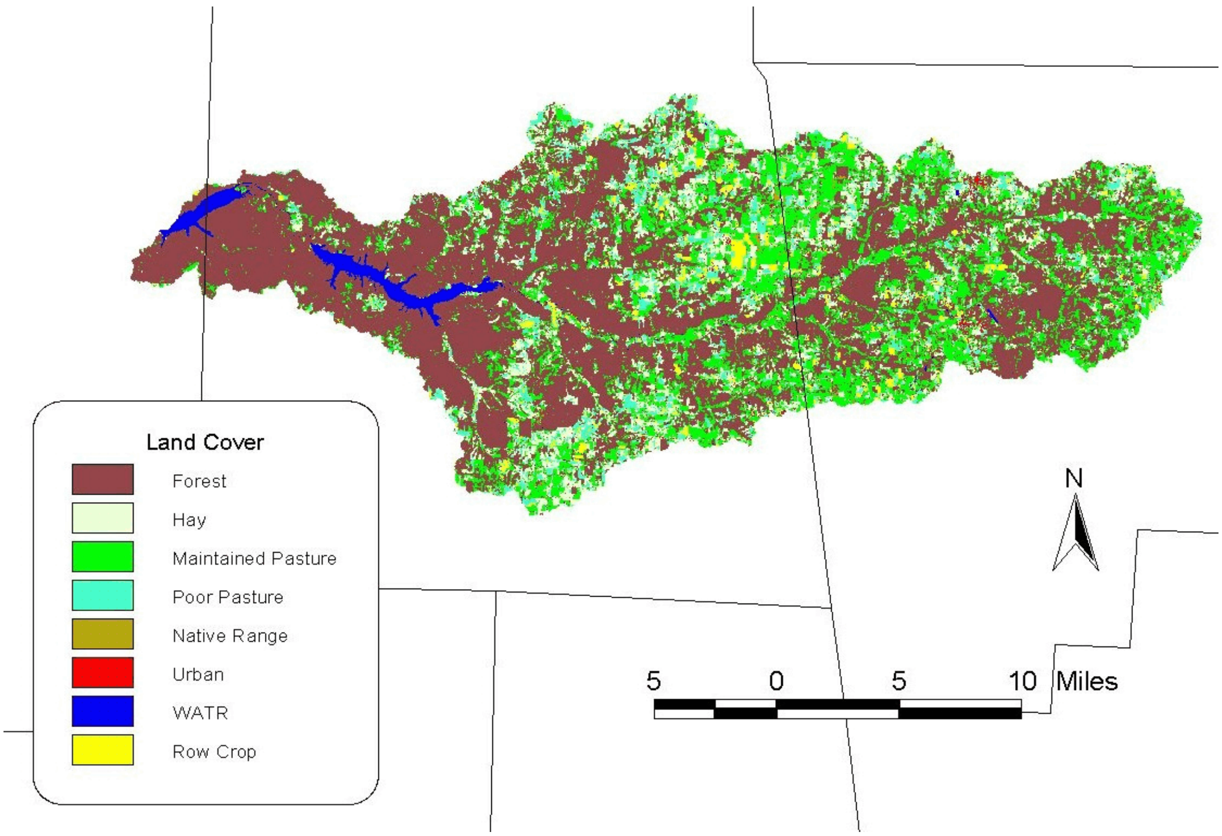


Figure 1.3 Landsat Thematic Mapper derived land cover for the Lake Eucha/Spavinaw basin. Source: Applied Analysis Inc.

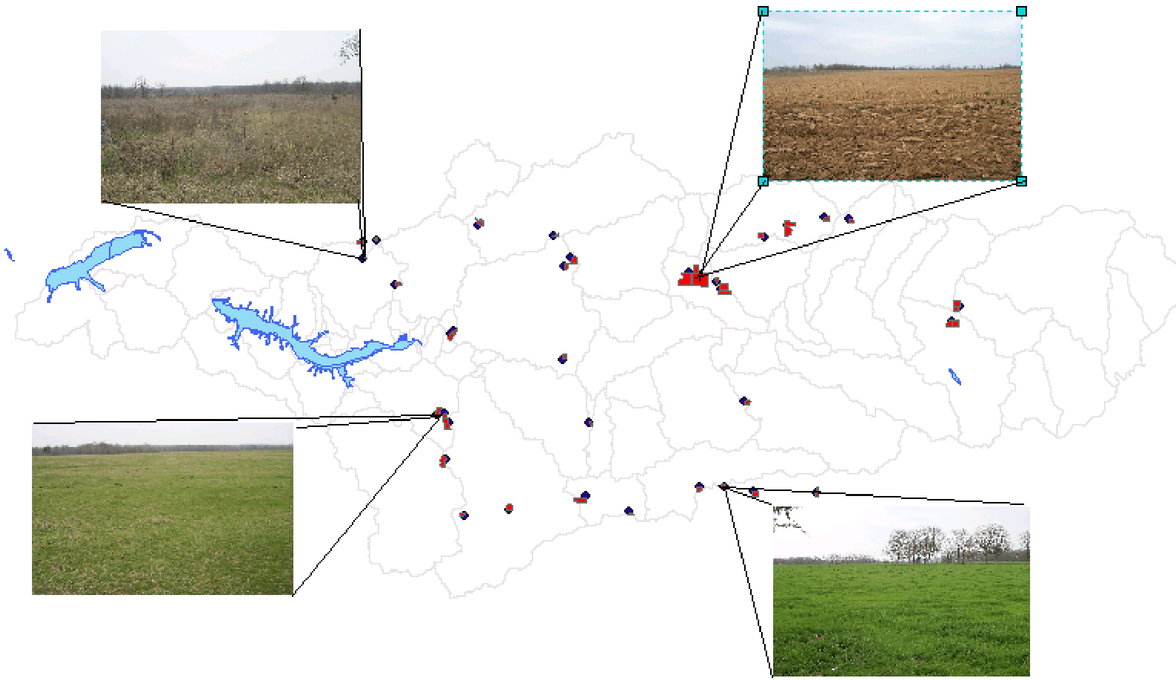


Figure 1.4 Ground truth locations and selected images provided to Applied Analysis Incorporated by Oklahoma State University. Starting upper right and progressing clockwise, the land covers depicted are range, row crop, well managed pasture, and hay.

Weather

SWAT can use observed weather data or simulate it using a database of weather statistics from stations across the United States. Observed daily precipitation and minimum and maximum temperature were used in the Lake Eucha/Spavinaw model. A combination of Next Generation Weather Radar (NEXRAD) radar derived precipitation and Cooperative Observation network gage data were used in the SWAT model for the Lake Eucha/Spavinaw basin.

Radar Derived Rainfall

NEXRAD Weather Surveillance Radar 88D (WSR-88D) derived precipitation estimates were incorporated into the SWAT model. WSR-88D Precipitation data were gage biased and archived by the Arkansas-Red Basin River Forecast Center (ABRFC). These data have a resolution of 4 km and are available from the ABRFC website in Network Common Data Form (NetCDF) format. These data are available in 1 hour, 6 hour, and 24 hour increments. SWAT requires daily rainfall, however the 24 hour increment data from the ABRFC runs from 6 am to 6 am Central Standard Time (CST). Daily data (12 am -12 am CST) were summarized from the 6 hour increment data for use in SWAT. Daylight-saving time was ignored to simplify these calculations.

A significant amount of conversion is required to use the NEXRAD weather data in SWAT. NetCDF format is most commonly used on a UNIX platform and thus PC compatible tools are scarce. A PC compatible text translator ncdumps.exe was written by the NOAAs Geophysical Fluid Dynamics Laboratory. This translator was called from a batch file to convert 6 hour increment NetCDF files to American Standard Code for Information Interchange (ASCII) text. A set of custom programs written in Microsoft Visual Basic were used to used to view and extract data covering the basin. Figure 1.5 contains a graphical representation of one 6 hour NEXRAD cumulative precipitation grid. The 1994 to 2002 precipitation estimates used in SWAT were derived from over 10,000 such grids.

Cooperative Observation Network

National Weather Service COOP (Cooperative Observing Network) station data from 27 stations from 1/1/1950 to 3/31/02 were used to supplement the NEXRAD weather data (Figure 1.6). COOP data are available from the NOAA (National Oceanic and Atmospheric Administration).

COOP data are seldom continuous for long periods of time. Missing days and even months are common. The period of record at stations are inconsistent, so the number of active stations changes with time. When SWAT detects missing data at a station, it generates simulated weather. Therefore, gaps in a station's record were filled using interpolated data from surrounding stations.

Due to the inclusion of NEXRAD data, temperature and precipitation processing methods were different. Temperature was only interpolated to patch the period of record at existing stations. Because SWAT requires a fixed network of weather stations, precipitation data were interpolated to the same grid as NEXRAD data (Figure 1.7). This grid interpolated precipitation data were prepared for the period 1/1/1950 to 3/31/02. These interpolated data were used exclusively before 1994 and used to patch holes in the subsequent NEXRAD data. Because of the large amount of data associated with these weather files, all processing and formatting was done using custom programs written in VBA (Visual Basic for Applications) and Microsoft Excel.

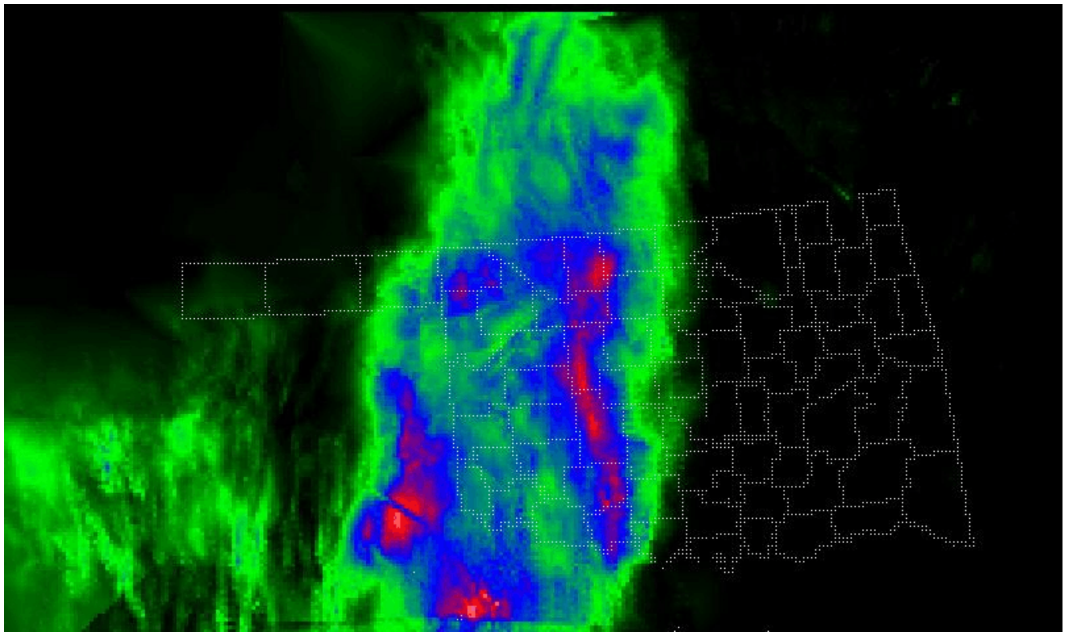


Figure 1.5 Example four kilometer resolution Next Generation Radar (NEXRAD) precipitation data for the State of Oklahoma, gage biased and archived by the Arkansas-Red Basin River Forecast Center (ABRFC).

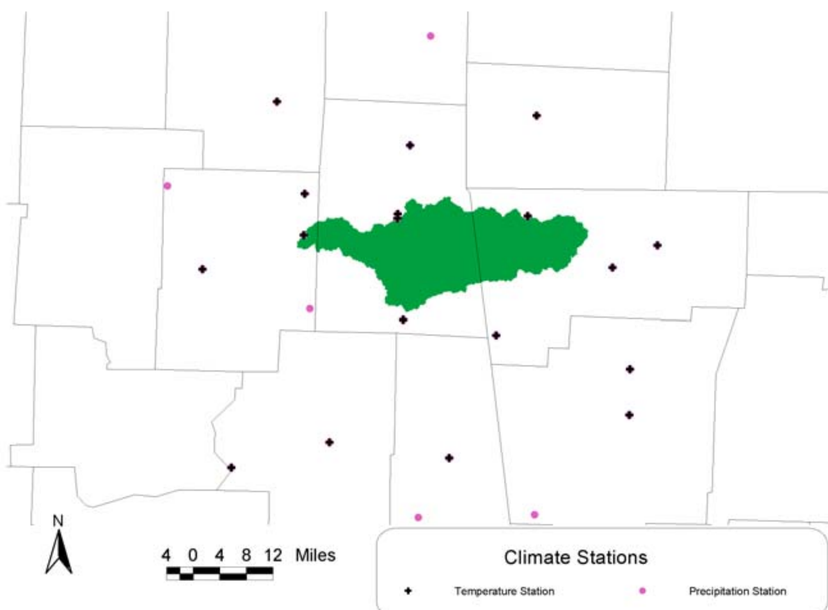


Figure 1.6 National Weather Service Cooperative Observation (COOP) network precipitation and temperature station locations near the Lake Eucha/Spavinaw Basin.

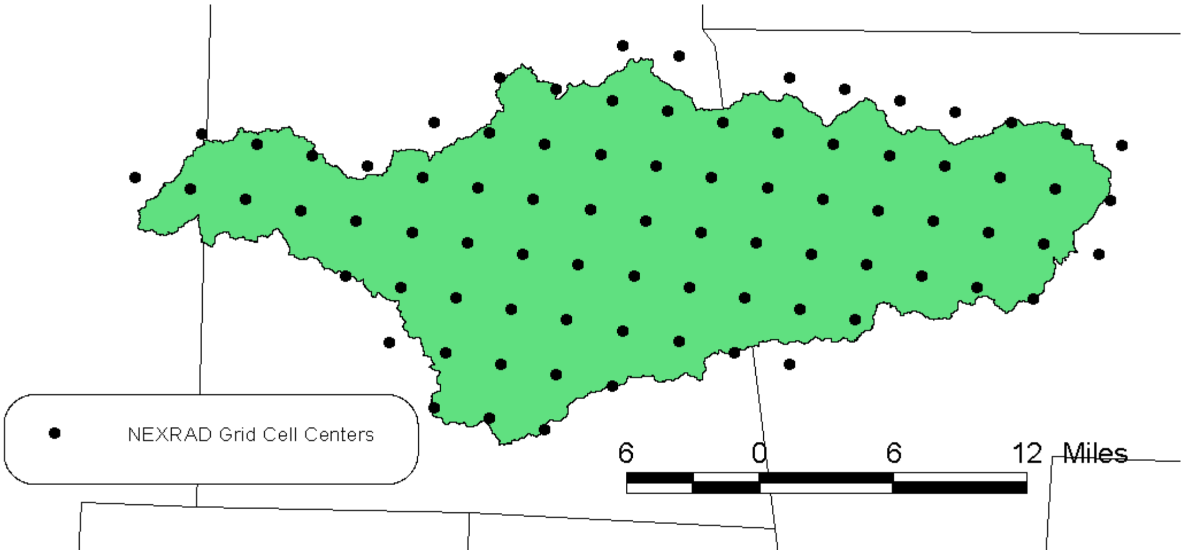


Figure 1.7 Four kilometer resolution Next Generation Radar (NEXRAD) grid cell centers used to define weather stations in the SWAT model for the Lake Eucha/Spavinaw Basin.

Subbasin Delineation

The subbasin layout was defined by SWAT using the DEM, a stream burn-in theme, and a table of additional outlets. The stream burn-in theme consists of digitized streams. Its purpose is to help SWAT define stream locations correctly in flat topography. A modified reach3 file from the US Environmental Protections Agency's BASINS (Better Assessment Science Integrating Point and Non-point Sources) model was used. The theme was modified to remove the outline of both lakes, which the model confused with a stream path. Model predictions are only available at subbasin outlets, so additional outlets were added at points of interest such as gage stations, water quality stations, or lake boundaries. A stream threshold value of 1000 ha was used to delineate subbasins. Threshold area is the minimum contributing upland area required to define a single stream. The result is 68 subbasins (Figure 1.8). Fewer subbasins would simplify the modeling process, but this level of detail was needed to adequately represent the basin.

HRU Distribution

Each of the 68 subbasins was split into HRUs (Hydraulic Response Units) by SWAT. The *land use [%] over subbasin area threshold* was changed from the default 20% to 1%. This threshold determines the minimum percentage of any land cover in a subbasin that will become an HRU. The *soil class [%] over subbasin area* was also reduced from its default value of 20% to 10%. By reducing these thresholds, the number of HRUs was increased to 1052.

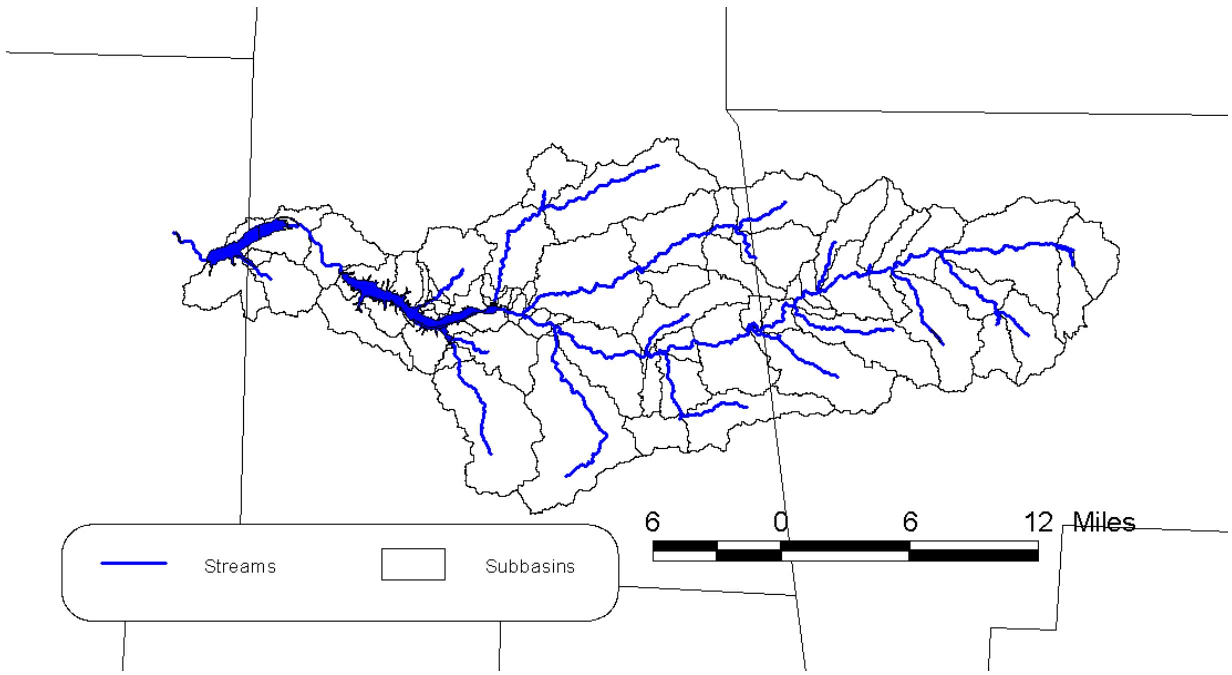


Figure 1.8 The Lake Eucha/Spavinaw basin divided into 68 subbasins. This configuration was used in all SWAT model predictions unless otherwise noted.

HRU Slope

One weakness of the SWAT 2000 Arcview Interface is that slope is considered uniform for all HRUs in a given subbasin. Forest and pasture HRUs are modeled using the same slope, when in reality they may be radically different. To eliminate this weakness, slopes were estimated from the DEM for each land cover in each subbasin manually. We derived slope for row crop/small grains only from fields larger than 10 acres, because it is unlikely that anyone would cultivate an area any smaller. These smaller areas are likely missclassifications in the land cover data. Forested areasin the basin had an averaged slope of 14.7 % while pasture (Figure 1.9) and row crop averaged 5.2 and 2.5%, respectively.

Ponds

Ponds affect the hydrology by impounding water and trapping nutrients. Water in ponds is subject to evaporation and seepage into the shallow aquifer. Nutrients and sediment settle out and are trapped. Test runs using the SWAT model indicate ponds significantly reduced nutrient and sediment concentrations.

Because of the difficulty associated with counting ponds in each subbasin, ponds were assumed uniformly distributed in agricultural portions of the basin. Heavily forested areas were assumed to have no ponds (Figure 1.10). All ponds in a single Beaty Creek subbasin were counted and summarized. These ponds were defined from 1:24,000 USGS DRG (Digital Raster Graphic). This level of detail was required to define the majority of ponds. These estimates were applied to all subbasins considered to have ponds. Other subbasins with similar land cover appeared visually similar, indicating that ponds are somewhat uniformly distributed throughout pasture areas in the basin. Of the total area in each subbasin, 20% was routed through ponds. Total surface area of all ponds in a subbasin was estimated as 0.32% of the total area of that subbasin. Each pond was assumed to have an average depth of 1.5 meters.

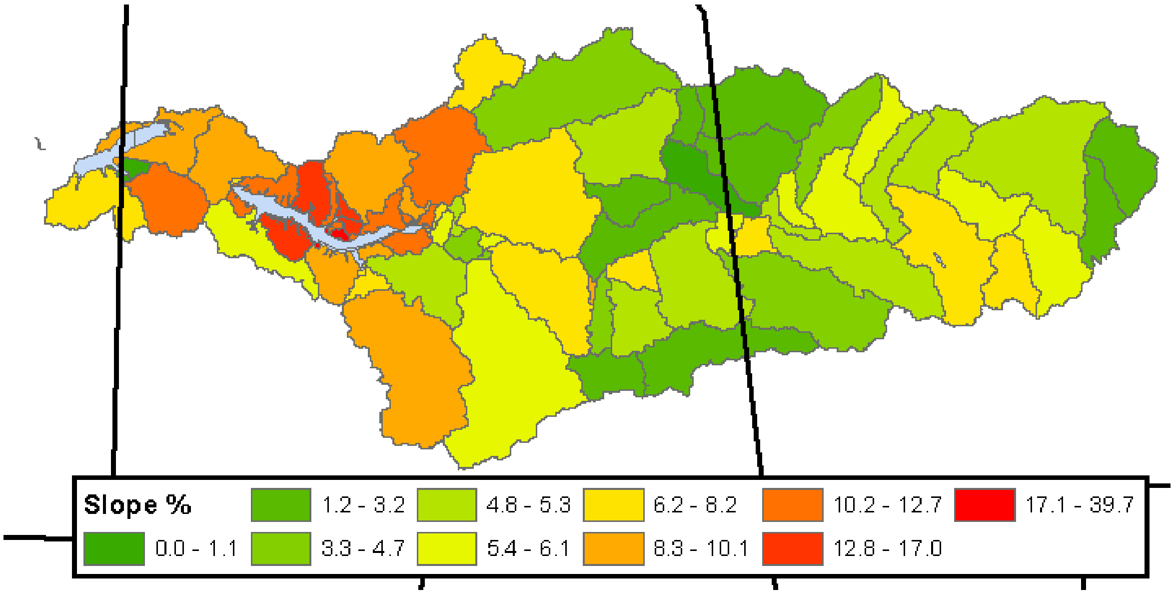


Figure 1.9 Pasture HRU slope by subbasin. Derived from land cover and 30 m Digital Elevation Model (DEM).

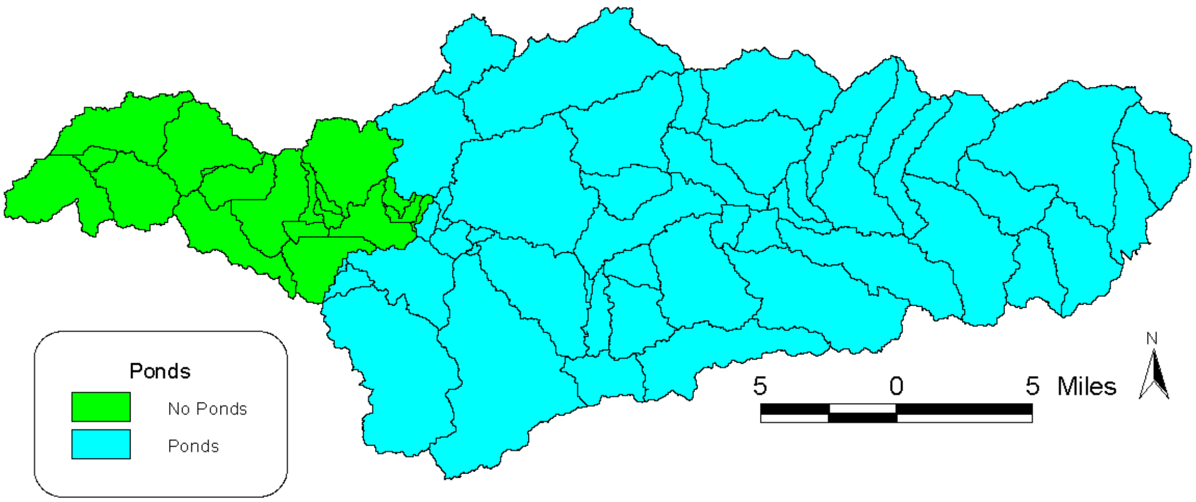


Figure 1.10 Subbasins in the Lake Eucha/Spavinaw basin assumed to have a significant number of ponds.

Management

SWAT defines management as a series of individual operations. The timing of these operations may be defined by a date, or as a fraction of the total heat units required by the crop. Each land cover is assigned a set of management operations. Following is a list of land covers and their relative coverage of the watershed as depicted in the SWAT Model:

•	Forest	51.3%
•	Hayed Pastures	13.3%
•	Well Managed Pastures	23.1%
•	Over-grazed or Poorly Managed Pastures	6.5%
•	Brushy Rangeland	0.1%
•	Urban	1.3%
•	Water	1.7%
•	Row Crop	2.6%

Heat Units

Heat unit scheduling is the default. Heat units are accumulated when the average daily temperature exceeds the base temperature of the crop. The base temperature is the minimum temperature required by the plant to grow. The amount of heat units accumulated each day is equal to the average daily temperature minus the base temperature of the plant. When no plants are growing the model uses a base temperature of 0^{o} C and keeps a separate running total. This base 0^{o}C running total is used to schedule planting dates because no heat units can be accumulated until plant growth begins.

Litter

Litter application rate was varied by land cover within each subbasin. Hay pasture received the base litter application rate. Poorly managed pastures received 70% of the base rate, while well managed pastures receive 130% of the base rate. Row crop received litter to supplement commercial fertilizer nitrogen application rates to recommended levels.

Pasture management is not uniform across the basin. The amount of litter applied in each subbasin is different. The SWAT interface was not used to generate these management files (.mgt), because that required each file to be manually modified. There is one management file for each of the 1052 HRUs. With multiple management changes, the task would be daunting. Therefore, a program was written to create files identical in format to those generated by the ArcView SWAT interface.

Cattle Stocking Rate

To verify the stocking rate used for pastures in th SWAT model, we estimated the actual number of cattle in the basin. County level National Agricultural Statistics Service (NASS) cattle estimates for the period 1998-2001 were combine with land cover data to estimate the number of cattle within the basin. We assumed that cattle are evenly distributed across all pastures in Delaware and Benton counties. From these data we estimate the number of cattle and calves in the basin to be 39,000 head.

The SWAT model does not simulate individual cattle. Instead a daily biomass removal and manure application are used to represent the presence of a grazing cow. The amount a cow will consume depends on the type and growth stage of the cow in question. Because there are many different types of cattle in the basin, we use the animal unit concept. Stocking rates are often expressed as animal units. One animal unit could be expressed as a cow and calf pair or two-400 lb stockers; both would consume a similar amount of grass. The total number of animal units simulated on pastures in the model is 24,500. Wheat is not included in this estimate because it is winter and spring grazing only, and thus this is a conservative estimate. Since the NASS derived estimate is the number of cattle and calves, these estimates are not directly comparable without assuming a specific type of animal (Table 1.1). The assumption of a 600 lb stocker cattle yields 35,000 head used in the SWAT model and a 10% error in the number of cattle simulated in the basin.

Row Crop

Row crop areas were managed as a winter wheat/green bean rotation. Grazing is suspended when dry biomass falls below 600 kg/ha (approximately 5 inch standing forage; OSU Extension Publication F-2586). Below are the row crop operations and dates used in the SWAT model.

Operation	Date
Grazing ½ Animal Unit/Acre	2/15
Litter Application	3/1
Harvest/Kill Wheat	5/1
Spring Plowing	5/4
Plant Green Bean	5/15
Harvest/Kill Green Bean	8/1

Commercial Fertilizer Application	8/5
Fall Plowing	8/10
Plant Wheat	9/1
Grazing 1/3 Animal Unit/Acre	11/1

Grazing on winter wheat was simulated at a stocking rate of 0.33 animal units per acre (Kansas State University Research and Extension Forage Facts Grazing Wheat Pasture), with 9.35 kg of dry biomass consumed and 3.0 kg of dry manure deposited per hectare (ASAE D384.1). Any time there is less than 1600 kg for well managed pastures and 600 kg/ha for poorly managed or over grazed pastures (dry weight) of biomass per hectare grazing is suspended.

Forest

Only minor modifications to the default management for forested areas were made. Ideal forest management would have contained no harvest operation. However, this operation was required to increase temporal stability.

Operation	Heat Units
Plant	0
Harvest	1.2

Hayed Pastures

A cool season grass was selected as the cover for hay pastures in the model. No grazing was simulated on hay pastures. Hay pastures receive the base litter application rate. The operations are listed below:

Operation	Date
Plant	1/1
Apply Litter	2/1
Cut Hay	4/1
Cut Hay	6/1
Cut Hay	8/1

Well Managed Pastures

Well managed pastures are simulated as lush pastures in good condition. Fertilization rate are increase to 130% of the base litter application rate, and curve numbers are reduced accordingly. Grazing is suspended when dry biomass falls below 1600 kg/ha (4-5 inches of dense cool season grass, Iowa State University Extension, *Estimating Available Pasture Forage*). Stocking rate is simulated at 1/3 AU/acre for 300 days.

Operation	Date
Plant	1/1
Apply Litter	2/1
Graze	3/1

Over-grazed or Poorly Managed Pastures

Poorly managed pastures are simulated as under fertilized pastures in poor condition. Fertilization rates are decreased to 70% of the base litter application rate, and curve numbers are increased. Grazing is suspended when dry biomass falls below 300 kg/ha (1 inch of fair condition cool season grass (Iowa State University Extension, *Estimating Available Pasture Forage*). Stocking rate is identical to that of well managed pastures.

Operation	Date
Plant	1/1
Apply Litter	2/1
Graze	3/1

Brushy Rangeland

Like forests, only minor modifications to the default management for rangeland were made. Rangeland was the most temporally unstable land cover simulated. The addition of a harvest operation increased the temporal stability, but as this cover represents only 0.1% of the basin further modification was deemed unnecessary.

Operation	Heat Units
Plant	0
Harvest	1.2

Urban

Urban parameters are not defined by the management. Management defines cover for pervious areas.

Operation	Date
Plant	1/1

Table 1.1 Estimates of the number of cattle in the basin derived from National Agricultural Statistics Service (NASS) and those used in the SWAT Model (pasture grazing only) assuming different types of animals.

Used in SWAT (Animal Units)	Type of animal	Animal Units Per Animal	Equivalent Animals in SWAT	NASS Estimate (Animals)	Difference
24,500	Adult Cow	1	24,500	39,000	-37%
24,500	600 lb stocker	0.7	35,000	39,000	-10%
24,500	Cow calf pair	1	49,000	39,000	26%
24,500	300 lb stocker	0.4	61,250	39,000	57%

Soil Phosphorus Content

Two distinctly different methods were used to estimate soil phosphorus content. Pasture and row crop soil phosphorus content were estimated using observed soil test data STP for forested area was not used directly in the SWAT model, but instead was used as a calibration parameter.

Pasture - Soil Phosphorus Content

Observed soil test data were used to estimate the soil phosphorus content for pasture portions of each subbasin. Pasture soil samples collected by the Oklahoma Conservation Commission in 1998 and analyzed by the Oklahoma State University (OSU) Soil, Water & Forage Analytical Laboratory were used for the Oklahoma portion of the watershed, which resulted in an average STP of 170 lb P/acre. Soil samples for the Arkansas portion of the basin were provided by the Arkansas Soil and Water Conservation Commission. These data were collected by the Benton County Conservation District during 1994 through 1997 and analyzed by the University of Arkansas Soil and Water Laboratory. A mean of 334 lb P/acre was derived from 261 pasture soil samples of Benton County.

Soil test phosphorus (STP) data for Oklahoma and Arkansas were analyzed in different labs using slightly different methods. Oklahoma soil samples were analyzed by the Oklahoma State University (OSU) Soil, Water & Forage Analytical Laboratory and Arkansas soil samples were analyzed by the University of Arkansas (UA) Soil Testing and Research Laboratory. OSU and UA use extraction ratios of 1:10 and 1:7, respectively, and use different instrumentation for analysis. OSU uses a colorimetric method and UA uses inductively coupled argon plasma spectrometry (ICAP). Dr. Nathan Slaton with the UA provided the following relationship for different extraction ratios ($n \approx 500$):

$$ICAP\,Mehlich\,III\,P(1{:}10) = 1.27\ ICAP\,Mehlich\,III\,P(1{:}7) + 14.9$$

where Mehlich III is in mg/l. Dr. Hailin Zhang with OSU provided the following relationship between ICAP and the colorimetric method (n=3577 R^2=0.98):

$$ICAP\,Mehlich\,III\,P(1{:}10) = 1.11\ Colormetic\,Mehlich\,III\,P(1{:}10) + 26.7$$

where Mehlich III is in mg/l. The average pasture STP level used for the Arkansas portion of the Lake Eucha basin was 334 lbs/ac. Based on these regression equations, an Arkansas STP of 334 lbs/ac corresponds to an OSU value of 372 lbs/ac.

Soil samples from the Oklahoma Conservation Commission were double checked to ensure that their locations were within the indicated subbasin. Some 14 samples fell outside the Lake Eucha basin or were unusable for other reasons. Samples less than 400 meters outside the basin were reassigned to the nearest subbasin. An area weighted soil test phosphorus was calculated for each of SWAT`s 58 subbasins (Figure 1.11).

Row Crop - Soil Phosphorus Content

County level soil test data for row crop/small grains fields were obtained for Benton and Delaware counties and incorporated into the SWAT model. Data for Benton county were taken from the University of Arkansas Soil Testing and Research Laboratory website (http://www.uark.edu/depts/soiltest/). County and crop codes required to utilize these data were obtained from Nathan Slayton (Director of Soil Testing, University of Arkansas Soil Testing and Research Laboratory). These data were corrected for differences in laboratory methods, yielding a Mehlich III STP value of 212 lb/acre for Benton county row crop/small grains. Data for Delaware county were compiled by the Oklahoma State Soil, Water & Forage Analytical Laboratory at our request. An average of 155 lb/acre was calculated for row crops/small grains in Delaware county. These county averages were weighted by the number of observations in each county to produce a weighted average of 188 lb/acre. Summaries of these soil test data are located in Tables 1.2 and 1.3.

Table 1.2 Soil test phosphorus observations for row crops and small grains in Delaware county, Oklahoma. Source: Oklahoma State Soil, Water & Forage Analytical Laboratory 1994-2001.

Crop	Samples	Average
Corn	2	360
Grain Sorghum	4	91
Oats	2	662
Small Grains for Grazing	9	83
Sorghum Ensilage	1	191
Sorghum-Sudan Hay	5	237
Soybeans	17	142
Wheat	30	134
Wheat Silage	1	71
Average	72	154.6

Table 1.3 Soil test phosphorus observations for row crops and small grains in Benton county, Arkansas. Source: University of Arkansas Soil Testing and Research Laboratory 1999-2001.

Crop	Samples	Average
BEANS - SNAP (ROWS LESS THAN 3 FT. APART AND IRRIGATED)	4	196
BEANS - SNAP (ROWS MORE THAN 3 FT. APART, NOT IRRIGATED OR IRR.)	23	144
CORN FOR GRAIN	2	168
CORN FOR SILAGE NON-IRRIGATED, HIGH YIELD POTENTIAL	4	193
CORN FOR SILAGE NON-IRRIGATED, MEDIUM YIELD POTENTIAL	5	225
OATS FOR GRAZING	3	359
RYE FOR GRAZING	6	229
RYEGRASS	17	187
SMALL GRAIN/RYEGRASS/CLOVER	11	107
SORGHUM X SUDAN	8	458
SOYBEANS ALONE - NON-IRRIGATED	10	123
SUDANGRASS	1	261
WHEAT FOR GRAIN	6	208
Average	100	195.4

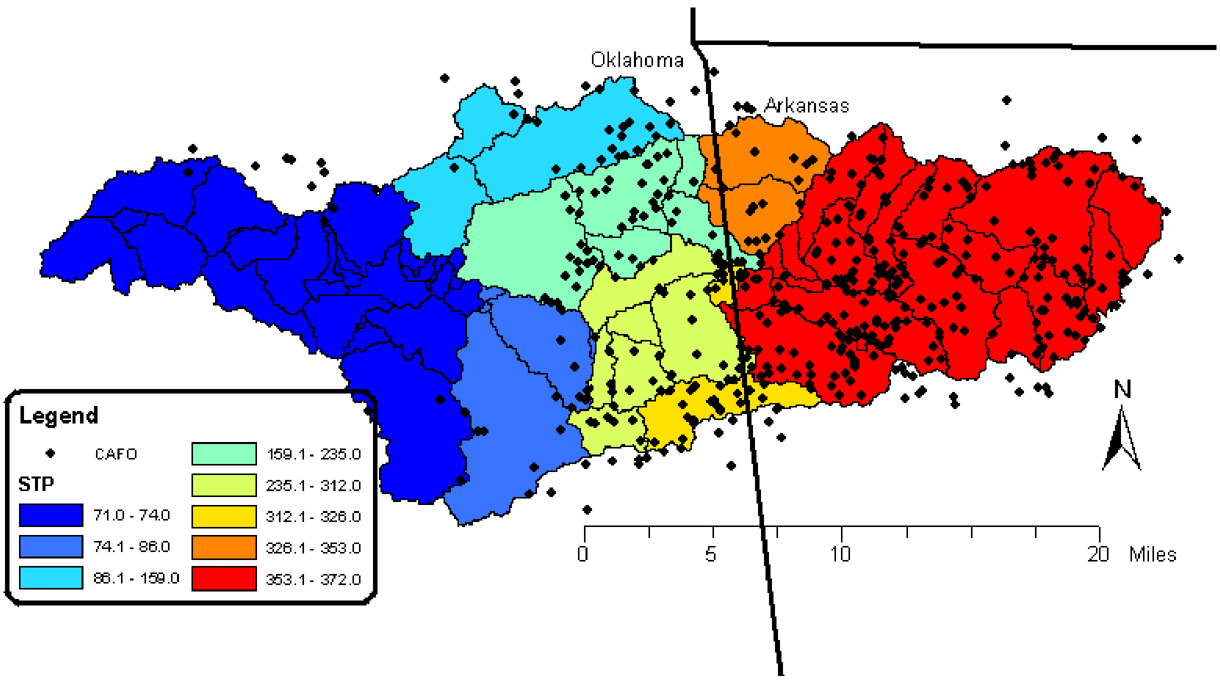


Figure 1.11 Mehlich III soil test phosphorus (STP) for pastures and row crop by subbasin for the Lake Eucha/Spavinaw Basin. Dots indicate poultry house locations.

Poultry Litter Application Rate

The number of poultry houses and the pasture area in each subbasin were used to determine poultry litter application rates. All litter produced in a subbasin was assumed to be uniformly applied to pastures in that subbasin.

Simmons Foods Inc. provided locations of several company farms which export poultry litter from the basin. The initial litter application rate was reduced in these areas to account for the exported litter. A total of 5883 ton/yr was exported. Other integrators also export litter but the locations of their houses were not available, and thus we were unable to remove the litter from the proper subbasins. It should be noted, however, that Simmons Foods Inc. represented a significant portion of the exported poultry litter in the basin.

Broiler, layer, and turkey production all contribute to the total litter production. Each type of operation produces a different amount of litter, and litter of a different composition (Table 1.4). The amount of litter contributed basin-wide by each type of operation is summarized in Table 1.5. The average litter composition was determined by using the relative amount of each litter applied in the basin and it's composition (Table 1.6).

The average amount of poultry litter applied to pastures was 1830 kg/ha (0.81 ton/acre). This is the total amount of litter produced in the basin divided by the total area of pasture and row crop. Because many pastures receive little or no poultry litter the average application rate would be somewhat higher. The maximum poultry litter rate was assigned to subbasin 52, 9310 kg/ha (4.1 ton/acre), which reflects the high number of poultry operations located in the small subbasin (Figure 1.12). A total of 91,700 tons of poultry litter was estimated to be applied in the Eucha/Spavinaw

Basin each year. This poultry litter contained approximately 1,140,000 kg phosphorus (1260 ton) and 3,800,000 kg nitrogen (4190 ton).

Table 1.4 Annual poultry litter production by house in the Lake Eucha/Spavinaw Basin and fractional composition by operation type. (Broilers assumed 5 batches per year)

Operation	Litter per 20,000 animal capacity	Mineral N	Mineral P	Organic N	Organic P	Source
Broiler	100 ton/yr	0.01000	0.00400	0.04000	0.01000	Storm et al. (1999) and SWAT Database
Layer	200 ton/yr	0.01300	0.00600	0.04000	0.01300	Finley (1994) and SWAT Database
Turkey	310 ton/yr	0.00700	0.00300	0.04500	0.01600	Vest (1994) and SWAT Database

Table 1.5 Poultry litter production in the Lake Eucha/Spavinaw Basin by operation type.

Type	Litter production t/yr	Realtive litter production
Broilers	72684	79.3%
Genetic	3000	3.3%
Genetic & Broiler	1200	1.3%
Layers	8200	8.9%
Pullets	1900	2.1%
Turkeys	4720	5.1%
Total	91704	100%

Table 1.6 Average fraction nutrient concentration of poultry litter produced in Lake Eucha/Spavinaw Basin.

Type	Realtive litter production	Mineral N	Organic N	Mineral P	Organic P
Broilers	79%	0.010	0.040	0.004	0.010
Genetic	3%	0.013	0.040	0.006	0.013
Genetic & Broiler	1%	0.010	0.040	0.004	0.010
Layers	9%	0.013	0.040	0.006	0.013
Pullets	2%	0.010	0.040	0.004	0.010
Turkeys	5%	0.007	0.045	0.003	0.016
Average		0.0102	0.0403	0.0042	0.0107
Used in SWAT Model		0.010	0.040	0.004	0.011

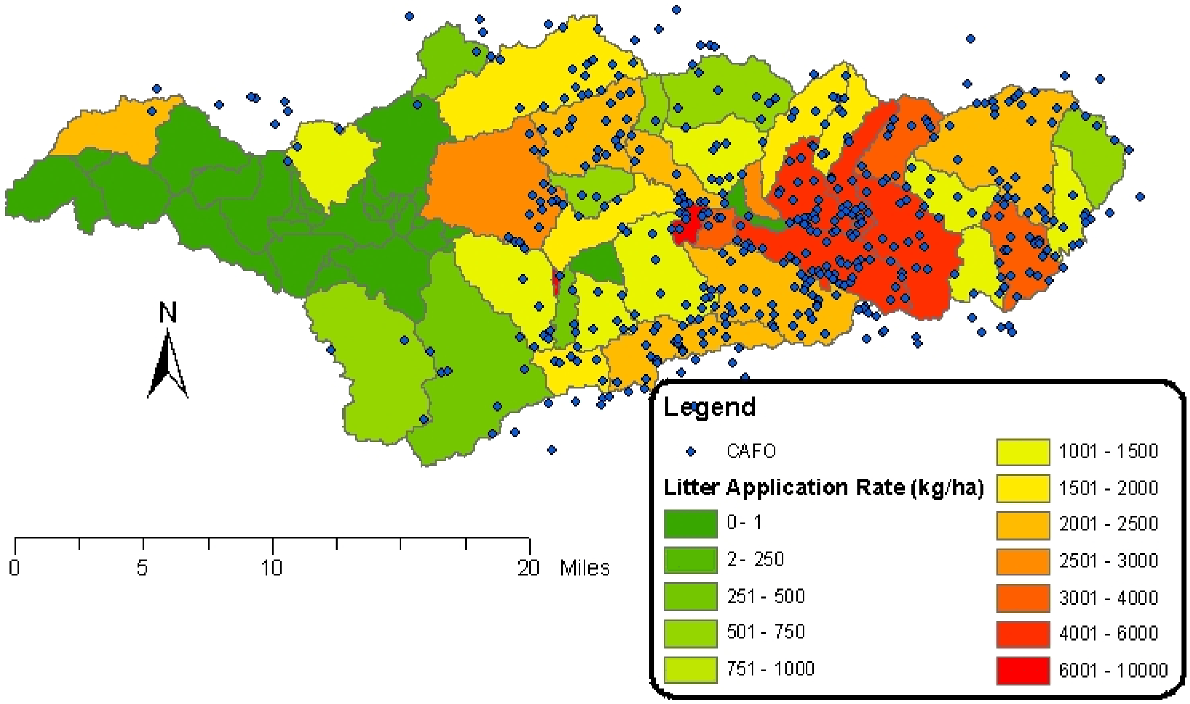


Figure 1.12 Poultry litter applied by subbasin and poultry house locations (black dots) for the Lake Eucha/Spavinaw basin.

Commercial Fertilizer Applications

To simplify the management input files, commercial nitrogen and phosphorus fertilizer sales in 1998 and 1999 for Delaware County, Oklahoma and Benton County, Arkansas were assumed to be uniformly applied to row crop in each county. Yearly rates for both counties were area weighed to estimate a single annual application rate for row crop the basin (32 kg/ha nitrogen and 0.42 kg/ha phosphorus). Phosphorus inputs from commercial fertilizer were negligible compared to inputs from poultry litter.

Observed Stream Flow

The Lake Eucha/Spavinaw Basin contains three USGS stream gages (Figure 1.13). These gages were used to calibrate the hydrologic portion of the model. Each gage station has a different period of record (Table 1.7.)

Table 1.7 Available period of record at U.S. Geographic Survey stream gage stations.

Gage Station	Start Date	End Date
Spavinaw Creek Near Sycamore	10/1/1961	Current
Beaty Creek Near Jay	7/31/1998	Current
Black Hollow Near Spavinaw	7/24/1998	9/30/2001

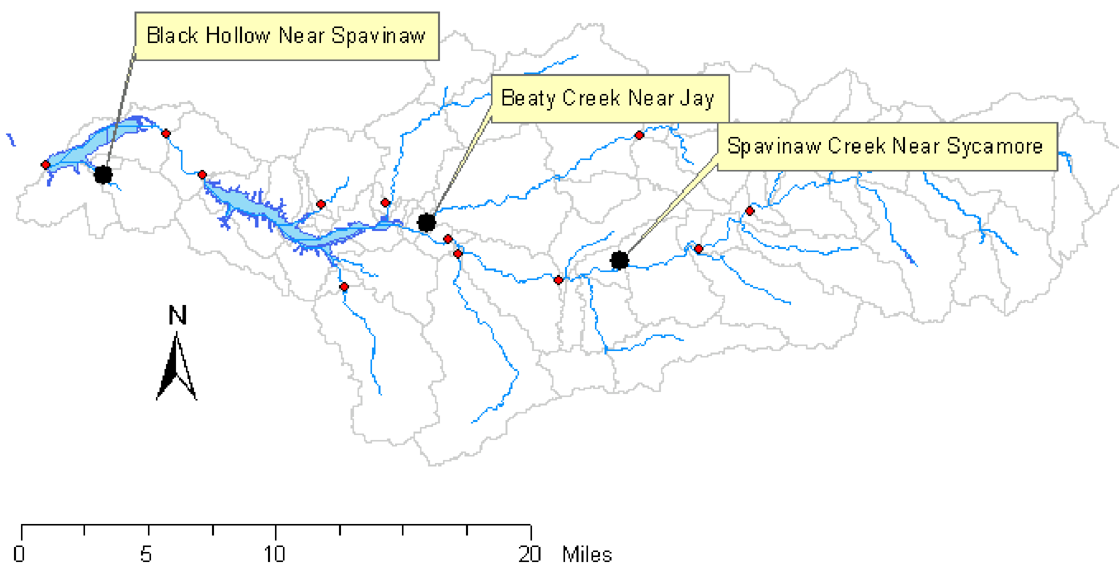


Figure 1.13 Active U.S. Geographic Survey stream gage stations used to calibrate the SWAT model for the Lake Eucha/Spavinaw Basin. (Red dots represent the City of Tulsa water quality stations)

Baseflow Separation

Stream flow has two primary sources, surface runoff and ground water. Ground water contributions to stream flow are known as baseflow. The SWAT model was calibrated separately against observed surface and baseflow. Baseflow was separated from the total observed stream flow using the USGS HYSEP sliding interval method. Baseflow fractions were relatively high throughout the basin, likely the result of the karst topography(Table 1.8). Karst features allow significant interaction between stream flow and ground water (Wagner and Woodruff 1997).

Table 1.8 Observed average flow and baseflow fractions as determined by the HYSEP sliding interval method.

Gage	Total Flow	Surface Runoff	Baseflow	Period
Blackhollow	0.109	36% - 22%	78% - 64%	8/98 to 9/01
Beaty Creek	1.33	59% - 52%	48% - 41%	8/98 to 3/02
Spavinaw Creek	3.3	60% - 43%	57% - 39%	8/98 to 3/02

Observed Loading Development

Water quality data were available for 10 suitable locations in the basin. Soluble and total phosphorus and nitrate loads were estimated at each of these stations (Figure 1.14). SWAT was calibrated for nutrients after the hydrologic calibration was completed.

Flow Estimation

Flow was estimated at each water quality station where flow data were unavailable. Initially, daily flow was estimated from the closest stream gage and assumed flow was proportional to drainage area. Flow data before 8/1998 were estimated from the Spavinaw station only, because Spavinaw was the only active station before 8/1998. To further refine the estimate, the flow at each station was separated into surface and baseflow fractions. The ratio of daily precipitation for the area above each water quality station and the area above each gage was used to bias surface runoff estimates. Baseflow fractions were not corrected. Surface runoff adjustments were limited to a maximum of three times and a minimum of 1/3 the original value.

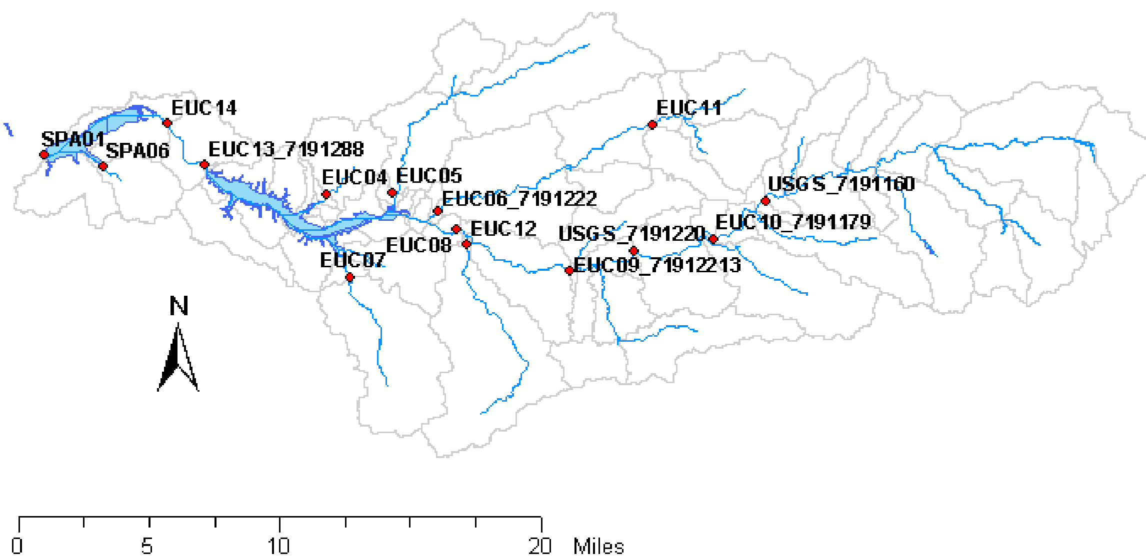


Figure 1.14 City of Tulsa and US Geographic Survey water quality station locations.

Nutrient Loading

Nutrient loads were estimated by station using the USGS DOS program LOADEST2 (Crawford, 1996). This program was developed by Charles Crawford (USGS Supervisory Hydrologist) to estimate loading using the rating curve method. The software has 10 models from which to choose, with models 1-8 are listed below:

moodel 1: ln(load) = b0 + b1 ln(flow)
model 2: ln(load) = b0 + b1 ln(flow) + b2 ln(flow)**2
model 3: ln(load) = b0 + b1 ln(flow) + b2 dectime
model 4: ln(load) = b0 + b1 ln(flow) + b2 sin(dectime) + b3 cos(dectime)
model 5: ln(load) = b0 + b1 ln(flow) + b2 ln(flow)**2 + b3 dectime
model 6: ln(load) = b0 + b1 ln(flow) + b2 ln(flow)**2 + b3 sin(dectime) + b4 cos(dectime)
model 7: ln(load) = b0 + b1 ln(flow) + b2 sin(dectime) + b3 cos(dectime) + b4 dectime
model 8: ln(load) = b0 + b1 ln(flow) + b2 ln(flow)**2 + b3 sin(dectime) + b4 cos(dectime + b5 dectime

Dectime is time in fractional years.

Each of these 8 models was used by LOADEST2 at each station. At each station 2 to 3 models were selected based on the estimated residual variance calculated by LOADEST2. These 2 to 3 models were then graphed as observed vs predicted concentrations. Visual comparisons of each graph and the estimated residual variance for each model were used to select the best model at each station (Table 1.9).

Table 1.9 Model type, estimated observed phosphorus load, and water quality data observations by station using Loadest2 (includes both point and nonpoint sources).

Station	Type	Model	LOAD kg/yr	Uncensored Observations
EUC04	Total P	4	166	26
EUC05	Total P	8	2489	33
EUC06	Total P	8	8461	218
EUC07	Total P	5	1161	40
EUC08	Total P	8	34841	174
EUC09	Total P	2	24886	71
EUC10	Total P	1	16591	67
EUC11	Total P	6	3982	68
EUC12	Total P	3	813	13
SPA06	Total P	6	114	74
EUC04	Soluble P	8	11	25
EUC05	Soluble P	8	979	32
EUC06	Soluble P	8	3650	137
EUC07	Soluble P	4	159	38
EUC08	Soluble P	8	14268	134
EUC09	Soluble P	8	23227	71
EUC10	Soluble P	7	16591	67
EUC11	Soluble P	8	1327	68
EUC12	Soluble P	1	498	13
SPA06	Soluble P	6	41	51
EUC04	Nitrate as N	4	5475	28
EUC05	Nitrate as N	8	23227	35
EUC06	Nitrate as N	8	114477	221
EUC07	Nitrate as N	7	10618	48
EUC08	Nitrate as N	6	514318	176
EUC09	Nitrate as N	6	530909	70
EUC10	Nitrate as N	8	365000	66
EUC11	Nitrate as N	6	64705	67
EUC12	Nitrate as N	7	33182	13
SPA06	Nitrate as N	6	2489	68

Point Source Loadings

Although most of the nutrient loading was attributed to non-point source pollution, one significant point source is located in the Lake Eucha/Spavinaw Basin at the City of Decatur, Arkansas. A poultry processing plant is located in City of Decatur, with waste from the plant processed by the City of Decatur waste water treatment plant. The treatment plant discharges to Colombia Hollow. The US Environmental Protection Agency PCS (Permit Compliance System) contains estimated monthly loading from Decatur (NPDES ID AR0022292). Only the average daily load was used (Table 1.10).

Table 1.10 City of Decatur, Arkansas point source average daily load for the period 1-98 to 3-02.

Parameter	Total P	Nitrate-N	Flow	Ammonia-N
Units	kg/day	kg/day	m^3/day	kg/day
Value	32	10	4829	40

CALIBRATION

The SWAT model was calibrated using observed stream and nutrient data. Three stream gage stations and eight water quality stations were used in the calibration. The model was calibrated for total flow, surface flow, baseflow, soluble phosphorus, and total phosphorus.

The model was first calibrated on stream flow at each of the three gages. Observed stream flow was split into surface runoff and baseflow. After the hydrologic calibration the model was calibrated for nutrients. SWAT model predicted loads were compared to loads estimated from samples taken at eight water quality stations, and relative error was calculated at each station. The relative error in load at each station was weighted by the area upstream each station and the number of high flow samples at that station were used to develop a single basin wide relative error. This average relative error was used to guide the nutrient calibration. The sum of the absolute relative error at all stations was also calculated and used as a secondary guide during the calibration.

$$\text{Relative Error (\%)} = (\text{Predicted- Observed})/\text{Observed} \ * 100\ \%$$

Hydrologic Calibration

Three gage stations, shown in Figure 1.15, were used in the calibration of total flow, surface runoff, and base flow. All available streamflow for the calibration period (8/1/1998 to 3/15/2002) were utilized. The period of available data from the three stations is not the same. Spavinaw Creek have data prior to 8/98 but it was not included in the calibration to allow a single calibration period for all stations.

We split the basin into three areas, each with a different set of calibration parameters. Subbasins not upstream of a gage were lumped with the most similar adjacent calibrated area. Land use, topography, geology, and location were used to determine subjectively how to lump each subbasin. Relative error was used to compare observed and predicted data and to guide the calibration process.

Modifications to model parameters were required to calibrate the model and are given in Table 1.11. Parameters governing ground water were modified to compensate for the karst topography of the region. Results of the calibration are shown in Table 1.12. Note relative error was less than 5% for the Spavinaw and Beaty Creek gages. Blackhollow was calibrated by visual comparison between observed and predicted flows, and thus the average annual relative error is not a good measure of the quality of the calibration at this station. The visual calibration was required due to long dry periods with no flow observed at the gage. Figures 1.16 and 1.17 detail the results of the calibration at the Spavinaw Creek Gage.

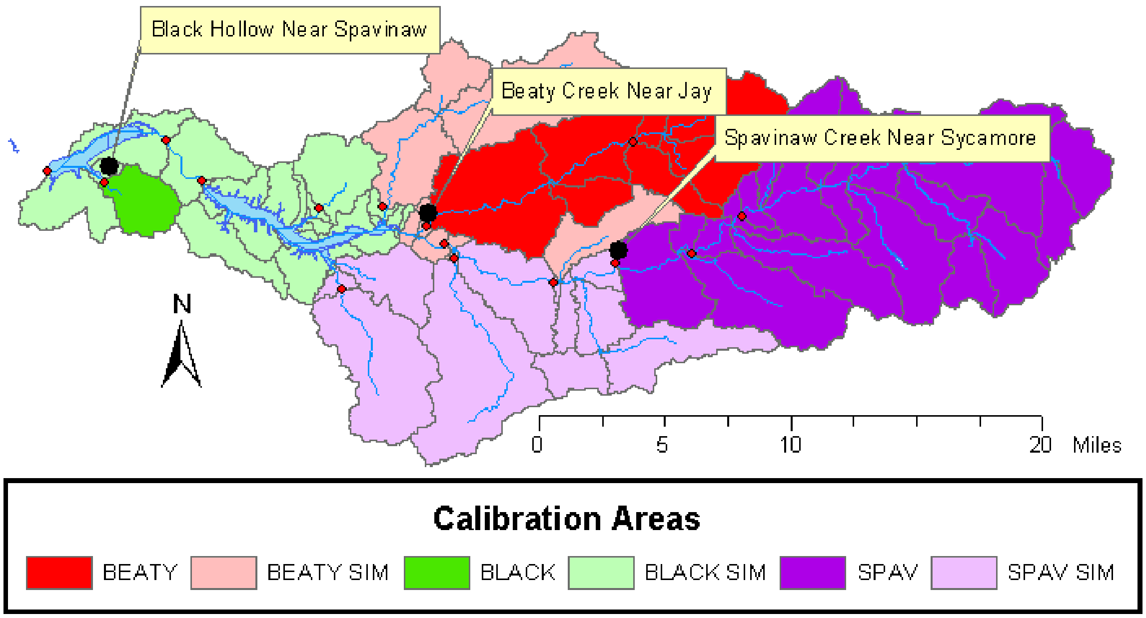


Figure 1.15 SWAT calibration regions for the Eucha/Spavinaw Basin (SIM denotes an area that is not upstream of a gage station).

Table 1.11 Parameter modifications made to calibrate the hydrologic portion of the SWAT model.

Parameter	Spavinaw	Beaty	Blackhollow
Initial depth of water in shallow aquifer (mm)	100	100	100
Baseflow delay (days)	1	1	1
Alpha baseflow factor	0.11	0.11	0.11
Min depth in shallow aquifer for baseflow (mm)	30	30	30
Revap Coff.	0.02	0.02	0.02
Min depth in shallow aquifer for revap (mm)	10	10	10
Fraction of shallow aquifer directed to deep aquifer	0.17	0.17	0.7
Mannings N for overland flow	0.15	0.15	0.15
Soil Evaporation Compensation Factor	0.63	0.63	0.63
Curve number adjustment	-5	0	-5
Channel permeability (mm/hr)	100	100	100
Mannings N for channel	0.1	0.1	0.1
Pond bottom permeability (mm/hr)	3	3	3

Table 1.12 Average annual results for the hydrologic calibration of the SWAT model at each USGS streamflow gage.

Gage	Observed			Predicted			Relative Error
	Total Flow	Surface Runoff	Baseflow	Total Flow	Surface Runoff	Baseflow	Total Flow
Blackhollow	0.109	36% - 22%	78% - 64%	0.094	53%	47%	-13.7%
Beaty Creek	1.33	59% - 52%	48% - 41%	1.37	52%	48%	2.9%
Spavinaw Creek	3.3	60% - 43%	57% - 39%	3.45	48%	52%	4.4%

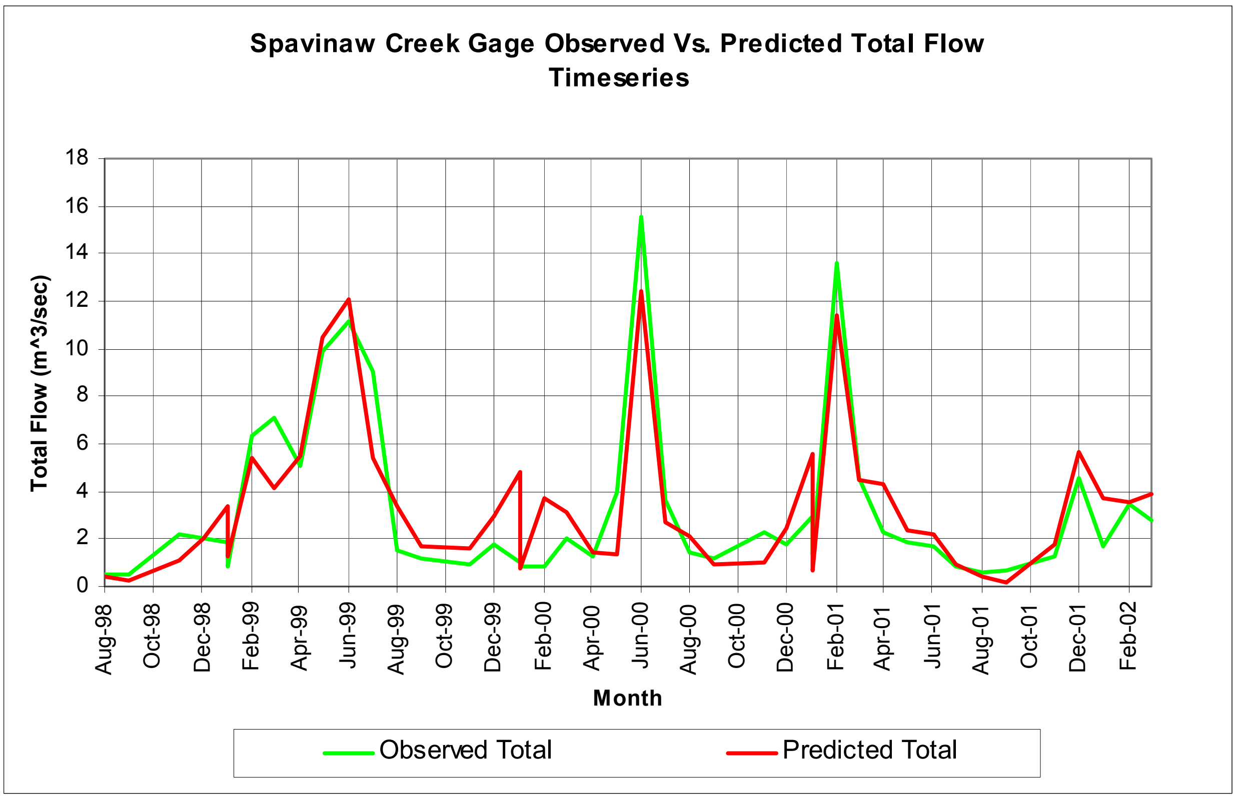


Figure 1.16 Time-series comparison of stream flow at Spavinaw Creek gage for the period 8/1/1998 to 3/15/2002.

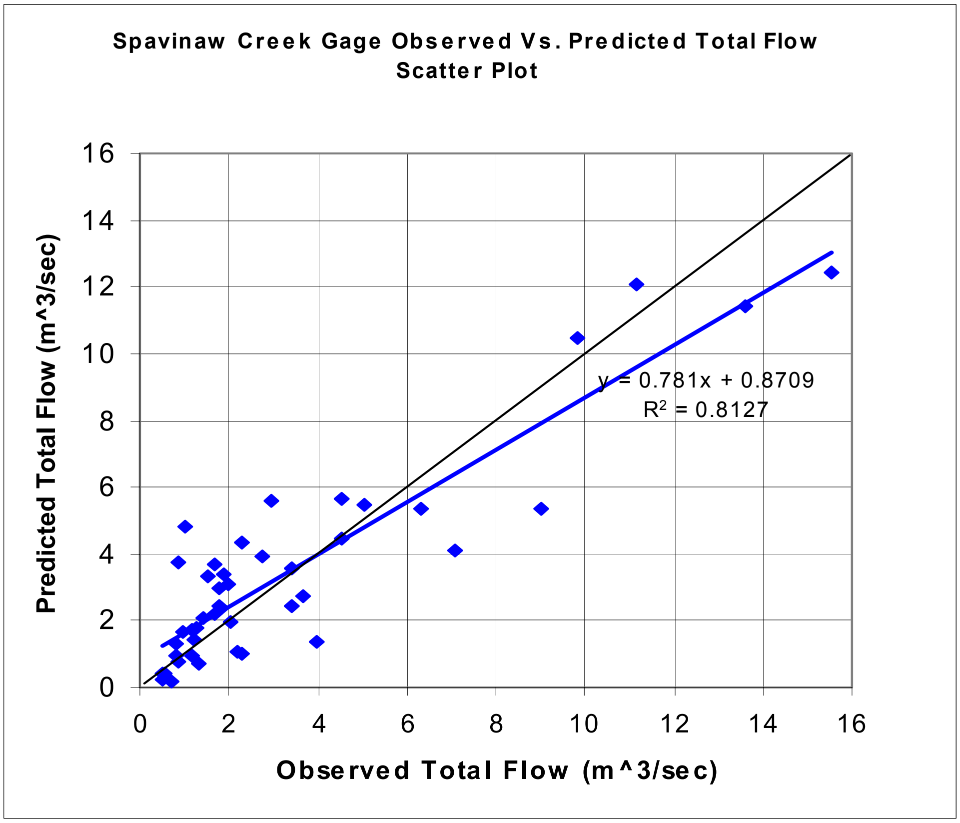


Figure 1.17 Time-series comparison of stream flow at Spavinaw Creek gage for the period 8/1/1998 to 3/15/2002.

Nutrient Calibration

The nutrient calibration was performed in a different manner than the hydrologic calibration, because many nutrient parameters are not specific to land covers or subbasins. A slightly different period was also used to calibrate the nutrient portion of the model, i.e.1-1-98 to 3-15-2002. The hydrologic calibration did not begin until 8-1-98. The basin was calibrated as a whole using comparisons at all stations simultaneously.

Sediment

Sediment was included in the calibration process because of its impact on nutrient load. No recent sediment data were available and thus sediment loss was adjusted to literature based levels (Table 1.13)

Table 1.13 Minimum C Factor and SWAT predicted sediment loss by land cover for the Lake Eucha/Spavinaw basin for the period 1-1-98 to 3-15-2002.

Land Cover	Minimum C Factor	Sediment Yield MT/ha
Urban	0.003	0.189
Forest	0.001	0.047
Hay	0.001	0.010
Poorly Managed Pasture	0.001	0.113
Range	0.002	0.093
Water	0	0.000
Well Managed Pasture	0.001	0.003
Row Crop	0.03	7.790

Phosphorus

Observed and predicted loads at 8 of the 10 stations were compared. The remaining two stations had little high flow sampling and were considered too uncertain for use in the calibration. Relative error was calculated at each station for soluble and total phosphorus. These relative errors were area weighted according to the contributing area at each water quality station and the number of high flow samples; the result was used to guide the calibration. The result of the nutrient calibration is shown in Table 1.14.

Some observed loads are calculated from samples taken downstream the City of Decatur point source. To quantify nonpoint source loading from the observed data, we remove the loading from City of Decatur point source by assuming the load was 90% soluble and simply subtracted it from all stations downstream. In reality much of this soluble phosphorus would be assimilated into the biota and only be measurable via total phosphorus. We do not have data to directly estimate how much of the point source load would be soluble when it reaches each of the downstream stations, and therefore our assumption was conservative.

Relative error at any given station may be off by a substantial amount. Because the majority of the parameters are not distributed, it is not possible to make an adjustment at one station without affecting all other stations. In addition, many stations do not have sufficient high flow sampling to accurately estimate loadings and thus little relative weight was given to these stations in the calibration process. The following parameters were adjusted basin wide in the basin input file (Basins.bsn):

NPERCO (Nitrogen Percolation Coefficient) = 2
PPERCO (Phosphorus Percolation Coefficient) = 3
PHOSKD (Phosphorus Soil Partitioning Coefficient) = 800
PSP (Phosphorus Sorption Coefficient)= 0.42

Additional parameters such as Biological Mixing Efficiency (BIOMIX) and Minimum Biomass for Grazing were also modified by land cover. These values are listed in Table 1.15.

STP was used to calibrate the nutrients from forested areas. Modifications to basin wide phosphorus parameters were required to calibrate the model form its response to surface application of poultry litter. These modifications required an increase in labile P in forested areas to 40 mg/kg to maintain satisfactory total P loading from heavily forested areas like Blackhollow.

Table 1.14 Observed and SWAT predicted average nonpoint source (NPS) annual nutrient load at City of Tulsa water quality stations for the period January 1998 to March 2002. City of Decatur point source loading removed from relevant stations assuming load is 90% soluble and is not modified instream. High flow sample is defined as three times the average flow; a maximum of two high flow samples are counted for each day. Relative weight is based on the number of high flow samples and the area above the station.

Station	AREA km^2	High Flow Total P Samples	Relative Weight	Observed Total P kg/yr	Predicted Total P kg/yr	Relative Error Total P	Observed Soluble P kg/yr	Predicted Soluble P kg/yr	Relative Error Soluble P
EUC04	20.9	4	0.01	166	278	-68%	11	140	-1158%
EUC05	87.1	4	0.03	2489	4045	-63%	979	1323	-35%
EUC06	153.0	28	0.31	8461	8243	3%	3650	3673	-1%
EUC07	50.6	2	0.01	1161	795	32%	159	280	-76%
EUC08	517.6	16	0.61	23341	22936	2%	3918	12388	-216%
EUC11	65.9	4	0.02	3982	3431	14%	1327	1766	-33%
EUC12	64.3	2	0.01	813	1247	-53%	498	425	15%
SPA06	15.6	12	0.01	114	110	4%	41	23	44%
Average Weighted Relative Error						0%			-140%

Table 1.15 Management parameters used to calibrate the nutrient portion of the SWAT model.

Land Cover	Biomix	BIO_MIN (kg/ha)
Hay	0.2	N/A
Poorly Managed Pasture	0.2	800
Well Managed Pasture	0.2	1600
Urban	0.05	N/A
Row Crop	0.05	600
Forest	0.05	N/A
Range	0.05	N/A

MODEL LIMITATIONS

There are several limitations that should be noted. Limitations may be the result of data used in the model, inadequacies in the model, or using the model to simulate situations for which it was not designed. Hydrologic models will always have limitations, because the science behind the model is not perfect nor complete, and a model by definition is a simplification of the real world. Understanding the limitations helps assure that accurate inferences are drawn from model predictions.

Weather is the driving force for any hydrologic model and thus uncertainty in the rainfall or the rainfall distribution across the watershed is important. Great care was, therefore, taken to include as much accurate, observed weather data as possible. The inclusion of NEXRAD derived weather data should in theory, improve the accuracy of the model and reduce this limitation. However this was not evaluated in this study. Rainfall is estimated on a 4 km grid. Rainfall can be quite variable even within a single grid cell, especially in the spring and summer when convective thunderstorms produce precipitation with a high degree of spatial variability. It may rain heavily at one location, but be dry a short distance away. On an average annual or average monthly basis, these errors have less influence since they are typically not additive. This limitation, among others, cautions us against using model output on a daily basis.

The SWAT model assumes total phosphorus includes labile, active, and stable forms in a fixed ratio. Phosphorus loading from pasture originates primarily from labile forms of soil phosphorus due to low erosion. Phosphorus loading from row crops, where erosion is high, contains all forms of soil phosphorus including labile, active and stable forms. The SWAT model calculates stable mineral phosphorus based on active and labile phosphorus. We assume that Mehlich III soil test is equal to the sum of the labile and active mineral forms, which is model input. The ratio of active to stable forms at equilibrium is set via a single basin-wide model input in SWAT. The equilibrium ratio of active and stable forms is fixed in SWAT, although both ratios probably vary with soil type. This assumption governs the relative loading from pasture and row crop. Therefore, if active and stable phosphorus forms are over estimated the relative contribution of phosphorus from row crop will be over predicted.

Scenarios involving radical departures from calibration conditions result in greater uncertainty. Although calibration assures the user that the results reflect the range of conditions encountered at the watershed, they do not assure the model will be accurate for drastic changes in land use or management.

Only a single point source was included in this analysis, although there are many other minor sources in the basin. These other sources, such as CAFOs, septic tanks and small communities, were considered negligible.

There is uncertainty associated with specifying uniform management for a land cover category. It is not practical to specify management for every field in the basin, and thus a typical management was selected and applied basin-wide for each land cover type. Management operations include grazing, fertilization, tillage, planting, and harvesting.

An important limitation is that SWAT simulates poultry litter applications as simple nutrient additions applied uniformly to the top 10 mm of the soil surface. In reality poultry litter lies on the soil surface until rainfall moves it into the soil. In the first few rainfall events after application the litter may interact more closely with surface runoff than simulated by SWAT. In the field we would expect high phosphorus concentrations in surface runoff when rainfall occurs immediately following litter application, but lower concentrations later in the season. In the SWAT model, high short term phosphorus concentrations may not be simulated, but through calibration accuracy is achieved for monthly and annual phosphorus loads. This limitation makes it inadvisable to use daily simulation results.

PART II

ECONOMIC ANALYSIS

INTRODUCTION

Several hydro-biological studies have found that external phosphorus loading to the Lake Eucha is the main contributor towards eutrophication of both lakes Eucha and Spavinaw, and recommended reduction of external phosphorus loading as the most effective remediation (Storm et *al.* (2002), OWRB (2001), OCC (1997)). There is a wide array of regulations, policies and practices that could be instituted to achieve the goal of reduced external phosphorus loading to the lakes. However, there is an efficient subset of them that will achieve the desired reduction of external phosphorus loading at least cost to the society. Economic analysis in this study attempts to determine that subset of economically efficient regulations, policies and practices.

Overview of the Economic Activity in the Region

The Eucha-Spavinaw watershed is predominantly located in portions of two counties, Benton County, Arkansas and Delaware County, Oklahoma. A summary of the economic activities in those two counties is provided to serve as an introduction to the economic analysis of the watershed.

Economic Changes in the Region from 1980-2000

The twenty-year period from 1980 to 2000 witnessed considerable economic growth in the Benton Co., Arkansas and Delaware Co., Oklahoma. Data from the Bureau of Economic Analysis in Figure 2.1. show that total population grew at 3.3 percent annually and nearly doubled from 102,000 in 1980 to 192,000 by the year 2000. Total real personal income had a sustained annual growth rate of 5.6 percent and tripled from

$1.5 billion to $4.6 billion by 2000. Income per capita in 1999-2001 dollars grew at an annual rate of 3.2 percent and increased from $14,000 to nearly $24,000 dollars by the year 2000.

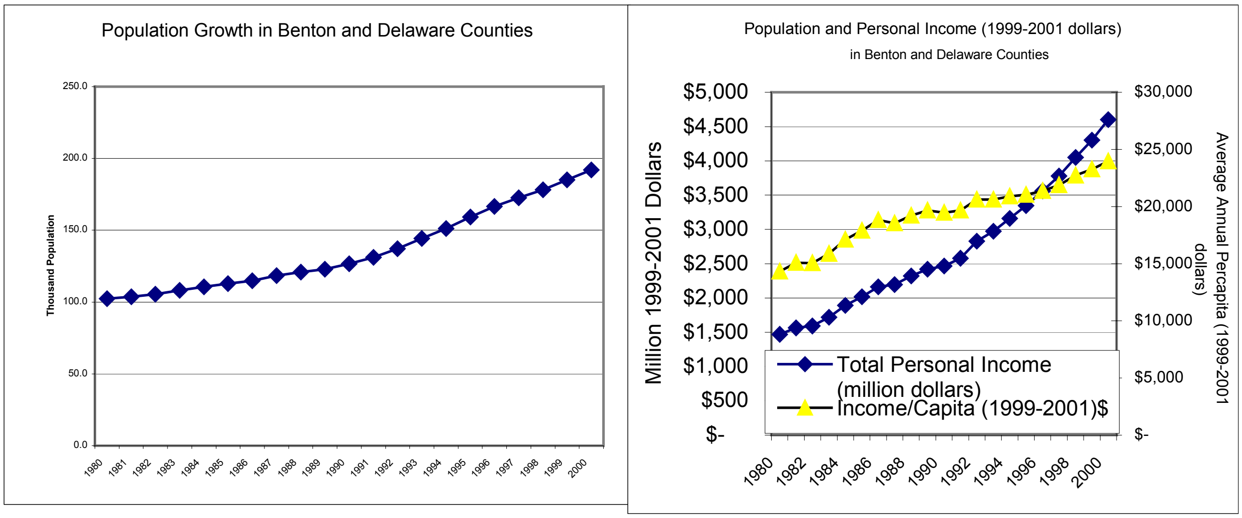
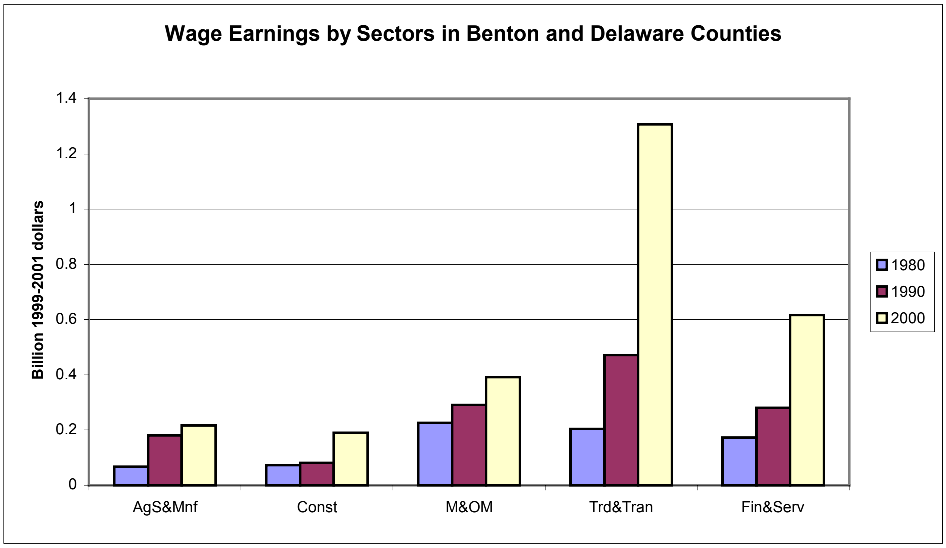


Figure 2.1. Population and Income Growth in the Benton County, Arkansas and Delaware County, Oklahoma Area.

Sources of Economic Growth from 1980 to 2000

The manufacturing and retail trade sectors experienced the largest increase in employment and wage payments. Much of the increase in the manufacturing sector was in food and kindred products because of the increase in feed manufacturing and poultry processing. Big portion of the increase in the retail sector could be attributed to the growth in the Wal-Mart chain. Figure 2.2. shows the wage earnings of workers and proprietors which have been aggregated into five sectors for the two-county economy.



*Abbreviations used, AgS&Mnf = Agricultural Services and Food and Kindred Products, Constr = Construction, M&OM = Mining and Other Manufacturing except Food and Kindred Products,

Figure 2.2. Wage and Proprietors Earnings by Sector in Benton and Delaware Counties in 1999-2001 Dollars.

It can be noted from Figure 2.2 that the largest increase in earnings was in the trade (wholesale and retail) and transportation sectors for the period 1990-2000. The finance and services sectors also experienced a corresponding growth during the last decade. Major growth in the agricultural services and food and kindred products sector during the first decade was related to growth in poultry production in the two-county area. Growth in the construction sector is a reflection of and dependent upon the growth in other sectors.

Table 2.1. describes the sector-by-sector growth in more detail. All sectors except the mining sector experienced positive economic growth over the past two decades. The fastest growing sectors were the retail trade, finance-realestate-insurance, and transportation sectors, which averaged more than seven percent growth per year from 1980 to 2000. The services, agricultural services, and food and kindred products sectors

averaged between 5 and 7 percent annual growth in real terms during the twenty-year period.

Table 2.1. Comparison of Changes in Earnings by Sector Between 1980 and 2000 in Benton and Delaware Counties.

Sector	1980	2000	Average Annual Growth
	million 1999-2001 dollars		%
Ag. services, forestry, fishing	5	18	6.7
Mining	7	4	-4.7
Construction	73	190	5.7
Manufacturing	282	586	3.9
Durable goods	160	244	2.8
Nondurable goods	121	343	4.9
Food and kindred products	62	199	5.5
Transportation and public utilities	46	203	7.1
Wholesale trade	23	115	9
Retail trade	136	989	9.5
Finance, insurance, and real estate	34	132	8.1
Services	138	485	6.6

Changes in Agricultural Structure, 1980 to 2000

The data presented in Figure 2.2. show that although agriculture is very important in the two-county area, the non-agricultural sector represents a much larger source of earnings. Agricultural marketing in the two-county area is dominated by livestock production and by poultry production in particular (breakdown by sources of agricultural income are shown in more detail later in the text). The importance of livestock marketing is shown in Figure 2.3. The top two panels of Figure 2.3. show agricultural receipts and expenses respectively in actual or nominal dollars. The two bottom panels show the same information expressed in constant prices (1999-2001 dollars). The two right hand panels of Figure 2.3. show that half of all agricultural expenses are just for purchases of feed and livestock. The increase in feed purchases represents the main avenue by which increased quantity of nutrients enter the region. It could be noted that there has been little increase in the purchases of fertilizer over the last two decades. The livestock marketing and purchases of feed and livestock are the major factors related to the growth in the Food and Kindred products sector discussed above.

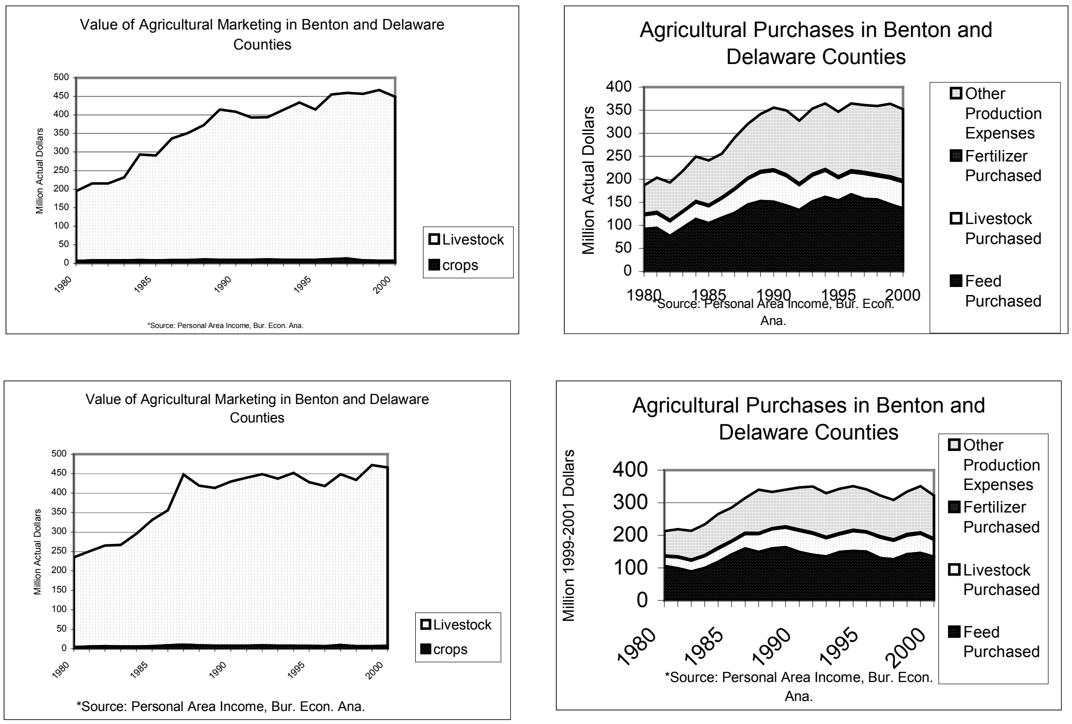


Figure 2.3. Agricultural Sales and Expenditures for Benton and Delaware Counties in Current and in 1999-2001 Prices.

The respective indices of prices received by farmers for livestock and poultry and for crops were used to deflate the agricultural sales. The indices with a base of 1991-93 were adjusted to a 1999-2000 base for this study. When the sales are shown in real prices, the data indicate that agricultural output grew rapidly until 1990 and has been nearly constant through the last decade. The agricultural expenditure data indicates that real purchases of feed and livestock have declined slightly during the 1990's. It should also be noted that expenditures for commercial fertilizer and lime represent a very small part of farm purchases and have been nearly constant since 1980. This indicates that the sources of nutrients (nitrogen and phosphorous) entering the watershed are more likely from purchased feed for livestock than from commercial fertilizers.

Sources of Agricultural Sales in Current and Constant Prices

Annual marketing data for the number of animals by type are not available for the two counties for the study period. Sales data from the Census of Agriculture are used to

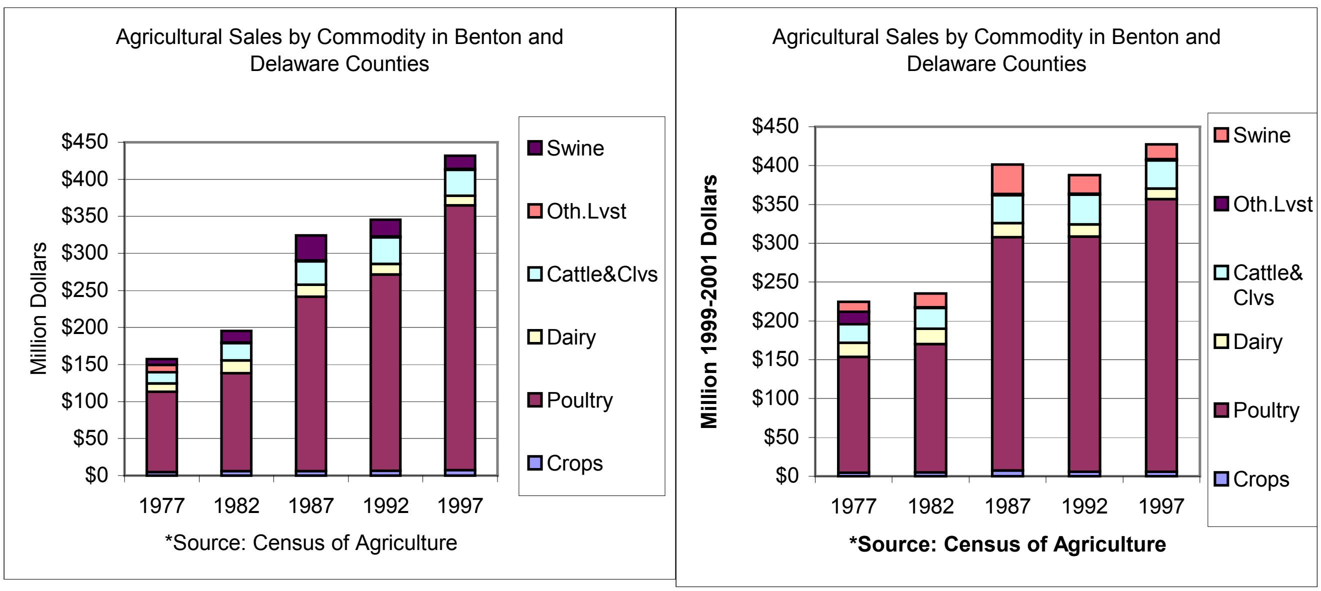


Figure 2.4. Agricultural Sales of Crop and Livestock Commodities from Benton and Delaware Counties in 1999-2001 Dollars

show the amounts of agricultural output for the census years in Figure 2.4. In the right panel of Figure 2.4., the sales data from the Census of Agriculture are converted to 1999-2001 dollars by using the GDP deflator. Total output in constant prices has been near $400 million since 1987. Total output is dominated by poultry production. The major expansion in poultry sales occurred between 1982 and 1987. Figure 2.5. shows that broiler production in Benton Co. (Arkansas Agricultural Statistics) and Delaware Co.

(Census of Agriculture) is still increasing but at a slower rate than during the early 1980 period.

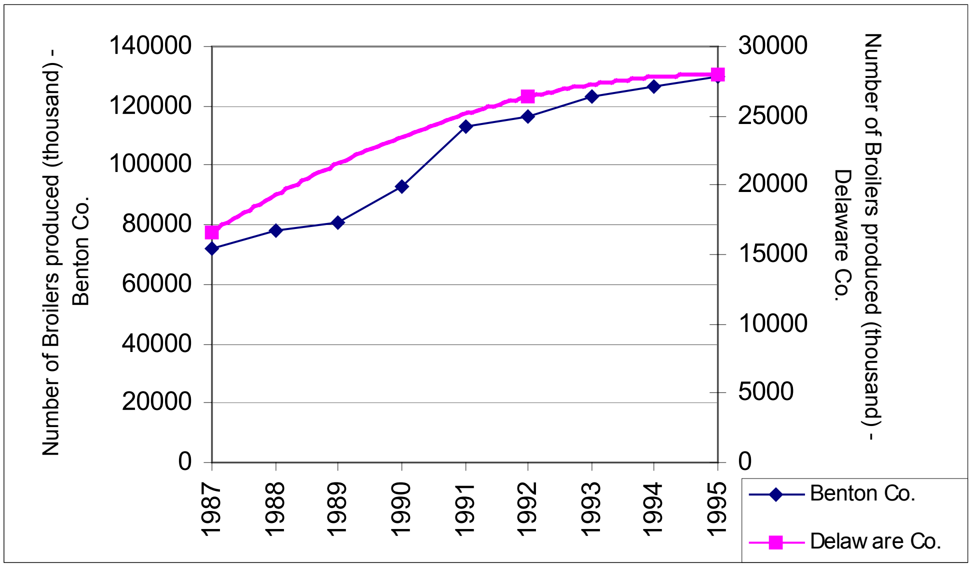


Figure 2.5. Broiler Production in Benton Co., AR, and Delaware Co., OK., 1987-1995.

The data presented in this summary shows that although agriculture is not the predominant economic activity in the area, it is significant and dominated by the poultry sector. The poultry industry is an important economic factor for the two counties that share the Eucha-Spavinaw watershed.

Political and Legislative Overview

Legislative Overview

One reason for the rapid increase in the number of poultry produced in the region was the relaxation of laws prohibiting corporate farming, first in Arkansas and latter in Oklahoma (Hipp, 2002). Following this regulatory relaxation, the presence of corporate swine and poultry farms increased dramatically. The regulatory relaxation increased protection against nuisance suits for concentrated animal feeding operations in Oklahoma, which attracted further growth of swine and poultry corporate farming. These concentrated animal feeding facilities tended to concentrate in relatively small geographic areas, Eastern Oklahoma and Western Arkansas for poultry and Western Oklahoma for swine, which contributed to relatively quick occurrence of the environmental problems.

Public response to environmental problems and public concerns related to odor and water quality started emerging by 1997 when legislative actions against CAFOs began to dominate. Oklahoma House Bill 1552 set up licensing requirements and notification of surrounding landowners for new CAFO facilities, stipulated setback rules, required a pollution prevention plan and increased penalties and fines (Oklahoma State Senate, 1997). The Executive Order 97-07, established the Governor's Animal Waste and Water Quality Protection Task Force, a body intended to develop a plan with a mechanism for progressive monitoring of the state's water quality and put forth recommendations for legislation, regulatory change, structural and operational change, private-public partnerships, incentives, and other measures to protect the quality of Oklahoma's water supply (Office of the Governor of Oklahoma, 1997). In the same year, The Oklahoma House Joint Resolution 1093 imposed moratorium on certain new hog farms until the next year or until new legislation was passed (Oklahoma State Senate, 1997). Also in 1997, the Arkansas – Oklahoma Arkansas River Compact Commission adopted a goal to reduce phosphorus pollution in the Illinois river by 40 percent (Hipp, 2002). The following year, 1998 was also marked by intensive legislative and regulatory activity. The EPA issued the Unified National Strategy for Animal Feeding Operations, where the principles, goals and expectations for control of pollution from Animal Feeding Operations were set forth (EPA, 1998). EPA amended and finalized this strategy with the Final Rules on Concentrated Animal Feeding Operations in December 2002 (EPA, 2002). Also in 1998, the Oklahoma legislature passed the Senate Bills 1170 and 1175 that imposed several additional requirements and restrictions on poultry farms and swine farms respectively (Oklahoma State Senate, 1998). In particular, SB 1170 defined "nutrient threatened " and "nutrient vulnerable" watersheds in Oklahoma. In response to the concentration of poultry litter in limited geographic areas, Oklahoma Legislature enacted the Oklahoma Poultry Waste Transfer Act in 2001, which provides tax relief to the parties that transport poultry waste from the regions where it is abundant and creates environmental problems (Eastern Oklahoma) to regions where phosphorus is in deficit (Central Oklahoma) (Oklahoma Statutes, 2001).

Regulatory Overview

On the regulatory stage, Oklahoma Water Quality Standards (OWRB, 1996) designate the following beneficial uses for the lakes Eucha and Spavinaw in the watershed: public and private water supply, cool water aquatic community, agricultural irrigation, primary body contact recreation and aesthetics. Both lakes are also designated as sensitive drinking water supply. The Oklahoma Water Resources Board (OWRB), through its Beneficial Uses Monitoring Program (BUMP) continuously monitors the compliance to the designated beneficial uses and has a regulatory power over the activities that endanger these uses. In a response to numerous complaints on odor and taste characteristics of the drinking water coming from the Lake Spavinaw, the OWRB conducted a comprehensive study on the water quality in the Eucha-Spavinaw watershed

(OWRB, 2002). The published report found that several of the designated beneficial uses of the lakes were impaired, most importantly the water supply and recreational uses. The report identified external phosphorus load as a main cause of impairment of lakes Eucha and Spavinaw. It further attributed most of the external phosphorus loading in the Lake Eucha to non-point agricultural sources and to a municipal point source in Arkansas. The report recommended a 54 percent reduction of total phosphorus load to the Lake Eucha and 44.6 percent reduction of total phosphorus load to the Lake Spavinaw to achieve the desired trophic state in the lakes.

Overview of Litigation Actions

Amid these reports and recommendations, the excessive phosphorus loading in the watershed continued, prompting the City of Tulsa to file a federal lawsuit against the poultry integrators and the municipality of Decatur, AR. On December 10, 2001, the City of Tulsa and the Tulsa Metropolitan Utility Authority (City of Tulsa et *al*.,) filled a complaint in the US District Court of the Northern District of Oklahoma against Tyson Foods, Inc., Cobb-Vantress, Inc., Peterson Farms, Inc., Simmons Foods, Inc., Cargill, Inc., George's, Inc., and the City of Decatur, Arkansas (Tyson Foods Inc. et *al*.). The complaint claimed that the defendants committed acts and omissions, which caused damages to the water supply of the City of Tulsa. The legal action sought damages and injunctive relief to remedy the wrongful pollution by the defendants.

The complaint cited that the deleterious conditions of the water supply, in terms of nutrient loading in the Eucha-Spavinaw watershed and consequent eutrophication of the lakes, were directly caused by the acts and omissions of the Defendants in the course of a "meteoric" growth in their business and pollution activities in the watershed. The massive concentration of the poultry operations in the watershed that is directly linked to the Defendants, results in enormous production of nutrient reach waste whose land application is directly responsible for the rapidly increasing levels of phosphorus in the lakes and is therefore a *proximate* cause of the eutrophication occurring in the lakes. In addition, the City of Decatur is alleged to contribute jointly with other Defendants to the pollution of the watershed by allowing enormous quantities of phosphorus discharge from its sewage treatment plant that also treats the wastewater from a poultry processing plant in the ownership of one of the other defendants. The complaint states that the Defendants have been aware of the rapidly increasing problems caused by their actions in the watershed. The City of Tulsa has pleaded and demanded the defendants eliminate their polluting activities, but to no effect. Based on these allegations the complaint requested punitive damages for the plaintiffs.

The complaint also states that irreparable damage will be done if the polluting actions of the Defendants are not stopped. Therefore, the complaint requested an injunctive relief to prevent this irreparable harm.

A lengthy pretrial process occurred after the complaint was filled. A number of expert witnesses were called for preliminary hearings. Just before the start of the trial, during the jury selection process, the parties announced out of court settlement. The settlement was announced on March 24th, 2003 (Tulsa World, March 25, 2003). Details of the settlement are not yet available to the public, but it is expected that the settlement includes a mandate to the City of Decatur to upgrade its wastewater treatment. Just very recently, Tulsa World reported (Tulsa World, April 27th, 2003), that the poultry integrators prevent their growers from litter application to their land and from selling and giving out litter to other farmers. It is believed that this new development is directly linked to the settlement.

Definition of the Problems Treated in the Economic Analysis

It is apparent from the numerous hydrological studies conducted (Storm et *al.*, 2002, ORWB, 2002, OCC, 1997) as well as from the legislative and litigation actions that reductions of phosphorus loads to lakes Eucha and Spavinaw are required. Since it is estimated that some 25 percent of the total phosphorus in the watershed is generated by the City of Decatur point source and that over 65 percent of the load comes from agricultural enterprises, reductions of phosphorus emissions will have to be achieved from both sources.

Economic theory and applied studies (Johansson, 2000, Jenq, 1982), show that when there are both point and non-point sources of pollution in a watershed, opportunities for tradeoffs in abatement between the two types of sources exist. In particular, there is an economically optimal, least-cost allocation of abatement between point and non-point sources for any given level of pollutant emissions. This optimal abatement corresponds to the point where the marginal abatement costs at the point source are just equal to the marginal abatement costs from the non-point sources. Stated differently, the optimal abatement for the point source is where the cost of removing another unit of pollution from the point source is equal to the cost of removing another unit of pollution from the non-point sources.

In addition to point versus non-point source tradeoffs, there are considerable economic tradeoffs regarding the abatement among the non-point sources. If the non-point agricultural sources are heterogeneous (non identical), the optimal, least cost solution would require non-uniform levels of abatement at each non-point source. In particular, it would be optimal to abate more at the non-point sources that have lower marginal cost of abatement than at the non-point sources that have higher marginal cost. At the optimal level of abatement, the marginal costs are equated across all point and non-point sources of pollution.

For the Eucha-Spavinaw watershed, the point source of phosphorus loading is the City of Decatur that has a combined sewage treatment plant with a poultry processing facility located in the town. The municipality currently emits an effluent with very high concentration of phosphorus (ARDEQ, 2001). The present study will consider a wastewater treatment technology that could be used to reduce the phosphorus concentration of the effluent. The cost to use this technology to attain a given phosphorus abatement level will be calculated. Most non-point sources of phosphorus loading come from agricultural activities in the watershed, whereby poultry litter is applied to various crops (pasture, hay, row crops). The study considers several technologies and policies related to poultry litter management that could be used by agricultural producers in the watershed to reduce phosphorus loading. The costs of these technologies to the agricultural producers are calculated.

Since the goal is to reduce total phosphorus loading in the watershed, an economic model was constructed to obtain a least cost solution to the set goal. The economic model was setup from the perspective of a watershed manager interested in overall social well being. Abatement costs for point and the non-point sources were equated at the margin. In addition, the economic model estimated the environmental damage costs caused by the phosphorus pollution, represented by the additional cost for drinking water treatment and by the loss of recreational values of the area lakes. The model then determined the optimal level of phosphorus abatement, accounting for both costs to the polluters (point and non-point sources) and costs to the parties that suffer from pollution (City of Tulsa, recreation users, etc). This optimal level of abatement was obtained by equating marginal abatement costs with the marginal environmental damage costs.

In a summary, the goals of the economic analysis in this study were to:

1) Determine the socially optimal level of phosphorus abatement in the Eucha-Spavinaw watershed.
2) Determine the level of optimal phosphorus abatement at the point source, corresponding to a particular level of use of the abatement technology.
3) Determine the level of optimal phosphorus abatement from non-point sources.
4) Determine the most cost effective technologies and policies to reduce phosphorus loading.
5) Determine the most efficient management practice (technology) for poultry litter and/particular policy for land use for each spatially distinct area in the watershed.

CONCEPTUAL FRAMEWORK FOR THE ECONOMIC ANALYSIS

The conceptual framework for the economic analysis in this study is based on minimizing the sum of pollution abatement costs and environmental damage costs (Freeman, Haveman and Kneese, 1973). To explain this concept, let W represent the total social well-being. Then, the following relationship can be stated

$$W = M + E, \tag{2.1}$$

where M represents the value of the market goods and services consumed in a society (poultry and agricultural crops for the study of interest), which are usually accounted for in the national accounts of a country and E represents the value of environmental services directly or indirectly consumed in a society (clean water). Define E^* as the maximum potential value of environmental services obtained from a pristine environment. Define D as the costs of environmental damages caused during the processes of production and consumption of market goods and services (ex. difference in drinking water treatment costs between treating polluted water and pristine water). The value of environmental services actually provided is then

$$E = E^* - D. \tag{2.2}$$

Let M^* denote the maximum value of market goods and services that could be produced in a society when no resources are devoted to pollution abatement. Then

$$M = M^* - A, \tag{2.3}$$

where A represents the costs associated to pollution abatement technologies (ex. more expensive poultry litter management practice that reduces the phosphorus runoff, and/or more expensive treatment of the municipal wastewater). The total social well-being function can then be written by substituting Eqs. (2.2) and (2.3) into Eq. (2.1) as

(2.4) $$W = (M^* - A) + (E^* - D) = M^* + E^* - (A + D).$$

Since M^* and E^* are fixed, the total social well- being can be maximized by minimizing the sum of pollution abatement costs and environmental damage costs.

Suppose that both the abatement costs and the damage costs are function of a single pollutant (p - phosphorus). It follows from Eq.(2.4) that the social well-being will also be a function of that pollutant. The following optimization problem arises

(2.5) $$\max_p W(p) = M^* + E^* - \left(A(p) + D(p)\right).$$

To obtain a solution to the above problem one needs to differentiate the well being function with respect to p and set the derivative equal to zero

(2.6) $$\frac{dW}{dp} = \frac{dA}{dp} - \frac{dD}{dp} = 0 \quad \Rightarrow \quad -\frac{dA}{dp} = \frac{dD}{dp},$$

where dA/dp represents marginal abatement (treatment) cost and dD/dp represents marginal environmental damage costs. The minus sign before the marginal abatement cost simply indicates that they are "read" from right to left. Marginal abatement cost is the change in treatment cost as an additional unit of pollutant is abated while marginal damage cost is the change in the cost of environmental damages as an additional unit of pollutant is discharged (not being abated). It follows directly from Eq. (2.6) that if the social well-being is to be maximized, the marginal abatement costs must be equal to the marginal environmental damage costs. Consequently, the optimal level of abatement (the one that will maximize W) occurs when the marginal cost of abating an additional unit of pollutant is just equal to the marginal cost of environmental damages caused by that unit of pollutant.

COSTS OF ALTERNATIVE TECHNOLOGIES TO REDUCE PHOSPHORUS LOADING

Non-Point Source Phosphorus Abatement Technologies and Associated Abatement Costs

Reducing Litter Application Rate

One way to reduce phosphorus loading is to reduce the amount of litter applied. Since the agricultural enterprises in the watershed are heterogenous with respect to grown crops, soil types, and topography, it is to be expected that the optimal litter application rate would be different for each spatially distinct agricultural HRU. The optimality of the litter application rate is regarded here both in relation to the crop yield response to nutrients applied with the litter (nitrogen and phosphorus) and in relation to the phosphorus runoff from any given HRU. The goal of economic modeling is to allocate the litter produced in the watershed to the agricultural HRUs according to the economic criterion of highest value of the marginal product and at the same time to account for the total phosphorus loading at the watershed level [1].

In previous modeling (Storm et *al*.,2002), the litter was allocated on a sub-basin basis, by allocating the litter produced in every sub-basin uniformly to the agricultural uses in that sub-basin. In the present study, a transportation component to the economic model was developed that allowed for litter shipment among the sub-basins in the watershed as well as shipping litter out of the watershed. Transportation costs within the watershed were estimated using the distances between sub-basins calculated with the Network Analyst Extension for ArcView. The costs for transporting litter out of the watershed were approximated by using the potential for manure phosphorus application

[1] The value of the marginal product is defined as the value of the product (crop yield) produced by using an additional unit of input (litter).

of the surrounding counties in the states of Oklahoma, Arkansas, Kansas and Missouri (Gollehon *et al*., 2001) and estimated distances. The transportation costs were computed by estimating the distance to haul the litter to the centroid of another county with sufficient capacity to receive manure phosphorus so that shipments of poultry litter could be made to that county.

If the farmers were required to reduce or halt the application of poultry litter on their land, they may choose to replace nitrogen by purchasing and applying commercial fertilizer. Under the profit maximization hypothesis, the farmers should apply nutrients up to the point where the value of the marginal product from nutrients is equal to the marginal cost of purchasing commercial fertilizer. In most cases commercial nitrogen is more expensive than nitrogen from poultry litter. Thus the study allows for lower nitrogen application rates with commercial fertilizer. Table 2.2, presents the alternative litter application rates by agricultural land uses in the watershed and the quantities of nitrogen applied under the two alternative strategies regarding nitrogen replacement with commercial fertilizer.

Table 2.2. Alternative Litter Application Rates for Agricultural Land Uses and Quantity of Nitrogen Applied under N-Replacement (N w. replac.) and no N-Replacement (N w/o replac) strategies in the Eucha-Spavinaw Watershed (all rates in kg/ha).

Land Uses											
HAY			OPAS			WPAS			WWHT*		
Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac	Litter rate	N w. replac	Nw/o replac
6000	300	300	3230	161.5	161.5	6000	300	300	1950	132.7	132.7
4800	240	240	2585	130	130	4800	240	240	1560	113	113
4000	200	200	2154	107.7	107.7	4000	200	200	1300	100	100
3400	200	170	1830	107.7	91.5	3400	200	170	1105	100	90.5
3000	200	150	1615	107.7	81	3000	200	150	975	100	84
2000	200	100	1077	107.7	54	2000	200	100	650	100	68
1000	200	50	538	107.7	27	1000	200	50	325	100	51
0	200	0	0	107.7	0	0	200	0	0	100	35.2

* The row crop receives 35.2 kg/ha nitrogen irrespective of litter application rate.

Phosphorus could only be applied using poultry litter (no substitution possibility with commercial fertilizer) and for each litter application rate, the applied phosphorus was calculated as 1.5 percent of the applied quantity of litter. The litter and nitrogen application rates were based on fertilization recommendations. For grassland land uses (hay (HAY) and well-maintained pasture (WPAST)) the rates were based on OSU Extension Fact sheet F-2559. Based on recommendations, litter application rate of 4000 kg./ha was assumed as a base case application rate. The two higher litter application rates (4800 kg/ha and 6000 kg/ha) assumed nitrogen always came from the poultry litter. The five lower application rates in Table 2.2 assumed that nitrogen could be replaced or not from commercial fertilizer. Overgrazed pasture (OPAS) was assumed to receive less fertilizer that well-maintained pasture (WPAS).

For row crops, fertilizer recommendations were based on OSU enterprise budgets for grazeout wheat, and on recommendations for green beans from various sources. These recommendations are reflected in the base litter application rate of 1300 kg/ha with two higher and five lower litter application rates.

The SWAT model was run for each of the litter application rates and for the two nitrogen replacement strategies for a total of thirteen SWAT simulation runs. Yield, produced biomass, grazed biomass and phosphorus runoff was read from the SWAT output files for each of the 695 agricultural HRUs in the watershed. These results were used as inputs to the mathematical programming model discussed below.

Net income from agricultural activities was estimated by using data from the SWAT model (yield and biomass data), the Oklahoma State University Enterprise Budgets (OCES, 2003), from various published (USDA, 2002) and from unpublished (personal communications) sources. An overview of the major prices used in the computations is provided in Table 2.3.

Table 2.3. Prices, Costs and Conversion Factors Used in Estimating Income from Agricultural Activities in the Eucha –Spavinaw Watershed.

Prices:		Cost :	
Hay	$60/ton	Litter appl.	$4/ton
Beef	$1300/ton	Urea appl.	$12/ha.
Green beans	$230/ton	Urea	$200/ton
		Alum	$220/ton
Conversion:		Transportation costs of litter	$0.12/ton/mile
Mixed pasture/Beef	10 kg / 1 kg		
Wheat pasture/ Beef	7 kg / 1 kg		

The net incomes for the four agricultural enterprises: HAY, overgrazed pasture (OPAS); well-maintained pasture, (WPAS); and row crop, (WWHT); in each HRU were estimated by using the OSU enterprise budgets (OCES, 2003). Revenues for hay was calculated using the prices in Table 2.3 and the yields obtained from the SWAT output. Net income was obtained as difference between revenues and costs. Revenues for well-maintained and overgrazed pasture were estimated using the exogenous price for beef and the calculated annual beef weight gain from the SWAT output. There was a difference in the cost structure for well-maintained and overgrazed pasture because of differences in management. Net income for the row crop was estimated by using the enterprise budget for grazeout wheat, the exogenous price for beef and the SWAT based calculations for beef weight gain and an enterprise budget for green beans.

Using Alum to Reduce Phosphorus Loading

Aluminum sulfate has been known for its potential to tie up soil labile phosphorus and transform it into more stable aluminum phosphate compounds that are not readily soluble and hence are not available for plant and algae uptake (Moore and Miller, 1994). The possibility to add aluminum sulfate to the litter was modeled using data published in Moore (1999). The alum product is added to litter in the poultry house in ratio of 1 part alum to 10 parts litter. Alum ties up phosphorus, thereby significantly reducing the potential for soluble phosphorus runoff once the litter is applied to the agricultural land. The reduction of phosphorus runoff with alum addition is estimated using the experimental data published by Moore (1999) from a controlled small-scale watershed experiment. The experiments showed that the addition of alum reduced the phosphorus runoff attributed to litter application by 75 percent. This result may be represented as

(2.7.) $$Prunoff\ alum = ((1- 0.75)(P\ current - P\ zero)) + P\ zero,$$

where *P current* is the phosphorus runoff under given litter application rate and *P zero* is the phosphorus runoff under zero application rate. Phosphorus runoff occurs even if no litter is applied because of phosphorus already in the soil. The net income estimates from the agricultural activities in HRUs where alum was added to the litter were lowered by 2 percent. Some studies found that the use of alum sulfate increases the income to the poultry growers, which is attributable to the reduction of ammonia emissions and consequent reductions of health related costs and ventilation costs as well as improvement in growth performance (Moore, 1999). However, a confirmation to this finding is not widely observed in the practice. Even if these economic effects of treating the litter with alum are present, they pertain to the poultry growers and integrators and are not necessarily passed on to crop and cattle growers. The reason for this may be asymmetric information and/or income distribution problems. It is conceivable to think that adding alum would inflict some costs, at least to crop producing farmers. Therefore a small, arbitrary reduction of income was assumed.

The possibility to add alum to the litter is treated as management practice for reduction of phosphorus loading in the watershed. Alum treated litter was regarded as a resource separate from the non-treated litter. In effect, the economic model takes the litter as produced in the poultry house and either allocates it to alum treated or non-treated litter. Both types of litter can be shipped between the sub-basins in the watershed. Finally, the model can apply one of the two types of litter at previously defined litter application rates to each agricultural HRU in the watershed. The litter application rates are the same as described in Table 2.2. Thus, including alum, the various litter application rates and the two strategies for nitrogen replacement there were twenty-four distinct litter management activities defined for each of the 694 HRU's (13 SWAT runs which can be either with alum treated or non-treated litter except for the zero litter application rate, where obviously no alum is applied, hence 13 + 11 = 24).

Litter Application According to Soil Test Phosphorus (STP)

Another possible management strategy for the watershed as a whole would be to allow litter application only to those soils where the Soil Test Phosphorus is not higher than certain prescribed values. For Oklahoma, this value is often stated as a STP value of 120 (120 lbs of P per acre), as described in OSU Extension Fact sheet F-2249. At this value, the soil has sufficient phosphorus that could be used for plant uptake. A high proportion of any additional phosphorus applied to those soils would runoff during storm events. Therefore, the usual recommendation is not to apply poultry litter on the soils with STP higher than 120. This recommendation was not followed in the Eucha-Spavinaw watershed in the past, especially not on the Arkansas side of the watershed where the litter is continuously used for its nitrogen fertilizer value. Thresholds of 200, 250 and 350 lbs per acre were also considered [2].

The strategy of applying poultry litter only to soils with STP values lower than a given threshold is directed toward reducing phosphorus loading in the watershed by preventing the runoff of the excess phosphorus during the storm events. This strategy is representative of the "command and control" regulatory approach, where threshold standards are set and enforced. This policy was modeled by not allowing for litter application on the agricultural land where STP was higher than a given threshold value.

On the land where litter application was allowed (STP lower than a given threshold value) various litter application rates, using alum treated or untreated litter were allowed as modeling options. Net income from agricultural activities for both HRU's that received litter and those that did not was calculated using the procedures and data described above.

Mandatory abatement at the point source level was coupled with the STP based litter application policy. Instituting mandatory point source abatement has the characteristics of "command and control" regulatory approach and is consistent with the STP based watershed management strategy. The rationale for this was that if the "watershed manager" were going to use the STP based criterion for the non-point sources, it would have used the mandatory abatement at the point source as well. The

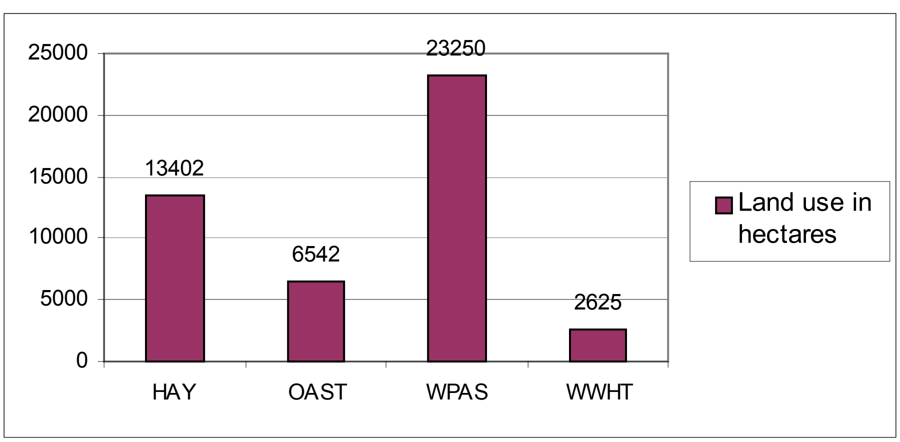
[2] Litter application is not recommended to any soil with STP higher than 120. In the economic analysis however the threshold values of 200, 250 and 350 were also included, to analyze the changes in the net income and in the transportation patterns when the STP criterion is relaxed.

mandatory abatement at the point source was set to achieve phosphorus concentration of the effluent of 1 mg/l.

The main issue from an economic perspective, is that the litter produced in the watershed has to be either land applied in the watershed (or used in some other activity, like methane and electricity generation) or be transported out of the watershed. If litter application is restricted only to soils with STP values lower than 120 or other threshold value, a great proportion of litter produced in the watershed could not be land applied. This was modeled by allowing for transportation of excess litter outside of the watershed. The distances necessary to haul litter out of the watershed were determined by locating counties in Arkansas, Kansas, Missouri, and Oklahoma to the East, North, West and South of the watershed where there is a potential for manure phosphorus application (Gollehon *et al*., 2001). Average transportation costs were calculated using average distance to the counties centroids in each direction and per ton mile transportation cost.

Changes in Land Use Patterns Directed Towards Reduction of Phosphorus Loading

As noted above, the agricultural land in the watershed is classified into four land use classes. Figure 2.5 represents the distribution of land area by agricultural land uses.



HAY = hay, OAST = overgrazed pasture, WPAS = maintained pasture, WWHT = row crop.

Figure 2.6. Agricultural Land Area by Land Uses in the Eucha-Spavinaw Watershed

As shown in Figure 2.5, the greatest land area is occupied by well-maintained pasture, followed by hay, overgrazed pasture and row crop. However, previous studies (Storm et *al*., 2002) (Ancev et *al*., 2003) found that despite the small land area they occupy, overgrazed pasture and row crop contribute relatively more to the phosphorus loading than do hay and well-maintained pasture. It was therefore decided to model the effect of potential land use change, whereby a conversion of overgrazed pasture to well-maintained pasture and conversion of row crops to hay was simulated. The decision was based on the fact that overgrazed pasture is situated on the land with similar characteristics to the well-maintained pasture, and main differences between the two land uses are with respect to quantity of applied nutrients (nitrogen, lower for the overgrazed pasture) and the minimum biomass when the grazing is allowed to begin (minimum biomass is lower for the overgrazed pasture). The parameters that control these characteristics were reconfigured in the SWAT model to simulate the land use conversion. In a similar fashion the conversion from row crop to hay was simulated. The same rates of litter application as described in Table 2.2 were used for the newly simulated agricultural enterprises in the watershed. Net income from the agricultural activities was calculated according to previously described procedures and data.

The study simulated two types of land use change policies. One type corresponded to mandatory uniform conversion where all land under overgrazed pasture and row crop was converted to well-maintained pasture and hay respectively. The other policy type corresponded to site-specific (optimal) land use conversion, where land areas were chosen for conversion based on their economic characteristics and phosphorus runoff potential.

Point Source Phosphorus Abatement Technology and Associated Abatement Costs

The City of Decatur, Arkansas is a major source of phosphorus loading in the Eucha-Spavinaw watershed. The reason is that the Peterson Farms poultry processing plant is located there. As is case in many small communities in the US (Rossi, Young and Epp, 1979), the wastewater treatment process for the municipality and the processing plant is combined in order to achieve greater economic efficiency. The current wastewater treatment system in the City of Decatur consists of treatment in bioreactors. This system discharges on average 1.16 million gallons per day (MGD) of flow into a surface water stream (Colombia Hollow). Some of the characteristics of the effluent are presented in the following table.

Table 2.4. Average Characteristics of the Effluent from the City of Decatur Sewage Treatment Plant for the period 1/31/1990 to 3/31/2001

Average Daily Flow	Average pH value	Average concentration of phosphorus*	Average concentration of nitrates	Average concentration of ammonia	Average concentration of BOD
MGD	Value	mg./l	mg./l	mg./l	mg./l
1.16	6.647	6.549	25.09	8.05	3.74

Source: Arkansas Department of Environmental Quality
* Measures of P concentration start from 11/30/1997.

Table 2.4 shows the effluent has a very high phosphorus concentration. The literature reports a value of around 1 mg./l phosphorus concentration of the effluent when using best available technology (Metcalf&Eddy, 2003). The concentration of the effluent from Decatur exceeds this benchmark by more than six times and consequently contributes an average of 11,686 kilograms of phosphorus per year to lake Eucha. This represents 24 percent of the estimated total phosphorus load of 48,000 kilograms (Storm *et al*., 2002). Therefore, a reduction of phosphorus concentration in the effluent from the

City of Decatur may provide significant and cost effective reduction of total phosphorus load.

In order to model the cost of phosphorus abatement in the wastewater effluent from the City of Decatur, a specific design for the additional wastewater treatment had to be modeled. A system of chemical treatment using aluminum sulfate was chosen due to its relative simplicity and cost effectiveness for comparably small treatment plants. The process is based on the chemical reaction involving the aluminum ion (Metcalf&Eddy),

$$Al^{+++} + H_n\,PO_4^{3-n} \leftrightarrow AlPO_4 + nH^{+}. \tag{2.8}$$

The aluminum ion precipitates phosphorus as flocs of aluminum phosphate that can be removed from wastewater in a form of sludge. The effectiveness of alum precipitation for reduction of phosphorus concentration in wastewater has been reported for a number of North American and European wastewater treatment plants (Klute and Herman, 1994), (WPCF, 1983).

The particular design used to estimate the costs of phosphorus abatement is presented in the Appendix Figure A.2.1. The design consists of several components: Structures and equipment for alum addition; Settling basin for flocs; Gravity thickener for primary sludge; Liquid/Solid Separation for secondary sludge; Transportation and landfilling of wastewater treatment residuals (WWTR).

1) Structures and Equipment for Alum addition

The structures and equipment for alum addition consist of storage for the alum product, conveyors, feeder, dissolver, holding tank, a pump and a flocculation chamber. The design and cost estimation is based on EPA, (1980), Fact Sheet 5.1.1. Since the cost calculations by EPA (1980) are based on an alum dose of 200mg./l , the effective flow was calculated for alternative alum dosages by using the suggested formula:

$$Q_E = Q_D * (\text{Actual Alum Dose} / 200 \text{ mg/l}),$$

where Q_E is the effective flow and Q_D is the design flow (equal to the average daily flow of 1.16 MGD). Construction costs for each effective flow were then read from the cost curve provided in the fact sheet. Operation and maintenance cost net of chemical cost (since the alum usage and price ($0.06/lbs) were obtained outside the fact sheet) for each effective flow were also read from the corresponding cost curve. Since the cost data in the fact sheet are expressed in 1976 prices, the costs were inflated by the factor 2.4514 to obtain current cost levels. This factor was determined by using an inflation calculator for adjusting costs from one year to another using the Gross Domestic Product (GDP) Deflator inflation index available at NASA web site (NASA, 2003). The inflation calculator is based on the inflation rate during the US Government Fiscal Year, which begins on October 1 and ends on September 30. The calculator is able to compute inflation for years 1940 to 2005.

The construction costs (capital costs) were annualized using the suggested 20-year amortization period and 6 percent interest rate. Total annual costs of alum addition were obtained as a sum of annualized capital costs and operation and maintenance cost.

2) Settling basin for flocculation.

After alum is added and flocculation is completed, the wastewater is directed toward a settling tank where the flocs settle and form sludge, which is collected in the bottom of the tank and released from there. The designed size of the settling tank was based on hydraulic retention time of 120 minutes, degree of flocculation of 30, on mean velocity gradient of 20, and safety factor of 10 percent (Henze et *al.*,1983).

The capacity of the settling tank was calculated at 106,400 gallons as a function of the average daily flow of wastewater and the required retention time, increased by the safety factor percentage. The cost of constructing the settling tank was obtained by using the data from MEANS Construction Costs (2000) (page 444). The costs for the desired capacity were extrapolated using the estimated function: $Y = 8.19 * X^{-.3815}$, where Y is the cost in \$/gallon and X is the capacity of the tank in thousand gallons. It was assumed that the sludge settled and removed from the settling tank contained 2 percent solids (Sitig, 1969). The relationship between sludge creation and alum addition was adopted from Klute and Hahn (1994) as 7 grams of sludge for each gram of alum added.

3) Gravity thickener for primary sludge

After exiting the settling tank, the sludge is directed through a gravity thickener in order to achieve higher concentration of solids and reduce the disposal costs. The design of gravity thickening process and estimation of associated costs were also based on EPA (1980), Fact Sheet 6.3.7. The calculations assumed three days retention time. The effective flow for various alum dosages and hence for various sludge quantities were calculated according to the proposed formula:

$$Q_E = Q_D * [\text{new sludge mass / 820 lb/MGD of flow}],$$

where Q_E is the effective flow and Q_D is the design flow (average daily flow of 1.16 MGD). The construction costs were read from the cost curve in the fact sheet for each effective flow. Operation and maintenance costs were calculated in a similar manner using the provided cost curve. Costs were translated to current prices using the above-mentioned inflation calculator. The construction costs were annualized using a 20 year amortization period and 6 percent interest rate. Total annual costs were calculated as a sum of the annualized construction and operation costs. The solids concentration of the sludge exiting the gravity thickener was assumed to be 10 percent.

4) Liquid/Solid Separation for secondary sludge

The sludge from the thickener was passed over an inclined screen separator in order to achieve greater solids concentration. The cost of separation is a function of the volume of sludge coming from the thickener, which was directly related to the alum dosage used. The Department of Agricultural Economics, Oklahoma State University has developed a swine waste management decision support system, which contains a routine for calculating Liquid/Solid separation costs (Ancev, Stoecker and Carreira, 2001). The decision support system was used to generate estimates of separation costs for various volumes of sludge coming form the thickener. Final waste materials after the separation were wastewater residuals that contain 40-50 percent solids.

5) Transportation and landfilling of wastewater treatment residuals (WWTR)

It was assumed the WWTR were transported 10 miles to a landfill site at cost of $20 per cubic yard, (MEANS 2000, page 64). A landfilling fee of $40 per ton was also assumed (MEANS 2000, page 50).

The actual cost calculations for all alum dosages are given in the Appendix Table A.2.1. These costs in effect represent abatement costs at the point source. For each alum dosage there is a corresponding level of phosphorus abatement and associated abatement cost. Abatement costs at the point source of phosphorus loading are used subsequently in the mathematical programming model, to determine marginal abatement costs for the whole watershed.

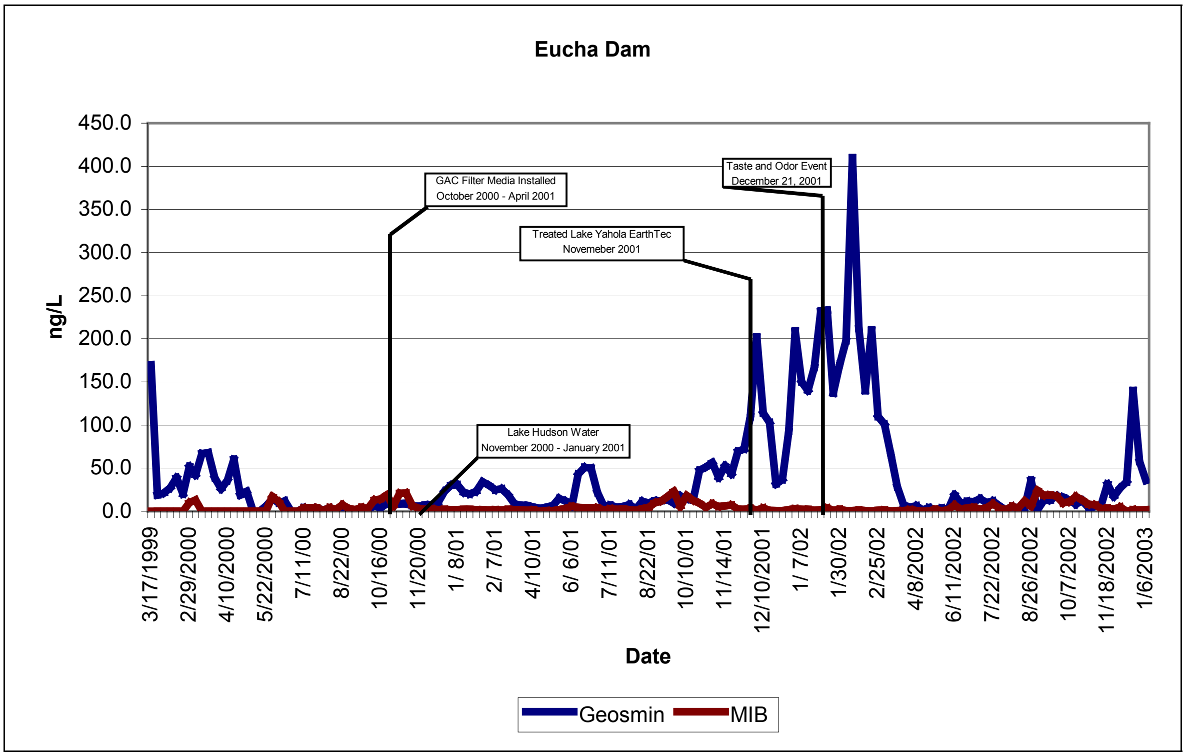
ENVIRONMENTAL DAMAGE COSTS

The study focused only on two types of environmental damages caused by phosphorus pollution in the watershed. One was the impairment of the quality of drinking water for the City of Tulsa (OWRB, 2002) and the other was the loss of recreational values of the area lakes, as reflected in the drastic reduction in the reported number of annual visits (OCC, 1997, OTRD, 2003)). Other possible environmental damages, such as long-term ecological values, were not treated because of lack of data.

Costs for Additional Drinking Water Treatment

The costs of additional drinking water treatment to the City of Tulsa are dependent on the taste and odor characteristics of the water, which are in turn determined by the concentration levels of the two chemicals, Geosmin and MIB (methyl iso-borneol) in the drinking water. These chemicals are produced in the process of algae die-off and are believed to cause the bad odor and taste of the water (OWRB, 2002). The OWRB conducted a thorough analysis on the algae community and chemicals related to water odor and taste in the Eucha and Spavinaw lakes. The study found increasing algae population in the lakes and increasing production of Geosmin and MIB. In recent years, the City of Tulsa has closely monitored the odor and taste characteristics of its water supply. Figure 2.6 provides information about the Geosmin and MIB concentration in the water at the lake Eucha Dam, as well as the taste and odor complaints for supplied water.

To control the odor and taste causing chemicals, the Tulsa Municipal Utility Authority (TMUA) is using additional filtration with powdered activated carbon at the Mohawk water treatment plant. Alternatively, the raw water supply to the Mohawk plant was occasionally diverted from Lake Spavinaw to Lake Hudson.



Source: The City of Tulsa

Figure 2.7. Geosmin and MIB Concentration and Taste and Odor Complaints.

Thus, the costs imposed on the City of Tulsa due to high concentrations of Geosmin and MIB, consist of costs for additional use of powdered activated carbon in water treatment and costs of pumping from an alternative water reservoir. The powdered activated carbon (PAC) is effective in removing odor and improving the taste of drinking water (AWWA, 2001), but is quite costly (the price of PAC is \$0.2/kg.). Diverting the water supply from Lake Spavinaw to water supply from Lake Hudson greatly reduces chemical treatment costs (very little or no PAC used) but inflicts high pumping costs (\$61.44 per million gallons). The data on water treatment costs were obtained from the City of Tulsa.

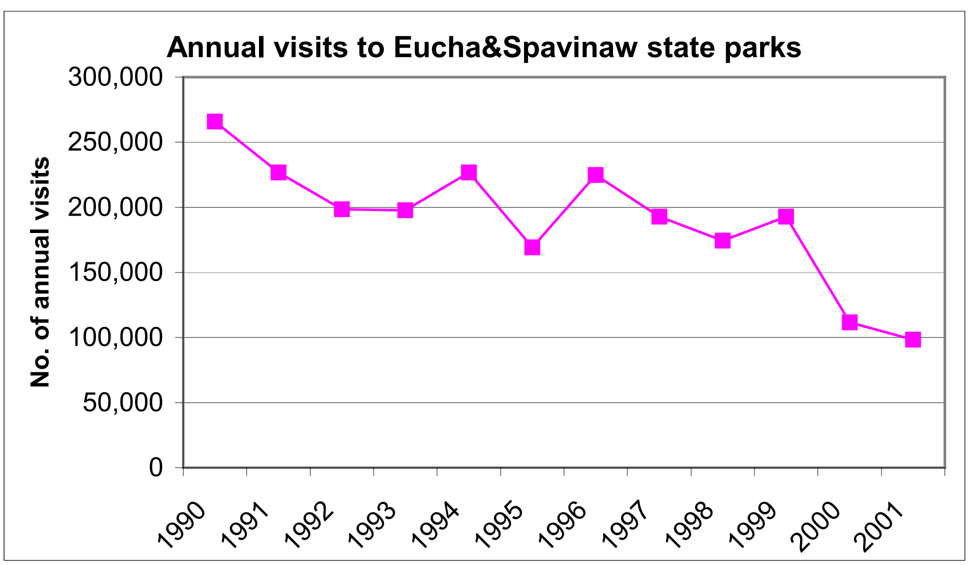
Regression analysis was used to estimate the costs for the additional drinking water treatment to the City of Tulsa. Observed average annual costs for PAC use and pumping costs from Lake Hudson were regressed on the SWAT simulated average levels of phosphorus loading in the watershed. The estimated equation (t-values in parenthesis)

$$CT_t = \underset{(-5.36)}{-226394} + \underset{(10.08)}{11.14}\, Z_t\,, \tag{2.9}$$

where CT_t denotes the average annual costs to the City of Tulsa at phosphorus loading level t, and Z_t is the observed average phosphorus load of level t, had an R^2 of 0.971. The estimated equation indicates strong positive linear relationship between the average annual phosphorus loading in the watershed and the average annual costs of additional drinking water treatment for the City of Tulsa. This is expected since the high phosphorus load results in intensive algae growth, which in turn results in production of Geosmin and MIB. It should be noted that average annual data were analyzed and that the distribution of costs and phosphorus loading within a year reflects the lagged effects of phosphorus loading on the Geosmin and MIB production. Results from the regression analysis were used in the subsequent computations of the total and marginal environmental damage costs.

Costs of Reduced Recreational Values

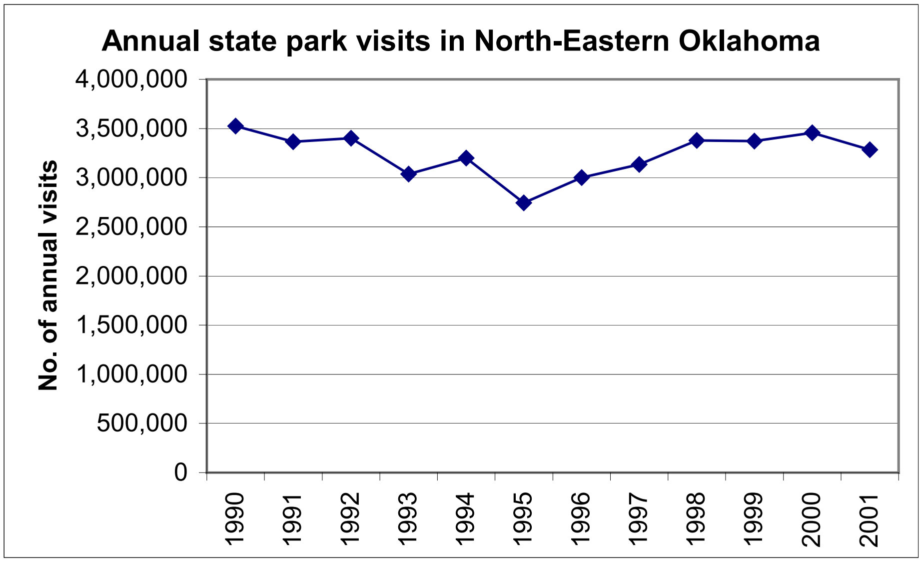
The Eucha-Spavinaw watershed is located in the Ozark region of East Oklahoma, and is characterized with hilly landscape, forested areas and attractive water bodies. This makes the region attractive for recreation activities that range from picnicking and fishing to camping and motor boating. The watershed is home to two state parks, Lake Eucha State Park and Spavinaw State Park, which were once very popular recreational sites. However, during the last decade the number of recreational visits to the two state parks decreased sharply (OTRD, 2003). This is in spite of the fact that the number of visits to the state parks for the whole region of North-East Oklahoma remained fairly stable during the same time period. Figure 2.7. presents combined data on the number of visitors to the Eucha-Spavinaw state parks over the 1990-2001. Figure 2.8. presents data on the number of visitors to all state parks in North -East Oklahoma for the same period.



Source: Oklahoma Tourism and Recreation Department

Figure 2.8. Number of Annual Recreational Visits to Eucha-Spavinaw State Parks

As Figure 2.7 suggests, the two state parks have experienced sharp drop in the annual number of visitors, from 265,000 visits in 1990 to a little less than 100,000 visits in 2001. In the same time, the number of recreational visits to all state parks in the North Eastern Oklahoma remained relatively stable at about 3,300,000 per year.



Source: Oklahoma Tourism and Recreation Department

Figure 2.9. Number of Annual Recreational Visits to All State Parks in North Eastern Oklahoma.

This reduction in the number of visits to Eucha and Spavinaw State Parks may be interpreted as a shift of recreational visits away from lakes Eucha and Spavinaw and toward other recreational sites in the area for the period 1990-2001. During this period, a significant increase in phosphorus loading in the watershed occurred and was followed by the increases in the phosphorus concentration in the lakes. This in turn ultimately resulted in eutrophication and in reduction of the subjective value of recreational experience (Feenberg and Mills, 1980). In the same period, there were significant public debates and numerous media reports regarding phosphorus pollution and the poultry industry in the Eucha-Spavinaw watershed (Tulsa World, various issues). The effect of the actual increase in the phosphorus loading to the lakes combined with the media reports and public debates, most probably played an important role leading toward drastic reduction of annual visits to the Eucha and Spavinaw Lakes. The analysis of the available visitation data for the Oklahoma State Parks did not reveal any other significant aspect that could be used to explain the reduction of annual visitation to the Eucha/Spavinaw state parks.

This reduction in annual visitation however, implies monetary costs to the current participants in recreation that travel to other sites when they would prefer a recreational experience at Eucha/Spavinaw state parks, were the water quality acceptable (revealed preference). Losses also accrue to current non-participants in recreation who would participate in recreation at Eucha/Spavinaw state parks if the phosphorus loading to the lakes were lower. These monetary losses can be expressed in economic terms as losses of Consumer Surplus. Consumer Surplus measures the gain for the consumer from being able to buy a product (recreation) of a given quality (phosphorus concentration, water clarity) below its reservation price (maximum willingness-to-pay). This is graphically represented in Figure 2.9.

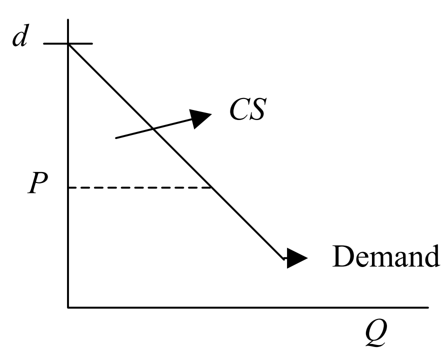


Figure 2.10. Illustrative Example of Consumer Surplus.

In the figure, the horizontal axis represents the quantity (number of visits) and the vertical axis represents the price (cost of travel to the site, cost of entrance fee etc.). Let *d* represent the maximum willingness-to-pay for the recreation at a particular site, corresponding to a price above which no visits to the site would be made. At prices lower than this, some visits to the recreational sites will be made. Let *P* denote the actual price that has to be paid to travel to and experience recreation at a given site. Then, the triangle area labeled *CS* denotes the consumer surplus at the price *P*. As the actual price increases the consumer surplus declines, while as the actual price decreases the consumer surplus rises. In economic terms, the consumer surplus is known as the area under the demand curve and above the price.

The travel cost method, which uses costs of travel to the recreation sites to represent the price for recreation, was used to derive the costs of lost recreational values due to increased phosphorus loading and phosphorus concentration of the area lakes (Bockstael et *al.*, 1991). The concept of travel cost uses estimates of the costs to travel to and from a recreational site, as well as the costs for preparation, gear, and entrance fees, to estimate a demand function for recreation at a particular site. The costs of lost recreational values are approximated as changes in the consumer surplus under various levels of phosphorus concentration in the lakes. In particular, it was assumed that the maximum willingness-to-pay (MWTP) for recreation changes as the phosphorus concentration in the lake changes. At higher levels of phosphorus concentration the MWTP for recreation is lower, while at lower levels of phosphorus concentration the MWTP is higher. This is graphically represented in Figure 2.10 where the number of visits decline from Q_1 to Q_2 as the MWTP declines from d_1 to d_2.

In the figure, d_1 corresponds to maximum willingness-to-pay for recreation at better water quality, say WC_1 (lower phosphorus concentration), while d_2 corresponds to

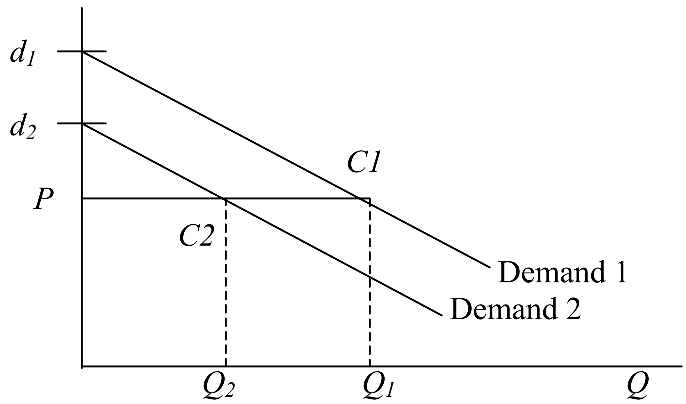


Figure 2.11. Changes in Consumer Surplus from Recreation under Various Levels of Phosphorus Concentration in the Lakes due to Changes in the Maximum Willingness-to-Pay

maximum willingness-to-pay for recreation at lower water quality, WC_2 (higher phosphorus concentration). Consumer surplus under the better water quality is represented by the triangle area bounded by d_1, P and C_1. Consumer surplus under the lower water quality is represented by the triangle area bounded by d_2, P and C_2. The difference between them, marked by the area d_1, d_2, C_1 and C_2 represents the change in consumer surplus. This change can be interpreted as a benefit obtained by increasing water quality from WC_2 to WC_1, or equivalently as a loss in recreational values when the water quality decreases from WC_1 to WC_2. This concept is used to empirically estimate the losses in recreational values under alternative phosphorus concentrations of water in the Eucha and Spavinaw lakes.

Data on annual visitations to the Eucha and Spavinaw state parks were obtained from the Oklahoma Tourism and Recreation Department (OTRD, 2003). Visitors to the lakes were divided in iso-travel cost zones according to survey results published in a report by the Oklahoma Conservation Commission (OCC, 1997). The iso-travel cost zones are geographic zones from which it would cost approximately the same to travel to a given recreational site. Four iso-travel zones were identified for the lakes Eucha and Spavinaw: Zone 1 – Tulsa Metropolitan Area, Zone 2 - Siloam Springs and Fayetteville, AR, Zone 3- visitors from Oklahoma other than Tulsa (mainly including cities and towns on the East of Tulsa), and Zone 4 – Local area (communities of Jay, Spavinaw and other smaller communities). Travel cost from each zone was calculated using road distances and average gasoline consumption and prices. The value of time spend on recreation (McConnel, 1992) was incorporated in the travel cost estimates using income data (USDC, 2000) to estimate the hourly earnings.

Demand equation for recreation in price flexibility form was estimated according to the following model

(2.10.) $$TC_l = \sum_{k=1}^{12} d_1^k D^k + d_2 Q_l,$$

where TC_l denotes the travel cost to the recreational site from the l^{th} zone, d_1^k denotes maximum willingness-to-pay at a given level of phosphorus concentration, D^k is a dummy variable for each level of phosphorus concentration (twelve levels, k), and Q_l is the observed number of visits from the zone l [3]. The results from the estimation are presented in Table A2.3 in the Appendix. The estimated maximum willingness–to–pay parameters were regressed on the observed phosphorus concentration to yield the following estimated equation (t-values in parenthesis)

(2.11.) $$d_1^k = \underset{(4.93)}{72.7} - \underset{(-2.1)}{788.5}\, PC^k \, ,$$

where PC is the observed phosphorus concentration in the lakes. Data published in OWRB, 2002, pp-120-121 were used to convert the phosphorus concentration to

[3] Dummy variable (or indicator variable) in this case is defined as unity at some particular level of k and zero otherwise . For example, $D^1 = 1$ for d_1^1 and zero otherwise.

phosphorus loading. Consequently, distinct intercepts (maximum willingness-to-pay) for each level of phosphorus loading in the watershed were calculated. The calculation of the consumer surplus and the change in the consumer surplus at the various levels of phosphorus load were conducted using the standard procedures as described above. The results are provided in Table A 2.3. in the Appendix.

Estimates for Total and Marginal Environmental Damage Costs

The sum of costs for drinking water treatment that City of Tulsa incurs and the cost of recreational losses calculated above result in an estimate of the total environmental damage cost for the Eucha-Spavinaw watershed [4]. As noted in the conceptual framework presentation, derivation of the marginal environmental damage costs may be quite useful for the further discussion.

The marginal damage costs could be obtained by first expressing the total damage costs as a function of phosphorus load and by differentiating the function with respect to the phosphorus load. The estimated total damage cost as a function of phosphorus load in the watershed was (t-values in parenthesis)

$$DC = \underset{(10.25)}{585446.9} - \underset{(-15.45)}{59.93}\ Zmax + \underset{(25.18)}{0.0015}\ Zmax^2, \tag{2.12.}$$

where *DC* is the total damage cost and *Z* is the phosphorus load in the watershed. The marginal damage cost is then

$$MDC = -59.93 + 0.003\ Zmax\ . \tag{2.13.}$$

Marginal damage costs expressed in this way are used in the subsequent discussion.

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4 The word "total" here is meant to make a distinction from the word "marginal". It is not claimed that these environmental cost estimates comprise all possible environmental damages in the watershed, so that the word "total" does not have a meaning of "all" environmental damages.

LINEAR PROGRAMMING SOLUTIONS

To find the least cost way to achieve any given level of phosphorus loading in the watershed, litter management practices are to be optimally allocated to agricultural enterprises (non-point sources of phosphorus loading), and the level of wastewater treatment is to be optimally assigned to the wastewater treatment plant at the City of Decatur (point source of phosphorus loading). In particular, the objective of the model was set to maximize the sum of agricultural income from all agricultural HRUs in the watershed minus the costs to the point source and the costs of transportation of litter, by choosing litter management practices and wastewater treatment level to meet a certain limit on total phosphorus loading in the entire watershed. This is best represented in the linear programming framework, which can be mathematically stated as,

(2.14.1) $$\max_{X_{ij},Y_q} \sum_{i=1}^{N}\sum_{j=1}^{695}\Pi_{ij} * X_{ij} - \sum_{q=1}^{35} PSC_q(Z_q) * Y_q - \sum_{s=1}^{695}\sum_{r=1}^{695}\sum_{t=1}^{2} Tt_{sr}c_{sr} - \sum_{b=1}^{B}\sum_{t=1}^{2} Tt_b ct_b$$

subject to

(2.14.2) $\sum_i X_{ij} = 1$ and $X_{ij} \geq 0$ (Select the most profitable BMP in each HRU)

(2.14.3) $\sum_q Y_q = 1$ and $Y_q \geq 0$ (Select a level of phosphorus abat. at point source)

(2.14.4) $T_s = \sum_{t=1}^{2} T_{st}$ (t =1 for litter without alum, 2 for alum)

(2.14.5) $T_{st} = T_{sst} + T_{rst} - T_{rst}$, $s \neq r$ (All litter applied or shipped out of the watershed)

(2.14.6) $Z_q + \sum_{i=1}^{N}\sum_{j=1}^{694} Z_{ij} X_{ij} \leq Z_{\max}$, (total phosphorus loading less than Z_{max})

where:

Π_{ij} is the net income from the i^{th} BMP in j^{th} HRU,
X_{ij} denotes the adoption of the i^{th} BMP in the j^{th} HRU.
PSC_q is point source abatement cost for the q^{th} level of phosphorus abatement (Y_q).
Ts is the total quantity of litter in produced in s^{th} subbasin.
T_{tsr} is the quantity of litter with treatment t shipped from the s^{th} to the r^{th} sub basin[5].
ct_{sr} is the cost of transporting litter with treatment t from the s^{th} to the r^{th} sub-basin.
T_b is the quantity of litter shipped out of the watershed from point b.
Z_{ij} is the amount of phosphorus runoff in tons from the j^{th} HRU under the i^{th} BMP.
Z_q is the q^{th} level of phosphorus loading from the point source.
Z_{max} is total allowed phosphorus loading,

The quantity of allowed phosphorus loading in the watershed, Z_{max} was varied from 18000 to 46000 kilograms per year. The upper level of 46000 kg./year corresponds to the estimate of total current phosphorus loading in the watershed from the non-point agricultural sources and the point source (Storm et *al*., 2002). The lowest level of 18000 kg/year corresponds to the estimated phosphorus load if no litter were applied in the watershed and if all agricultural land uses received the required nitrogen from commercial fertilizer, and also there were no phosphorus loading from the point source (maximum abatement at the point source) [6]. The intermediate phosphorus loading targets, (40000, 35000, 30000, 25000, 20000 (all in kg/year)) were chosen to determine how the marginal abatement cost curve changed as the amount of abatement changed. The program was solved using standard MPS linear programming format in the C-WHIZ Version 4 Linear Programming Optimizer (Ketron Management Science).

[5] The SWAT model divides the watershed in total of sixty nine subbasins.
[6] In the modeling of phosphorus loading within the SWAT framework the quantity of nitrogen applied, whether from litter or commercial fertilizer is of great importance. If too little or no nitrogen is applied, the agricultural land uses will have fairly low intensity of land cover, which will promote higher erosion and runoff. For this reason, hydrologic modelers use constant quantity of nitrogen applied to determine the effects of variation of litter application on phosphorus loading. In an economic analysis however, allowing for a choice whether to substitute nitrogen with commercial fertilizer when litter application is reduced is of significant importance as discussed above.

As noted above, the notation X_{ij} denotes the i^{th} litter management practice which can be chosen in the j^{th} HRU of the watershed. The basic litter management practices were described above as twenty-four distinct activities (eight litter application rates using either alum treated or non-treated litter and substituting for nitrogen with commercial fertilizer for lower litter application rates). These base activities were used for the linear programming runs under four distinct simulated policies. The policies differ by the set of choices (options) available for reducing phosphorus loading in the watershed from the non-point sources. The abatement technology at the point source was the same across each of the alternative policies, but the amount of abatement was optimally chosen.

Policy 1 – Using the Litter Management Practices

The first policy was the one that used only the described basic twenty-four litter management practices and point source abatement to meet a phosphorous target. The linear program was solved to maximize the sum of the net income from agricultural activities in the watershed, minus the cost of the point source abatement, less the cost for litter transportation. The model selected one of the twenty-four basic litter management practices for each particular HRU in the watershed and a level of phosphorus abatement at the point source. This policy was used to simulate the possibilities for short-run reduction of phosphorus loading in the watershed by transporting litter across individual sub-basins, varying litter application rates, using alum as a litter amendment, choosing whether to substitute nitrogen with commercial fertilizer, and choosing the optimal level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed, (Z_{max}, the phosphorus constraint was parametrically varied). Results from the linear programming runs are presented in the following section. Of particular interest in the analysis of this policy was to observe the use of alum, the intensity of transportation within the watershed, the average litter application rates for soil type-land use, and the level of abatement at the point source, as the allowed phosphorus loading for the watershed was parametrically reduced.

Policy 2 – Applying Litter According to the STP Criterion

The next policy considered was the application of poultry litter according to the soil test phosphorus (STP) criterion. As discussed before, there are numerous policy recommendations that litter application would be allowed only on the land that meets a certain phosphorus based criteria. One such criterion is the STP, which uniformly classifies the soils according to their phosphorus content. Another criterion that addresses better the specific characteristics of individual soils and land uses is the Phosphorus Risk Index (PRI) (Storm and Smolen, 2001). Although PRI is generally preferred, especially from an economic standpoint, its practical application is fairly limited. At present time a research effort is underway at Oklahoma State University, which attempts to classify the soils in the Eucha-Spavinaw watershed according to the PRI criterion. However, since the results from that research are still not available, a policy that uses the STP criterion was simulated in the present study.

Under this policy, litter application is only allowed on soils that have STP lower than a certain threshold value [7]. All other land cannot receive poultry litter. For the agricultural HRUs that do not receive litter, required nitrogen could either be replaced by commercial fertilizer or not. In the linear programming framework, in effect, there were

[7] Threshold values of 120, 200, 250 and 350 STP were analyzed.

just two options available for the HRUs that do not receive litter, to substitute or not for nitrogen using commercial fertilizer. If the nitrogen was substituted, the phosphorus load from a particular HRU was reduced due to improved plant growth and better land cover. (nitrate runoff however may increase). At the same time, net agricultural income was reduced due to the cost of commercial fertilizer and its application. For the HRUs that were allowed to receive litter (STP lower than a particular threshold value) the twenty-four basic litter management practices were available as options in the linear programming runs. Abatement at the point source was modeled as mandated by a regulation, so a full abatement to a level of 1 mg/l phosphorus concentration of the effluent was simulated. The linear program was run to maximize the sum of the net income from agricultural activities in the watershed minus the litter transportation cost by choosing one of the twenty-four basic litter management practices for HRUs that were allowed to receive litter in the watershed, and by choosing whether to replace the required nitrogen by commercial fertilizer or not for HRUs that were not allowed to receive litter. Note that under this policy there is no constraint on the phosphorus loading. The policy in itself implies phosphorus abating actions (not applying litter to high STP soils) and a further constraint on phosphorus would be infeasible from political and regulatory aspects. Therefore, the total phosphorus constraint was "freed" in the linear program to reflect this situation.

The linear programming model was run for four levels of STP thresholds (120, 200, 250, 350). Results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe the transportation activities within and out of the watershed, the use of commercial nitrogen by agricultural land uses and the litter application rates on the HRUs where litter application was allowed.

Policy 3 – Mandatory Land Use Conversion

The third policy analyzed in the study assumed mandatory changes in agricultural land use patterns in the watershed. This policy is used to represent a simulation of a mandatory (uniform) conversion of overgrazed pasture to maintained pasture and conversion of row crop to hay. Since the overgrazed pasture and row crop land uses were identified as contributing the most to the phosphorus loading, the simulated policy comprised of a mandatory order to the land owners to convert those two land uses to well-maintained pasture and hay respectively. These changes in land use patterns in the watershed present a significant opportunity for phosphorus load reduction, but are only attainable in the longer run and require changes in the economic structure of the agriculture and related industry in the watershed. Also, mandatory land use change may not be very popular and for that matter politically feasible policy.

SWAT model was used to simulate the conversion of the overgrazed pasture to maintained pasture and from row crops to hay. The SWAT simulation provided estimates of the phosphorus load, crop yield, and biomass for the newly converted HRUs. For the HRUs where the conversion was conducted, the calculations of the net agricultural income were repeated for the newly assigned land uses. The basic twenty-four litter management practices were then used as options in the linear programming model.

The linear program was run to maximize the sum of the net income from hay and maintained pasture agricultural activities in the watershed minus the abatement cost at the point source and the litter transportation cost by choosing one of the twenty-four basic litter management practices for each HRU, and by choosing a level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed (the phosphorus constraint was parametrically varied). The results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe how the possibility of land use change affects the use of alum, the intensity of transportation within the watershed, average litter application rates for particular land uses, the level of abatement at the point source, and to compare the net income for the watershed as a whole to the policies that do not allow for land use change. These characteristics were observed as the allowed phosphorus loading for the whole watershed was varied from higher to lower levels.

Policy 4 – Site Specific (Optimal) Land Use Conversion

As opposed to the policy of uniform (mandatory) land use conversion, the last policy considered in this study was to simulate a site-specific (optimal) land use conversion. This was achieved by combining Policy 1 and Policy 3 in a single linear programming model. Separate production activities for each of the two policies were constructed in each HRU and were combined together. For the part of the linear program pertaining to Policy 1, the basic twenty-four litter management practices were assigned as possible production activities for each HRU. For the part of the linear program pertaining to Policy 3, the overgrazed pasture and row crop HRUs were first converted to maintained pasture and hay HRUs respectively and the basic twenty-four litter management practices were assigned to each HRU in the watershed. Each production activity for each HRU was specifically labeled to distinguish between alternative policies.

The linear program was run to maximize the sum of the net income from agricultural activities in the watershed minus the abatement cost at the point source and the litter transportation costs, by choosing whether to convert a particular HRU, and then by choosing one of the twenty-four basic litter management practices for each HRU, and by choosing a level of phosphorus abatement at the point source. The linear programming model was run for each level of allowed phosphorus loading in the watershed. Results from the linear programming runs are presented in the following section. Of particular interest for this policy was to observe the optimality of land use change, the use of alum by land uses, average litter application rates by land uses, the level of abatement at the point source and to compare the net income for the watershed as a whole to the individual policies discussed above. It is to be expected that since this policy contains two of the above policies, it is least restrictive and hence should yield the higher value of the net income for the watershed as a whole.

Tracing the Total and Marginal Abatement Cost Curve

For each of the four policies analyzed in the study for which linear programs were run, the total and marginal abatement costs were determined. Total abatement cost were determined as a difference in the value of the objective function of the linear program under the estimated current level of phosphorus loading (46000 kg./year) and the value of the objective function at each other level of phosphorus loading for which a linear program was run (for example, value of the objective function at the allowed phosphorus loading of 46000 kg./year minus the value of the objective function at the allowed phosphorus loading of 30000 kg./year represents total cost of abating 16000 kg./year of phosphorus loading in the watershed using for example, Policy 1.).

Marginal abatement costs were determined using the shadow price on the phosphorus constraint from the linear program (Eq.2.14.6). In the linear programming framework (Beneke and Winterboer, 1973) (Hazel and Norton, 1986) each binding constraint has an associated shadow price (Lagrangian multiplier). The shadow price states the amount by which the value of the objective function changes as the constraint in question is relaxed (or constrained further) by an additional unit. The interpretation in the sense of a Lagrange multiplier is that the shadow price states the value of a partial derivative of the objective function with respect to the constraining variable. Thus the shadow price on phosphorus loading in the linear program represents the change in the value of the objective function as that constraint is changed by one more unit. This corresponds exactly to the definition of the marginal abatement costs discussed before. Therefore, the shadow prices on phosphorus, which are obtained as output from the linear programming runs, are used to represent the marginal abatement costs. The marginal abatement cost curve is traced out by formulating a mathematical function that maps from the set of observed levels of phosphorus loading to the set of the observed marginal costs. A quadratic function was specified and the quadratic term was tested for significance (using Wald or Likelihood Ratio type statistical tests) to determine whether the appropriate function is quadratic or linear.

Spatial Detail of Optimal Solutions

In addition to the aspects that are of interest when examining individual policies described above, there is interest to observe the spatial characteristics of the HRUs, classifying them by optimal litter management practices assigned by the mathematical program. The spatial characteristics of the HRUs are mainly composed of soil type, slope steepness and geographic location (sub-basin). For example, it is of interest to observe what are the spatial characteristics of HRUs that were assigned alum treated litter by the linear program runs, and it is of interest to observe the spatial characteristics of the HRUs where conversion of say row crop to hay was found optimal by the linear program runs.

Also, in the linear programming framework, since each HRU has to be assigned a specific litter management practice (constraint represented in Eq. 2.14.2), there was a shadow price on each HRU. This shadow price essentially represents the value that would be added to the objective function if a specific HRU was duplicated and added to the watershed. In other words, the shadow price is the marginal value that the agricultural area represented by an HRU adds to the overall objective function. The shadow price reflects both the economic and environmental value of an HRU. If the agricultural production in an HRU is profitable, its shadow price would be high and vice versa. On the other hand if the phosphorus runoff from an HRU is high its shadow price would be low (even negative), reflecting the high marginal contribution of that HRU towards the fulfillment of the binding constraint on phosphorus loading.

The spatial distributions of optimal litter management practices have important policy implications. They provide guidelines for more effective regulation and management. Therefore a summary of the spatial characteristics of HRUs by land use and chosen management practice is provided in the Appendix for the optimal solutions of each of the analyzed policies.

RESULTS FROM THE ALTERNATIVE POLICIES

Policy 1 – Changing Litter Management Practices

The aggregate results obtained from the linear program runs for the base twenty-four litter management practices (change in litter application rates, with and without alum amendments, with and without nitrogen replacement by commercial fertilizer) are presented in Table 2.5.

Table 2.5. Results from the Linear Program Runs for Policy 1.

Phosphorus loading (Zmax)	Value of the objective function	Marginal Phosphorus Abatement Costs	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source
kg / year	Dollars	dollars	Dollars	Dollars
46000	5,616,335	9.17	0	0
40000	5,546,346	14.53	57139	12,850
35000	5,473,694	14.53	56645	85,996
30000	5,387,629	22.46	98573	130,133
25000	5,221,834	56.75	226826	167,675
20000	3,605,787	886.56	1826188	184,360
18000*	1,610,470	Inf	3821505	184,360

* Solution not feasible

The results show that the changes in litter management practices and point source abatement can reduce the total phosphorus load to 20 tons per year. For example, the phosphorus load could be reduced from current 46 tons/year to 30 tons/year (16 tons reduction) at total cost of about $230,000 distributed to agricultural enterprises ($100,000) and to the point source ($130,000). However, any further reduction comes at excessively high costs, characterized by the dramatically increasing marginal abatement cost at lower levels of phosphorus loading. The burden of this drastic phosphorus load reduction is almost exclusively on the agricultural enterprises, since the maximum reduction at the point source has already been achieved.

To determine the socially optimal level of phosphorus abatement in the watershed using Policy 1, a summary of costs to the City of Tulsa and losses of recreational values, as well as the abatement costs for the various levels of phosphorus loading is provided in Table 2.6. The optimal level of abatement is indicated in the rightmost column of Table 2.6 at the point where the sum of abatement plus damage costs is at minimum (See Eq.2.5).

Table 2.6. A Summary of the Abatement and Damages Costs and their Sum from a Policy of changing Litter Management Practices and Point Source Abatement.

P loading	City of Tulsa Costs	Predicted Total Number of Visits to State Parks	Consumer Surplus	Total damage costs	Abatement costs	Sum of abatement and damage costs
kg/year	dollars	count	dollars	dollars	dollars	dollars
18000	0	263256	633222	0	inf	
20000	7693	198325	579518	61397	2010548	2071945
25000	52281	151756	457509	227995	394501	622496
30000	99758	138890	353001	379980	228706	608686
35000	168849	96826	265994	536077	142641	678718
40000	232107	60840	195939	669390	69989	739379
46000	276863	17238	129851	780235	0	780235

The optimal level is found at the phosphorus load in between 25 and 30 tons per year. At the exact optimal point, the marginal abatement costs will be equal to marginal damage costs (Eq.2.6). As discussed above, the marginal abatement cost curve is traced out by formulating a quadratic function, which in this case was of the form (t-values in parenthesis)

(2.15)
$$MAC_1 = \underset{(3.43)}{300.72} - \underset{(-2.74)}{0.01422}\, Zmax_k + \underset{(2.42)}{0.000000173}\, Zmax_k^2.$$

with an R^2 of 0.925. Solving simultaneously for the *Zmax* using calculated marginal damage costs (Eq.2.13.) and abatement costs yields a quadratic equation with a root of

26062, which represents the socially optimal level of phosphorus loading in kilograms per year using Policy 1. Figure 2.11 graphically presents the point of optimal phosphorus abatement where the marginal abatement costs are equal to marginal damage costs. The linear program was rerun for this optimal phosphorus constraint. The optimal level of phosphorus abatement at the point source was 9687 kg/year, which corresponds to the effluent phosphorus concentration of 1.13 mg./litter.

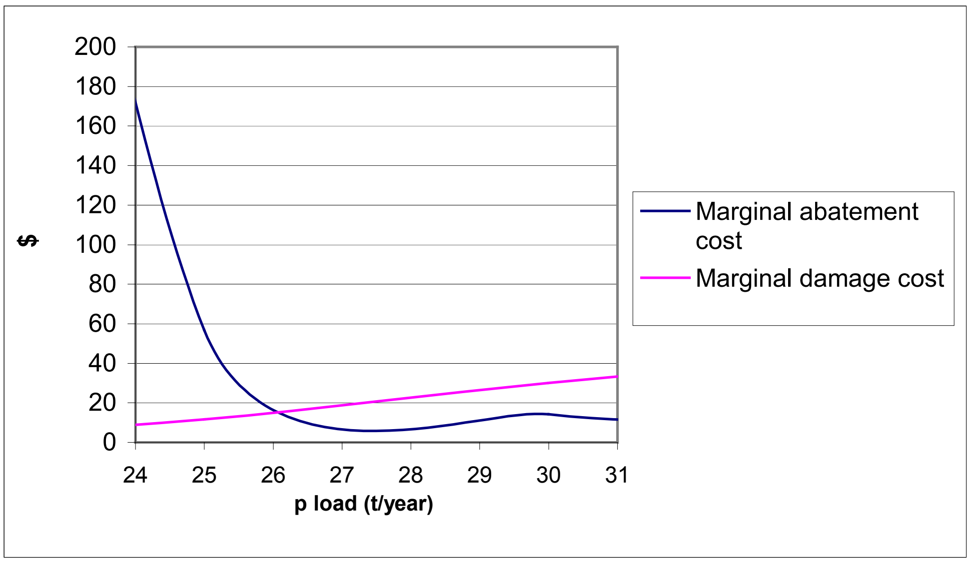

Figure 2.12. Marginal Abatement and Marginal Damage Costs for Policy 1.

Results for the alum use and the average litter application rates for the HRUs, as well as the intensity of transportation and the level of abatement at the point source are observed for the linear program runs under the current phosphorus loading (46000 kg./year), under the optimal phosphorus loading (26000 kg./year) and under the minimum attainable phosphorus loading (20000 kg./year). These levels of phosphorus loading were chosen, so that the changes in optimal uses could be observed as the allowed phosphorus loading is reduced from higher to lower levels.

Results on the optimal litter application rates and the optimal decision on nitrogen replacement for hay and well-maintained pasture are reported for the three levels of phosphorus loading in Table 2.7. The results show that at the current level of phosphorus loading, application of litter would be more profitable for hay than for well-maintained pasture. As the allowed phosphorus loading is reduced, the amount of litter applied is reduced and the use of commercial nitrogen is increased. It was found more efficient to replace nitrogen on hay than on pasture.

Table 2.7. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the HAY and WPAS Under Policy 1.

		Land use					
		HAY			WPAS		
Litter application rates		Land area at current P load (46t.)	Land area at optimal P load (26 t.)	Land area at minimum P load (20 t.)	Land area at current P load (46t.)	Land area at optimal P load (26 t.)	Land area at minimum P load (20 t.)
tons/ha		ha	ha	ha	Ha	Ha	ha
0	w. N replac	0	0	6913	0	0	468
	w/o N replac	11	11	10	12458	13961	15973
1	w. N replac	0	0	113	0	0	0
	w/o N replac	0	0	0	10230	8611	1493
2	w. N replac	0	0	0	0	0	0
	w/o N replac	0	0	0	562	677	4307
3	w. N replac	0	0	0	0	0	0
	w/o N replac	0	0	0	0	0	932
3.4	w. N replac	102.5	0	227	0	0	0
	w/o N replac	0	0	0	0	0	0
4		4101	2831	850	0	0	77
4.8		5610	5706	2612	0	0	0
6		3578	4854	2677	0	0	0

Results on optimal litter application rates and the optimal decision on nitrogen replacement for overgrazed pasture (OAST) and row crop (WWHT) are reported for the three levels of phosphorus loading shown in Table 2.8. The results for these two land uses show that they are responsive to litter application and in general to nitrogen application, in both economic and environmental terms. However, since these two land uses were identified as most susceptible to phosphorus runoff, the optimal litter application rates are reduced as the allowed phosphorus loading is reduced. As this is taking place, nitrogen is substituted from commercial sources to ensure good land cover, which reduces phosphorus runoff. This does take a toll on the net agricultural income, which is reflected in the low income at lower allowed levels of phosphorus loading.

Table 2.8. Litter Application Rates and the Choice of Nitrogen Replacement by Commercial Fertilizer for the OPAS and WWHT Under Policy 1.

OPAS					WWHT				
Litter application rates		Current P load (46t.)	Optimal P load (26 t.)	Minimum P load (20 t.)	Litter application rates		Current P load (46t.)	Optimal P load (26 t.)	Minimum P load (20 t.)
tons		Land Area (ha.)			tons		Land Area (ha.)		
0	w. N rep	4674	1338	5656	0	w. N rep	938	2049	2619
	w/o N rep	0	3636	8		w/o N rep	456	14	0
0.54	w. N rep	0	0	0	0.32	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	199	47	0
1.08	w. N rep	0	0	0	0.65	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	137	53	0
1.62	w. N rep	0	0	0	0.975	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	11	10	0
1.83	w. N rep	0	0	0	1.1	w. N rep	0	0	0
	w/o N rep	0	0	0		w/o N rep	45	28	0
2.15		0	0	0	1.3		7	1	0
2.6		407	21.3	0	1.56		28	0	0
3.2		1356	1546	878	1.95		804	424	7

The results on the use of alum for hay and well-maintained pasture (WPAS) are reported for the three levels of phosphorus loading in Table 2.9. The results show that the use of alum is quite important as an optimal solution for hay.

Table 2.9. Use of Alum for HAY and WPAS Under Policy 1.

	HAY			WPAS		
Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)
tons	Land Area (ha.)			Land Area (ha.)		
1	0	0	113	844	7234	1493
2	0	0	0	274	677	4307
3	0	0	0	0	0	932
3.4	0	0	227	0	0	0
4	2606	2831	850	0	0	77
4.8	3030	5706	2612	0	0	0
6	1020	4854	2677	0	0	0

On all levels of allowed phosphorus loading, higher litter application rates are combined with the use of alum treated litter. For the well-maintained pasture, the optimal use of alum increases significantly as the allowed level of phosphorus loading is reduced.

Results on the use of alum for overgrazed pasture (OPAS) and row crop (WWHT) are reported for the three levels of phosphorus loading in Table 2.10. The results show that the alum use is important optimal solution for these two land uses as well, especially at higher rates of litter application. However, as the allowed phosphorus loading is reduced, the application of litter is halted on most land and hence the alum is not used as well. At the 20 tones P loading constraint, there is very little opportunity to apply litter and since litter had to be shipped out of the watershed, treating litter with alum was not optimal (it is cheaper to ship non-treated litter out of the watershed).

Table 2.10 . Use of Alum for the OPAS and WWHT Under Policy 1.

OPAS				WWHT			
Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)	Litter application rates	Alum use at current P load (46t.)	Alum use at optimal P load (26t.)	Alum use at minimum P load (20t.)
Tons	ha	ha	ha	tons	ha	ha	ha
0.54	0	0	0	0.32	0	0	0
1.08	0	0	0	0.65	9.6	36	0
1.62	0	0	0	0.975	0	0	0
1.83	0	0	0	1.1	14	28	0
2.15	0	0	0	1.3	7	1	0
2.6	407	21.3	0	1.56	15	0	0
3.2	105	350	0	1.95	523	387	7

The pattern of transportation and total alum use under the three phosphorus loading levels is reported in Table 2.11.

Table 2.11. Transportation of Litter and Use of Alum Treated Litter for the Three Levels of Phosphorus Loading Under Policy 1.

	Transport of litter		Total litter used	
Phosphorus Loading	Within the watershed	Out of the watershed	Alum treated	Non-treated
	Thous. ton miles*	Thous. ton miles*	Thous.tons	Thous.tons
Current (46t.)	566.5	0	34	50
Optimal (26t.)	567.3	0	78.6	5.4
Minimum (20 t).	691.2	1220.1	46.1	37.9

* ton miles denote transportation of one ton of litter at distance of one mile.

The results show that transportation of litter within the watershed is very important activity if the net income on the watershed level is to be maximized. The optimal level of litter transportation intensified as the allowed phosphorus loading was restricted. At the 46 t. and 26 t. levels of phosphorus loading, it was not optimal to ship litter out of the watershed. However, if greater reduction in phosphorus loading was desired, considerable amount of litter had to be shipped out of the watershed and at considerable distance. This is one of the most significant reasons for the dramatic increase of abatement costs (reduction of net income) at lower levels of phosphorus loading. The results also show that it is optimal to use alum treated litter to efficiently prevent phosphorus loading. At the optimal solution, almost all litter used in the watershed is treated with alum. At lower phosphorus loading levels, since the litter is shipped out of the watershed, the use of alum is lower than at the optimal rate.

The summary of optimal litter application rates by average slope of the agricultural land for hay and maintained pasture is provided below in Table 2.12 while the summary of for overgrazed pasture and row crop is provided in Table 2.13. The results show that in general, applying litter on land with steeper slopes is not optimal, especially if a reduction of P loading is desired. This general finding however, needs to be addressed carefully since there is significant interaction between the slope of a land area, the crop grown, and the initial phosphorus content in the soil. Therefore, these interactions have to be taken into account when devising policies to reduce phosphorus loading in the watershed.

The results for the optimal litter application rate with respect to soil types, for hay are presented in Table 2.14. The results could be used to identify the areas within soil types for where litter could be applied on hay land at six tons per hectare even for drastic reductions of the phosphorus loading target. Those soils are Doniphan, Newtonia, Razort and Tonti. The results could be also used to identify the soil types for which litter application on hay land use was not found optimal as the target P loading was reduced. These soils are Captina, Nixa, and Macedonia.

Table 2.12. Optimal Litter Application by Average Slope of the Agricultural Land for Hay and Well-maintained Pasture Under Policy 1.

	Land Use					
	Hay			Well-maintained Pasture		
Current P loading (46 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<
tons	ha	ha	ha		ha	ha
0	0	1	10	4779	6119	1560
1	0	0	0	4893	4779	557
2	0	0	0	177	111	274
3.4	0	39	63	0	0	0
4	2133	1634	334	0	0	0
4.8	2088	2368	1154	0	0	0
6	1241	2281	56	0	0	0
Optimal P loading (26 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<
tons	ha	ha	ha	ha	ha	ha
0	0	1	10	5706	6208	2047
1	0	0	0	3966	4411	235
2	0	0	0	177	390	110
4	1510	1067	253	0	0	0
4.8	2085	2329	1292	0	0	0
6	1867	2925	62	0	0	0
Minimum P loading (20 t.)						
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<
tons	ha	ha	ha	ha	ha	ha
0	3392	3148	382	6527	7940	1975
1	0	0	113	652	646	195
2	0	0	0	2447	1642	218
3	0	0	0	224	703	4
3.4	0	28	199	0	0	0
4	109	613	128	0	77	
4.8	808	1245	560	0	0	0
6	1153	1289	234	0	0	0
Total land (ha):	5462	6323	1617	9849	11009	2392

Table 2.13. Optimal Litter Application by Average Slope of the Agricultural Land for Overgrazed Pasture and Row Crop Under Policy 1.

Land Uses							
Overgrazed Pasture				Row crop			
Current P loading (46 t.)							
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<	Litter application rates	Land with slope<5%	Land with slope 5%<8%	Land with slope 8%<
Tons	ha	ha	ha	tons	Ha	ha	ha
0	1677	2266	731	0	1275	76	44
0.54	276	130	0	0.32	80	49	69
1.08	0	0	0	0.65	109	40	0
2.15	0	0	0	1.1	44	0	1
2.6	0	0	0	1.56	0	0	15
3.2	899	551	10	1.95	733	61	8
Optimal P loading (26 t.)							
Litter application rates	Land with slope <5%	Land with slope 5%<8%	Land with slope 8%<	Litter application rates	Land with slope<5%	Land with slope 5%<8%	Land with slope 8%<
Tons	ha	ha	ha	tons	ha	ha	ha
0	1976	2266	731	0	1722	197	143
0.54	0	0	0	0.32	47	0	0
1.08	0	0	0	0.65	41	12	0
1.62	0	0	0	0.975	10	0	0
1.83	0	0	0	1.1	28	0	0
2.6	21	0	0	1.56	0	0	0
3.2	855	680	10	1.95	407	16	0
Minimum P loading (20 t.)							
Litter application rates	Land with slope 3%<5%	Land with slope 5%<8%	Land with slope 8%<	Litter application rates	Land with slope<5%	Land with slope 5%<8%	Land with slope 8%<
Tons	ha	ha	ha	tons	ha	ha	ha
0	2405	2520	738	0	2248	226	144
3.2	446	427	4	1.95	7		
Total land:	1741	2947	742		2255	226	144

Table 2.14. Optimal Litter Application by Soil Type for Hay Under Policy 1.

Soil Type	Current P load (46t.)					Optimal P load (26t.)				MinimumP load (20t.)					
	Litter application rate (t./ha)					Litter application rate (t./ha)				Litter application rate (t./ha)					
	0	3.4	4	4.8	6	0	4	4.8	6	0	1	3.4	4	4.8	6
	Land Area (ha.)					Land Area (ha.)				Land Area (ha.)					
Tonti	0	0	34	0	1039	0	34	0	1039	315	0	21	0	0	737
Clarksville	0	47	454	2812	727	0	226	2678	1136	1123	0	176	641	1941	159
Captina	0	7	1025	684	201	0	695	816	407	1916	0	0	0	2	0
Nixa	0	7	1228	407	260	0	1183	460	260	1860	0	7	36	0	0
Peridge	0	4	162	31	0	0	103	95	0	193	0	0	0	5	0
Britwater	1	0	97	96	19	1	82	111	19	76	113	0	7	18	0
Healing	0	26	27	0	0	0	53	0	0	0	0	23	0	29	0
Noark	0	0	35	0	0	0	35	0	0	0	0	0	0	35	0
Jay	0	0	182	0	0	0	182	0	0	182	0	0	0	0	0
Razort	0	11	393	46	0	0	135	159	156	58	0	0	166	42	183
Doniphan	0	0	0	756	1113	0	0	544	1324	0	0	0	0	541	1328
Macedonia	0	0	0	410	156	0	0	354	212	566	0	0	0	0	0
Parsons	0	0	59	122	0	0	59	122	0	181	0	0	0	0	0
Taloka	0	0	45	0	0	0	45	0	0	45	0	0	0	0	0
Newtonia	0	0	360	234	60	0	0	360	294	397	0	0	0	0	256

Results for the optimal litter application rates with respect to soil types, for well-maintained pasture are presented in Table 2.15. The results could be used to identify the soil types for which litter application on well maintained pasture was found optimal even for drastic reduction of phosphorus loading target. Those soils are Doniphan, Sacesh and Tonti. The results could be also used to identify the soil types for which litter application on well maintained pasture was not found optimal as the target P loading is reduced. These soils were Captina, Nixa, and Taloka.

Results for the optimal litter application rate with respect to soil types, for overgrazed pasture are presented in Table 2.16. The results single out two soil types where litter application was found optimal even for drastic reduction of phosphorus loading target. Those soils were Captina and Peridge.

Table 2.15. Optimal Litter Application by Soil Type for Well-maintained Pasture Under Policy 1.

	Current P load (46t.)			Optimal P load (26t.)			MinimumP load (20t.)				
	Litter application Rates (t/ha)			Litter application Rates (t/ha)			Litter application Rates (t/ha)				
Soil Type	0	1	2	0	1	2	0	1	2	3	4
	Land Area (ha.)			Land Area (ha.)			Land Area (ha.)				
Tonti	52	1666	0	52	1500	166	52	0	1666	0	0
Clarksville	2330	4334	111	2828	3663	284	5256	1111	408	0	0
Captina	2035	566	0	2119	483	0	2602	0	0	0	0
Nixa	3797	35	274	4072	35	0	4106	0	0	0	0
Peridge	795	0	0	795	0	0	795	0	0	0	0
Britwater	325	151	0	333	143	0	476	0	0	0	0
Noark	517	0	0	517	0	0	517	0	0	0	0
Jay	417	0	0	417	0	0	417	0	0	0	0
Razort	740	71	0	742	69	0	146	25	636	4	0
Doniphan	12	1159	177	12	1110	227	44	0	384	921	0
Secesh	0	77	0	0	77	0	0	0	0	0	77
Macedonia	504	219	0	504	219	0	623	100	0	0	0
Taloka	411	761	0	703	469	0	1172	0	0	0	0
Newtonia	434	1164	0	779	818	0	152	256	1189	0	0

The soil type Captina was identified for the two previous land uses as the one where litter application was not optimal. For the overgrazed pasture however, the opposite conclusion holds true. The reason for this is the fact that on overgrazed pasture, the litter application on this soil type has beneficial effect on the improvement of land cover, which significantly reduces phosphorus runoff.

The results for the optimal litter application rate with respect to soil types, for the row crop are presented in Table 2.17. The results show that litter application was optimal on two soil types for moderate reduction of phosphorus loading target. These soil types were Nixa and Tonti. For the row crop, the litter application was not found optimal on any soil at more drastic reductions of phosphorus loading.

Table 2.16. Optimal Litter Application by Soil Type of the Agricultural Land for Overgrazed Pasture Under Policy 1.

	Current P load (46t.)			Optimal P load (26t.)			Minimum P load (20t.)	
	Litter application Rates (t/ha)			Litter application Rates (t/ha)			Litter application Rates (t/ha)	
Soil Type	0	2.6	3.2	0	2.6	3.2	0	3.2
	Land Area (ha.)			Land Area (ha.)			Land Area (ha.)	
Tonti	84	122	240	84	21	240	445	0
Claksville	1464	48	0	1483	0	30	1512	0
Captina	173	0	823	221	0	775	278	718
Nixa	738	0		738	0	0	738	0
Peridge	0	0	209	0	0	209	50	159
Britwater	82	0	0	82	0	0	82	0
Jay	49	0	0	49	0	0	49	0
Razort	124	0	6	124	0	6	131	0
Doniphan	1097	0	0	1097	0	0	1097	0
Macedonia	477	0	0	477	0	0	477	0
Parsons	73	0	0	73	0	0	73	0
Taloka	154	0	0	154	0	0	154	0
Newtonia	96	236	182	332	0	182	514	0

Table 2.17. Optimal Litter Application by Soil Type for Row Crop Under Policy 1.

	Current P Loading (46 t.)						Optimal P Loading (26 t.)					Minimum P Loading (20 t.)	
	Litter Application Rates (t./ha)						Litter Application Rates (t./ha)					Litter Application Rates (t./ha)	
Soil Type	0	0.32	0.65	1.1	1.56	1.95	0	0.32	0.65	1.1	1.95	0	1.95
	Land Area (ha.)						Land Area (ha.)					Land Area (ha.)	
Tonti	0	0	0	0	0	185	5	0	0	0	180	185	0
Clarksville	61	162	113	25	13	8	273	34	53	10	17	389	0
Captina	408	12	10	0	0	82	512	0	0	0	0	512	0
Nixa	0	0	0	0	0	248	36	0	0	0	213	248	0
Peridge	13	0	0	0	0	147	160	0	0	0	0	160	0
Britwater	46	0	0	0	0	19	63	0	0	0	0	63	0
Doniphan	186	24	0	16	0	0	197	13	0	16	0	226	0
Macedonia	111	0	0	0	0	0	111	0	0	0	0	111	0
Taloka	146	0	0	0	0	101	247	0	0	0	0	247	0
Newtonia	340	0	15	0	0	0	357	0	0	0	0	357	0

Policy 2 – Applying Litter According to the STP Criterion

STP Threshold of 120

The results were obtained from the linear programming runs for four levels of the STP threshold values, 120, 200, 250 and 350. For the policy that allowed litter application only to the soils that have STP lower than 120, the model calculated a value of the objective function of $3.38 million, which represents the value of the net agricultural income minus the abatement costs at the point source and the transportation costs [8]. Simulated phosphorus loading under the policy was 43367 kg./year. This represented a 2600 kg. reduction from the current estimated phosphorus load of 46000 kg./year. But, in comparison to Policy 1 described above, this reduction comes at extremely high cost. The average cost of phosphorus abatement was calculated as $877/kg (the value of the objective function for the current load (46 t.) is $5.61 mill., subtracting $3.38 million and dividing by 2600 (reduced P) one obtains $877). The main effect on the increased cost of abatement can be attributed to transportation of litter inside and outside the watershed. The intensity of transportation within the watershed is calculated at 1,218 thousand ton miles, while the intensity of transporting litter out of the watershed is 1,270 thousand ton miles [9]. This intensity of transportation is much higher than that calculated for Policy 1 (Table 2.11).

Despite of being quite expensive, the policy to apply litter according to STP is not very effective in reducing P loading. The reason for this is that the litter is applied non-discriminatory with respect to phosphorus runoff from particular land areas. The linear

[8] As noted before, full abatement at the point source was assumed to be instituted with this policy.
[9] Ton mile is defined as the quantity of one metric ton of litter shipped at the distance of one mile.

programming model chooses liter application rates according to the criteria that would minimize transportation costs within and out of the watershed. Litter would be applied on a particular HRU if the cost of transporting the litter to that HRU were less than the cost of transporting that quantity of litter out of the watershed. Another important contribution toward excessive phosphorus runoff is that nitrogen that would normally come from litter is not replaced with commercial fertilizer, once litter application is not allowed. This results in poor plant growth that reduces the quality of land cover and increases phosphorus runoff. Also, this study allowed for the use of relatively high litter application rates. In the case of STP based policy, applying litter at these high rates causes high phosphorus runoff. Results on litter application rates and the replacement of nitrogen with commercial fertilizer are shown in Table 2.18. The results show that a great majority of the land areas where litter application was allowed (where the initial soil test is below the threshold), received high litter application rates. On a significant portion of this land, litter is just applied to avoid shipping it out of the watershed.

Table 2.18. Litter Application Rates and Nitrogen Replacement by Land Uses for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter applied (STP<120)			Litter not applied (STP>120)		
	Low	Medium	High	Nitrogen replacement Yes	No	Total land
Land Use	Land Area (ha.)			Land Area (ha.)		ha.
Hay	10	0	3325	9690	375	13402
Well Maint. Past.	36	539	3477	0	19197	23250
Overgrazed Past.	52	136	1311	0	5042	6542
Row Crop	0	0	404	364	1857	2625
Total land (ha.)	98	675	8517	10054	26471	45819

Litter application rates for hay and well-maintained pasture were classified as follows: Low: 0-2 t./ha, Medium: 2- 4 t./ha, High: 4-6 t/ha. Litter application rates for overgrazed pasture were classified: Low: 0-1.1 t./ha, Medium: 1.1- 1.8 t./ha, High: 1.8-3.2 t/ha. Litter application rates for row crop were classified: Low: 0- 0.65 t./ha, Medium: 0.65- 1.3 t./ha, High: 1.3-2 t/ha.

In addition, on the land where litter application was not allowed, if nitrogen is not supplied from commercial fertilizer, the land cover is poor and there is greater potential for phosphorus runoff. This was especially apparent with the overgrazed pasture and row crop. Table 2.19. reports the average phosphorus runoff rates when no nitrogen is applied to the land for the four agricultural land uses.

Table 2.19. Average Phosphorus Runoff from Agricultural Land Uses if no Nitrogen is Applied.

	Land Uses			
	Hay	Overgrazed Past.	Well Maint. Past	Row Crop
Phosphorus runoff (Total P, kg/ha/year)	0.279	2.022	0.138	4.962

As it is apparent from the table, the row crop and overgrazed pasture have extremely high phosphorus runoff rates when nitrogen is not substituted with commercial fertilizer. Since it is not economical to replace nitrogen from litter with more expensive commercial nitrogen, plant cover is poor, and phosphorus runoff is not reduced as much as expected, which altogether results in reduced effectiveness of the STP based policies.

Table 2.20. presents the results for litter application rates and replacement of nitrogen with commercial fertilizer by soil types aggregated across agricultural land uses (litter application rates classified as described previously in Table 2.18.) The results by soil types do not show any significant pattern by which one could isolate particular soil types with respect to litter application rates or with respect to nitrogen replacement. For the STP based policy, the litter application rates are governed by the spatial location of the HRUs (HRUs to which it is less expensive to transport litter receive high litter application rates). On the other hand, the determination whether to replace for nitrogen with commercial fertilizer or not is completely dominated by the grown crop relative to soil type (nitrogen is replaced where it is profitable, mainly on hay and row crops).

Table 2.20. Litter Application Rates and Nitrogen Replacement by Soil Types for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter Application Rates			Nitrogen Replacement	
	Low	Medium	High	YES	NO
Soil Type	Land Area (ha.)				
Tonti	0	52	56	1224	2090
Clarksville	21	601	4535	2264	5295
Captina	0	0	31	1977	4020
Nixa	0	0	42	1527	5427
Peridge	0	0	0	198	1164
Britwater	28	114	270	120	302
Noark	0	0	0	35	535
Jay	0	0	35	182	470
Razort	0	23	644	211	546
Doniphan	0	637	1870	804	1230
Macedonia	0	0	148	510	1219
Taloka	0	0	2	190	1480
Stigler	0	0	0	45	171
Newtonia	0	0	0	765	2358

However, Table 2.20. provides a good overview of the soils that tend to have high STP in the watershed. Those soils would not be available for litter application under the STP based policy. Some of the high STP soils are Captina, Nixa, Noark, Taloka and Newtonia.

Table 2.21. presents the results for litter application rates and replacement of nitrogen with commercial fertilizer by land slopes aggregated across agricultural land uses. Inspection of the results presented in Table 2.21, reveals another reason for high phosphorus loading when using the STP based policy. Under this policy, unless there is a requirement to limit litter application on the soils that satisfy the STP criterion,

Table 2.21. Litter Application Rates and Nitrogen Replacement by Land Slopes for the Policy that Restricts Litter Application only to Soils with STP < 120.

	Litter Application Rates			Nitrogen Replacement		
	Low	Medium	High	YES	NO	Total Land
Average Slope	Land Area (ha.)					ha.
<5%	0	48	982	5295	14094	20420
5-8%	2	735	3933	4395	11440	20504
>8%	98	653	2842	364	938	4895

considerable amounts of litter would be applied even on relatively steep slopes to save on costs to transport litter from the watershed. Since a majority of the land with steeper slopes is very susceptible to phosphorus runoff, litter application on that land leads to excessive phosphorus loading in the watershed. Also, it is very likely that the land with steeper slopes would have lower STP because it did not receive as much litter as less steep land due to difficulties with application. So, a policy based on STP would indirectly create perverse incentives to apply litter to land that would otherwise remain without litter and would retain its low STP.

Other STP thresholds – 200, 250, 350

The level of 120 STP is often cited as a maximum level above which all litter application to the agricultural land has to be stopped, and hence the STP based policy towards reduction of phosphorus loading in the watershed would likely employ this threshold value. Nevertheless, an analysis was conducted for other values of the STP threshold to explore the effects of varying the STP threshold level on the use of litter, transportation of litter, net income and phosphorus loading. The analyzed STP thresholds were 200, 250, and 350. Table 2.22. presents a summary of the levels of income, phosphorus loading and transportation of litter for the three STP threshold levels. The table shows that as the threshold value for STP is raised, effectively increasing the land area where litter application is eligible, net income on the watershed level increases as well [10].

[10] Net income on the watershed level is composed of net income to the agricultural enterprises, minus cost of abatement at the point source (it is assumed that the point source performs full abatement under this policy) and minus the cost of litter transportation.

Table 2.22. Net Income on the Watershed Level, Phosphorus Loading and Transportation of Litter for Various Threshold Levels of STP.

		STP 200	STP 250	STP 350
Land eligible for litter application	ha.	12,840	19,597	26,297
Net Income on the Watershed Level	Dollars	3,787,319	4,454,717	4,959,332
P loading	kg/year	50,643	57,215	57,439
Transportation out of the watershed	ton miles (0000)	731.4	0	0
Transportation within watershed	ton miles (0000)	1250	1500	1326
Use of Alum	Ton	0	0	0

This is mainly due to a reduction in transportation of litter outside of the watershed, as more litter could be applied within the watershed. Phosphorus loading increases at higher levels of STP thresholds (because of high litter application rates applied) but also tends to level off. For all STP threshold levels no alum treated litter is used, reflecting the absence of the phosphorus constraint in the linear program.

Table 2.23. presents the results by litter application rates and whether or not nitrogen is replaced with commercial fertilizer aggregated over the agricultural land uses (litter application rates classified as described previously in Table 2.18.), for the levels of STP at 200, 250 and 350. The results in Table 2.23 show why the total phosphorus loading tends to level off at higher values of the STP threshold (57.4 t./year at STP 350, 57.2t./year at STP 250). At high STP threshold the restrictions on land are significantly smaller, causing the change in the use of litter. With a low STP threshold, litter is a liability since its land application is very restricted and it has to be transported out of the watershed. Litter is “dumped” using high application rates at any land

Table 2.23. Litter Application Rates and Nitrogen Replacement by Threshold Values of STP.

	Litter application rates			Nitrogen Replacement	
	Low	Medium	High	YES	NO
	Land Area (ha.)				
STP200	100	1436	11304	8659	24320
STP250	578	5667	32986	6587	19635
STP350	3426	10657	12214	5032	14490

available, causing high phosphorus loading. As the STP threshold increases, more land is available for litter application and the litter becomes a more valuable resource. Application rates now reflect the value of the marginal product of litter.

In general, results obtained from the analysis of STP based litter application policy suggest that this "command and control" policy is neither effective nor economically efficient in reducing phosphorus loading in the Eucha-Spavinaw watershed.

Policy 3 – Mandatory (Uniform) Land Use Change

The results obtained from the linear programming runs for a simulated policy of a mandatory land use change are provided in Table 2.24. The results show that this policy may be very effective in preventing phosphorus runoff. The value of the objective function at the maximum phosphorus loading level is just slightly lower than the values observed under Policy 1 in Table 2.5. However at this level, the phosphorus constraint is not binding. This means that is a policy of mandatory land use change alone would reduce phosphorus loading to 31,000 kg. per year of which 20,000 kg comes from agricultural sources.

Table 2.24. Results from the Linear Program Runs for the Simulated Mandatory Land Use Change Policy.

Phosphorus loading (Z max)	Value of the objective function	Marginal abatement cost for P	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source	Sum of Total Abatement and Damage Costs
kg / year	dollars	dollars/kg	dollars	dollars	dollars
46000	5,563,561	0.00	0	0	780,235
40000	5,563,561	0.00	0	0	669,390
35000	5,563,561	0.00	0	0	536,077
30000	5,559,250	5.07	4,311	0	384,291
25000	5,519,893	10.55	43,668	0	271,663
20000	5,451,277	14.53	67,111	45,173	218,854
18000	5,422,216	14.53	67,013	74,332	241,345

A combination of land use changes and Pigouvian taxes or subsidies will be required to gain further reductions. In the linear program, further reductions were simulated by parametrically varying the phosphorus constraint.

The optimal level of phosphorus abatement can be found by looking for the minimum of the sum of abatement and damage costs. The optimal solution is obtained by equating marginal abatement costs to marginal damage costs. The marginal abatement costs for this policy can be expressed as a function of the phosphorus load by

(2.16) $$MAC_3 = 25.165 - 0.0006\, Zmax_k.$$

Solving simultaneously for phosphorus loading using the marginal abatement costs and marginal damage costs (Eq.2.13) one obtains the value of 23637, which is the socially optimal level of phosphorus load in kilograms per year under the mandatory policy of land use change. At this level, the entire phosphorus abatement is done by the agricultural sources, with no abatement at the point source. Figure 2.12., graphically represents the marginal abatement and damage costs and the point of optimal phosphorus loading.

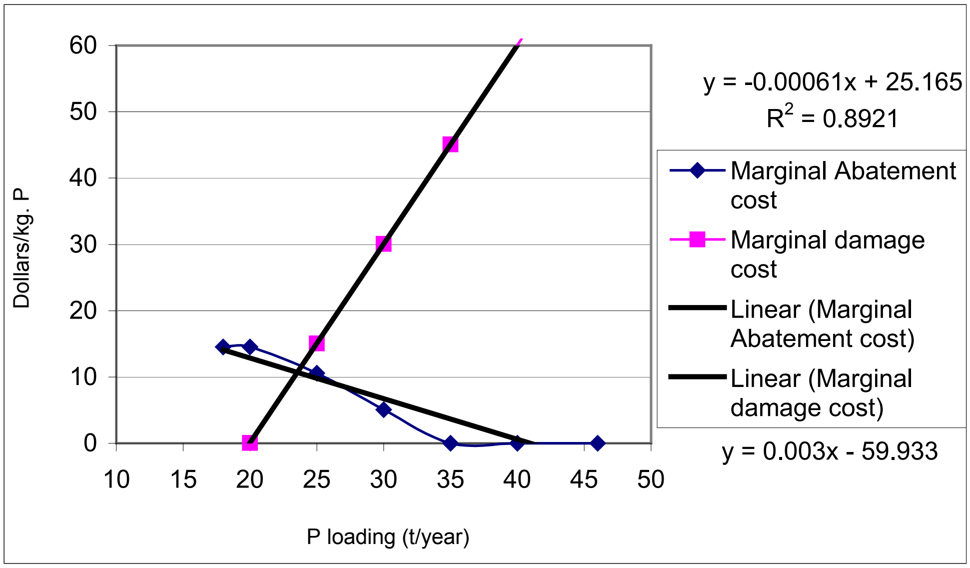

Figure 2.13. Marginal Abatement and Damage Costs for Policy 3.

Table 2.25. presents the litter application rates for the three different levels of allowed phosphorus loading on the watershed level and by the two land uses (hay and well-maintained pasture) under the policy of mandatory land use conversion. The results show that higher litter application rates are used more on hay relative to the well-maintained pasture. This happens because for pasture the manure is deposited back on the land while with hay, more nutrients are removed from the land. The results do not suggest any significant changes in the litter application rates as the allowed phosphorus loading is reduced. It appears that most important for the reduction of phosphorus loading is land conversion itself, especially conversion from overgrazed to well-maintained pasture. The initial difference between overgrazed and well-maintained pasture is in two main aspects, the quantity of nutrients (nitrogen) that is applied and the stocking rates of cattle allowed to graze. The overgrazed pasture receives lower quantity of nitrogen and has a higher stocking rate than the well-maintained pasture.

Table 2.25. Litter Application Rates for Three Levels of Allowed Phosphorus Loading, for Hay and Well-maintained Pasture Land Uses under the Policy of Mandatory Land Conversion.

Hay		Well-maintained Pasture	
Current P loading (46.t)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	19642
3.4	585	1	10149
4	6186		
4.8	6641		
6	2604		
Optimal P loading (23.6t.)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	20621
3.4	623	1	9171
4	5582		
4.8	7624		
6	2185		
Minimum P loading (18t.)			
Litter application rates (t./ha)	Land Area (ha.)	Litter application rates (t./ha)	Land Area (ha.)
0	13	0	20983
3.4	626	1	8809
4	5622		
4.8	6773		
6	2993		
Total land	16028		29792

Results from Table 2.25. show that reducing the stocking rate dominates the effect of nitrogen (litter) application when conducting the conversion from overgrazed pasture to well-maintained pasture. This implies that reduction of stocking rates on the current overgrazed pasture in the watershed would potentially provide quite significant reduction of phosphorus loading.

Another observation that could be made from Table 2.25. is that production of hay is likely to be increased if the reduction of phosphorus loading is desired. Higher litter application on hay would result in greater hay production. On one hand, this would bring excess supply of hay in the region and likely cause its price to fall, while on the other hand baled hay may be most efficient way of exporting some of the nutrients out of the watershed that initially enter through the purchased poultry feed, which is then transformed into litter.

The results on the use of alum under the policy of mandated land use change is presented in Table 2.26. The results show that alum use would be required in order to reduce the phosphorous loading at the watershed level even if mandatory land use change were instituted.

Table 2.26. Alum Use Under the Policy of Mandatory Land Use Change.

	Hay	Well Maint. Pasture	Alum Treated Litter
	Alum Use		
	Land Area (ha.)	Land Area (ha.)	Total Quantity (tons)
Current P load (46t.)	0	0	0
Optimal P load (23.6t.)	12445	517	25325
Minimum P load (18t.)	13585	517	19431

The use of alum is emphasized on hay where about 80 percent of total land receives alum treated litter. The reduction in total quantity of alum treated litter at the minimum phosphorus loading comes about because of the reduced per hectare litter application rates for hay.

Results on the alum use by particular soil types for both hay and well-maintained pasture are presented in Table 2.27. Presented results could be used to identify soil types where alum use is more pronounced.

Table 2.27. Alum Use by Soil Types (all land uses) for Policy of Mandatory Land Use Change

Soil Type	Land Area of Particular Soil Type Receiving Alum Treated Litter	Total Land Area of a Particular Soil Type	Proportion of Land Area Receiving Alum Treated Litter to Total Land of Particular Soil Type
	Ha.	ha.	fraction
Tonti	1210	3421	0.35
Clarksville	3932	12716	0.31
Captina	2306	6028	0.38
Nixa	2151	6996	0.31
Peridge	356	1362	0.26
Britwater	283	834	0.34
Noark	35	570	0.06
Jay	222	687	0.32
Razort	45	1424	0.03
Doniphan	607	4541	0.13
Macedonia	678	1878	0.36
Newtonia	933	1673	0.56
Eldorado	62	215	0.29
Stigler	119.40	3122.65	0.04

Alum use was found most intensive on Newtonia, Captina, Macedonia and Tonti soils. Alum use was not found very intensive on the Razort, Stigler, Noark and Doniphan soil types. These results refer only to policy of mandated land use change. The optimal level of transportation of litter within the watershed is fairly stable across the three levels of required phosphorus loading ranging from 610 to 640 thousand ton miles. Export of litter outside the watershed was not required to meet the optimal phosphorus target of 23.6 metric tons per year.

In general, the policy of mandatory land use change is economically efficient in reducing phosphorus loading in the watershed. However, the mandate for land conversion it imposes on the landowners makes it very difficult to implement in practice.

Policy 4 – Site Specific (Optimal) Land Use Change

The results obtained from the linear programming runs for the simulated policy of a site-specific land use change are presented in Table 2.28. The results show that a

Table2.28. Results from the Linear Program Runs for the Simulated Site Specific Land Use Change Policy.

Phosphorus loading (Z max)	Value of the objective function	Marginal abatement cost for P	Total abatement cost for Agricultural Enterprises	Total abatement cost to the point source	Sum of Total Abatement and Damage Costs
kg / year	dollars	dollars/kg	dollars	dollars	Dollars
46000	5802664	2.19	0	0	780235
40000	5781731	5.28	20933	0	690323
35000	5747528	8.12	55136	0	566243
30000	5701701	10.67	100963	0	453257
25000	5634879	14.53	167785	33113	363324
20000	5562011	15.16	240653	101207	345111
18000	5529492	18.11	273172	112484	381661

significant reduction of phosphorus load can be achieved at quite low cost. For example, the phosphorus load could be reduced from current 46 tons/year to 30 tons/year at total cost of about $100,000 through a combination of revised litter management practices including alum and land use changes. Further reductions from both point and non-point sources could reduce total loading to 18 tons per year for an annual abatement cost of approximately $380,000 per year. The results suggest that allowing for site-specific land use changes would be a very effective and economically efficient way to reduce phosphorus loading in the watershed. In the same time this policy is more efficient than the policy with uniform land use change, which can be detected by comparing the values of the objective function for the two policies at all levels of phosphorus loading.

The socially optimal level of phosphorus loading using the policy of site-specific land conversion is found at the minimum of the sum of abatement and damage costs. The exact optimal solution is obtained by equating marginal abatement costs to marginal damage costs. The marginal abatement costs for this policy can be expressed as a function of the phosphorus load by

(2.17) $$MAC_4 = 27.357 - 0.00054\ Zmax_k.$$

Solving simultaneously for phosphorus load using the marginal abatement cost and marginal damage (Eq. 2.13) costs one obtains the value of 24526, which is the socially optimal level of phosphorus load in kilograms per year under the policy of site specific (optimal) land use change. At this level, costs of agricultural abatement activities are around $165,000, while the costs at the point source are about $33,000. The point source would abate about 2.3 metric tons of phosphorus annually. Figure 2.13, graphically presents the marginal abatement and damage costs and the point of optimal phosphorus loading obtained by equating them.

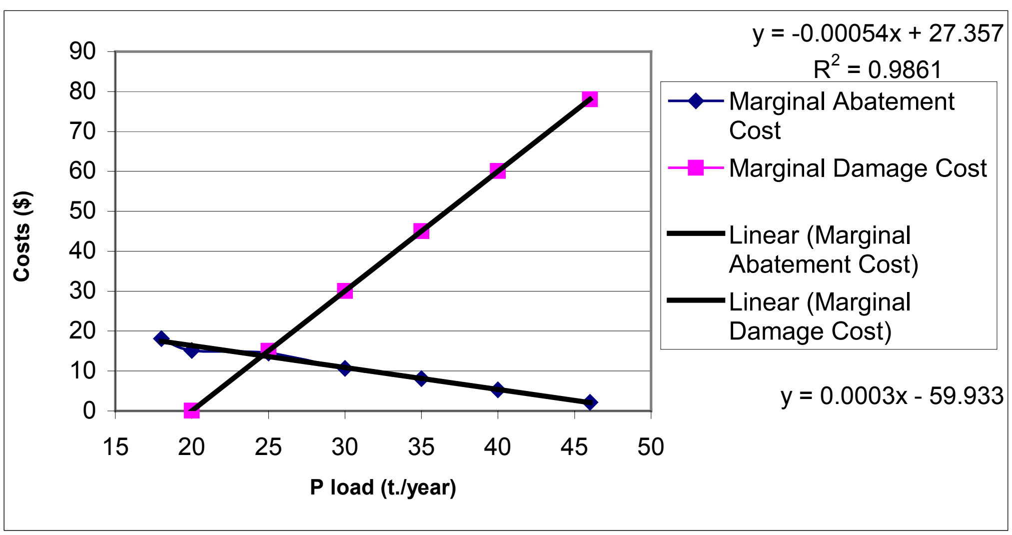

Figure 2.14. Marginal Abatement and Damage Costs for Site Specific Land Use Change Policy

This policy allows for analysis of the optimality of land use conversion from overgrazed to well-maintained pasture and from row crop to hay. Table 2.29. presents the results on the optimal land area converted for the three levels of allowed phosphorus loading (maximum 46t./ha ; optimum 24.5 t/ha ; and minimum 18 t./ha).

Table 2.29. Optimal Land Conversion of Overgrazed to Well-maintained Pasture and of Row Crop to Hay for the Three Levels of P loading for Site-Specific Land Use Change Policy.

	Max P load (46t.)		Opt. P load (24.5 t.)		Min. P load (18 t.)	
	Land converted	Land not converted	Land converted	Land not converted	Land converted	Land not converted
	ha.	ha.	ha.	ha.	ha.	ha.
Overgrazed Pasture	6537	5	6537	5	4725	1816
Row Crop	385	2240	1106	1519	1792	834

The results presented in Table 2.29 show that the conversion of overgrazed pasture plays a more important role in reducing phosphorus loading than conversion of row crop. At the optimal phosphorus loading, virtually all overgrazed pasture is converted while only about forty percent of the row crop is converted. It is interesting to note that as allowed phosphorus loading is further restricted to 18 tons per year, the amount of overgrazed pasture land not converted actually increases, while more of the of row crop land is converted to hay. This is explained by looking at the Table 2.30. which presents results on optimal litter application rates. The results in Table 2.30 show that at the maximum and optimum phosphorus loadings, the overgrazed pasture is converted to well-maintained pasture by essentially reducing the cattle stocking rates. If further reduction of phosphorus load is required, then the conversion of overgrazed pasture to well-maintained pasture requires increased fertilization in addition to reduced stocking rates. Results with respect to optimal litter application rates for the other land uses are similar to those observed for previously discussed policies.

Table 2.30. Litter Application Rates by Original Land Uses for the Three Levels of Allowed P loading, for the Site Specific Land Use Change Policy.

		Hay	Well Past	Overgrazed		Row Crop	
				Converted to Well P.	Not Converted	Converted to Hay	Not Converted
		Land Area (ha.)					
Max P loading (46t.)	Litter Application Rates						
	Low	11	22852	6446	5	0	462
	Medium	320	398	91	0	0	472
	High	13071	0	0	0	385	1306
Opt. P loading (24.5 t.)	Litter Application Rates						
	Low	11	22852	6446	5	0	840
	Medium	316	398	87	0	0	128
	High	13075	0	0	0	1106	550
Min P loading (18t.)	Litter Application Rates						
	Low	3433	20006	2749	347*	1220	736
	Medium	927	334	55	5	28	47
	High	9041	2910	1922	1464	545	51

*338 ha with N replacement

Classification of litter application rates is as follows: for hay and well-maintained pasture, low litter application rate is between 0-2 tons, medium is between 2-4 tons and high is 4-6 tons/ha. For overgrazed pasture, low: 0-1.1 t./ha, medium: 1.1- 1.8 t./ha, high: 1.8-3.2 t/ha., for row crop. low: 0- 0.65 t./ha, medium: 0.65- 1.3 t./ha, high: 1.3-2 t/ha.

It is important to observe alum use as the total maximum phosphorus targets are varied for this simulated policy. The results are presented in the Table 2.31. Alum use increases as the allowed phosphorus loading is reduced. Alum use is also greater with higher litter application rates. At the optimal level of phosphorus loading, most of the hay crop is fertilized with alum treated litter. The total quantity of alum treated litter used was only 508 tons for the current phosphorus loading (46 t.), but 64.2 thousand tons for the optimal phosphorus loading (24.5 t.), and would increase to 74.1 thousand tons for the minimum phosphorus loading (18 t.).

Table 2.31. Alum Use on Land Area by Original Land Uses for the Three Levels of Allowed P loading, by Litter Application Rates for the Site Specific Land Use Change Policy.

	Hay	Well Past	Overgrazed		Row Crop	
			Converted to Well	Not Converted	Converted to Hay	Not Converted
Alum Used on Land Area (ha.)						
Maximum P load (46 t.)						
Litter Application Rates						
Low	0	0	0	0	0	0
Medium	0	0	0	0	0	12
High	0	0	0	0	0	252
Optimum P load (24.5 t.)						
Litter Application Rates						
Low	0	1530	48	0	0	0
Medium	295	220	12		0	43
High	11591	0	0	0	630	280
Minimum P load (18 t.)						
Litter Application Rates						
Low	367	898	75	0	0	36
Medium	499	234	55	5	28	13
High	7530	2846	1878	1300	545	34

Classification of litter application rates as defined in Table 2.30.

The change in the amount of litter transport varies less dramatically as the total phosphorus limit is lowered. The litter transport within the watershed was calculated at 605 thousand ton miles for the current phosphorus loading (46 t.), 658 thousand ton miles for the optimal phosphorus loading (24.5 t.), and 673 thousand ton miles for the minimum phosphorus loading (18 t.).

The optimal land conversion of overgrazed pasture to well-maintained pasture and from row crops to hay is summarized by in Tables 2.32. and 2.33. Essentially all of the overgrazed pasture would be converted to well-maintained pasture at the optimal phosphorus loading level (24.5t.). At the minimum phosphorus loading level, the soils where conversion was found not optimal (the pasture becomes more heavily fertilized) were Tonti, Taloka and Nixa. For the conversion of the row crop to hay, it appeared optimal to conduct conversion on the soil types Macedonia, Doniphan, and Captina under both levels of allowed phosphorus loading.

The analysis of optimal land use changes by land slope was also an important aspect to investigate. Results for the changes in land use by slopes for the optimal (24.5t.) and minimum (18 t.) phosphorus load level are presented for the overgrazed pasture and row crop in the following Table 2.34 [11].

Table 2.32. Optimal Conversion of Overgrazed Pasture to Well-maintained Pasture by Soil Type for the Optimal (24.5t.) and Minimum (18 t.) P loading for the Site Specific Land Use Change Policy.

Overgrazed Pasture							
	Optimal P load (24.5 t.)			Minimum P load (18 t.)			
Soil Type	Land by Soil Type Not Converted	Land Converted to Well M Past.	Proportion of Land Converted	Land by Soil Type Not Converted	Land Converted to Well M Past.	Proportion of Land Converted	Total Land of Particular Soil Type
Tonti	5	445	0.99	270	175	0.39	450
Clarksville	0	1512	1.00	367	1145	0.76	1512
Captina	0	996	1.00	164	832	0.84	996
Nixa	0	738	1.00	309	429	0.58	738
Peridge	0	209	1.00	38	171	0.82	209
Razort	0	131	1.00	0	131	1.00	131
Doniphan	0	1097	1.00	217	880	0.8	1097
Macedonia	0	477	1.00	144	332	0.7	477
Taloka	0	73	1.00	32	41	0.56	73
Stigler	0	154	1.00	18	136	0.88	154
Newtonia	0	514	1.00	186	328	0.64	514

[11] Results in this section are reported only for the optimal (24.5t.) and minimum (18 t.) phosphorus loading, since the results for the current (46 t.) and the optimal (24.5t.) are quite similar, especially regarding the land uses of interest (overgrazed pasture and row crop).

Table 2.33. Optimal Conversion of Row Crop to Hay by Soil Type for the Optimal (24.5t.) and Minimum (18 t.) P loading for the Site Specific Land Use Change Policy.

Row Crops							
	Optimal P load (24.5 t.)			Minimum P load (18 t.)			
Soil Type	Land by Soil Type Not Converted	Land Converted to Hay.	Proportion of Land Converted	Land by Soil Type Not Converted	Land Converted to Hay.	Proportion of Land Converted	Total Area of Each Soil Type
Captina	259	253	0.49	189	323	0.63	512
Nixa	240	8	0.03	85	163	0.66	248
Peridge	129	31	0.19	33	127	0.79	160
Britwater	12	51	0.81	12	51	0.81	63
Tonti	185	0	0.00	12	173	0.94	185
Clarksville	274	115	0.30	89	300	0.77	389
Doniphan	13	213	0.94	16	210	0.93	226
Macedonia	0	111	1.00	17	95	0.85	111
Taloka	208	39	0.16	130	117	0.47	247
Newtonia	126	232	0.65	170	187	0.52	357

Table 2.34. Optimal Land Conversion of Overgrazed Pasture to Well-maintained Pasture and Row Crop to Hay, for the Optimal and Minimum P loading rate, for the Site Specific Land Use Change Policy.

		Average Slope				
		<1%	1-3%	3-5%	5-8%	>8%
Optimal P load (24.5t)		Land Area (ha.)				
Overgrazed Pasture	Land Converted to WPAS	0	1112	1741	2947	737
	Land not Converted	0	0	0	0	5
Row Crop	Land Converted to HAY	0	647	259	79	121
	Land not Converted	132	691	526	146	23
Minimum P load (18t)		Land Area (ha.)				
Overgrazed Pasture	Land Converted to WPAS	0	799	1228	2291	407
	Land not Converted	0	313	513	656	335
Row Crop	Land Converted to HAY	132	850	497	178	135
	Land not Converted	0	488	289	48	10

As expected, the results show that it is optimal to convert more of the land with steeper slopes than land with less slope. However this tendency cannot be generalized. Even at very low phosphorus loading levels, there are some areas with slopes in excess of eight percent which are not converted. For example, overgrazed pasture may be heavily fertilized with commercial nitrogen. This result may not hold if nitrogen runoff were also a concern.

SUMMARY AND CONCLUSION

The economic analysis conducted within this project attempted to assess cost effective technologies and policies for managing phosphorus pollution from both non-point sources and the point source in the Eucha-Spavinaw watershed. The analysis used the approach of minimizing the sum of abatement and damage costs to derive the socially optimal pattern and method of phosphorus abatement in the watershed. The perspective was that of a watershed manager. All costs and benefits were internalized in the optimal solutions presented. The preferences of the society, translated directly into the preferences of a hypothetical watershed manager were expressed in a form of social well-being function. The optimal level of phosphorus abatement in the watershed would maximize this well-being function. The maximum point of the well-being function corresponds to the minimum of the sum of total abatement and damages costs and also corresponds to the point of equivalence between the marginal abatement and damage costs.

The analysis of the abatement costs was based on the costs of reducing phosphorus emissions from both point and the non-point sources of phosphorus loading in the watershed. Abatement costs at the point source (the City of Decatur, AR) were determined using engineering data. For the non-point agricultural sources, a spatial bio-physical model (SWAT) was used to simulate phosphorus loading from each agricultural enterprise at each selected poultry litter management practice. Twenty-four poultry litter management practices were simulated. These consisted of various litter application rates with and without commercial nitrogen replacement for each of the major land uses in the watershed. The possibility to use litter amended with ten percent aluminum sulfate was also considered. For each of these litter management practices, net agricultural income was calculated using SWAT data, enterprise budgeting and price data.

Environmental damage costs considered in this study included the cost of additional drinking water treatment for the City of Tulsa and the value of lost recreational visits to the lakes Eucha and Spavinaw. These costs were estimated using the observed data and were combined to calculate total damage costs. This provides an estimate of the environmental damage costs. This study does not claim that all possible damage costs are accounted for. For example the cost of long term damages to the ecological values in the watershed were ignored. Nevertheless, the environmental damage costs included in this study represent a significant part of the actual environmental damage cost from phosphorus loading in the Eucha-Spavinaw watershed, and therefore provide a relevant estimate of the damage costs. Marginal damage cost curve was calculated as a derivative from the total damage cost curve.

Four policy simulations involving broiler litter management practices, land use changes, increased point source phosphorus abatement that could be used to reduce the phosphorus loading in the Eucha-Spavinaw along with estimates of the environmental damages caused by phosphorus loads were presented. The first policy examined the potential of using only poultry litter management practices (including alum treated litter) and point source abatement. SWAT simulations with twenty-four litter management practices for each land use-soil type combination (HRU) in the watershed were conducted. These results were included in a linear programming model and the least cost method of meeting phosphorus targets was determined. These management practices were subsequently used in all simulated policies. The second policy was that of limiting litter applications according to a soil test phosphorus (STP) criterion. The third policy considered mandatory conversion of overgrazed pasture to well-maintained pasture and of conversion of row crops to hay in the watershed. The fourth policy represented a combination of policies one and three except that land conversion was optional. With respect to the time frame the polices could be used in, the first policy would represent a short-run solution, second policy short to medium run solution, while the last two policies would represent long run solutions. However all policies and analysis are short run with respect to phosphorus dynamics, because long-term phosphorus accumulation in soils beyond current levels was not considered.

For each policy, a linear programming model was used to maximize net income at the watershed level (net income from agriculture minus costs of abatement at the point source, minus litter transportation costs). The linear program for each policy was run for seven distinct levels of allowed phosphorus loading in the watershed. Marginal abatement costs were obtained as shadow prices on phosphorus loading from the linear program runs. They were than equated to the marginal damage costs to obtain a socially optimal level of phosphorus loading in the watershed for each simulated policy. The linear programs were rerun for the determined optimal level of phosphorus loading, resulting in the optimal level of abatement at the point source and at each of the non-point sources. Since the non-point sources could be identified at considerable level of spatial detail, the results imply spatially optimal litter management practices for the agricultural enterprises in the watershed.

Several conclusions could be derived from the results. First, from the determined optimal levels of phosphorus loading to the lakes in the watershed under the various policies analyzed, it appears that a reasonable target for phosphorus loading could be set in a range of 23,000 to 26,000 kilograms per year. At these levels, costs for phosphorus abatement would not be excessively expensive especially in longer run. Further reductions in phosphorous loadings below these levels are attainable, but would be more costly to achieve, especially in the short-run. However, given the uncertainties and limitation of both the bio-physical model (SWAT) and the economic model, it is difficult to set an exact optimal level of allowed phosphorus loading in the watershed. Nevertheless, the predicted economically optimal phosphorus loadings from the social perspective are not far from the recommendations issued by Oklahoma Water Resources Board, (OWRB, 2002)

Second, the use of the STP criterion alone to regulate the litter application and phosphorus loading in the watershed seems not to be a very effective and/or efficient policy. This policy was modeled as preventing litter application on high STP soils regardless of soil type, land use, or the probability of phosphorus loss, and with no provisions for possibilities of chemical litter amendments (alum). In this form, the STP policy alone caused high losses of agricultural income and increased the amount of litter hauled out of the watershed. The policy of this type created perverse incentives for applying litter at high application rates, indiscriminately where the STP level was below the limit just to avoid hauling it out of the watershed. Consequently, the model predicted litter would be applied to soils that were very susceptible to phosphorus runoff (steep slopes, erodable soils etc). Applying litter using the Phosphorus Risk Index (Storm and Smolen, 2001) as a criterion instead of using STP, may improve the performance of this regulatory strategy. Research is currently under way to determine Phosphorus Indices for the soils in the Eucha-Spavinaw watershed.

Third, land use changes appear to be an important component of an efficient long-term solution to the problem of phosphorus pollution in the watershed. However, this would require more time and changes in the economic structure of the agricultural production in the watershed. In particular, site-specific land use change, where a choice of which land should be converted is allowed is superior policy to the mandatory land use change. The results show that it would be optimal to convert the overgrazed pasture to well-maintained pasture almost in entirety, while it is optimal to convert only a part of the row crops to hay.

Fourth, amending poultry litter with alum appears to be effective and efficient way of reducing phosphorus loading at the watershed level. The use of alum played a significant role in all optimal solutions for the analyzed policies. The optimality of alum use is quite pronounced with high litter application rates, implying that if higher litter application rates are used, a significant reduction of phosphorus runoff could be achieved if the litter is treated with alum.

Fifth, the transportation of litter both within and out of the watershed is a significant part of the optimal solutions for phosphorus loading reduction. It is important to note again that the economic analysis in this report was from a social perspective, or a perspective of a hypothetical watershed manager. From this perspective, the litter transportation costs are internal to the optimal decisions, and hence the transportation is a part of the optimal solutions. From a perspective of an individual agricultural producer however, the transportation costs are bore privately. That is why an analysis from pure private perspective (ignoring the pollution) would result with different findings regarding the transportation of litter. However, any solution to the phosphorus loading in the Eucha-Spavinaw watershed would require an analysis that takes into consideration both social and private objectives and recommends policies where the discrepancies between the two would be minimized. Some of these policies are subsidizing transportation of litter and/or tax credit incentives.

Sixth, significant phosphorus abatement at the point source would be optimal, especially in the short run. In the short-run, the abatement at the point source could be achieved at lower cost than the abatement at the majority of agricultural enterprises (some agricultural enterprises would be able to abate even cheaper than the point source), and thus it is optimal to abate phosphorus and to drive the phosphorus concentration of the effluent from the point source to slightly higher than 1 mg/l. Even though in the long-run, using land use conversion, the abatement at the agricultural sources would be marginally less expensive than the abatement at the point source, the time frame and the urgency of the problem would require significant abatement at the point source.

Finally, and possibly most important, the methodology used in this study provides for assessing the optimal solutions at considerable level of spatial detail. For each unique agricultural land area (HRU) the study has assigned an optimal litter management practice for each simulated policy. The determined optimal litter management practices and policies could be applied on the site-specific basis given the average land area of only 65 hectares for the agricultural HRUs. This would enable economic efficiency, as compared to use of rules and policies on the uniform basis. The results on the spatial detail for the optimal solutions for each policy are presented by HRUs in the Appendix. In addition, the spatial detail has been aggregated to derive results with respect to soil types and slope steepness. Using this aggregation, it may possible to draw some inference about the types of soils where litter application should be first restricted, where alum use is most beneficial, or the slopes for which the conversion of land uses is most optimal. However, these are general inferences and by no means they apply uniformly to particular soil type or slope category. These aggregated results therefore may just provide general guidelines, but should not be used for policy formation when disaggregated results are available.

Limitations of the economic modeling presented in this study stem from lack of data (environmental damages), modeling imperfections (estimation, aggregation and averaging) and technical difficulties (ex. assessing the value of alum treated litter that is transported out of the watershed). Nevertheless, the study provides significant insights on the economics of phosphorus pollution in the Eucha-Spavinaw watershed.

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APPENDIX

Table A.2.1. Costs of Various Components of the Chemical Wastewater Treatment at the Point Source.

P load in the watershed kg/year	Alum AlSO4 used (50% product) mg/l	P concentration in efluent mg/l	Alum used kg/year	Alum annual cost	Annualized cost of alum addition	Annualized cost of settling basin	Annulized cost of gravity thickening	Annualized separation costs	Annualized transportation costs	Annualized Landfiling Cost	Total annual cost	Capital (estimated initial) cost)	P removed (abatted) Kg./year
11686.02	0	6.63	0	0	0	0	0	0	0	0	0	0	0
11008.77	5	6.25	8813	$1,165	$8,754	$13,111	$12,891	$1,950	$321	$494	$38,684	$362,514	677
10365.68	10	5.88	17626	$2,329	$9,267	$13,111	$14,345	$2,339	$642	$987	$43,020	$382,409	1,320
9755.448	15	5.53	26439	$3,494	$9,674	$13,111	$16,654	$2,729	$962	$1,481	$48,105	$410,885	1,931
9176.832	20	5.21	35252	$4,659	$10,188	$13,111	$19,232	$3,119	$1,283	$1,974	$53,565	$443,668	2,509
8628.626	25	4.90	44065	$5,824	$10,552	$13,111	$20,974	$3,508	$1,604	$2,468	$58,040	$465,150	3,057
8109.663	30	4.60	52878	$6,988	$10,948	$13,111	$22,716	$3,898	$1,925	$2,961	$62,546	$486,999	3,576
7618.817	35	4.32	61691	$8,153	$11,355	$13,111	$24,458	$4,287	$2,246	$3,455	$67,064	$508,971	4,067
7155.001	40	4.06	70504	$9,318	$11,751	$13,111	$26,200	$4,677	$2,566	$3,948	$71,571	$530,820	4,531
6717.162	45	3.81	79317	$10,482	$12,179	$13,111	$27,942	$5,067	$2,887	$4,442	$76,109	$553,036	4,969
6304.286	50	3.58	88130	$11,647	$12,564	$13,111	$29,684	$5,456	$3,208	$4,935	$80,606	$574,763	5,382
5915.392	55	3.36	96943	$12,812	$12,993	$13,111	$31,426	$5,846	$3,529	$5,429	$85,144	$596,979	5,771
5549.534	60	3.15	105756	$13,977	$13,335	$13,111	$33,168	$6,236	$3,850	$5,922	$89,598	$638,216	6,136
5205.796	65	2.95	114569	$15,141	$13,849	$13,111	$34,910	$6,625	$4,170	$6,416	$94,222	$661,412	6,480
4883.297	70	2.77	123382	$16,306	$14,362	$13,111	$36,652	$7,015	$4,491	$6,909	$98,846	$684,609	6,803
4581.182	75	2.60	132195	$17,471	$14,833	$13,111	$38,394	$7,404	$4,812	$7,403	$103,428	$707,316	7,105
4298.63	80	2.44	141008	$18,635	$15,304	$13,111	$40,136	$7,794	$5,133	$7,896	$108,009	$730,022	7,387
4034.846	85	2.29	149821	$19,800	$15,668	$13,111	$41,878	$8,184	$5,453	$8,390	$112,484	$751,504	7,651
3789.063	90	2.15	158634	$20,965	$16,054	$13,111	$43,620	$8,573	$5,774	$8,883	$116,980	$773,230	7,897
3560.54	95	2.02	167447	$22,130	$16,503	$13,111	$45,362	$8,963	$6,095	$9,377	$121,540	$795,692	8,125
3348.564	100	1.90	176260	$23,294	$16,814	$13,111	$47,104	$9,353	$6,416	$9,871	$125,962	$816,561	8,337
3152.446	105	1.79	185073	$24,459	$16,875	$13,111	$48,846	$9,742	$6,737	$10,364	$130,133	$837,430	8,534
2971.52	110	1.69	193886	$25,624	$16,935	$13,111	$50,588	$10,132	$7,057	$10,858	$134,304	$858,299	8,715
2805.145	115	1.59	202699	$26,788	$16,996	$13,111	$52,330	$10,521	$7,378	$11,351	$138,476	$879,168	8,881
2652.702	120	1.50	211512	$27,953	$17,057	$13,111	$54,072	$10,911	$7,699	$11,845	$142,647	$900,037	9,033
2513.595	125	1.43	220325	$29,118	$17,117	$13,111	$55,814	$11,301	$8,020	$12,338	$146,818	$940,906	9,172
2387.247	130	1.35	229138	$30,283	$17,178	$13,111	$57,556	$11,690	$8,341	$12,832	$150,990	$961,775	9,299
2273.104	135	1.29	237951	$31,447	$17,239	$13,111	$59,298	$12,080	$8,661	$13,325	$155,161	$982,644	9,413
2170.631	140	1.23	246764	$32,612	$17,299	$13,111	$61,040	$12,470	$8,982	$13,819	$159,332	$1,003,513	9,515
2079.311	145	1.18	255577	$33,777	$17,360	$13,111	$62,782	$12,859	$9,303	$14,312	$163,504	$1,024,382	9,607
1998.647	150	1.13	264390	$34,941	$17,421	$13,111	$64,524	$13,249	$9,624	$14,806	$167,675	$1,045,252	9,687
1928.16	155	1.09	273203	$36,106	$17,481	$13,111	$66,266	$13,638	$9,945	$15,299	$171,846	$1,066,121	9,758
1867.388	160	1.06	282016	$37,271	$17,542	$13,111	$68,008	$14,028	$10,265	$15,793	$176,018	$1,086,990	9,819
1815.886	165	1.03	290829	$38,436	$17,603	$13,111	$69,750	$14,418	$10,586	$16,286.40	$180,189	$1,107,859	9,870
1773.224	170	1.01	299642	$39,600	$17,663	$13,111	$71,492	$14,807	$10,907	$16,779.93	$184,360	$1,128,728	9,913

Figure A.2.1. A Schematic of the Design for Chemical Wastewater Treatment using Alum for City of Decatur, AR.

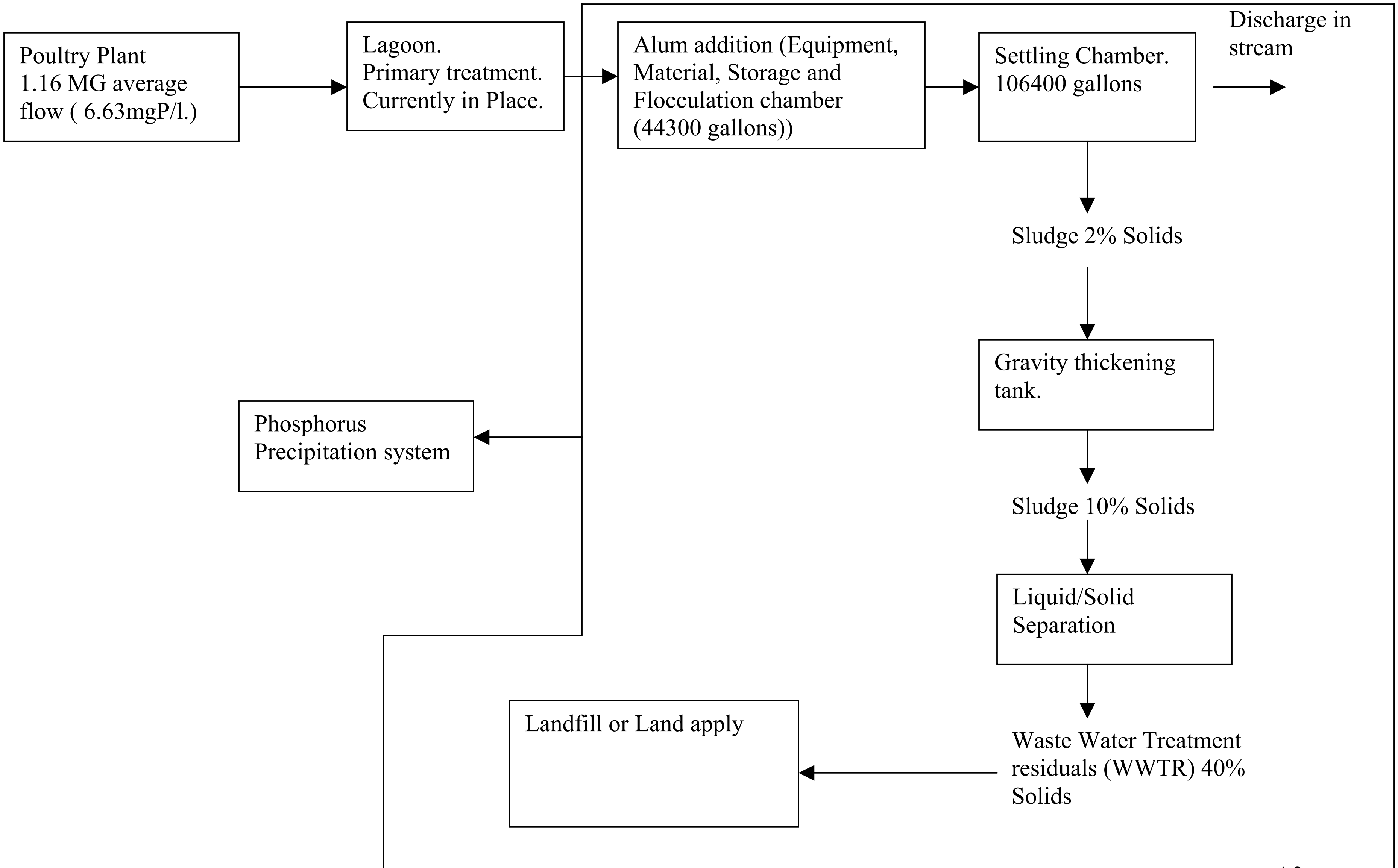

Table A 2.2. Results from Estimation of the Demand Equation for Recreation in a Price Flexibility Form (Eq.3)

Effect	Pconc. level	Estimate	Error	DF	t Value	Pr > |t|
Q		-0.00157	0.000079	35	-19.85	<.0001
d_1^1	0.037675	43.1634	1.4812	35	29.14	<.0001
d_1^2	0.038232	42.4313	1.4706	35	28.85	<.0001
d_1^3	0.038719	41.8975	1.4634	35	28.63	<.0001
d_1^4	0.039133	41.8838	1.4633	35	28.62	<.0001
d_1^5	0.039477	42.4304	1.4706	35	28.85	<.0001
d_1^6	0.039749	41.347	1.4565	35	28.39	<.0001
d_1^7	0.039887	39.0826	1.4333	35	27.27	<.0001
d_1^8	0.03995	42.3921	1.4701	35	28.84	<.0001
d_1^9	0.040042	39.6035	1.4379	35	27.54	<.0001
d_1^{10}	0.04008	41.7904	1.4621	35	28.58	<.0001
d_1^{11}	0.040126	41.7886	1.462	35	28.58	<.0001
d_1^{12}	0.040139	41.4425	1.4577	35	28.43	<.0001

Q = number of visits per 1000 population, d_1^i = MWTP (maximum willingness-to-pay) for recreation at the i^{th} phosphorus concentration level. Price of recreation (travel cost) is dependent variable.

Table A 2.3. Estimated Maximum WTP, Consumer Surplus (CS) and Change in Consumer Surplus (relative to 46000 kg/year) from Each Iso- Travel Cost Region

		Region 1		Region 2		Region 3		Region 4	
Pload (kg/year)	Estimated intercept (Max WTP)	CS	ΔCS	CS	ΔCS	CS	ΔCS	CS	ΔCS
18000	55.01798	33250.66	33250.66	109208.8	104510.8	127617.7	118533.6	363145.3	247076
20000	53.96961	26777.6	26777.6	97193.35	92495.41	114600.6	105516.6	340946.7	224877.4
25000	51.34868	13657.7	13657.7	70217.58	65519.63	85120.78	76036.74	288512.9	172443.5
30000	48.72775	4913.122	4913.122	47617.14	42919.19	60016.26	50932.22	240454.3	124385
35000	46.10682	543.8776	543.8776	29392.03	24694.08	39287.08	30203.04	196771.2	80701.83
40000	43.48589	0	0	15542.25	10844.3	22933.23	13849.19	157463.3	41393.98
46000	40.34078	0	0	4697.947	0	9084.038	0	116069.3	0

Table A.2.4. Spatial Detail for the Optimal Solution for Policy 1.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0.00	w/o N rep	3651
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0.00	w/o N rep	6586
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0.00	w/o N rep	2588
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	1.00	w alum; w/o N rep	2168
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	0.00	w/o N rep	-1385
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	0.00	w/o N rep	443
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	0.00	w N rep	-3598
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	0.00	w/o N rep	-177
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	0.00	w N rep	-2269
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	4.00	w alum;	7143
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	4.80	w alum;	13570
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	4.80	w alum;	5065
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	4.00	w alum;	5902
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	4.00	w alum;	4440
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	4.80	w alum;	6547
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0.00	w/o N rep	327
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	0.00	w N rep	547
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0.00	w N rep	247
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0.00	w/o N rep	15954
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0.00	w/o N rep	8737
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	1.00	w alum; w/o N rep	9508
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0.00	w/o N rep	7209
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	0.00	w/o N rep	-916
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	0.00	w N rep	-9608
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	0.00	w N rep	-9381
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	0.00	w/o N rep	440
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	0.00	w N rep	-6677
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	4.80	w alum;	41793
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	4.80	w alum;	40046
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	4.80	w alum;	47301
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0.00	w N rep	3424
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	0.00	w N rep	-3730
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	0.00	w N rep	4250
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	0.00	w N rep	-4089
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0.00	w/o N rep	10030
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0.00	w/o N rep	18515
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	1.00	w alum; w/o N rep	13243
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0.00	w/o N rep	13801
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0.00	w/o N rep	9490
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	0.00	w N rep	-3753
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	0.00	w N rep	-4024
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	0.00	w/o N rep	898
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	3.23		-893
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	4.00	w alum;	19221
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	4.00	w alum;	12350
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	4.00	w alum;	16146
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	4.00	w alum;	10369
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0.00	w N rep	2303
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0.00	w N rep	1007
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0.00	w N rep	3954
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	1.95	w alum;	4846
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0.00	w/o N rep	10865
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	1.00	w alum; w/o N rep	20002
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0.00	w/o N rep	7514
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	3.23		-1450
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	0.00	w N rep	-2156
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	3.23	w alum;	-3000
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	0.00	w/o N rep	482
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	4.00	w alum;	16851
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	4.80	w alum;	15927
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	4.00	w alum;	10960
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	6.00	w alum;	9801
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0.00	w N rep	607
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0.00	w N rep	1278
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	1.95	w alum;	1940

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0.00	w N rep	2441
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0.00	w/o N rep	10
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	0.00	w/o N rep	4
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0.00	w N rep	243
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0.00	w/o N rep	9671
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0.00	w/o N rep	18748
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	0.00	w N rep	-2047
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	3.23	w alum;	-2789
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	4.00	w alum;	6148
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	4.80	w alum;	17236
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0.00	w N rep	9525
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0.00	w N rep	8202
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	1.00	w alum; w/o N rep	15932
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0.00	w/o N rep	6807
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	1.00	w/o N rep	12291
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0.00	w/o N rep	5628
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	3.23		97
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	0.00	w/o N rep	236
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	2.58	w alum;	-85
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	6.00	w alum;	18870
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	6.00	w alum;	2700
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	6.00	w alum;	9567
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0.00	w N rep	1976
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	1.95		1287
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	1.95	w alum;	3585
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	1.00	w alum; w/o N rep	9874
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0.00	w/o N rep	5707
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	1.00	w/o N rep	14333
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	3.23		-83
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	0.00	w/o N rep	303
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	0.00	w/o N rep	-317
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	6.00	w alum;	7946
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	6.00	w alum;	3630
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	6.00	w alum;	9150
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0.00	w N rep	3037
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0.00	w N rep	737
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	1.95	w alum;	5774
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	32805
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	14386
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0.00	w/o N rep	12976
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	3.23		-1957
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	-308
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	3.23	w alum;	-3238
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	4.80	w alum;	15132
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	4.80	w alum;	36139
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	6.00	w alum;	26602
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0.00	w N rep	1455
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	1.95	w alum;	9590
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	1.95	w alum;	3626
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	2.00	w alum; w/o N rep	3321
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	5486
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	1.00	w/o N rep	3960
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	1.00	w alum; w/o N rep	3603
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	0.00	w N rep	-1134
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	-151
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	3.23		95
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	3.23		-446
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	4.80	w alum;	5315
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	4.00	w alum;	8495
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	6.00	w alum;	6227
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	0.00	w N rep	-97
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	1.95	w alum;	795
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0.00	w N rep	1024
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0.00	w/o N rep	1279
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	1.00	w alum; w/o N rep	1766

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0.00	w/o N rep	-940
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	0.00	w/o N rep	55
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	0.00	w/o N rep	-2
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	4.00	w alum;	1446
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	4.00	w alum;	2757
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0.00	w/o N rep	17339
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	17238
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0.00	w/o N rep	8520
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0.00	w/o N rep	7568
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	0.00	w/o N rep	-341
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	0.00	w/o N rep	-1277
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	0.00	w/o N rep	609
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	0.00	w/o N rep	-747
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	0.00	w N rep	-8486
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	6.00	w alum;	16793
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	4.80	w alum;	18566
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	4.80	w alum;	12939
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	6.00	w alum;	14626
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	6.00	w alum;	15677
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0.00	w N rep	2634
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0.33	w/o N rep	2422
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	0.00	w N rep	2125
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	0.00	w N rep	-602
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	0.00	w N rep	-1694
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	1.00	w alum; w/o N rep	2237
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0.00	w/o N rep	4576
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0.00	w/o N rep	2835
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0.00	w/o N rep	4080
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	0.00	w/o N rep	466
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	0.00	w N rep	-2013
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	0.00	w N rep	-3382
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	4.80	w alum;	8965
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	4.00	w alum;	8454
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	6.00	w alum;	16378
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0.00	w N rep	1388
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	0.00	w N rep	-2586
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	0.00	w N rep	261
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	5013
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	11663
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0.00	w/o N rep	7531
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	3.23		-1013
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	120
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	3.23		821
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	4.80	w alum;	6879
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	4.00	w alum;	7156
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	6.00	w alum;	17478
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	4.00	w alum;	3575
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0.00	w N rep	-22
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	1.95	w alum;	1374
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	1.95	w alum;	3453
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0.00	w N rep	618
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	1.00	w alum; w/o N rep	10025
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0.00	w/o N rep	13859
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0.00	w/o N rep	12790
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	0.00	w/o N rep	-746
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	3.23		-4490
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	4.80	w alum;	4591
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	4.80	w alum;	3947
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	4.00	w alum;	8927
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	4.80	w alum;	3526
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0.00	w N rep	421
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0.00	w N rep	1234
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	1.95	w alum;	2100
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0.00	w N rep	2881
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	2589

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0.00	w/o N rep	3194
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	4954
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	1.00	w/o N rep	6607
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0.00	w/o N rep	2917
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	3.23		-276
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	37
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	3.23		231
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	0.00	w/o N rep	184
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	4.80	w alum;	5877
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	4.00	w alum;	3988
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	6.00	w alum;	8503
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0.00	w N rep	50
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	1.95	w alum;	1379
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	1.95	w alum;	2055
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	3337
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0.00	w/o N rep	4448
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	4075
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	1.00	w/o N rep	3423
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	3.23		-1368
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	74
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	3.23	w alum;	-565
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	4.80	w alum;	10454
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	4.80	w alum;	4452
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	6.00	w alum;	8259
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	0.00	w N rep	345
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	1.95		989
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	1.95	w alum;	2953
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	1905
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	1044
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0.00	w/o N rep	643
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0.00	w/o N rep	1520
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	0.00	w/o N rep	-355
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	4.00	w alum;	1073
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	4.00	w alum;	1362
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	4.00	w alum;	1172
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	4.80	w alum;	1063
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	4.00	w alum;	2421
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0.00	w/o N rep	1755
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	1.00	w alum; w/o N rep	6341
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	3.23		-142
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	0.00	w/o N rep	-1461
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	4.00	w alum;	2014
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	4.80	w alum;	11063
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0.00	w/o N rep	12175
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0.00	w/o N rep	7093
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	1.00	w/o N rep	6707
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	3.23		-909
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	0.00	w/o N rep	386
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	4.80	w alum;	16320
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	4.00	w alum;	8685
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	6.00	w alum;	5595
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0.00	w N rep	337
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	1.95	w alum;	835
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	1.95	w alum;	722
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0.00	w N rep	364
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	1.00	w alum; w/o N rep	10168
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0.00	w/o N rep	8737
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0.00	w/o N rep	8988
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	3.23		-2275
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	0.00	w/o N rep	33
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	3.23	w alum;	-561
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	3.23		-296
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	4.80	w alum;	2343
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	4.00	w alum;	7012
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	4.00	w alum;	3054

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	6.00	w alum;	3650
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0.00	w N rep	2815
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	1.95		1181
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	1.95	w alum;	3069
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0.00	w/o N rep	728
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0.00	w/o N rep	311
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0.00	w/o N rep	317
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0.00	w/o N rep	372
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	3.23		-11
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	3.23		34
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	4.80	w alum;	256
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	4.80	w alum;	305
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	4.00	w alum;	309
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	4.80	w alum;	643
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	8849
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0.00	w/o N rep	6653
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	21479
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0.00	w/o N rep	12336
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	3.23		-1984
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	-206
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	0.00	w N rep	-2162
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	3.23		-585
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	4.80	w alum;	5738
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	4.00	w alum;	7035
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	4.00	w alum;	15879
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	4.80	w alum;	6832
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	0.00	w N rep	-5554
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	1.95	w alum;	1888
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	0.00	w N rep	-618
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	690
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0.00	w/o N rep	116
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0.00	w/o N rep	-168
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	4.80	w alum;	283
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	0.00	w/o N rep	-60
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0.00	w/o N rep	99
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0.00	w/o N rep	52
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0.00	w/o N rep	-76
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	4.80	w alum;	282
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	4.80	w alum;	136
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	6.00	w alum;	145
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0.00	w/o N rep	190
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	1.00	w/o N rep	77
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	4.80	w alum;	1106
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	2.00	w alum; w/o N rep	5995
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0.00	w/o N rep	16006
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	2.00	w alum; w/o N rep	10069
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	0.00	w/o N rep	72
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	0.00	w/o N rep	-276
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	6.00	w alum;	4407
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	6.00	w alum;	12772
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	6.00	w alum;	6933
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0.00	w N rep	434
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0.00	w N rep	418
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	2.00	w alum; w/o N rep	5999
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0.00	w/o N rep	12078
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	0.00	w/o N rep	-6
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	3.23		-181
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	0.00	w/o N rep	-90
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	6.00	w alum;	1079
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	6.00	w alum;	4003
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0.00	w/o N rep	355
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0.00	w/o N rep	533
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	1.00	w alum; w/o N rep	261
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0.00	w/o N rep	766
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	0.00	w/o N rep	84

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	0.00	w/o N rep	64
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	4.80	w alum;	400
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	4.80	w alum;	861
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	6.00	w alum;	624
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	4.00	w alum;	750
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0.00	w/o N rep	899
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0.00	w/o N rep	1519
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0.00	w/o N rep	1763
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	0.00	w/o N rep	161
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	0.00	w/o N rep	92
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	0.00	w/o N rep	-96
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	3.23		16
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	4.80	w alum;	812
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	4.80	w alum;	1131
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	4.00	w alum;	3352
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	1.11	w alum; w/o N rep	1465
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	0.65	w/o N rep	307
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	0.00	w N rep	510
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	1254
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0.00	w/o N rep	229
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0.00	w/o N rep	-188
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	-106
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	0.00	w N rep	-236
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	0.00	w N rep	-309
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0.00	w/o N rep	-158
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	4.80	w alum;	2397
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	4.80	w alum;	886
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	4.80	w alum;	651
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	0.00	w/o N rep	-232
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0.00	w/o N rep	1226
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0.00	w/o N rep	1354
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	4.80	w alum;	539
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	4.00	w alum;	1515
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0.00	w/o N rep	4868
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	5491
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0.00	w/o N rep	4068
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0.00	w/o N rep	2429
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	1.00	w alum; w/o N rep	2651
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0.00	w/o N rep	3698
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	0.00	w/o N rep	332
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	3.23	w alum;	325
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	0.00	w/o N rep	361
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	0.00	w/o N rep	-783
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	0.00	w/o N rep	317
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	0.00	w/o N rep	-852
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	6.00	w alum;	6634
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	6.00	w alum;	12427
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	6.00	w alum;	6104
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	6.00	w alum;	5570
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	6.00	w alum;	7793
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	1.11	w alum; w/o N rep	1473
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	0.65	w/o N rep	2485
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	0.33	w/o N rep	1068
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	0.00	w N rep	859
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	1.95		1125
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0.00	w/o N rep	13
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	1.00	w alum; w/o N rep	48
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	0.00	w/o N rep	-165
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	0.00	w/o N rep	59
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	4.80	w alum;	407
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	0.00	w N rep	508
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	0.00	w N rep	447
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	1.95		1388
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	1.00	w alum; w/o N rep	1892
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0.00	w/o N rep	2902
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0.00	w/o N rep	1877
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	0.00	w/o N rep	63

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	3.23		-97
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	0.00	w N rep	-441
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	0.00	w/o N rep	46
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	3.23		5
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4.00	w alum;	751
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	4.80	w alum;	791
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	4.00	w alum;	2003
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	4.00	w alum;	613
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	1.95	w alum;	614
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0.00	w N rep	780
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	1.95		452
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0.00	w N rep	393
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	1.00	w alum; w/o N rep	11936
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0.00	w/o N rep	23735
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0.00	w/o N rep	14125
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	1.00	w alum; w/o N rep	21321
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	3.23		-5385
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	0.00	w/o N rep	131
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	3.23		-1005
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	4.80	w alum;	6554
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	4.00	w alum;	12540
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	4.00	w alum;	10132
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	6.00	w alum;	11016
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	0.00	w N rep	746
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	1.95	w alum;	4566
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	1.95	w alum;	13862
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0.00	w N rep	4796
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1212
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0.00	w/o N rep	878
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	1.00	w alum; w/o N rep	5084
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	-84
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	93
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	3.23		-39
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	6.00	w alum;	3485
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	6.00	w alum;	1903
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	6.00	w alum;	2550
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	1.00	w alum; w/o N rep	4804
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	5319
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0.00	w/o N rep	2500
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0.00	w/o N rep	2763
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	2.00	w alum; w/o N rep	2588
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	1.00	w alum; w/o N rep	2483
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	156
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	-70
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	0.00	w N rep	-1783
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	6.00	w alum;	5032
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	6.00	w alum;	3586
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	6.00	w alum;	6669
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	6.00	w alum;	5394
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	0.00	w N rep	374
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0.00	w N rep	760
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	0.00	w N rep	336
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	0.00	w N rep	-1414
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	1.00	w alum; w/o N rep	4723
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0.00	w/o N rep	4095
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0.00	w/o N rep	4897
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0.00	w/o N rep	10952
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	0.00	w/o N rep	1402
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	0.00	w N rep	-6108
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	0.00	w N rep	-3878
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	6.00	w alum;	5880
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	6.00	w alum;	7607
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	6.00	w alum;	5688
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	4.80	w alum;	8984
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	4.80	w alum;	4834
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	6.00	w alum;	8873

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0.00	w N rep	5122
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	0.00	w N rep	9686
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0.00	w/o N rep	3484
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0.00	w/o N rep	2610
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	1.00	w alum; w/o N rep	2890
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	3.23		-283
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	0.00	w N rep	-1949
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	0.00	w N rep	-1330
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	6.00	w alum;	1992
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	6.00	w alum;	2175
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	6.00	w alum;	3164
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	6.00	w alum;	2997
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	6.00	w alum;	4737
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	0.00	w N rep	329
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	0.00	w N rep	630
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	0.00	w N rep	-364
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	2.00	w alum; w/o N rep	9625
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	1.00	w alum; w/o N rep	4688
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	1.00	w alum; w/o N rep	4947
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	0.00	w/o N rep	458
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	0.00	w N rep	-3641
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	6.00	w alum;	6415
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	6.00	w alum;	25108
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	6.00	w alum;	12772
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	0.00	w N rep	802
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	1.11	w alum; w/o N rep	1998
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	0.00	w N rep	2759
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	1.00	w alum; w/o N rep	15164
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0.00	w/o N rep	15551
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	1.00	w alum; w/o N rep	17959
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	0.00	w/o N rep	-99
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	3.23		-77
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	0.00	w/o N rep	-942
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	0.00	w N rep	-4029
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	6.00	w alum;	14172
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	6.00	w alum;	26789
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	4.80	w alum;	10377
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0.00	w N rep	5677
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0.00	w N rep	5588
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0.00	w/o N rep	3151
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	8805
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	2759
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	-268
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	344
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	0.00	w/o N rep	45
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	4.80	w alum;	3867
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	4.80	w alum;	16135
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	4.80	w alum;	6781
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0.00	w/o N rep	3209
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	12895
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0.00	w/o N rep	2652
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	0.00	w/o N rep	-376
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	-3406
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	0.00	w/o N rep	204
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	4.00	w alum;	6025
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	4.80	w alum;	19606
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	4.80	w alum;	5812
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	4.80	w alum;	4079
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0.00	w N rep	1709
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0.00	w/o N rep	1207
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0.00	w/o N rep	22636
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0.00	w/o N rep	7916
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0.00	w/o N rep	9721
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	0.00	w/o N rep	-2020
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	0.00	w/o N rep	616
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	0.00	w N rep	-6565

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	0.00	w/o N rep	-367
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	0.00	w N rep	-6556
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	4.80	w alum;	33539
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	4.80	w alum;	13784
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	4.80	w alum;	25034
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0.00	w N rep	2912
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0.65	w alum; w/o N rep	1169
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	0.00	w N rep	-2418
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	0.00	w N rep	1030
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	0.00	w N rep	-345
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0.00	w/o N rep	11051
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	27292
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0.00	w/o N rep	9197
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	-2105
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	0.00	w/o N rep	1850
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	0.00	w/o N rep	396
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	4.80	w alum;	18051
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	4.80	w alum;	40330
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	4.80	w alum;	18495
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	4.80	w alum;	14494
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	0.00	w N rep	2002
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	0.00	w N rep	3935
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	0.00	w N rep	2498
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0.00	w/o N rep	88
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0.00	w/o N rep	15
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	0.00	w/o N rep	8
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	0.00	w/o N rep	27
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	4.80	w alum;	166
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	1.95	w alum;	353
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	0.00	w N rep	84
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	1.95		343
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0.00	w/o N rep	131
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	1.00	w alum; w/o N rep	140
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0.00	w/o N rep	301
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	0.00	w/o N rep	-11
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	0.00	w N rep	-167
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	6.00	w alum;	191
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	6.00	w alum;	699
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	6.00	w alum;	251
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	6.00	w alum;	269
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	1.30	w alum;	120
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1295
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	1.00	w alum; w/o N rep	2260
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	1.00	w alum; w/o N rep	1127
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0.00	w/o N rep	2566
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	0.00	w/o N rep	65
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	0.00	w N rep	-306
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	0.00	w/o N rep	83
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	3.23		-59
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	4.80	w alum;	1970
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	4.80	w alum;	1341
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	4.80	w alum;	714
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	4.00	w alum;	1216
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0.00	w N rep	484
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	0.00	w N rep	-437
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0.00	w/o N rep	1712
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	1.00	w alum; w/o N rep	1651
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0.00	w/o N rep	1191
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	1.00	w alum; w/o N rep	4933
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	0.00	w N rep	-2532
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	4.00	w alum;	1631
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	4.80	w alum;	10624
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0.00	w N rep	857
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	29460
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	1.00	w alum; w/o N rep	18245
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	1.00	w alum; w/o N rep	30409
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	0.00	w/o N rep	-245

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	0.00	w/o N rep	1019
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	6.00	w alum;	52524
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	6.00	w alum;	32158
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	6.00	w alum;	122400
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	0.65	w alum; w/o N rep	2983
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	0.00	w N rep	454
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	0.00	w N rep	1356
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	0.00	w N rep	8621
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0.00	w/o N rep	26
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0.00	w/o N rep	21
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0.00	w/o N rep	1
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0.00	w/o N rep	-12
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0.00	w/o N rep	-7
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	1.95		62
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	1.00	w alum; w/o N rep	2417
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0.00	w/o N rep	5897
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	0.00	w/o N rep	91
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	0.00	w/o N rep	54
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	0.00	w/o N rep	-1158
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	4.00	w alum;	3039
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	4.00	w alum;	7468
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	4.00	w alum;	2788
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0.00	w/o N rep	20
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0.00	w/o N rep	42
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0.00	w/o N rep	25
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0.00	w/o N rep	144
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0.00	w/o N rep	230
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0.00	w/o N rep	139
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0.00	w/o N rep	392
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0.00	w/o N rep	104
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0.00	w/o N rep	119
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	0.00	w/o N rep	6
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	0.00	w/o N rep	10
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0.00	w/o N rep	-13
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	4.80	w alum;	853
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	4.80	w alum;	212
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	286
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	1.00	w alum; w/o N rep	61
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0.00	w/o N rep	178
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	4.80	w alum;	297
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	4.80	w alum;	216
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	4542
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0.00	w/o N rep	5527
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	1.00	w alum; w/o N rep	2458
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	221
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	882
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	795
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	0.00	w N rep	-1436
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	4.80	w alum;	6833
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	4.80	w alum;	14397
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	6.00	w alum;	13644
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	0.33	w/o N rep	640
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	0.98	w/o N rep	1384
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	0.33	w/o N rep	1619
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	0.00	w N rep	381
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0.00	w/o N rep	334
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0.00	w/o N rep	337
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0.00	w/o N rep	157
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	4.80	w alum;	553
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	4.80	w alum;	672
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	4.80	w alum;	611
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0.00	w/o N rep	483
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0.00	w/o N rep	835
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0.00	w/o N rep	842
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	4.00	w alum;	785
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	4.00	w alum;	1046
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	4.00	w alum;	585

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum, With (w N rep) or without (w/o N rep) N replacement	HRU shadow price
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0.00	w/o N rep	-86
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	976
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	1.00	w alum; w/o N rep	1247
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	1.00	w alum; w/o N rep	1408
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0.00	w/o N rep	540
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	4.00	w alum;	801
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	4.00	w alum;	1042
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	4.00	w alum;	517
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0.00	w/o N rep	285
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	1.00	w alum; w/o N rep	1416
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	15241
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	1.00	w alum; w/o N rep	10959
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0.00	w/o N rep	10890
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	1.00	w/o N rep	10165
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	0.00	w/o N rep	545
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	3.23		-488
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	0.00	w/o N rep	-56
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	3.23		359
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	4.00	w alum;	11385
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	4.80	w alum;	14204
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	4.00	w alum;	8684
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	6.00	w alum;	8609
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	1.95	w alum;	1861
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0.00	w N rep	1671
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	1.95	w alum;	10907
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0.00	w/o N rep	634
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0.00	w/o N rep	420
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0.00	w/o N rep	814
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0.00	w/o N rep	1381
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	3.23		-137
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	0.00	w/o N rep	52
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	3.23		-38
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	4.00	w alum;	798
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	4.00	w alum;	283
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	4.00	w alum;	178
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	4.00	w alum;	294
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	4.00	w alum;	478

Table A.2.5. Spatial Detail for the Optimal Solution for Policy 2.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	w/o N rep	3891
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	w/o N rep	7244
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	w/o N rep	3096
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	w/o N rep	2326
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	0	w/o N rep	2061
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	0	w/o N rep	1386
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	0	w/o N rep	1340
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	0	w/o N rep	852
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	0	w/o N rep	1032
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	0	w N rep	4329
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	0	w N rep	7736
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	0	w N rep	1256
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	0	w N rep	4865
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	0	w N rep	3667
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	0	w N rep	3239
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0	w/o N rep	380
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	0	w/o N rep	2156
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0	w/o N rep	1139
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	w/o N rep	17251
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	w/o N rep	9913
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	0	w/o N rep	9871
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	w/o N rep	10684
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	0	w/o N rep	5792
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	0	w/o N rep	6161
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	0	w/o N rep	5558
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	0	w/o N rep	5632
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	0	w/o N rep	4075
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	0	w N rep	24317
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	0	w N rep	30637
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	0	w N rep	24589
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0	w/o N rep	6015
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	0	w/o N rep	8823
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	0	w/o N rep	9611
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	0	w/o N rep	7496
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	w/o N rep	11495
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	w/o N rep	23529
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	w/o N rep	14859
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	w/o N rep	16689
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	w/o N rep	10766
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	0	w/o N rep	1766
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	0	w/o N rep	2210
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	0	w/o N rep	3207
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	0	w/o N rep	1612
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	0	w N rep	15445
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	0	w N rep	9885
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	0	w N rep	202
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	0	w N rep	8057
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0	w/o N rep	5735
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0	w/o N rep	5573
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0	w N rep	5833
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	0	w N rep	3989
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	w/o N rep	16230
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	0	w/o N rep	21248
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	w/o N rep	8983
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	0	w/o N rep	1734
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	0	w/o N rep	1409

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	0	w/o N rep	2056
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	0	w/o N rep	1230
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	0	w N rep	12740
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	0	w N rep	12124
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	0	w/o N rep	41
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	0	w N rep	4436
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0	w/o N rep	2734
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0	w/o N rep	2664
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	0	w/o N rep	1621
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0	w/o N rep	5018
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	w/o N rep	11
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	0	w/o N rep	6
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0	w/o N rep	323
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	w/o N rep	12598
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	w/o N rep	20013
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	0	w/o N rep	1081
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	0	w/o N rep	4582
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	0	w N rep	2271
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	0	w N rep	12168
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0	w/o N rep	19489
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0	w N rep	11183
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	0	w/o N rep	18050
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	w/o N rep	7882
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	0	w/o N rep	9949
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	w/o N rep	6070
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	0	w/o N rep	2017
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	0	w/o N rep	663
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	0	w/o N rep	779
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	0	w N rep	12534
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	0	w/o N rep	38
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	0	w N rep	4701
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0	w N rep	4608
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	0	w/o N rep	1013
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	0	w N rep	3686
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	0	w/o N rep	10965
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	w/o N rep	6640
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	0	w/o N rep	11493
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	0	w/o N rep	2366
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	0	w/o N rep	860
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	0	w/o N rep	1158
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	0	w N rep	5462
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	0	w/o N rep	41
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	0	w N rep	4488
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0	w N rep	8358
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0	w N rep	2367
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	0	w N rep	6097
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	w/o N rep	38672
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	0	w/o N rep	12013
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	w/o N rep	14144
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	0	w/o N rep	2215
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	0	w/o N rep	5427
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	0	w/o N rep	2991
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	0	w N rep	12600
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	0	w N rep	2276
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	0	w N rep	11814
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0	w/o N rep	5540

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	0	w/o N rep	7968
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	0	w N rep	3316
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	0	w/o N rep	3450
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	w/o N rep	6544
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	0	w/o N rep	4024
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	0	w/o N rep	2994
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	0	w/o N rep	411
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	0	w/o N rep	1193
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	0	w/o N rep	344
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	0	w/o N rep	626
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	0	w N rep	3650
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	0	w N rep	1019
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	0	w N rep	2900
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	0	w/o N rep	952
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	0	w/o N rep	1263
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0	w N rep	1342
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	3	w/o N rep	1979
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	3	w/o N rep	3665
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	w/o N rep	-938
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	3.23076		332
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	0.53846	w/o N rep	967
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	6		3099
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	6		6436
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	w/o N rep	18493
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	w/o N rep	19067
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9263
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	w/o N rep	8944
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	0	w/o N rep	4302
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	0	w/o N rep	1813
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	0	w/o N rep	2276
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	0	w/o N rep	2164
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	0	w/o N rep	3714
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	0	w N rep	10046
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	0	w N rep	9240
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	0	w N rep	3054
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	0	w N rep	6446
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	0	w N rep	11521
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0	w/o N rep	4664
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0	w/o N rep	3171
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	0	w/o N rep	3531
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	0	w/o N rep	10048
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	0	w/o N rep	4396
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	w/o N rep	2379
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5254
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	w/o N rep	3367
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4365
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	0	w/o N rep	1207
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	0	w/o N rep	1537
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	0	w/o N rep	2941
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	0	w N rep	5105
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	0	w N rep	5244
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	0	w N rep	10722
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0	w/o N rep	2370
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	0	w/o N rep	7209
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	0	w/o N rep	2894
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	w/o N rep	5836

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	0	w/o N rep	9698
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	w/o N rep	8152
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	0	w/o N rep	1771
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	0	w/o N rep	805
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	0	w/o N rep	2669
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	0	w N rep	5605
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	0	w N rep	1165
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	0	w N rep	8362
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	0	w N rep	1053
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0	w/o N rep	2926
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	0	w/o N rep	1486
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	0	w N rep	3615
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0	w/o N rep	2926
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	0	w/o N rep	10692
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	w/o N rep	16823
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	w/o N rep	16545
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	0	w/o N rep	1935
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	0	w/o N rep	2936
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	0	w N rep	671
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	0	w N rep	3198
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	0	w N rep	1174
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	0	w N rep	2733
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0	w/o N rep	2357
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0	w N rep	2750
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	0	w/o N rep	1872
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0	w/o N rep	9272
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	0	w/o N rep	2726
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	w/o N rep	3712
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	w/o N rep	5808
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	0	w/o N rep	5487
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	w/o N rep	3160
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	0	w/o N rep	431
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	0	w/o N rep	786
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	0	w/o N rep	1336
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	0	w/o N rep	657
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	0	w N rep	5003
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	0	w N rep	668
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	0	w N rep	4190
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0	w/o N rep	840
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	0	w/o N rep	1601
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	0	w N rep	2160
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	0	w/o N rep	3484
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	w/o N rep	5156
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	w/o N rep	4752
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	0	w/o N rep	2760
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	0	w/o N rep	1860
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	0	w/o N rep	830
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	0	w/o N rep	1386
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	0	w N rep	8371
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	0	w N rep	768
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	0	w N rep	3901
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	0	w/o N rep	1920
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	0	w/o N rep	816
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	0	w N rep	2659
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	6		3660
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	3	w/o N rep	1953

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	6		1339
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	3	w/o N rep	2815
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	3.23076		2417
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	6		2210
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	6		3092
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	6		2774
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	6		2407
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	6		5680
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	6		3149
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	6		14337
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	3.23076		768
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	2.58461		2593
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	6		4233
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	6		26239
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	w/o N rep	13948
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	w/o N rep	8194
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	0	w/o N rep	5498
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	0	w/o N rep	2152
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	0	w/o N rep	1757
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	0	w N rep	13916
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	0	w N rep	1491
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	0	w N rep	2730
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0	w/o N rep	1496
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	0	w/o N rep	718
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	0	w N rep	642
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0	w/o N rep	799
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	0	w/o N rep	10867
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	w/o N rep	10638
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	w/o N rep	10673
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	0	w/o N rep	1905
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	0	w/o N rep	666
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	0	w/o N rep	674
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	0	w/o N rep	514
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	0	w N rep	392
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	0	w N rep	5978
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	0	w N rep	456
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	0	w N rep	1823
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0	w/o N rep	5452
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	0	w/o N rep	835
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	0	w N rep	2416
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	w/o N rep	806
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	w/o N rep	353
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	w/o N rep	334
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	w/o N rep	408
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	0	w/o N rep	196
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	0	w/o N rep	354
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	0	w N rep	194
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	0	w N rep	192
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	0	w N rep	46
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	0	w N rep	484
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9231
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	w/o N rep	7921
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	w/o N rep	25481
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	w/o N rep	14510
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	0	w/o N rep	1687
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	0	w/o N rep	2843

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	0	w/o N rep	1032
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	0	w/o N rep	1024
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	0	w N rep	837
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	0	w N rep	5747
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	0	w N rep	2373
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	0	w N rep	5489
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	0	w/o N rep	9827
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	0	w/o N rep	4113
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	0	w/o N rep	6411
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	6		1483
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	6		265
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	w/o N rep	-168
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	6		644
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	1	w/o N rep	-58
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	6		223
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	6		127
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	w/o N rep	-76
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	6		629
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	6		326
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	6		326
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	6		419
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	6		160
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	6		2400
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	0	w/o N rep	5877
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	w/o N rep	19458
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	0	w/o N rep	8310
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	0	w/o N rep	438
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	0	w/o N rep	2501
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	0	w N rep	503
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	0	w/o N rep	129
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	0	w N rep	3366
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0	w/o N rep	679
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0	w/o N rep	3856
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	0	w/o N rep	5943
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	w/o N rep	14567
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	0	w/o N rep	146
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	0	w/o N rep	150
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	0	w/o N rep	343
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	0	w N rep	147
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	0	w N rep	530
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	6		669
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	6		1161
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	6		561
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	6		1442
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	2.58461		405
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	1.83076	w/o N rep	102
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	6		815
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	6		1910
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	6		1444
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	6		1521
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	6		1592
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	6		3123
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	6		3085
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	2.58461		532
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	1.83076	w/o N rep	129
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	2.58461		469

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	3.23076		489
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	6		1629
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	6		2453
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	6		6693
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	1.95		2168
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	1.95		460
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	1.95		1180
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	6		2675
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	6		529
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-188
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	2.58461		789
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	3.23076		390
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	2.58461		130
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0	w/o N rep	-157
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	6		5409
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	6		2044
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	6		1528
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	1	w/o N rep	-225
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	6		2445
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	3.4	w/o N rep	2669
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	6		1197
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	6		3577
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	6		9221
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	6		12074
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	6		8595
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	6		5697
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	6		6331
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	6		9230
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	3.23076		2865
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	3.23076		3657
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	2.58461		695
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	3.23076		2357
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	2.58461		863
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	2.58461		1161
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	6		12872
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	6		25836
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	6		13083
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	6		11383
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	6		16800
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	1.95		2097
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	1.95		3835
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	1.95		1453
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	1.95		2070
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	1.95		1423
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	6		23
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	6		101
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	2.58461		316
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	2.58461		118
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	6		814
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	1.95		837
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	1.95		1839
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	1.95		1814
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1964
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	w/o N rep	3243
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	w/o N rep	2078
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	0	w/o N rep	132

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	0	w/o N rep	385
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	0	w/o N rep	140
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	0	w/o N rep	125
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	0	w/o N rep	210
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	w N rep	362
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	w N rep	137
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	0	w N rep	1586
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	0	w N rep	94
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	0	w/o N rep	580
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0	w/o N rep	1340
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	0	w/o N rep	329
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0	w/o N rep	505
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	0	w/o N rep	12730
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	w/o N rep	28482
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	w/o N rep	16666
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	0	w/o N rep	17877
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	0	w/o N rep	4667
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	0	w/o N rep	1626
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	0	w/o N rep	2193
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	0	w N rep	906
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	0	w N rep	10181
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	0	w N rep	1409
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	0	w N rep	5510
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	0	w/o N rep	13700
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	0	w/o N rep	3742
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	0	w N rep	12720
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0	w/o N rep	9913
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	0	w/o N rep	1269
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	w/o N rep	930
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	w/o N rep	5804
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	0	w/o N rep	265
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	0	w/o N rep	199
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	0	w/o N rep	104
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	0	w N rep	2133
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	0	w N rep	622
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	0	w N rep	1584
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	w/o N rep	4997
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	0	w/o N rep	5695
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2681
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	w/o N rep	3179
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2671
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	w/o N rep	3177
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	0	w/o N rep	372
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	0	w/o N rep	1006
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	0	w/o N rep	858
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	0	w N rep	2917
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	0	w N rep	1041
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	0	w N rep	3386
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	0	w N rep	3379
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	0	w/o N rep	781
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0	w/o N rep	1283
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	0	w/o N rep	725
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	0	w/o N rep	2168
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	0	w/o N rep	5026
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4412
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	w/o N rep	6013

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	w/o N rep	12175
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	0	w/o N rep	3098
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	0	w/o N rep	3415
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	0	w/o N rep	2218
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	0	w N rep	2931
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	0	w N rep	1882
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	0	w N rep	2391
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	0	w N rep	5053
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	0	w N rep	2095
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	0	w N rep	5851
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0	w/o N rep	22328
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	0	w/o N rep	23486
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	w/o N rep	3952
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	w/o N rep	2949
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	w/o N rep	3530
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	0	w/o N rep	603
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	0	w/o N rep	981
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	0	w/o N rep	712
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	0	w N rep	1185
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	0	w N rep	656
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	0	w N rep	2495
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	0	w N rep	1518
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	0	w N rep	2994
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	0	w/o N rep	863
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	0	w/o N rep	1232
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	0	w/o N rep	396
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	0	w/o N rep	9127
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5410
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	0	w/o N rep	5412
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	0	w/o N rep	2734
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	0	w/o N rep	2201
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	0	w N rep	3819
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	0	w N rep	12903
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	0	w N rep	8034
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	0	w/o N rep	1774
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	0	w/o N rep	2461
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	0	w/o N rep	5194
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	0	w/o N rep	15615
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	w/o N rep	17414
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	0	w/o N rep	27534
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	0	w/o N rep	1303
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	0	w/o N rep	2825
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	0	w/o N rep	1102
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	0	w/o N rep	1345
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	0	w N rep	8390
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	0	w N rep	20349
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	0	w N rep	5196
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0	w/o N rep	8233
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0	w/o N rep	8881
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	6		5752
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	6		19232
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	6		5664
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	3.23076		3558
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	1.83076	w/o N rep	733
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	1.83076	w/o N rep	259
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	6		7900

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	6		36775
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	6		15713
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	w/o N rep	3464
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	w/o N rep	14503
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	w/o N rep	2872
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	0	w/o N rep	1277
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	0	w/o N rep	3047
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	0	w/o N rep	2032
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	0	w N rep	3664
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	0	w N rep	10659
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	0	w N rep	1263
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	0	w N rep	2946
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0	w/o N rep	3248
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0	w/o N rep	1815
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	w/o N rep	24899
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	w/o N rep	8525
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	w/o N rep	12748
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	0	w/o N rep	2997
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	0	w/o N rep	1865
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	0	w/o N rep	2737
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	0	w/o N rep	1505
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	0	w/o N rep	2916
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	0	w N rep	18956
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	0	w N rep	3227
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	0	w N rep	17008
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0	w/o N rep	4957
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0	w/o N rep	1636
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	0	w/o N rep	2520
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	0	w/o N rep	1687
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	0	w/o N rep	2743
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	6		19771
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	6		56799
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	3.4	w/o N rep	17900
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	2.58461		15515
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	1.83076	w/o N rep	3896
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	1.83076	w/o N rep	3358
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	6		36237
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	6		86928
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	6		40738
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	6		30838
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	1.95		4998
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	1.95		14745
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	1.95		6185
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	6		163
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	6		33
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	3.23076		45
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	2.58461		51
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	6		333
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	1.95		498
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	1.95		179
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	1.95		428
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	6		250
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	6		313
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	6		738
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	3.23076		346
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	3.23076		638

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	6		368
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	6		1494
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	6		532
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	6		547
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	1.95		193
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	0	w/o N rep	1345
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	w/o N rep	2631
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	w/o N rep	1152
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	w/o N rep	2940
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	0	w/o N rep	294
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	0	w/o N rep	132
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	0	w/o N rep	224
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	0	w/o N rep	240
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	0	w N rep	335
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	0	w N rep	890
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	0	w/o N rep	144
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	0	w N rep	960
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0	w/o N rep	1035
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	0	w/o N rep	1033
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	w/o N rep	1804
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	w/o N rep	1795
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	w/o N rep	1331
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	w/o N rep	5303
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	0	w/o N rep	1628
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	0	w N rep	911
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	0	w N rep	8789
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0	w N rep	1229
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	6		70722
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	6		43780
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	6		79340
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	1.07692	w/o N rep	5770
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	1.83076	w/o N rep	21257
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	6		107200
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	6		67175
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	6		246500
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	1.95		4747
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	1.95		6939
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	1.95		10164
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	1.95		15815
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	w/o N rep	29
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	w/o N rep	24
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0	w/o N rep	4
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0	w/o N rep	8
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0	w/o N rep	-7
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	1.95		86
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	3	w/o N rep	5090
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	3.4	w/o N rep	12111
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	3.23076		447
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	1.07692	w/o N rep	179
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	0.53846	w/o N rep	1385
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	6		7393
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	6		19918
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	6		6411
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	6		36
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	6		91
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	6		59

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	6		257
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	6		506
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	6		257
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	6		859
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	6		213
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	6		274
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	2.58461		138
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	1.83076	w/o N rep	17
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0	w/o N rep	-13
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	6		1870
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	6		479
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	6		621
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	6		132
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	6		335
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	6		662
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	6		474
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	6		9549
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	6		10893
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	6		5644
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	3.23076		2204
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	2.58461		1485
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	1.83076	w/o N rep	1819
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	3.23076		2145
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	6		14459
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	6		31597
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	6		28715
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	1.95		1119
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	1.95		2005
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	1.95		2517
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	1.95		3879
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	6		580
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	6		684
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	6		342
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	6		1109
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	6		1451
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	6		1337
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	6		800
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	6		1711
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	6		1871
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	6		1648
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	6		2457
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	6		1480
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0	w/o N rep	-86
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	3	w/o N rep	1938
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	3.4	w/o N rep	2668
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	4	w N rep	3388
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	3	w/o N rep	1040
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	6		1936
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	6		2632
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	6		1573
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	3	w/o N rep	439
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	3	w/o N rep	2912
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	0	w/o N rep	15685
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	w/o N rep	11664
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	w/o N rep	12421
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	0	w/o N rep	9868

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil Type	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	0	w/o N rep	1429
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	0	w/o N rep	1189
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	0	w/o N rep	1046
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	0	w/o N rep	837
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	0	w N rep	5389
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	0	w N rep	2175
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	0	w N rep	6976
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	0	w N rep	3807
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	0	w/o N rep	1970
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0	w/o N rep	4481
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	0	w N rep	9028
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	w/o N rep	686
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	w/o N rep	472
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	w/o N rep	931
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	w/o N rep	1545
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	0	w/o N rep	263
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	0	w/o N rep	161
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	0	w/o N rep	132
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	0	w N rep	695
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	0	w N rep	201
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	0	w N rep	26
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	0	w N rep	228
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	0	w N rep	406

Table A.2.6. Spatial Detail for the Optimal Solution for Policy 3.

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	w/o N rep	3811
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	w/o N rep	7025
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	w/o N rep	2927
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	w/o N rep	2273
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	WPAS	0	w/o N rep	3219
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	WPAS	0	w/o N rep	2087
11	1	36.44	-94.67	37	Captina	0.07	60.98	WPAS	0	w/o N rep	2179
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	WPAS	0	w/o N rep	1212
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	WPAS	0	w/o N rep	1462
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAST	4	w N rep	7076
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAST	4.8	w alum;	13247
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAST	4	w alum;	4836
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAST	4	w alum;	6381
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAST	3.4	w alum; w/o N rep	5372
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAST	4.8	w alum;	6276
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	HAST	4	w alum;	283
24	1	36.44	-94.67	12	Captina	0.05	60.98	HAST	4	w N rep	1650
25	1	36.44	-94.67	5	Taloka	0.05	60.98	HAST	4	w alum;	676
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	w/o N rep	16820
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	w/o N rep	9522
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	1	w/o N rep	9738
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	w/o N rep	9528
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	WPAS	0	w/o N rep	9213
35	2	36.43	-94.7	136	Captina	0.04	60.98	WPAS	0	w/o N rep	8211
36	2	36.43	-94.7	91	Taloka	0.04	60.98	WPAS	0	w/o N rep	5892
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	WPAS	1	w/o N rep	8083
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	WPAS	0	w/o N rep	5868
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAST	4.8	w alum;	40359
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAST	4.8	w alum;	41008
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAST	4.8	w alum;	45154
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	HAST	4.8	w alum;	4543
47	2	36.43	-94.7	58	Captina	0.03	60.98	HAST	4.8	w alum;	7811
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	HAST	4.8		9116
49	2	36.43	-94.7	39	Taloka	0.03	60.98	HAST	4.8	w alum;	4728
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	w/o N rep	11007
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	w/o N rep	21861
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	w/o N rep	14307
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	w/o N rep	15728
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	w/o N rep	10341
61	3	36.42	-94.67	48	Captina	0.02	91.46	WPAS	0	w/o N rep	2876
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	WPAS	0	w/o N rep	3388
63	3	36.42	-94.67	88	Nixa	0.02	91.46	WPAS	0	w/o N rep	4268
64	3	36.42	-94.67	44	Peridge	0.02	91.46	WPAS	0	w/o N rep	2599
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAST	4	w alum;	19419
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAST	3.4	w alum; w/o N rep	12966
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAST	3.4	w alum; w/o N rep	16219
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAST	4	w alum;	10362
71	3	36.42	-94.67	28	Captina	0.02	91.46	HAST	4	w alum;	3309
72	3	36.42	-94.67	23	Jay	0.02	91.46	HAST	3.4	w alum; w/o N rep	2611
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	HAST	4	w N rep	3330
74	3	36.42	-94.67	15	Tonti	0.02	91.46	HAST	4.8	w alum;	1583
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	w/o N rep	14445
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	1	w/o N rep	21002
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	w/o N rep	8494

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
85	4	36.4	-94.57	46	Captina	0.02	121.95	WPAS	0	w/o N rep	2775
86	4	36.4	-94.57	30	Jay	0.02	121.95	WPAS	0	w/o N rep	1829
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	WPAS	1	w/o N rep	3146
88	4	36.4	-94.57	34	Nixa	0.02	121.95	WPAS	0	w/o N rep	1617
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAST	4	w alum;	16831
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAST	4	w N rep	15524
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAST	4	w alum;	10924
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAST	6	w alum;	9191
95	4	36.4	-94.57	13	Captina	0.02	121.95	HAST	4	w alum;	1527
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	HAST	4	w N rep	1780
97	4	36.4	-94.57	13	Nixa	0.02	121.95	HAST	4	w alum;	945
98	4	36.4	-94.57	22	Peridge	0.02	121.95	HAST	4	w alum;	2579
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	w/o N rep	10
102	5	36.41	-94.63	0	Razort	0.03	36.58	WPAS	0	w/o N rep	6
105	5	36.41	-94.63	1	Razort	0.04	36.58	HAST	0	w/o N rep	66
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	w/o N rep	11624
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	w/o N rep	19592
114	6	36.38	-94.61	30	Taloka	0.01	121.95	WPAS	0	w/o N rep	1528
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	WPAS	0	w/o N rep	7123
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAST	4	w alum;	6303
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAST	4	w N rep	16680
121	6	36.38	-94.61	69	Taloka	0.01	121.95	HAST	4	w alum;	7444
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	HAST	4	w N rep	7438
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	1	w/o N rep	17238
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	w/o N rep	7524
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	1	w/o N rep	12583
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	w/o N rep	5923
130	7	36.4	-94.31	55	Captina	0.03	91.46	WPAS	1	w/o N rep	3193
131	7	36.4	-94.31	18	Nixa	0.03	91.46	WPAS	0	w/o N rep	882
132	7	36.4	-94.31	21	Tonti	0.03	91.46	WPAS	1	w/o N rep	1348
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAST	6	w alum;	18647
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAST	4.8	w alum;	2618
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAST	6	w alum;	8991
140	7	36.4	-94.31	21	Captina	0.02	91.46	HAST	6	w alum;	2796
141	7	36.4	-94.31	7	Nixa	0.02	91.46	HAST	4.8	w alum;	597
142	7	36.4	-94.31	13	Tonti	0.02	91.46	HAST	6		1580
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	1	w/o N rep	10756
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	w/o N rep	6329
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	1	w/o N rep	14765
149	8	36.37	-94.33	65	Captina	0.03	91.46	WPAS	1	w/o N rep	3798
150	8	36.37	-94.33	24	Nixa	0.03	91.46	WPAS	0	w/o N rep	1140
151	8	36.37	-94.33	32	Tonti	0.03	91.46	WPAS	1	w/o N rep	2035
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAST	6	w alum;	7860
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAST	4.8	w alum;	3508
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAST	6	w alum;	8608
160	8	36.37	-94.33	39	Captina	0.02	91.46	HAST	6	w alum;	5271
161	8	36.37	-94.33	9	Taloka	0.02	91.46	HAST	4.8	w alum;	1091
162	8	36.37	-94.33	21	Tonti	0.02	91.46	HAST	6	w alum;	2608
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	w/o N rep	36720
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	1	w/o N rep	15091
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	w/o N rep	13755
169	9	36.4	-94.37	61	Captina	0.05	60.98	WPAS	0	w/o N rep	3592
170	9	36.4	-94.37	149	Nixa	0.05	60.98	WPAS	0	w/o N rep	7510
171	9	36.4	-94.37	82	Tonti	0.05	60.98	WPAS	1	w/o N rep	5476

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAST	4	w alum;	15915
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAST	4	w alum;	35490
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAST	6	w alum;	25398
178	9	36.4	-94.37	26	Captina	0.04	60.98	HAST	4.8	w alum;	3319
179	9	36.4	-94.37	60	Nixa	0.04	60.98	HAST	4	w alum;	5308
180	9	36.4	-94.37	12	Tonti	0.04	60.98	HAST	6	w alum;	1545
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	1	w/o N rep	3410
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	w/o N rep	6192
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	1	w/o N rep	4418
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	1	w/o N rep	3810
188	10	36.37	-94.41	11	Britwater	0.06	60.98	WPAS	1	w alum; w/o N rep	633
189	10	36.37	-94.41	33	Nixa	0.06	60.98	WPAS	0	w/o N rep	1646
190	10	36.37	-94.41	9	Tonti	0.06	60.98	WPAS	1	w/o N rep	630
191	10	36.37	-94.41	17	Peridge	0.06	60.98	WPAS	0	w/o N rep	1007
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAST	4.8	w alum;	5576
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAST	4	w alum;	8436
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAST	6	w alum;	5982
198	10	36.37	-94.41	5	Britwater	0.06	60.98	HAST	4.8	w alum;	553
199	10	36.37	-94.41	10	Nixa	0.06	60.98	HAST	4	w alum;	834
200	10	36.37	-94.41	5	Tonti	0.06	60.98	HAST	6	w alum;	607
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0	w/o N rep	1324
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	1	w/o N rep	1887
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	w/o N rep	-938
206	11	36.4	-94.99	3	Razort	0.10	24.39	WPAS	0	w/o N rep	201
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	WPAS	1	w/o N rep	1084
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAST	3.4	w/o N rep	1429
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAST	3.4	w alum; w/o N rep	2711
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	w/o N rep	18109
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	w/o N rep	18430
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	w/o N rep	9016
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	w/o N rep	8487
223	13	36.41	-94.66	71	Razort	0.05	60.98	WPAS	0	w/o N rep	5044
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	WPAS	0	w/o N rep	2826
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	WPAS	0	w/o N rep	3420
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	WPAS	1	w/o N rep	3068
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	WPAS	0	w/o N rep	5351
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAST	4	w N rep	16473
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAST	4.8	w alum;	18119
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAST	4.8	w alum;	12426
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAST	4.8	w alum;	14053
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAST	4.8	w alum;	16024
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	HAST	4.8	w alum;	3354
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	HAST	4.8	w alum;	2519
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	HAST	4.8	w alum;	3332
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	HAST	4.8		8582
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	HAST	4.8	w alum;	3154
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	w/o N rep	2326
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	w/o N rep	5028
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	w/o N rep	3190
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4270
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	WPAS	0	w/o N rep	1699
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	WPAS	0	w/o N rep	2242
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	WPAS	0	w/o N rep	4062
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAST	4.8	w alum;	8789

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAST	4	w alum;	8657
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAST	4.8		15900
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	HAST	4.8	w alum;	1751
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	HAST	4.8	w alum;	6123
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	HAST	4.8		2675
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	w/o N rep	5562
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	1	w/o N rep	12098
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	w/o N rep	7945
270	15	34.4	-94.44	48	Captina	0.05	60.98	WPAS	0	w/o N rep	2917
271	15	34.4	-94.44	22	Nixa	0.05	60.98	WPAS	0	w/o N rep	1119
272	15	34.4	-94.44	73	Tonti	0.05	60.98	WPAS	1	w/o N rep	4849
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAST	4	w alum;	7054
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAST	4	w alum;	7029
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAST	6	w alum;	16570
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAST	4	w alum;	3431
280	15	34.4	-94.44	14	Captina	0.04	60.98	HAST	4	w alum;	1770
281	15	34.4	-94.44	11	Nixa	0.04	60.98	HAST	4	w alum;	934
282	15	34.4	-94.44	13	Tonti	0.04	60.98	HAST	6	w alum;	1590
283	15	34.4	-94.44	13	Peridge	0.04	60.98	HAST	4	w alum;	1676
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	1	w/o N rep	10561
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	w/o N rep	15837
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	w/o N rep	15296
290	16	36.35	-94.44	53	Nixa	0.07	60.98	WPAS	0	w/o N rep	2659
291	16	36.35	-94.44	80	Peridge	0.07	60.98	WPAS	0	w/o N rep	4573
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAST	4.8	w alum;	4402
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAST	4	w alum;	4412
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAST	4	w alum;	8908
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAST	4.8	w alum;	3798
299	16	36.35	-94.44	12	Captina	0.05	60.98	HAST	4	w alum;	1480
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	HAST	4.8		1809
301	16	36.35	-94.44	15	Nixa	0.05	60.98	HAST	4	w alum;	1295
302	16	36.35	-94.44	42	Peridge	0.05	60.98	HAST	4.8	w alum;	5377
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	1	w/o N rep	2686
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	w/o N rep	3540
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	w/o N rep	5524
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	1	w/o N rep	6885
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	w/o N rep	3079
311	17	36.41	-94.48	12	Captina	0.06	60.98	WPAS	0	w/o N rep	710
312	17	36.41	-94.48	22	Nixa	0.06	60.98	WPAS	0	w/o N rep	1090
313	17	36.41	-94.48	37	Tonti	0.06	60.98	WPAS	1	w/o N rep	2406
314	17	36.41	-94.48	18	Noark	0.06	60.98	WPAS	0	w/o N rep	1087
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAST	4	w alum;	6146
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAST	4	w alum;	3922
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAST	6	w alum;	8076
322	17	36.41	-94.48	4	Captina	0.04	60.98	HAST	4	w alum;	500
323	17	36.41	-94.48	12	Nixa	0.04	60.98	HAST	4	w alum;	981
324	17	36.41	-94.48	8	Tonti	0.04	60.98	HAST	6	w alum;	926
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	1	w/o N rep	3457
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	w/o N rep	4920
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	w/o N rep	4527
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	1	w/o N rep	3543
331	18	36.39	-94.47	51	Captina	0.05	60.98	WPAS	0	w/o N rep	3015
332	18	36.39	-94.47	23	Nixa	0.05	60.98	WPAS	0	w/o N rep	1152
333	18	36.39	-94.47	38	Tonti	0.05	60.98	WPAS	1	w/o N rep	2550

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAST	4	w alum;	10869
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAST	4	w alum;	4370
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAST	6	w alum;	7799
340	18	36.39	-94.47	10	Captina	0.03	60.98	HAST	4	w alum;	1222
341	18	36.39	-94.47	6	Nixa	0.03	60.98	HAST	4	w alum;	539
342	18	36.39	-94.47	10	Tonti	0.03	60.98	HAST	6	w alum;	1171
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1976
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0	w/o N rep	1079
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0	w/o N rep	660
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0	w/o N rep	1610
350	19	36.35	-94.92	22	Tonti	0.06	24.39	WPAS	0	w/o N rep	1282
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAST	3.4	w/o N rep	1062
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAST	4	w N rep	1327
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAST	4	w N rep	1131
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAST	4	w N rep	1026
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAST	4	w alum;	2377
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0	w/o N rep	1823
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	0	w/o N rep	6825
363	20	36.36	-94.89	6	Razort	0.16	24.39	WPAS	0	w/o N rep	455
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	WPAS	0	w/o N rep	2033
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAST	4	w N rep	2012
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAST	4	w alum;	11006
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	w/o N rep	13358
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	w/o N rep	7827
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	1	w/o N rep	6909
372	21	36.41	-94.51	59	Captina	0.04	60.98	WPAS	0	w/o N rep	3551
373	21	36.41	-94.51	48	Nixa	0.04	60.98	WPAS	0	w/o N rep	2483
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAST	4	w alum;	16675
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAST	4	w alum;	8514
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAST	6	w alum;	5250
379	21	36.41	-94.51	7	Captina	0.03	60.98	HAST	4	w alum;	874
380	21	36.41	-94.51	6	Nixa	0.03	60.98	HAST	4	w alum;	457
381	21	36.41	-94.51	2	Tonti	0.03	60.98	HAST	6		272
382	21	36.41	-94.51	4	Peridge	0.03	60.98	HAST	4	w alum;	432
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	1	w/o N rep	10628
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	w/o N rep	10005
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	w/o N rep	10113
389	22	36.37	-94.51	51	Captina	0.06	36.58	WPAS	0	w/o N rep	2989
390	22	36.37	-94.51	18	Nixa	0.06	36.58	WPAS	0	w/o N rep	920
391	22	36.37	-94.51	18	Tonti	0.06	36.58	WPAS	1	w/o N rep	1198
392	22	36.37	-94.51	14	Peridge	0.06	36.58	WPAS	0	w/o N rep	821
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAST	4	w alum;	2252
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAST	4	w alum;	7445
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAST	4	w alum;	3024
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAST	6	w alum;	3468
399	22	36.37	-94.51	25	Captina	0.05	36.58	HAST	4	w alum;	3109
400	22	36.37	-94.51	7	Nixa	0.05	36.58	HAST	4	w alum;	577
401	22	36.37	-94.51	9	Tonti	0.05	36.58	HAST	6	w alum;	1059
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	w/o N rep	780
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	w/o N rep	339
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	w/o N rep	328
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	w/o N rep	396
409	23	36.36	-94.55	5	Captina	0.05	24.39	WPAS	0	w/o N rep	326
410	23	36.36	-94.55	10	Peridge	0.05	24.39	WPAS	0	w/o N rep	575

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAST	4	w alum;	252
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAST	4	w alum;	299
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAST	4	w alum;	301
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAST	4	w alum;	632
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	1	w/o N rep	9226
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	w/o N rep	7499
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	w/o N rep	24150
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	w/o N rep	13787
425	24	36.34	-94.49	46	Captina	0.05	60.98	WPAS	0	w/o N rep	2753
426	24	36.34	-94.49	78	Nixa	0.05	60.98	WPAS	0	w/o N rep	3930
427	24	36.34	-94.49	28	Secesh	0.05	60.98	WPAS	1	w/o N rep	1622
428	24	36.34	-94.49	28	Peridge	0.05	60.98	WPAS	0	w/o N rep	1639
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAST	4	w alum;	5512
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAST	4	w alum;	7449
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAST	4	w alum;	15745
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAST	4	w alum;	7089
435	24	36.34	-94.49	52	Captina	0.04	60.98	HAST	4	w alum;	6349
436	24	36.34	-94.49	33	Nixa	0.04	60.98	HAST	4	w alum;	2730
437	24	36.34	-94.49	31	Peridge	0.04	60.98	HAST	4	w alum;	3820
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0	w/o N rep	724
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0	w/o N rep	125
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	w/o N rep	-168
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAST	4.8	w alum;	273
446	25	36.37	-94.87	2	Water	0.11	24.39	HAST	0	w/o N rep	-60
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0	w/o N rep	104
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0	w/o N rep	58
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	w/o N rep	-76
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAST	4.8	w alum;	275
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAST	4.8	w alum;	142
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAST	4.8		136
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0	w/o N rep	197
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	1	w/o N rep	77
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAST	4.8	w alum;	1062
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	1	w/o N rep	6030
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	w/o N rep	18309
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	1	w/o N rep	10511
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	WPAS	1	w/o N rep	655
475	29	36.34	-94.36	68	Nixa	0.06	60.98	WPAS	0	w/o N rep	3279
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAST	6	w alum;	4147
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAST	6	w alum;	12496
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAST	6	w alum;	6637
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	HAST	6	w alum;	454
482	29	36.34	-94.36	28	Nixa	0.06	60.98	HAST	6	w alum;	2390
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	1	w/o N rep	6191
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	w/o N rep	13739
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	WPAS	1	w/o N rep	225
489	30	36.33	-94.39	4	Captina	0.08	36.58	WPAS	0	w/o N rep	241
490	30	36.33	-94.39	9	Nixa	0.08	36.58	WPAS	0	w/o N rep	465
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAST	4.8	w alum;	1043
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAST	4.8	w alum;	4021
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0	w/o N rep	365
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0	w/o N rep	554
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	1	w/o N rep	264
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0	w/o N rep	799

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	WPAS	0	w/o N rep	401
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	WPAS	0	w/o N rep	138
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAST	4	w N rep	391
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAST	4.8	w alum;	827
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAST	4.8		585
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAST	4	w N rep	744
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0	w/o N rep	922
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0	w/o N rep	1572
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0	w/o N rep	1823
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	WPAS	0	w/o N rep	520
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	WPAS	0	w/o N rep	187
516	32	36.35	-94.77	7	Britwater	0.05	18.29	WPAS	0	w/o N rep	415
517	32	36.35	-94.77	4	Healing	0.05	18.29	WPAS	0	w/o N rep	293
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAST	4	w N rep	796
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAST	4.8	w alum;	1082
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAST	4	w N rep	3327
523	32	36.35	-94.77	6	Razort	0.03	18.29	HAST	4	w N rep	939
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	HAST	4.8		241
525	32	36.35	-94.77	4	Britwater	0.03	18.29	HAST	4.8		565
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0	w/o N rep	1314
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0	w/o N rep	248
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-188
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	WPAS	0	w/o N rep	517
536	33	36.35	-94.82	3	Britwater	0.11	24.39	WPAS	0	w/o N rep	193
537	33	36.35	-94.82	2	Taloka	0.11	24.39	WPAS	0	w/o N rep	131
538	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	w/o N rep	-186
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAST	4.8	w alum;	2325
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAST	4.8	w alum;	844
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAST	4.8	w alum;	665
543	33	36.35	-94.82	6	Water	0.11	24.39	HAST	0	w/o N rep	-231
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0	w/o N rep	1282
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0	w/o N rep	1460
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAST	4	w N rep	521
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAST	4	w alum;	1520
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0	w/o N rep	4978
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	1	w/o N rep	5604
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0	w/o N rep	4187
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0	w/o N rep	2564
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	1	w/o N rep	2678
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0	w/o N rep	4017
563	35	36.32	-94.71	23	Razort	0.07	18.29	WPAS	0	w/o N rep	1647
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1736
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	WPAS	0	w/o N rep	813
566	35	36.32	-94.71	20	Britwater	0.07	18.29	WPAS	0	w/o N rep	1166
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	WPAS	1	w/o N rep	1000
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	WPAS	0	w/o N rep	1061
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAST	4	w N rep	6460
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAST	4.8	w alum;	11909
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAST	4.8	w alum;	5818
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAST	4.8		5304
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAST	4.8	w alum;	7726
577	35	36.32	-94.71	6	Razort	0.04	18.29	HAST	4	w N rep	990
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	HAST	4.8		2110
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	HAST	4.8	w alum;	936

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
580	35	36.32	-94.71	7	Britwater	0.04	18.29	HAST	6	w alum;	1079
581	35	36.32	-94.71	5	Elsah	0.04	18.29	HAST	6		661
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0	w/o N rep	13
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	1	w/o N rep	49
587	36	36.34	-94.76	5	Britwater	0.05	60.98	WPAS	0	w/o N rep	283
588	36	36.34	-94.76	2	Elsah	0.05	60.98	WPAS	1	w/o N rep	123
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAST	4	w N rep	398
593	36	36.34	-94.76	2	Razort	0.02	60.98	HAST	4	w N rep	372
594	36	36.34	-94.76	7	Britwater	0.02	60.98	HAST	4.8	w alum;	903
595	36	36.34	-94.76	6	Elsah	0.02	60.98	HAST	4.8		700
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	1	w/o N rep	1939
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	w/o N rep	3130
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	w/o N rep	2011
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	WPAS	1	w/o N rep	193
603	37	36.36	-94.59	11	Captina	0.06	24.39	WPAS	0	w/o N rep	632
604	37	36.36	-94.59	4	Taloka	0.06	24.39	WPAS	0	w/o N rep	196
605	37	36.36	-94.59	3	Nixa	0.06	24.39	WPAS	0	w/o N rep	177
606	37	36.36	-94.59	6	Peridge	0.06	24.39	WPAS	0	w/o N rep	342
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAST	4	w alum;	721
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAST	4	w alum;	753
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAST	4	w alum;	2000
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAST	4	w alum;	592
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	HAST	4	w alum;	398
613	37	36.36	-94.59	6	Captina	0.05	24.39	HAST	4	w N rep	776
614	37	36.36	-94.59	3	Nixa	0.05	24.39	HAST	4	w alum;	205
615	37	36.36	-94.59	2	Peridge	0.05	24.39	HAST	4	w N rep	271
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	1	w/o N rep	12426
620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	w/o N rep	26903
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	w/o N rep	15821
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	1	w/o N rep	22320
623	38	36.32	-94.53	128	Captina	0.05	60.98	WPAS	0	w/o N rep	7605
624	38	36.32	-94.53	45	Nixa	0.05	60.98	WPAS	0	w/o N rep	2251
625	38	36.32	-94.53	60	Tonti	0.05	60.98	WPAS	1	w/o N rep	3933
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAST	4	w alum;	6319
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAST	4	w alum;	13198
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAST	4	w alum;	10038
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAST	6	w alum;	10482
632	38	36.32	-94.53	80	Captina	0.03	60.98	HAST	4	w alum;	9944
633	38	36.32	-94.53	31	Nixa	0.03	60.98	HAST	4	w alum;	2567
634	38	36.32	-94.53	45	Tonti	0.03	60.98	HAST	6	w alum;	5354
635	38	36.32	-94.53	46	Peridge	0.03	60.98	HAST	4	w alum;	5704
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1253
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	w/o N rep	913
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	w/o N rep	5561
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	WPAS	1	w/o N rep	422
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	WPAS	0	w/o N rep	310
646	41	36.33	-94.65	3	Captina	0.07	24.39	WPAS	0	w/o N rep	175
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAST	4.8	w alum;	3335
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAST	4.8	w alum;	1806
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAST	6	w alum;	2509
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	w/o N rep	4923
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	1	w/o N rep	5557
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2621
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	w/o N rep	3040

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	1	w/o N rep	2651
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	w/o N rep	2942
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	WPAS	0	w/o N rep	569
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	WPAS	0	w/o N rep	1478
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	WPAS	0	w/o N rep	1233
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAST	4.8	w alum;	4823
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAST	4.8	w alum;	3415
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAST	4.8		6305
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAST	4.8	w alum;	5387
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	HAST	4.8	w alum;	602
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	HAST	4.8	w alum;	1038
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	HAST	4.8		688
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	HAST	4.8	w alum;	1701
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	1	w/o N rep	4911
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4307
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	w/o N rep	5642
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	w/o N rep	11768
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	WPAS	0	w/o N rep	4663
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	WPAS	0	w/o N rep	4942
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	WPAS	0	w/o N rep	3457
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAST	4.8	w alum;	5657
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAST	4.8	w alum;	7241
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAST	4.8	w alum;	5378
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAST	4.8	w alum;	8875
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAST	4.8	w alum;	5167
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAST	4.8		8619
694	43	36.36	-94.65	99	Taloka	0.01	60.98	HAST	4.8	w alum;	13113
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	HAST	4.8		21930
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	w/o N rep	3797
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	w/o N rep	2836
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	w/o N rep	3309
703	44	36.3	-94.68	17	Captina	0.04	60.98	WPAS	0	w/o N rep	1012
704	44	36.3	-94.68	18	Taloka	0.04	60.98	WPAS	0	w/o N rep	1178
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	WPAS	0	w/o N rep	1036
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAST	6	w alum;	1895
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAST	4.8	w alum;	2058
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAST	4.8	w alum;	3139
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAST	4.8		2841
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAST	4.8	w alum;	4681
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	HAST	4.8	w alum;	664
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	HAST	4.8	w alum;	1079
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	HAST	4.8	w alum;	353
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	1	w/o N rep	9597
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	1	w/o N rep	5375
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	1	w/o N rep	5277
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	WPAS	1	w/o N rep	4058
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	WPAS	1	w/o N rep	3184
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAST	6	w alum;	6145
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAST	6		23853
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAST	6	w alum;	12579
733	45	36.28	-94.67	10	Captina	0.02	91.46	HAST	6		1570
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	HAST	6		2362
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	HAST	6	w alum;	4782
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	1	w/o N rep	15840

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	w/o N rep	16795
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	1	w alum; w/o N rep	24279
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	WPAS	1	w/o N rep	2101
745	46	36.29	-94.61	75	Captina	0.03	60.98	WPAS	0	w/o N rep	4522
746	46	36.29	-94.61	30	Tonti	0.03	60.98	WPAS	1	w/o N rep	1738
747	46	36.29	-94.61	37	Taloka	0.03	60.98	WPAS	1	w alum; w/o N rep	1938
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAST	4.8	w alum;	13546
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAST	4.8	w alum;	26592
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAST	4.8	w alum;	10957
755	46	36.29	-94.61	41	Captina	0.02	60.98	HAST	4.8		6052
756	46	36.29	-94.61	31	Taloka	0.02	60.98	HAST	4.8	w alum;	4343
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0	w/o N rep	3236
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0	w/o N rep	9245
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0	w/o N rep	2861
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	WPAS	0	w/o N rep	1751
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	WPAS	0	w/o N rep	1019
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	WPAS	0	w/o N rep	341
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAST	4	w N rep	3824
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAST	4.8	w alum;	15652
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAST	4.8	w alum;	6460
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	w/o N rep	3379
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	w/o N rep	13968
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	w/o N rep	2799
776	48	36.4	-94.79	23	Razort	0.11	24.39	WPAS	0	w/o N rep	1626
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	WPAS	0	w/o N rep	4622
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	WPAS	0	w/o N rep	3055
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAST	4	w alum;	5995
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAST	4	w alum;	19368
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAST	4	w alum;	5573
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAST	4	w alum;	4397
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	HAST	4	w alum;	2021
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	HAST	4	w alum;	1156
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	w/o N rep	24146
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	w/o N rep	8323
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	w/o N rep	11741
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	WPAS	0	w/o N rep	4750
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	WPAS	0	w/o N rep	2811
795	49	36.37	-94.73	45	Taloka	0.07	36.58	WPAS	0	w/o N rep	2835
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	WPAS	0	w/o N rep	2140
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	WPAS	0	w/o N rep	4111
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAST	4.8	w alum;	32717
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAST	4.8	w alum;	13186
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAST	4.8	w alum;	26198
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	HAST	4.8	w alum;	3404
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	HAST	4.8	w alum;	1378
805	49	36.37	-94.73	12	Taloka	0.06	36.58	HAST	4	w alum;	1669
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	HAST	4.8		1430
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	HAST	4.8	w alum;	2081
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0	w/o N rep	11371
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0	w/o N rep	28500
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0	w/o N rep	9505
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	WPAS	0	w/o N rep	11183
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	WPAS	0	w/o N rep	5683
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	WPAS	0	w/o N rep	4631

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAST	4	w N rep	17839
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAST	4.8	w alum;	39075
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAST	4.8		17685
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAST	4.8		14005
821	50	36.27	-94.81	15	Razort	0.09	24.39	HAST	4	w N rep	2286
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	HAST	4.8		8414
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	HAST	4.8		4005
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0	w/o N rep	90
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0	w/o N rep	16
830	51	36.35	-94.75	0	Razort	0.06	15.24	WPAS	0	w/o N rep	26
831	51	36.35	-94.75	1	Elsah	0.06	15.24	WPAS	1	w/o N rep	53
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAST	4	w N rep	161
835	51	36.35	-94.75	1	Razort	0.01	15.24	HAST	4	w N rep	217
836	51	36.35	-94.75	1	Britwater	0.01	15.24	HAST	4.8	w alum;	87
837	51	36.35	-94.75	1	Elsah	0.01	15.24	HAST	4.8		164
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0	w/o N rep	133
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	1	w/o N rep	143
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	w/o N rep	322
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	WPAS	0	w/o N rep	266
849	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	w/o N rep	320
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAST	4.8		184
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAST	4.8	w alum;	661
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAST	6	w alum;	247
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAST	4.8		254
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	HAST	4.8		111
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	1	w/o N rep	1334
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	w/o N rep	2491
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	w/o N rep	1139
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	w/o N rep	2816
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	WPAS	1	w/o N rep	430
869	53	36.35	-94.57	4	Britwater	0.07	24.39	WPAS	1	w/o N rep	199
870	53	36.35	-94.57	6	Waben	0.07	24.39	WPAS	0	w/o N rep	386
871	53	36.35	-94.57	7	Peridge	0.07	24.39	WPAS	0	w/o N rep	386
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAST	4	w alum;	1872
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAST	4	w alum;	1350
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAST	4.8		663
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAST	4	w alum;	1224
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	HAST	4	w alum;	718
880	53	36.35	-94.57	8	Nixa	0.12	24.39	HAST	4	w alum;	641
883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	w/o N rep	1774
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	w/o N rep	1746
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	w/o N rep	1285
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	w/o N rep	5162
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	WPAS	0	w/o N rep	2482
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAST	4	w alum;	1576
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAST	4	w N rep	10448
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	HAST	4	w N rep	729
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	1	w/o N rep	30551
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	0	w/o N rep	18921
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	1	w/o N rep	31266
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	WPAS	1	w/o N rep	7825
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	WPAS	1	w/o N rep	26630
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAST	4.8	w alum;	50705
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAST	4.8	w alum;	30600

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAST	4.8		116400
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	HAST	4.8	w alum;	3197
911	55	36.27	-94.74	31	Captina	0.04	60.98	HAST	4.8		4773
912	55	36.27	-94.74	40	Britwater	0.04	60.98	HAST	6	w alum;	5941
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	HAST	6		11560
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	w/o N rep	28
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	w/o N rep	23
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAST	0	w/o N rep	3
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAST	0	w/o N rep	1
925	56	36.38	-94.44	0	Water	0.08	60.98	HAST	0	w/o N rep	-7
926	56	36.38	-94.44	0	Elsah	0.09	60.98	HAST	0	w/o N rep	3
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	1	w/o N rep	2580
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0	w/o N rep	6539
929	57	36.39	-94.94	4	Razort	0.09	18.29	WPAS	0	w/o N rep	268
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	WPAS	1	w/o N rep	210
931	57	36.39	-94.94	27	Britwater	0.09	18.29	WPAS	0	w/o N rep	1550
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAST	3.4	w alum; w/o N rep	2964
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAST	3.4	w alum; w/o N rep	7831
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAST	3.4	w/o N rep	2857
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0	w/o N rep	21
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0	w/o N rep	44
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0	w/o N rep	28
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0	w/o N rep	149
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0	w/o N rep	243
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0	w/o N rep	142
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0	w/o N rep	407
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	w/o N rep	107
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0	w/o N rep	127
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	w/o N rep	114
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	WPAS	0	w/o N rep	23
954	60	36.37	-94.81	0	Water	0.10	18.29	WPAS	0	w/o N rep	-15
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAST	4.8	w alum;	821
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAST	4.8	w alum;	201
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0	w/o N rep	298
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	1	w/o N rep	62
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0	w/o N rep	186
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAST	4.8	w alum;	286
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAST	4.8		206
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	0	w/o N rep	4680
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0	w/o N rep	5683
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2488
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	WPAS	0	w/o N rep	1103
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	WPAS	0	w/o N rep	1977
973	62	36.33	-94.8	45	Doniphan	0.05	36.58	WPAS	0	w/o N rep	2409
974	62	36.33	-94.8	18	Jay	0.05	36.58	WPAS	0	w/o N rep	1156
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAST	4.8		6572
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAST	4.8		13714
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAST	4.8		13075
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	HAST	4.8		637
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	HAST	4.8		1224
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	HAST	4.8		1707
984	62	36.33	-94.8	17	Jay	0.03	36.58	HAST	4	w alum;	2277
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0	w/o N rep	341
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0	w/o N rep	349

HRU ID	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU shadow price ($)
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0	w/o N rep	165
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAST	4	w N rep	544
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAST	4.8		646
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAST	4.8	w alum;	599
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0	w/o N rep	498
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0	w/o N rep	880
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0	w/o N rep	939
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAST	4	w N rep	781
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAST	4	w N rep	1026
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAST	4	w alum;	615
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAST	0	w/o N rep	-86
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1020
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	1	w/o N rep	1286
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	1	w/o N rep	1486
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0	w/o N rep	579
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAST	3.4	w/o N rep	787
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAST	3.4	w/o N rep	1014
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAST	3.4	w alum; w/o N rep	511
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0	w/o N rep	293
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	1	w/o N rep	1510
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	1	w/o N rep	16025
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	w/o N rep	11395
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	w/o N rep	11911
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	1	w/o N rep	10466
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	WPAS	0	w/o N rep	2063
1026	68	36.33	-94.61	33	Captina	0.05	36.58	WPAS	0	w/o N rep	1970
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	WPAS	1	w/o N rep	1519
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	WPAS	1	w/o N rep	1492
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAST	4	w alum;	11055
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAST	4	w alum;	13632
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAST	4	w alum;	8879
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAST	6	w alum;	8093
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	HAST	4	w alum;	1301
1037	68	36.33	-94.61	24	Captina	0.04	36.58	HAST	4	w N rep	2851
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	HAST	6		3679
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	w/o N rep	669
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	w/o N rep	455
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	w/o N rep	892
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	w/o N rep	1490
1043	69	36.35	-95.01	7	Captina	0.06	24.39	WPAS	0	w/o N rep	395
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	WPAS	0	w/o N rep	228
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	WPAS	0	w/o N rep	206
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAST	3.4	w alum; w/o N rep	812
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAST	3.4	w alum; w/o N rep	281
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAST	3.4	w alum; w/o N rep	175
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAST	3.4	w/o N rep	295
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAST	3.4	w alum; w/o N rep	478

Table A.2.7. Spatial Detail for the Optimal Solution for Policy 4.

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
5	1	36.44	-94.67	53	Razort	0.07	60.98	WPAS	0	0.00	w/o N rep	3805
6	1	36.44	-94.67	123	Clarksville	0.07	60.98	WPAS	0	0.00	w/o N rep	7009
7	1	36.44	-94.67	49	Captina	0.07	60.98	WPAS	0	0.00	w/o N rep	2914
8	1	36.44	-94.67	44	Doniphan	0.07	60.98	WPAS	0	0.00	w/o N rep	2270
9	1	36.44	-94.67	56	Clarksville	0.07	60.98	OPAS	1	0.00	w/o N rep	3212
10	1	36.44	-94.67	38	Clarksville	0.07	60.98	OPAS	1	0.00	w/o N rep	2083
11	1	36.44	-94.67	37	Captina	0.07	60.98	OPAS	1	0.00	w/o N rep	2170
12	1	36.44	-94.67	23	Doniphan	0.07	60.98	OPAS	1	0.54	w/o N rep	1210
13	1	36.44	-94.67	28	Macedonia	0.07	60.98	OPAS	1	0.00	w/o N rep	1454
17	1	36.44	-94.67	52	Razort	0.07	60.98	HAY	0	4.00	w N rep	7227
18	1	36.44	-94.67	117	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	13711
19	1	36.44	-94.67	47	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	5022
20	1	36.44	-94.67	51	Captina	0.07	60.98	HAY	0	4.00	w alum;	6528
21	1	36.44	-94.67	45	Taloka	0.07	60.98	HAY	0	4.00	w alum;	5480
22	1	36.44	-94.67	54	Doniphan	0.07	60.98	HAY	0	4.80	w alum;	6493
23	1	36.44	-94.67	3	Clarksville	0.05	60.98	WWHT	0	0.33	w/o N rep	361
24	1	36.44	-94.67	12	Captina	0.05	60.98	WWHT	1	1.30	w N rep	1688
25	1	36.44	-94.67	5	Taloka	0.05	60.98	WWHT	0	0.00	w N rep	733
30	2	36.43	-94.7	290	Clarksville	0.04	60.98	WPAS	0	0.00	w/o N rep	16788
31	2	36.43	-94.7	158	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	9493
32	2	36.43	-94.7	186	Doniphan	0.04	60.98	WPAS	0	1.00	w/o N rep	9869
33	2	36.43	-94.7	184	Taloka	0.04	60.98	WPAS	0	0.00	w/o N rep	9444
34	2	36.43	-94.7	159	Clarksville	0.04	60.98	OPAS	1	0.00	w/o N rep	9196
35	2	36.43	-94.7	136	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	8186
36	2	36.43	-94.7	91	Taloka	0.04	60.98	OPAS	1	0.00	w/o N rep	5853
37	2	36.43	-94.7	154	Doniphan	0.04	60.98	OPAS	1	0.54	w/o N rep	8192
38	2	36.43	-94.7	112	Macedonia	0.04	60.98	OPAS	1	0.00	w/o N rep	5844
43	2	36.43	-94.7	343	Clarksville	0.04	60.98	HAY	0	4.80	w alum;	41734
44	2	36.43	-94.7	314	Captina	0.04	60.98	HAY	0	4.80	w alum;	42184
45	2	36.43	-94.7	373	Doniphan	0.04	60.98	HAY	0	4.80	w alum;	46674
46	2	36.43	-94.7	38	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	4806
47	2	36.43	-94.7	58	Captina	0.03	60.98	WWHT	1	1.56	w alum;	8043
48	2	36.43	-94.7	75	Doniphan	0.03	60.98	WWHT	1	1.56	w alum;	9422
49	2	36.43	-94.7	39	Taloka	0.03	60.98	WWHT	1	1.56	w alum;	4872
56	3	36.42	-94.67	186	Captina	0.02	91.46	WPAS	0	0.00	w/o N rep	10972
57	3	36.42	-94.67	366	Jay	0.02	91.46	WPAS	0	0.00	w/o N rep	21740
58	3	36.42	-94.67	256	Newtonia	0.02	91.46	WPAS	0	1.00	w/o N rep	14297
59	3	36.42	-94.67	324	Nixa	0.02	91.46	WPAS	0	0.00	w/o N rep	15658
60	3	36.42	-94.67	176	Peridge	0.02	91.46	WPAS	0	0.00	w/o N rep	10310
61	3	36.42	-94.67	48	Captina	0.02	91.46	OPAS	1	0.00	w/o N rep	2867
62	3	36.42	-94.67	61	Newtonia	0.02	91.46	OPAS	1	0.54	w/o N rep	3388
63	3	36.42	-94.67	88	Nixa	0.02	91.46	OPAS	1	0.00	w/o N rep	4250
64	3	36.42	-94.67	44	Peridge	0.02	91.46	OPAS	1	0.00	w/o N rep	2592
67	3	36.42	-94.67	166	Captina	0.02	91.46	HAY	0	4.00	w alum;	19946
68	3	36.42	-94.67	116	Jay	0.02	91.46	HAY	0	3.40	w alum; w/o N rep	13260
69	3	36.42	-94.67	226	Nixa	0.02	91.46	HAY	0	4.00	w alum;	16908
70	3	36.42	-94.67	88	Peridge	0.02	91.46	HAY	0	4.00	w alum;	10647
71	3	36.42	-94.67	28	Captina	0.02	91.46	WWHT	0	0.00	w N rep	4485
72	3	36.42	-94.67	23	Jay	0.02	91.46	WWHT	0	0.00	w N rep	3489
73	3	36.42	-94.67	28	Newtonia	0.02	91.46	WWHT	0	0.00	w N rep	5162
74	3	36.42	-94.67	15	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	5609
82	4	36.4	-94.57	292	Taloka	0.02	121.95	WPAS	0	1.00	w alum; w/o N rep	14431
83	4	36.4	-94.57	377	Newtonia	0.02	121.95	WPAS	0	1.00	w/o N rep	21253
84	4	36.4	-94.57	174	Nixa	0.02	121.95	WPAS	0	0.00	w/o N rep	8458
85	4	36.4	-94.57	46	Captina	0.02	121.95	OPAS	1	0.00	w/o N rep	2768
86	4	36.4	-94.57	30	Jay	0.02	121.95	OPAS	1	0.00	w/o N rep	1821
87	4	36.4	-94.57	56	Newtonia	0.02	121.95	OPAS	1	0.54	w/o N rep	3184

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
88	4	36.4	-94.57	34	Nixa	0.02	121.95	OPAS	1	0.00	w/o N rep	1610
91	4	36.4	-94.57	144	Captina	0.02	121.95	HAY	0	4.00	w alum;	17294
92	4	36.4	-94.57	130	Newtonia	0.02	121.95	HAY	0	4.80	w alum;	15922
93	4	36.4	-94.57	151	Nixa	0.02	121.95	HAY	0	4.00	w alum;	11411
94	4	36.4	-94.57	84	Tonti	0.02	121.95	HAY	0	6.00	w alum;	9619
95	4	36.4	-94.57	13	Captina	0.02	121.95	WWHT	0	0.00	w N rep	1779
96	4	36.4	-94.57	15	Newtonia	0.02	121.95	WWHT	0	0.00	w N rep	2036
97	4	36.4	-94.57	13	Nixa	0.02	121.95	WWHT	0	1.95		2560
98	4	36.4	-94.57	22	Peridge	0.02	121.95	WWHT	0	0.00	w N rep	3972
101	5	36.41	-94.63	0	Britwater	0.03	36.58	WPAS	0	0.00	w/o N rep	10
102	5	36.41	-94.63	0	Razort	0.03	36.58	OPAS	1	0.00	w/o N rep	6
105	5	36.41	-94.63	1	Razort	0.04	36.58	WWHT	0	1.11	w alum; w/o N rep	297
112	6	36.38	-94.61	227	Taloka	0.01	121.95	WPAS	0	0.00	w/o N rep	11553
113	6	36.38	-94.61	345	Newtonia	0.01	121.95	WPAS	0	0.00	w/o N rep	19562
114	6	36.38	-94.61	30	Taloka	0.01	121.95	OPAS	1	0.00	w/o N rep	1519
115	6	36.38	-94.61	125	Newtonia	0.01	121.95	OPAS	1	0.54	w/o N rep	7112
119	6	36.38	-94.61	59	Taloka	0.01	121.95	HAY	0	4.00	w alum;	6487
120	6	36.38	-94.61	142	Newtonia	0.01	121.95	HAY	0	4.00	w N rep	17121
121	6	36.38	-94.61	69	Taloka	0.01	121.95	WWHT	0	0.00	w N rep	15643
122	6	36.38	-94.61	63	Newtonia	0.01	121.95	WWHT	0	0.00	w N rep	10119
126	7	36.4	-94.31	299	Captina	0.03	91.46	WPAS	0	1.00	w alum; w/o N rep	17326
127	7	36.4	-94.31	155	Nixa	0.03	91.46	WPAS	0	0.00	w/o N rep	7498
128	7	36.4	-94.31	199	Tonti	0.03	91.46	WPAS	0	1.00	w/o N rep	12673
129	7	36.4	-94.31	103	Noark	0.03	91.46	WPAS	0	0.00	w/o N rep	5912
130	7	36.4	-94.31	55	Captina	0.03	91.46	OPAS	1	0.54	w/o N rep	3207
131	7	36.4	-94.31	18	Nixa	0.03	91.46	OPAS	1	0.00	w/o N rep	879
132	7	36.4	-94.31	21	Tonti	0.03	91.46	OPAS	1	0.54	w/o N rep	1358
137	7	36.4	-94.31	143	Captina	0.03	91.46	HAY	0	6.00	w alum;	19089
138	7	36.4	-94.31	32	Nixa	0.03	91.46	HAY	0	4.80	w alum;	2699
139	7	36.4	-94.31	73	Tonti	0.03	91.46	HAY	0	6.00	w alum;	9235
140	7	36.4	-94.31	21	Captina	0.02	91.46	WWHT	0	0.00	w N rep	3668
141	7	36.4	-94.31	7	Nixa	0.02	91.46	WWHT	0	1.95		1530
142	7	36.4	-94.31	13	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	4282
146	8	36.37	-94.33	184	Captina	0.03	91.46	WPAS	0	1.00	w alum; w/o N rep	10835
147	8	36.37	-94.33	131	Nixa	0.03	91.46	WPAS	0	0.00	w/o N rep	6307
148	8	36.37	-94.33	230	Tonti	0.03	91.46	WPAS	0	1.00	w/o N rep	14866
149	8	36.37	-94.33	65	Captina	0.03	91.46	OPAS	1	0.54	w/o N rep	3812
150	8	36.37	-94.33	24	Nixa	0.03	91.46	OPAS	1	0.00	w/o N rep	1136
151	8	36.37	-94.33	32	Tonti	0.03	91.46	OPAS	1	0.54	w/o N rep	2049
157	8	36.37	-94.33	58	Captina	0.03	91.46	HAY	0	6.00	w alum;	8041
158	8	36.37	-94.33	41	Nixa	0.03	91.46	HAY	0	6.00	w alum;	3630
159	8	36.37	-94.33	69	Tonti	0.03	91.46	HAY	0	6.00	w alum;	8836
160	8	36.37	-94.33	39	Captina	0.02	91.46	WWHT	0	0.00	w N rep	6459
161	8	36.37	-94.33	9	Taloka	0.02	91.46	WWHT	0	0.00	w N rep	1785
162	8	36.37	-94.33	21	Tonti	0.02	91.46	WWHT	0	1.95	w alum;	7032
166	9	36.4	-94.37	728	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	36577
167	9	36.4	-94.37	226	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	15246
168	9	36.4	-94.37	231	Noark	0.05	60.98	WPAS	0	0.00	w/o N rep	13727
169	9	36.4	-94.37	61	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	3576
170	9	36.4	-94.37	149	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	7482
171	9	36.4	-94.37	82	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	5534
175	9	36.4	-94.37	128	Captina	0.05	60.98	HAY	0	4.80	w alum;	16376
176	9	36.4	-94.37	407	Nixa	0.05	60.98	HAY	0	4.80	w alum;	36909
177	9	36.4	-94.37	201	Tonti	0.05	60.98	HAY	0	6.00	w alum;	26408
178	9	36.4	-94.37	26	Captina	0.04	60.98	WWHT	0	0.00	w N rep	4028
179	9	36.4	-94.37	60	Nixa	0.04	60.98	WWHT	0	1.95		12981
180	9	36.4	-94.37	12	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	4427
184	10	36.37	-94.41	63	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	3432

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
185	10	36.37	-94.41	123	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	6166
186	10	36.37	-94.41	77	Secesh	0.06	60.98	WPAS	0	1.00	w/o N rep	4440
187	10	36.37	-94.41	57	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	3831
188	10	36.37	-94.41	11	Britwater	0.06	60.98	OPAS	1	0.54	w alum; w/o N rep	636
189	10	36.37	-94.41	33	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	1640
190	10	36.37	-94.41	9	Tonti	0.06	60.98	OPAS	1	0.54	w/o N rep	634
191	10	36.37	-94.41	17	Peridge	0.06	60.98	OPAS	1	0.00	w/o N rep	1003
195	10	36.37	-94.41	47	Britwater	0.06	60.98	HAY	0	4.80	w alum;	5682
196	10	36.37	-94.41	98	Nixa	0.06	60.98	HAY	0	4.00	w alum;	8635
197	10	36.37	-94.41	48	Tonti	0.06	60.98	HAY	0	6.00	w alum;	6137
198	10	36.37	-94.41	5	Britwater	0.06	60.98	WWHT	1	1.56	w alum;	564
199	10	36.37	-94.41	10	Nixa	0.06	60.98	WWHT	0	1.95		1686
200	10	36.37	-94.41	5	Tonti	0.06	60.98	WWHT	0	1.95	w alum;	1600
203	11	36.4	-94.99	19	Razort	0.10	24.39	WPAS	0	0.00	w/o N rep	1322
204	11	36.4	-94.99	35	Clarksville	0.10	24.39	WPAS	0	1.00	w/o N rep	1908
205	11	36.4	-94.99	24	Water	0.10	24.39	WPAS	0	0.00	w/o N rep	-938
206	11	36.4	-94.99	3	Razort	0.10	24.39	OPAS	1	0.00	w/o N rep	200
207	11	36.4	-94.99	20	Clarksville	0.10	24.39	OPAS	1	0.54	w/o N rep	1097
209	11	36.4	-94.99	11	Razort	0.10	24.39	HAY	0	3.40	w alum; w/o N rep	1458
210	11	36.4	-94.99	25	Clarksville	0.10	24.39	HAY	0	3.40	w alum; w/o N rep	2780
219	13	36.41	-94.66	255	Razort	0.05	60.98	WPAS	0	0.00	w/o N rep	18081
220	13	36.41	-94.66	325	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	18412
221	13	36.41	-94.66	164	Clarksville	0.05	60.98	WPAS	0	0.00	w/o N rep	8998
222	13	36.41	-94.66	152	Newtonia	0.05	60.98	WPAS	0	0.00	w/o N rep	8453
223	13	36.41	-94.66	71	Razort	0.05	60.98	OPAS	1	0.00	w/o N rep	5037
224	13	36.41	-94.66	50	Clarksville	0.05	60.98	OPAS	1	0.54	w/o N rep	2827
225	13	36.41	-94.66	62	Clarksville	0.05	60.98	OPAS	1	0.00	w/o N rep	3413
226	13	36.41	-94.66	59	Doniphan	0.05	60.98	OPAS	1	0.54	w/o N rep	3109
227	13	36.41	-94.66	96	Newtonia	0.05	60.98	OPAS	1	0.00	w/o N rep	5331
232	13	36.41	-94.66	114	Razort	0.05	60.98	HAY	0	4.80	w alum;	16848
233	13	36.41	-94.66	148	Clarksville	0.05	60.98	HAY	0	4.80	w alum;	18705
234	13	36.41	-94.66	109	Clarksville	0.05	60.98	HAY	0	4.80	w alum;	12867
235	13	36.41	-94.66	112	Doniphan	0.05	60.98	HAY	0	4.80	w alum;	14504
236	13	36.41	-94.66	119	Newtonia	0.05	60.98	HAY	0	4.80	w alum;	16472
237	13	36.41	-94.66	27	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	3538
238	13	36.41	-94.66	22	Clarksville	0.03	60.98	WWHT	0	0.33	w/o N rep	3072
239	13	36.41	-94.66	26	Doniphan	0.03	60.98	WWHT	1	1.56	w alum;	3439
240	13	36.41	-94.66	62	Newtonia	0.03	60.98	WWHT	1	1.56		8806
241	13	36.41	-94.66	25	Clarksville	0.03	60.98	WWHT	1	1.56	w alum;	3252
246	14	36.37	-94.66	40	Clarksville	0.03	91.46	WPAS	0	1.00	w/o N rep	2334
247	14	36.37	-94.66	95	Macedonia	0.03	91.46	WPAS	0	0.00	w/o N rep	5012
248	14	36.37	-94.66	51	Jay	0.03	91.46	WPAS	0	0.00	w/o N rep	3177
249	14	36.37	-94.66	74	Newtonia	0.03	91.46	WPAS	0	0.00	w/o N rep	4263
250	14	36.37	-94.66	33	Doniphan	0.03	91.46	OPAS	1	0.54	w/o N rep	1721
251	14	36.37	-94.66	42	Macedonia	0.03	91.46	OPAS	1	0.00	w/o N rep	2235
252	14	36.37	-94.66	71	Newtonia	0.03	91.46	OPAS	1	0.00	w/o N rep	4056
257	14	36.37	-94.66	70	Macedonia	0.03	91.46	HAY	0	4.80	w alum;	9064
258	14	36.37	-94.66	67	Jay	0.03	91.46	HAY	0	4.00	w alum;	8864
259	14	36.37	-94.66	115	Newtonia	0.03	91.46	HAY	0	4.80		16324
260	14	36.37	-94.66	14	Clarksville	0.02	91.46	WWHT	0	1.11	w alum; w/o N rep	1878
261	14	36.37	-94.66	48	Macedonia	0.02	91.46	WWHT	1	1.56	w alum;	6315
262	14	36.37	-94.66	19	Newtonia	0.02	91.46	WWHT	1	1.56		2747
267	15	34.4	-94.44	110	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	5542
268	15	34.4	-94.44	183	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	12229
269	15	34.4	-94.44	132	Noark	0.05	60.98	WPAS	0	0.00	w/o N rep	7930
270	15	34.4	-94.44	48	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	2908
271	15	34.4	-94.44	22	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	1115
272	15	34.4	-94.44	73	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	4902

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
276	15	34.4	-94.44	57	Captina	0.05	60.98	HAY	0	4.80	w alum;	7245
277	15	34.4	-94.44	85	Nixa	0.05	60.98	HAY	0	4.00	w alum;	7306
278	15	34.4	-94.44	138	Tonti	0.05	60.98	HAY	0	6.00	w alum;	17272
279	15	34.4	-94.44	35	Noark	0.05	60.98	HAY	0	4.00	w alum;	3548
280	15	34.4	-94.44	14	Captina	0.04	60.98	WWHT	0	0.00	w N rep	1853
281	15	34.4	-94.44	11	Nixa	0.04	60.98	WWHT	0	1.95		2184
282	15	34.4	-94.44	13	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	4651
283	15	34.4	-94.44	13	Peridge	0.04	60.98	WWHT	0	0.00	w N rep	1980
287	16	36.35	-94.44	195	Clarksville	0.07	60.98	WPAS	0	1.00	w/o N rep	10623
288	16	36.35	-94.44	317	Nixa	0.07	60.98	WPAS	0	0.00	w/o N rep	15765
289	16	36.35	-94.44	271	Peridge	0.07	60.98	WPAS	0	0.00	w/o N rep	15205
290	16	36.35	-94.44	53	Nixa	0.07	60.98	OPAS	1	0.00	w/o N rep	2647
291	16	36.35	-94.44	80	Peridge	0.07	60.98	OPAS	1	0.00	w/o N rep	4547
295	16	36.35	-94.44	41	Clarksville	0.07	60.98	HAY	0	4.80	w alum;	4508
296	16	36.35	-94.44	37	Captina	0.07	60.98	HAY	0	4.80	w alum;	4470
297	16	36.35	-94.44	102	Nixa	0.07	60.98	HAY	0	4.00	w alum;	9116
298	16	36.35	-94.44	31	Peridge	0.07	60.98	HAY	0	4.80	w alum;	3865
299	16	36.35	-94.44	12	Captina	0.05	60.98	WWHT	0	0.00	w N rep	1601
300	16	36.35	-94.44	14	Newtonia	0.05	60.98	WWHT	0	0.00	w N rep	2209
301	16	36.35	-94.44	15	Nixa	0.05	60.98	WWHT	0	1.95		2771
302	16	36.35	-94.44	42	Peridge	0.05	60.98	WWHT	0	0.00	w N rep	6583
306	17	36.41	-94.48	50	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	2720
307	17	36.41	-94.48	59	Captina	0.06	60.98	WPAS	0	0.00	w/o N rep	3527
308	17	36.41	-94.48	109	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	5503
309	17	36.41	-94.48	105	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	6959
310	17	36.41	-94.48	51	Noark	0.06	60.98	WPAS	0	0.00	w/o N rep	3073
311	17	36.41	-94.48	12	Captina	0.06	60.98	OPAS	1	0.00	w/o N rep	708
312	17	36.41	-94.48	22	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	1086
313	17	36.41	-94.48	37	Tonti	0.06	60.98	OPAS	1	0.54	w/o N rep	2432
314	17	36.41	-94.48	18	Noark	0.06	60.98	OPAS	1	0.00	w/o N rep	1085
319	17	36.41	-94.48	51	Captina	0.06	60.98	HAY	0	4.00	w alum;	6301
320	17	36.41	-94.48	49	Nixa	0.06	60.98	HAY	0	4.00	w alum;	4080
321	17	36.41	-94.48	70	Tonti	0.06	60.98	HAY	0	6.00	w alum;	8428
322	17	36.41	-94.48	4	Captina	0.04	60.98	WWHT	0	0.00	w N rep	552
323	17	36.41	-94.48	12	Nixa	0.04	60.98	WWHT	0	1.95		2308
324	17	36.41	-94.48	8	Tonti	0.04	60.98	WWHT	0	1.95	w alum;	2772
327	18	36.39	-94.47	65	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	3500
328	18	36.39	-94.47	83	Captina	0.05	60.98	WPAS	0	1.00	w alum; w/o N rep	4916
329	18	36.39	-94.47	89	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	4511
330	18	36.39	-94.47	53	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	3581
331	18	36.39	-94.47	51	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	3005
332	18	36.39	-94.47	23	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	1148
333	18	36.39	-94.47	38	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	2577
337	18	36.39	-94.47	89	Captina	0.05	60.98	HAY	0	4.00	w alum;	11139
338	18	36.39	-94.47	53	Nixa	0.05	60.98	HAY	0	4.00	w alum;	4542
339	18	36.39	-94.47	65	Tonti	0.05	60.98	HAY	0	6.00	w alum;	8128
340	18	36.39	-94.47	10	Captina	0.03	60.98	WWHT	1	1.30	w alum;	1254
341	18	36.39	-94.47	6	Nixa	0.03	60.98	WWHT	0	1.95		1287
342	18	36.39	-94.47	10	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	3556
346	19	36.35	-94.92	34	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	1974
347	19	36.35	-94.92	19	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	1078
348	19	36.35	-94.92	12	Doniphan	0.06	24.39	WPAS	0	0.00	w/o N rep	659
349	19	36.35	-94.92	27	Tonti	0.06	24.39	WPAS	0	0.00	w/o N rep	1607
350	19	36.35	-94.92	22	Tonti	0.06	24.39	OPAS	1	0.00	w/o N rep	1279
354	19	36.35	-94.92	7	Razort	0.06	24.39	HAY	0	4.00	w N rep	1085
355	19	36.35	-94.92	11	Clarksville	0.06	24.39	HAY	0	4.00	w N rep	1360
356	19	36.35	-94.92	10	Clarksville	0.06	24.39	HAY	0	4.00	w N rep	1162
357	19	36.35	-94.92	9	Doniphan	0.06	24.39	HAY	0	4.80		1058

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
358	19	36.35	-94.92	21	Tonti	0.06	24.39	HAY	0	4.00	w alum;	2446
361	20	36.36	-94.89	26	Razort	0.16	24.39	WPAS	0	0.00	w/o N rep	1821
362	20	36.36	-94.89	122	Clarksville	0.16	24.39	WPAS	0	1.00	w alum; w/o N rep	6819
363	20	36.36	-94.89	6	Razort	0.16	24.39	OPAS	1	0.00	w/o N rep	454
364	20	36.36	-94.89	36	Clarksville	0.16	24.39	OPAS	1	0.54	w/o N rep	2031
367	20	36.36	-94.89	14	Razort	0.16	24.39	HAY	0	4.00	w N rep	2052
368	20	36.36	-94.89	92	Clarksville	0.16	24.39	HAY	0	4.80	w alum;	11352
369	21	36.41	-94.51	222	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	13315
370	21	36.41	-94.51	152	Nixa	0.04	60.98	WPAS	0	0.00	w/o N rep	7801
371	21	36.41	-94.51	105	Tonti	0.04	60.98	WPAS	0	1.00	w/o N rep	6986
372	21	36.41	-94.51	59	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	3540
373	21	36.41	-94.51	48	Nixa	0.04	60.98	OPAS	1	0.00	w/o N rep	2474
376	21	36.41	-94.51	139	Captina	0.04	60.98	HAY	0	4.00	w alum;	17108
377	21	36.41	-94.51	104	Nixa	0.04	60.98	HAY	0	4.00	w alum;	8855
378	21	36.41	-94.51	45	Tonti	0.04	60.98	HAY	0	6.00	w alum;	5480
379	21	36.41	-94.51	7	Captina	0.03	60.98	WWHT	0	0.00	w N rep	1066
380	21	36.41	-94.51	6	Nixa	0.03	60.98	WWHT	0	1.95		1124
381	21	36.41	-94.51	2	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	866
382	21	36.41	-94.51	4	Peridge	0.03	60.98	WWHT	0	0.00	w N rep	618
386	22	36.37	-94.51	202	Clarksville	0.06	36.58	WPAS	0	1.00	w/o N rep	10755
387	22	36.37	-94.51	172	Captina	0.06	36.58	WPAS	0	0.00	w/o N rep	9959
388	22	36.37	-94.51	201	Nixa	0.06	36.58	WPAS	0	0.00	w/o N rep	10072
389	22	36.37	-94.51	51	Captina	0.06	36.58	OPAS	1	0.00	w/o N rep	2976
390	22	36.37	-94.51	18	Nixa	0.06	36.58	OPAS	1	0.00	w/o N rep	917
391	22	36.37	-94.51	18	Tonti	0.06	36.58	OPAS	1	0.54	w/o N rep	1211
392	22	36.37	-94.51	14	Peridge	0.06	36.58	OPAS	1	0.00	w/o N rep	818
395	22	36.37	-94.51	21	Clarksville	0.06	36.58	HAY	0	4.80	w alum;	2327
396	22	36.37	-94.51	62	Captina	0.06	36.58	HAY	0	4.00	w alum;	7629
397	22	36.37	-94.51	35	Nixa	0.06	36.58	HAY	0	4.00	w alum;	3139
398	22	36.37	-94.51	29	Tonti	0.06	36.58	HAY	0	6.00	w alum;	3616
399	22	36.37	-94.51	25	Captina	0.05	36.58	WWHT	0	0.00	w N rep	4108
400	22	36.37	-94.51	7	Nixa	0.05	36.58	WWHT	0	1.95		1347
401	22	36.37	-94.51	9	Tonti	0.05	36.58	WWHT	0	1.95	w alum;	3364
405	23	36.36	-94.55	13	Captina	0.05	24.39	WPAS	0	0.00	w/o N rep	778
406	23	36.36	-94.55	7	Nixa	0.05	24.39	WPAS	0	0.00	w/o N rep	338
407	23	36.36	-94.55	5	Healing	0.05	24.39	WPAS	0	0.00	w/o N rep	328
408	23	36.36	-94.55	7	Peridge	0.05	24.39	WPAS	0	0.00	w/o N rep	395
409	23	36.36	-94.55	5	Captina	0.05	24.39	OPAS	1	0.00	w/o N rep	326
410	23	36.36	-94.55	10	Peridge	0.05	24.39	OPAS	1	0.00	w/o N rep	573
413	23	36.36	-94.55	2	Captina	0.05	24.39	HAY	0	4.00	w alum;	259
414	23	36.36	-94.55	3	Britwater	0.05	24.39	HAY	0	4.80	w alum;	307
415	23	36.36	-94.55	4	Nixa	0.05	24.39	HAY	0	4.00	w alum;	312
416	23	36.36	-94.55	5	Peridge	0.05	24.39	HAY	0	4.00	w alum;	649
421	24	36.34	-94.49	171	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	9285
422	24	36.34	-94.49	126	Captina	0.05	60.98	WPAS	0	0.00	w/o N rep	7468
423	24	36.34	-94.49	480	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	24053
424	24	36.34	-94.49	234	Peridge	0.05	60.98	WPAS	0	0.00	w/o N rep	13734
425	24	36.34	-94.49	46	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	2742
426	24	36.34	-94.49	78	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	3915
427	24	36.34	-94.49	28	Secesh	0.05	60.98	OPAS	1	0.54	w/o N rep	1632
428	24	36.34	-94.49	28	Peridge	0.05	60.98	OPAS	1	0.00	w/o N rep	1633
431	24	36.34	-94.49	52	Clarksville	0.05	60.98	HAY	0	4.00	w alum;	5625
432	24	36.34	-94.49	62	Captina	0.05	60.98	HAY	0	4.00	w alum;	7560
433	24	36.34	-94.49	190	Nixa	0.05	60.98	HAY	0	4.00	w alum;	16136
434	24	36.34	-94.49	59	Peridge	0.05	60.98	HAY	0	4.00	w alum;	7199
435	24	36.34	-94.49	52	Captina	0.04	60.98	WWHT	1	1.30	w alum;	6449
436	24	36.34	-94.49	33	Nixa	0.04	60.98	WWHT	0	1.95		5038
437	24	36.34	-94.49	31	Peridge	0.04	60.98	WWHT	1	1.30	w alum;	3882

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
441	25	36.37	-94.87	13	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	723
442	25	36.37	-94.87	2	Britwater	0.11	24.39	WPAS	0	0.00	w/o N rep	125
443	25	36.37	-94.87	4	Water	0.11	24.39	WPAS	0	0.00	w/o N rep	-168
445	25	36.37	-94.87	2	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	282
446	25	36.37	-94.87	2	Water	0.11	24.39	HAY	0	0.00	w/o N rep	-60
453	27	36.36	-94.8	2	Clarksville	0.13	36.58	WPAS	0	0.00	w/o N rep	104
454	27	36.36	-94.8	1	Britwater	0.13	36.58	WPAS	0	0.00	w/o N rep	57
455	27	36.36	-94.8	2	Water	0.13	36.58	WPAS	0	0.00	w/o N rep	-76
458	27	36.36	-94.8	2	Clarksville	0.13	36.58	HAY	0	4.80	w alum;	284
459	27	36.36	-94.8	1	Britwater	0.13	36.58	HAY	0	4.80	w alum;	146
460	27	36.36	-94.8	1	Elsah	0.13	36.58	HAY	0	6.00		141
463	28	36.36	-94.79	3	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	197
464	28	36.36	-94.79	1	Elsah	0.07	24.39	WPAS	0	1.00	w/o N rep	78
468	28	36.36	-94.79	8	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	1095
471	29	36.34	-94.36	111	Clarksville	0.06	60.98	WPAS	0	2.00	w alum; w/o N rep	6170
472	29	36.34	-94.36	384	Nixa	0.06	60.98	WPAS	0	0.00	w/o N rep	18226
473	29	36.34	-94.36	166	Tonti	0.06	60.98	WPAS	0	1.00	w/o N rep	10577
474	29	36.34	-94.36	12	Clarksville	0.06	60.98	OPAS	1	1.08	w alum; w/o N rep	666
475	29	36.34	-94.36	68	Nixa	0.06	60.98	OPAS	1	0.00	w/o N rep	3265
478	29	36.34	-94.36	37	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	4268
479	29	36.34	-94.36	144	Nixa	0.06	60.98	HAY	0	6.00	w alum;	12945
480	29	36.34	-94.36	53	Tonti	0.06	60.98	HAY	0	6.00	w alum;	6808
481	29	36.34	-94.36	4	Clarksville	0.06	60.98	WWHT	0	1.95	w alum;	601
482	29	36.34	-94.36	28	Nixa	0.06	60.98	WWHT	0	1.95		3275
486	30	36.33	-94.39	110	Clarksville	0.08	36.58	WPAS	0	2.00	w alum; w/o N rep	6241
487	30	36.33	-94.39	274	Nixa	0.08	36.58	WPAS	0	0.00	w/o N rep	13679
488	30	36.33	-94.39	4	Clarksville	0.08	36.58	OPAS	1	0.54	w/o N rep	226
489	30	36.33	-94.39	4	Captina	0.08	36.58	OPAS	1	0.00	w/o N rep	240
490	30	36.33	-94.39	9	Nixa	0.08	36.58	OPAS	1	0.00	w/o N rep	463
494	30	36.33	-94.39	9	Clarksville	0.08	36.58	HAY	0	6.00	w alum;	1063
495	30	36.33	-94.39	42	Nixa	0.08	36.58	HAY	0	6.00	w alum;	4104
496	31	36.36	-94.78	5	Razort	0.05	24.39	WPAS	0	0.00	w/o N rep	365
497	31	36.36	-94.78	9	Clarksville	0.05	24.39	WPAS	0	0.00	w/o N rep	554
498	31	36.36	-94.78	4	Elsah	0.05	24.39	WPAS	0	1.00	w/o N rep	267
499	31	36.36	-94.78	11	Healing	0.05	24.39	WPAS	0	0.00	w/o N rep	798
500	31	36.36	-94.78	7	Clarksville	0.05	24.39	OPAS	1	0.00	w/o N rep	400
501	31	36.36	-94.78	2	Clarksville	0.05	24.39	OPAS	1	0.00	w/o N rep	138
504	31	36.36	-94.78	3	Razort	0.05	24.39	HAY	0	4.00	w N rep	399
505	31	36.36	-94.78	7	Clarksville	0.05	24.39	HAY	0	4.80	w alum;	854
506	31	36.36	-94.78	5	Elsah	0.05	24.39	HAY	0	4.80		605
507	31	36.36	-94.78	5	Healing	0.05	24.39	HAY	0	4.00	w N rep	759
511	32	36.35	-94.77	13	Razort	0.05	18.29	WPAS	0	0.00	w/o N rep	921
512	32	36.35	-94.77	27	Clarksville	0.05	18.29	WPAS	0	0.00	w/o N rep	1570
513	32	36.35	-94.77	25	Healing	0.05	18.29	WPAS	0	0.00	w/o N rep	1820
514	32	36.35	-94.77	9	Clarksville	0.05	18.29	OPAS	1	0.00	w/o N rep	519
515	32	36.35	-94.77	3	Clarksville	0.05	18.29	OPAS	1	0.00	w/o N rep	187
516	32	36.35	-94.77	7	Britwater	0.05	18.29	OPAS	1	0.00	w/o N rep	414
517	32	36.35	-94.77	4	Healing	0.05	18.29	OPAS	1	0.00	w/o N rep	292
520	32	36.35	-94.77	5	Razort	0.05	18.29	HAY	0	4.00	w N rep	806
521	32	36.35	-94.77	9	Clarksville	0.05	18.29	HAY	0	4.80	w alum;	1103
522	32	36.35	-94.77	22	Healing	0.05	18.29	HAY	0	4.00	w N rep	3367
523	32	36.35	-94.77	6	Razort	0.03	18.29	WWHT	0	1.11	w/o N rep	1701
524	32	36.35	-94.77	2	Clarksville	0.03	18.29	WWHT	0	0.65	w/o N rep	349
525	32	36.35	-94.77	4	Britwater	0.03	18.29	WWHT	0	1.95	w alum;	735
532	33	36.35	-94.82	23	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	1312
533	33	36.35	-94.82	4	Britwater	0.11	24.39	WPAS	0	0.00	w/o N rep	247
534	33	36.35	-94.82	5	Water	0.11	24.39	WPAS	0	0.00	w/o N rep	-188
535	33	36.35	-94.82	9	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	516

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
536	33	36.35	-94.82	3	Britwater	0.11	24.39	OPAS	1	0.00	w/o N rep	192
537	33	36.35	-94.82	2	Taloka	0.11	24.39	OPAS	1	0.00	w/o N rep	130
538	33	36.35	-94.82	5	Water	0.11	24.39	OPAS	0	0.00	w/o N rep	-157
540	33	36.35	-94.82	19	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	2370
541	33	36.35	-94.82	7	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	862
542	33	36.35	-94.82	5	Britwater	0.11	24.39	HAY	0	4.80	w alum;	676
543	33	36.35	-94.82	6	Water	0.11	24.39	HAY	0	0.00	w/o N rep	-231
547	34	36.33	-94.86	22	Clarksville	0.10	24.39	WPAS	0	0.00	w/o N rep	1280
548	34	36.33	-94.86	25	Tonti	0.10	24.39	WPAS	0	0.00	w/o N rep	1456
550	34	36.33	-94.86	4	Clarksville	0.10	24.39	HAY	0	4.80	w alum;	530
551	34	36.33	-94.86	13	Tonti	0.10	24.39	HAY	0	4.00	w alum;	1544
557	35	36.32	-94.71	69	Razort	0.07	18.29	WPAS	0	0.00	w/o N rep	4974
558	35	36.32	-94.71	95	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	5643
559	35	36.32	-94.71	73	Clarksville	0.07	18.29	WPAS	0	0.00	w/o N rep	4183
560	35	36.32	-94.71	44	Britwater	0.07	18.29	WPAS	0	0.00	w/o N rep	2559
561	35	36.32	-94.71	50	Doniphan	0.07	18.29	WPAS	0	1.00	w/o N rep	2701
562	35	36.32	-94.71	73	Macedonia	0.07	18.29	WPAS	0	0.00	w/o N rep	4006
563	35	36.32	-94.71	23	Razort	0.07	18.29	OPAS	1	0.00	w/o N rep	1646
564	35	36.32	-94.71	30	Clarksville	0.07	18.29	OPAS	1	0.54	w/o N rep	1749
565	35	36.32	-94.71	14	Clarksville	0.07	18.29	OPAS	1	0.00	w/o N rep	813
566	35	36.32	-94.71	20	Britwater	0.07	18.29	OPAS	1	0.00	w/o N rep	1164
567	35	36.32	-94.71	19	Doniphan	0.07	18.29	OPAS	1	0.54	w/o N rep	1009
568	35	36.32	-94.71	19	Macedonia	0.07	18.29	OPAS	1	0.00	w/o N rep	1058
572	35	36.32	-94.71	41	Razort	0.07	18.29	HAY	0	4.80		6546
573	35	36.32	-94.71	87	Clarksville	0.07	18.29	HAY	0	6.00	w alum;	12148
574	35	36.32	-94.71	46	Clarksville	0.07	18.29	HAY	0	4.80	w alum;	5942
575	35	36.32	-94.71	38	Doniphan	0.07	18.29	HAY	0	4.80		5394
576	35	36.32	-94.71	56	Macedonia	0.07	18.29	HAY	0	4.80	w alum;	7869
577	35	36.32	-94.71	6	Razort	0.04	18.29	WWHT	0	1.11	w/o N rep	1675
578	35	36.32	-94.71	15	Clarksville	0.04	18.29	WWHT	0	0.65	w/o N rep	2879
579	35	36.32	-94.71	7	Clarksville	0.04	18.29	WWHT	0	0.33	w/o N rep	1134
580	35	36.32	-94.71	7	Britwater	0.04	18.29	WWHT	0	1.95	w alum;	1276
581	35	36.32	-94.71	5	Elsah	0.04	18.29	WWHT	0	1.95		1150
585	36	36.34	-94.76	0	Razort	0.05	60.98	WPAS	0	0.00	w/o N rep	13
586	36	36.34	-94.76	1	Elsah	0.05	60.98	WPAS	0	1.00	w/o N rep	49
587	36	36.34	-94.76	5	Britwater	0.05	60.98	OPAS	1	0.00	w/o N rep	282
588	36	36.34	-94.76	2	Elsah	0.05	60.98	OPAS	1	0.54	w/o N rep	124
592	36	36.34	-94.76	3	Razort	0.05	60.98	HAY	0	4.00	w N rep	403
593	36	36.34	-94.76	2	Razort	0.02	60.98	WWHT	0	0.98	w/o N rep	618
594	36	36.34	-94.76	7	Britwater	0.02	60.98	WWHT	1	1.56	w alum;	920
595	36	36.34	-94.76	6	Elsah	0.02	60.98	WWHT	0	1.95		1465
599	37	36.36	-94.59	36	Clarksville	0.06	24.39	WPAS	0	1.00	w/o N rep	1967
600	37	36.36	-94.59	52	Captina	0.06	24.39	WPAS	0	0.00	w/o N rep	3121
601	37	36.36	-94.59	34	Peridge	0.06	24.39	WPAS	0	0.00	w/o N rep	2006
602	37	36.36	-94.59	4	Clarksville	0.06	24.39	OPAS	1	0.54	w/o N rep	196
603	37	36.36	-94.59	11	Captina	0.06	24.39	OPAS	1	0.00	w/o N rep	631
604	37	36.36	-94.59	4	Taloka	0.06	24.39	OPAS	1	0.00	w/o N rep	195
605	37	36.36	-94.59	3	Nixa	0.06	24.39	OPAS	1	0.00	w/o N rep	176
606	37	36.36	-94.59	6	Peridge	0.06	24.39	OPAS	1	0.00	w/o N rep	341
608	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	4.00	w alum;	745
609	37	36.36	-94.59	7	Clarksville	0.06	24.39	HAY	0	4.00	w alum;	780
610	37	36.36	-94.59	17	Captina	0.06	24.39	HAY	0	4.00	w alum;	2060
611	37	36.36	-94.59	7	Nixa	0.06	24.39	HAY	0	4.00	w alum;	619
612	37	36.36	-94.59	4	Clarksville	0.05	24.39	WWHT	0	1.95		655
613	37	36.36	-94.59	6	Captina	0.05	24.39	WWHT	0	0.00	w N rep	1040
614	37	36.36	-94.59	3	Nixa	0.05	24.39	WWHT	0	1.95		506
615	37	36.36	-94.59	2	Peridge	0.05	24.39	WWHT	0	1.95	w alum;	504
619	38	36.32	-94.53	233	Clarksville	0.05	60.98	WPAS	0	1.00	w/o N rep	12507

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620	38	36.32	-94.53	454	Captina	0.05	60.98	WPAS	0	0.00	w/o N rep	26788
621	38	36.32	-94.53	314	Nixa	0.05	60.98	WPAS	0	0.00	w/o N rep	15759
622	38	36.32	-94.53	342	Tonti	0.05	60.98	WPAS	0	1.00	w/o N rep	22455
623	38	36.32	-94.53	128	Captina	0.05	60.98	OPAS	1	0.00	w/o N rep	7575
624	38	36.32	-94.53	45	Nixa	0.05	60.98	OPAS	1	0.00	w/o N rep	2242
625	38	36.32	-94.53	60	Tonti	0.05	60.98	OPAS	1	0.54	w/o N rep	3957
628	38	36.32	-94.53	61	Clarksville	0.05	60.98	HAY	0	4.00	w alum;	6440
629	38	36.32	-94.53	110	Captina	0.05	60.98	HAY	0	4.00	w alum;	13377
630	38	36.32	-94.53	123	Nixa	0.05	60.98	HAY	0	4.00	w alum;	10268
631	38	36.32	-94.53	90	Tonti	0.05	60.98	HAY	0	6.00	w alum;	10751
632	38	36.32	-94.53	80	Captina	0.03	60.98	WWHT	1	1.30	w alum;	10096
633	38	36.32	-94.53	31	Nixa	0.03	60.98	WWHT	0	1.95		5895
634	38	36.32	-94.53	45	Tonti	0.03	60.98	WWHT	0	1.95	w alum;	16664
635	38	36.32	-94.53	46	Peridge	0.03	60.98	WWHT	0	1.95	w alum;	8013
641	41	36.33	-94.65	22	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	1262
642	41	36.33	-94.65	16	Clarksville	0.07	24.39	WPAS	0	0.00	w/o N rep	911
643	41	36.33	-94.65	97	Britwater	0.07	24.39	WPAS	0	0.00	w/o N rep	5543
644	41	36.33	-94.65	7	Clarksville	0.07	24.39	OPAS	1	0.54	w/o N rep	425
645	41	36.33	-94.65	5	Clarksville	0.07	24.39	OPAS	1	0.00	w/o N rep	309
646	41	36.33	-94.65	3	Captina	0.07	24.39	OPAS	1	0.00	w/o N rep	174
651	41	36.33	-94.65	24	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	3391
652	41	36.33	-94.65	14	Clarksville	0.07	24.39	HAY	0	4.80	w alum;	1839
653	41	36.33	-94.65	18	Britwater	0.07	24.39	HAY	0	6.00	w alum;	2557
654	42	36.3	-94.65	69	Razort	0.05	36.58	WPAS	0	1.00	w/o N rep	4952
655	42	36.3	-94.65	96	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	5591
656	42	36.3	-94.65	47	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	2616
657	42	36.3	-94.65	53	Britwater	0.05	36.58	WPAS	0	0.00	w/o N rep	3030
658	42	36.3	-94.65	50	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	2673
659	42	36.3	-94.65	56	Macedonia	0.05	36.58	WPAS	0	0.00	w/o N rep	2925
660	42	36.3	-94.65	10	Clarksville	0.05	36.58	OPAS	1	0.00	w/o N rep	568
661	42	36.3	-94.65	28	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	1487
662	42	36.3	-94.65	23	Macedonia	0.05	36.58	OPAS	1	0.00	w/o N rep	1226
666	42	36.3	-94.65	35	Clarksville	0.05	36.58	HAY	0	6.00	w alum;	4921
667	42	36.3	-94.65	27	Clarksville	0.05	36.58	HAY	0	4.80	w alum;	3477
668	42	36.3	-94.65	46	Doniphan	0.05	36.58	HAY	0	6.00	w alum;	6440
669	42	36.3	-94.65	40	Macedonia	0.05	36.58	HAY	0	6.00	w alum;	5477
670	42	36.3	-94.65	4	Clarksville	0.05	36.58	WWHT	1	1.95	w alum;	614
671	42	36.3	-94.65	8	Clarksville	0.05	36.58	WWHT	0	0.00	w/o N rep	1078
672	42	36.3	-94.65	5	Doniphan	0.05	36.58	WWHT	1	1.95	w alum;	703
673	42	36.3	-94.65	13	Macedonia	0.05	36.58	WWHT	1	1.95	w alum;	1727
678	43	36.36	-94.65	87	Clarksville	0.03	60.98	WPAS	0	1.00	w/o N rep	4974
679	43	36.36	-94.65	77	Clarksville	0.03	60.98	WPAS	0	0.00	w/o N rep	4299
680	43	36.36	-94.65	107	Macedonia	0.03	60.98	WPAS	0	0.00	w/o N rep	5615
681	43	36.36	-94.65	207	Newtonia	0.03	60.98	WPAS	0	0.00	w/o N rep	11738
682	43	36.36	-94.65	85	Clarksville	0.03	60.98	OPAS	1	0.00	w/o N rep	4655
683	43	36.36	-94.65	94	Macedonia	0.03	60.98	OPAS	1	0.00	w/o N rep	4919
684	43	36.36	-94.65	61	Newtonia	0.03	60.98	OPAS	1	0.00	w/o N rep	3449
688	43	36.36	-94.65	44	Clarksville	0.03	60.98	HAY	0	4.80	w alum;	5852
689	43	36.36	-94.65	61	Clarksville	0.03	60.98	HAY	0	4.80	w alum;	7513
690	43	36.36	-94.65	41	Doniphan	0.03	60.98	HAY	0	6.00	w alum;	5584
691	43	36.36	-94.65	68	Macedonia	0.03	60.98	HAY	0	4.80	w alum;	9166
692	43	36.36	-94.65	40	Taloka	0.03	60.98	HAY	0	4.80	w alum;	5325
693	43	36.36	-94.65	60	Newtonia	0.03	60.98	HAY	0	4.80		8862
694	43	36.36	-94.65	99	Taloka	0.01	60.98	WWHT	0	0.00	w N rep	14844
695	43	36.36	-94.65	150	Newtonia	0.01	60.98	WWHT	1	1.95		22598
700	44	36.3	-94.68	62	Captina	0.04	60.98	WPAS	0	0.00	w/o N rep	3785
701	44	36.3	-94.68	48	Britwater	0.04	60.98	WPAS	0	0.00	w/o N rep	2828
702	44	36.3	-94.68	63	Macedonia	0.04	60.98	WPAS	0	0.00	w/o N rep	3293

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
703	44	36.3	-94.68	17	Captina	0.04	60.98	OPAS	1	0.00	w/o N rep	1010
704	44	36.3	-94.68	18	Taloka	0.04	60.98	OPAS	1	0.00	w/o N rep	1172
705	44	36.3	-94.68	20	Macedonia	0.04	60.98	OPAS	1	0.00	w/o N rep	1031
710	44	36.3	-94.68	13	Clarksville	0.04	60.98	HAY	0	6.00	w alum;	1936
711	44	36.3	-94.68	16	Clarksville	0.04	60.98	HAY	0	6.00	w alum;	2099
712	44	36.3	-94.68	21	Captina	0.04	60.98	HAY	0	6.00	w alum;	3187
713	44	36.3	-94.68	20	Doniphan	0.04	60.98	HAY	0	6.00		2900
714	44	36.3	-94.68	33	Macedonia	0.04	60.98	HAY	0	4.80	w alum;	4755
715	44	36.3	-94.68	5	Clarksville	0.08	60.98	WWHT	1	1.95	w alum;	678
716	44	36.3	-94.68	8	Clarksville	0.08	60.98	WWHT	1	1.95	w alum;	1100
717	44	36.3	-94.68	3	Macedonia	0.08	60.98	WWHT	1	1.56	w alum;	358
721	45	36.28	-94.67	177	Doniphan	0.03	91.46	WPAS	0	2.00	w/o N rep	9696
722	45	36.28	-94.67	100	Macedonia	0.03	91.46	WPAS	0	1.00	w/o N rep	5396
723	45	36.28	-94.67	92	Newtonia	0.03	91.46	WPAS	0	1.00	w/o N rep	5310
724	45	36.28	-94.67	75	Doniphan	0.03	91.46	OPAS	1	1.08	w/o N rep	4102
725	45	36.28	-94.67	59	Macedonia	0.03	91.46	OPAS	1	0.54	w/o N rep	3197
730	45	36.28	-94.67	40	Clarksville	0.03	91.46	HAY	0	6.00	w alum;	6266
731	45	36.28	-94.67	158	Doniphan	0.03	91.46	HAY	0	6.00		24311
732	45	36.28	-94.67	83	Macedonia	0.03	91.46	HAY	0	6.00	w alum;	12816
733	45	36.28	-94.67	10	Captina	0.02	91.46	WWHT	1	1.95		1598
734	45	36.28	-94.67	16	Doniphan	0.02	91.46	WWHT	1	1.95		2408
735	45	36.28	-94.67	31	Macedonia	0.02	91.46	WWHT	1	1.95	w alum;	4876
741	46	36.29	-94.61	269	Clarksville	0.03	60.98	WPAS	0	1.00	w/o N rep	15940
742	46	36.29	-94.61	277	Captina	0.03	60.98	WPAS	0	0.00	w/o N rep	16749
743	46	36.29	-94.61	469	Taloka	0.03	60.98	WPAS	0	1.00	w alum; w/o N rep	24402
744	46	36.29	-94.61	36	Clarksville	0.03	60.98	OPAS	1	0.54	w/o N rep	2114
745	46	36.29	-94.61	75	Captina	0.03	60.98	OPAS	1	0.00	w/o N rep	4511
746	46	36.29	-94.61	30	Tonti	0.03	60.98	OPAS	1	0.54	w/o N rep	1746
747	46	36.29	-94.61	37	Taloka	0.03	60.98	OPAS	1	0.54	w alum; w/o N rep	1938
752	46	36.29	-94.61	101	Clarksville	0.03	60.98	HAY	0	6.00	w alum;	13805
753	46	36.29	-94.61	184	Captina	0.03	60.98	HAY	0	4.80	w alum;	27000
754	46	36.29	-94.61	82	Taloka	0.03	60.98	HAY	0	4.80	w alum;	11116
755	46	36.29	-94.61	41	Captina	0.02	60.98	WWHT	0	0.00	w N rep	7205
756	46	36.29	-94.61	31	Taloka	0.02	60.98	WWHT	0	1.95	w alum;	7525
757	47	36.39	-94.84	45	Razort	0.09	24.39	WPAS	0	0.00	w/o N rep	3233
758	47	36.39	-94.84	159	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	9229
759	47	36.39	-94.84	51	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	2857
760	47	36.39	-94.84	30	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	1748
761	47	36.39	-94.84	18	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	1017
762	47	36.39	-94.84	6	Doniphan	0.09	24.39	OPAS	1	0.00	w/o N rep	340
766	47	36.39	-94.84	26	Razort	0.09	24.39	HAY	0	4.00	w N rep	3903
767	47	36.39	-94.84	129	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	16166
768	47	36.39	-94.84	57	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	6690
773	48	36.4	-94.79	48	Razort	0.11	24.39	WPAS	0	0.00	w/o N rep	3373
774	48	36.4	-94.79	247	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	13929
775	48	36.4	-94.79	51	Clarksville	0.11	24.39	WPAS	0	0.00	w/o N rep	2794
776	48	36.4	-94.79	23	Razort	0.11	24.39	OPAS	1	0.00	w/o N rep	1623
777	48	36.4	-94.79	82	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	4610
778	48	36.4	-94.79	56	Clarksville	0.11	24.39	OPAS	1	0.00	w/o N rep	3049
781	48	36.4	-94.79	45	Razort	0.11	24.39	HAY	0	4.00	w alum;	6140
782	48	36.4	-94.79	176	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	20031
783	48	36.4	-94.79	54	Clarksville	0.11	24.39	HAY	0	4.80	w alum;	5775
784	48	36.4	-94.79	38	Britwater	0.11	24.39	HAY	0	4.80	w alum;	4522
785	48	36.4	-94.79	18	Clarksville	0.07	24.39	WWHT	0	0.00	w N rep	2324
786	48	36.4	-94.79	11	Clarksville	0.07	24.39	WWHT	0	0.00	w/o N rep	1598
790	49	36.37	-94.73	418	Clarksville	0.07	36.58	WPAS	0	0.00	w/o N rep	24091
791	49	36.37	-94.73	151	Clarksville	0.07	36.58	WPAS	0	0.00	w/o N rep	8308
792	49	36.37	-94.73	230	Macedonia	0.07	36.58	WPAS	0	0.00	w/o N rep	11667

HRU	Sub-basin	Latitude at the center of sub-basin	Longitude at the center of sub-basin	Area (ha.)	Soil name	Slope (m/m)	Slope Length (m)	Land Use	Land Use Change (1= change, 0 = not)	Litter application rate (tons)	With (w alum) or without (w/o) alum; With (w N rep) or without (w/o N rep) N replacement	HRU Shadow Price ($)
793	49	36.37	-94.73	82	Clarksville	0.07	36.58	OPAS	1	0.00	w/o N rep	4740
794	49	36.37	-94.73	51	Clarksville	0.07	36.58	OPAS	1	0.00	w/o N rep	2806
795	49	36.37	-94.73	45	Taloka	0.07	36.58	OPAS	1	0.00	w/o N rep	2809
796	49	36.37	-94.73	41	Doniphan	0.07	36.58	OPAS	1	0.00	w/o N rep	2136
797	49	36.37	-94.73	80	Macedonia	0.07	36.58	OPAS	1	0.00	w/o N rep	4088
800	49	36.37	-94.73	270	Clarksville	0.07	36.58	HAY	0	4.80	w alum;	33789
801	49	36.37	-94.73	117	Clarksville	0.07	36.58	HAY	0	4.80	w alum;	13660
802	49	36.37	-94.73	217	Macedonia	0.07	36.58	HAY	0	4.80	w alum;	26995
803	49	36.37	-94.73	28	Clarksville	0.06	36.58	WWHT	0	0.65	w alum; w/o N rep	3868
804	49	36.37	-94.73	12	Clarksville	0.06	36.58	WWHT	0	0.65	w/o N rep	1527
805	49	36.37	-94.73	12	Taloka	0.06	36.58	WWHT	1	1.30	w alum;	1705
806	49	36.37	-94.73	11	Doniphan	0.06	36.58	WWHT	1	1.56	w alum;	1475
807	49	36.37	-94.73	17	Macedonia	0.06	36.58	WWHT	1	1.56	w alum;	2146
808	50	36.27	-94.81	159	Razort	0.09	24.39	WPAS	0	0.00	w/o N rep	11359
809	50	36.27	-94.81	489	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	28456
810	50	36.27	-94.81	167	Clarksville	0.09	24.39	WPAS	0	0.00	w/o N rep	9494
811	50	36.27	-94.81	192	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	11167
812	50	36.27	-94.81	100	Clarksville	0.09	24.39	OPAS	1	0.00	w/o N rep	5677
813	50	36.27	-94.81	86	Doniphan	0.09	24.39	OPAS	1	0.00	w/o N rep	4626
817	50	36.27	-94.81	118	Razort	0.09	24.39	HAY	0	4.00	w N rep	18064
818	50	36.27	-94.81	300	Clarksville	0.09	24.39	HAY	0	4.80	w alum;	39754
819	50	36.27	-94.81	146	Clarksville	0.09	24.39	HAY	0	4.80		18011
820	50	36.27	-94.81	107	Doniphan	0.09	24.39	HAY	0	4.80		14254
821	50	36.27	-94.81	15	Razort	0.09	24.39	WWHT	0	0.00	w N rep	2956
822	50	36.27	-94.81	64	Clarksville	0.09	24.39	WWHT	1	1.56		8552
823	50	36.27	-94.81	33	Clarksville	0.09	24.39	WWHT	1	1.56		4079
828	51	36.35	-94.75	1	Razort	0.06	15.24	WPAS	0	0.00	w/o N rep	90
829	51	36.35	-94.75	0	Clarksville	0.06	15.24	WPAS	0	0.00	w/o N rep	16
830	51	36.35	-94.75	0	Razort	0.06	15.24	OPAS	1	0.00	w/o N rep	26
831	51	36.35	-94.75	1	Elsah	0.06	15.24	OPAS	1	0.54	w/o N rep	53
834	51	36.35	-94.75	1	Razort	0.06	15.24	HAY	0	4.00	w N rep	164
835	51	36.35	-94.75	1	Razort	0.01	15.24	WWHT	0	1.11	w/o N rep	396
836	51	36.35	-94.75	1	Britwater	0.01	15.24	WWHT	0	1.95	w alum;	119
837	51	36.35	-94.75	1	Elsah	0.01	15.24	WWHT	0	1.95		351
845	52	36.32	-94.68	2	Razort	0.10	24.39	WPAS	0	0.00	w/o N rep	133
846	52	36.32	-94.68	2	Clarksville	0.10	24.39	WPAS	0	1.00	w/o N rep	144
847	52	36.32	-94.68	6	Britwater	0.10	24.39	WPAS	0	0.00	w/o N rep	321
848	52	36.32	-94.68	5	Clarksville	0.10	24.39	OPAS	1	0.54	w/o N rep	266
849	52	36.32	-94.68	6	Britwater	0.10	24.39	OPAS	1	0.00	w/o N rep	319
854	52	36.32	-94.68	1	Razort	0.10	24.39	HAY	0	4.80		188
855	52	36.32	-94.68	5	Clarksville	0.10	24.39	HAY	0	4.80	w alum;	679
856	52	36.32	-94.68	2	Britwater	0.10	24.39	HAY	0	6.00	w alum;	254
857	52	36.32	-94.68	2	Doniphan	0.10	24.39	HAY	0	6.00	w alum;	261
858	52	36.32	-94.68	1	Clarksville	0.09	24.39	WWHT	0	0.98	w/o N rep	140
864	53	36.35	-94.57	25	Clarksville	0.07	24.39	WPAS	0	1.00	w/o N rep	1353
865	53	36.35	-94.57	45	Britwater	0.07	24.39	WPAS	0	1.00	w alum; w/o N rep	2526
866	53	36.35	-94.57	18	Waben	0.07	24.39	WPAS	0	1.00	w/o N rep	1154
867	53	36.35	-94.57	48	Peridge	0.07	24.39	WPAS	0	0.00	w/o N rep	2807
868	53	36.35	-94.57	8	Clarksville	0.07	24.39	OPAS	1	0.54	w/o N rep	437
869	53	36.35	-94.57	4	Britwater	0.07	24.39	OPAS	1	0.54	w/o N rep	202
870	53	36.35	-94.57	6	Waben	0.07	24.39	OPAS	1	0.54	w/o N rep	391
871	53	36.35	-94.57	7	Peridge	0.07	24.39	OPAS	1	0.00	w/o N rep	385
875	53	36.35	-94.57	18	Clarksville	0.07	24.39	HAY	0	4.00	w alum;	1940
876	53	36.35	-94.57	12	Britwater	0.07	24.39	HAY	0	4.00	w alum;	1391
877	53	36.35	-94.57	6	Waben	0.07	24.39	HAY	0	4.80	w alum;	692
878	53	36.35	-94.57	10	Peridge	0.07	24.39	HAY	0	4.00	w alum;	1259
879	53	36.35	-94.57	7	Clarksville	0.12	24.39	WWHT	0	0.00	w N rep	778
880	53	36.35	-94.57	8	Nixa	0.12	24.39	WWHT	1	1.30	w alum;	669

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883	54	36.42	-94.62	25	Razort	0.02	91.46	WPAS	0	0.00	w/o N rep	1771
884	54	36.42	-94.62	31	Clarksville	0.02	91.46	WPAS	0	0.00	w/o N rep	1742
885	54	36.42	-94.62	23	Britwater	0.02	91.46	WPAS	0	0.00	w/o N rep	1281
886	54	36.42	-94.62	93	Newtonia	0.02	91.46	WPAS	0	1.00	w/o N rep	5205
887	54	36.42	-94.62	45	Newtonia	0.02	91.46	OPAS	1	0.54	w/o N rep	2505
892	54	36.42	-94.62	15	Clarksville	0.02	91.46	HAY	0	4.00	w alum;	1627
893	54	36.42	-94.62	88	Newtonia	0.02	91.46	HAY	0	4.00	w N rep	10714
894	54	36.42	-94.62	6	Newtonia	0.02	91.46	WWHT	0	0.00	w N rep	1096
898	55	36.27	-94.74	520	Clarksville	0.06	60.98	WPAS	0	1.00	w/o N rep	30727
899	55	36.27	-94.74	347	Clarksville	0.06	60.98	WPAS	0	0.00	w/o N rep	18894
900	55	36.27	-94.74	586	Doniphan	0.06	60.98	WPAS	0	1.00	w/o N rep	31508
901	55	36.27	-94.74	133	Clarksville	0.06	60.98	OPAS	1	0.54	w/o N rep	7871
902	55	36.27	-94.74	499	Doniphan	0.06	60.98	OPAS	1	0.54	w/o N rep	26837
907	55	36.27	-94.74	348	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	51720
908	55	36.27	-94.74	228	Clarksville	0.06	60.98	HAY	0	6.00	w alum;	31188
909	55	36.27	-94.74	808	Doniphan	0.06	60.98	HAY	0	6.00	w alum;	118800
910	55	36.27	-94.74	24	Clarksville	0.04	60.98	WWHT	0	0.65	w/o N rep	3490
911	55	36.27	-94.74	31	Captina	0.04	60.98	WWHT	1	1.56		4839
912	55	36.27	-94.74	40	Britwater	0.04	60.98	WWHT	1	1.95	w alum;	6058
913	55	36.27	-94.74	79	Doniphan	0.04	60.98	WWHT	1	1.95		11793
918	56	36.38	-94.44	1	Clarksville	0.08	60.98	WPAS	0	0.00	w/o N rep	28
919	56	36.38	-94.44	0	Britwater	0.08	60.98	WPAS	0	0.00	w/o N rep	23
923	56	36.38	-94.44	0	Clarksville	0.08	60.98	HAY	0	0.00	w/o N rep	3
924	56	36.38	-94.44	1	Britwater	0.08	60.98	HAY	0	0.00	w/o N rep	1
925	56	36.38	-94.44	0	Water	0.08	60.98	HAY	0	0.00	w/o N rep	-7
926	56	36.38	-94.44	0	Elsah	0.09	60.98	WWHT	0	1.95		66
927	57	36.39	-94.94	48	Clarksville	0.09	18.29	WPAS	0	1.00	w/o N rep	2611
928	57	36.39	-94.94	114	Britwater	0.09	18.29	WPAS	0	0.00	w/o N rep	6516
929	57	36.39	-94.94	4	Razort	0.09	18.29	OPAS	1	0.00	w/o N rep	268
930	57	36.39	-94.94	4	Clarksville	0.09	18.29	OPAS	1	0.54	w/o N rep	212
931	57	36.39	-94.94	27	Britwater	0.09	18.29	OPAS	1	0.00	w/o N rep	1545
934	57	36.39	-94.94	28	Clarksville	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	3045
935	57	36.39	-94.94	74	Britwater	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	8021
936	57	36.39	-94.94	23	Healing	0.09	18.29	HAY	0	3.40	w alum; w/o N rep	2919
938	58	36.35	-94.85	0	Razort	0.15	18.29	WPAS	0	0.00	w/o N rep	21
939	58	36.35	-94.85	1	Clarksville	0.15	18.29	WPAS	0	0.00	w/o N rep	44
940	58	36.35	-94.85	0	Britwater	0.15	18.29	WPAS	0	0.00	w/o N rep	28
943	59	36.36	-94.86	2	Razort	0.17	18.29	WPAS	0	0.00	w/o N rep	148
944	59	36.36	-94.86	4	Clarksville	0.17	18.29	WPAS	0	0.00	w/o N rep	243
948	60	36.37	-94.81	2	Razort	0.10	18.29	WPAS	0	0.00	w/o N rep	142
949	60	36.37	-94.81	7	Clarksville	0.10	18.29	WPAS	0	0.00	w/o N rep	407
950	60	36.37	-94.81	2	Clarksville	0.10	18.29	WPAS	0	0.00	w/o N rep	107
951	60	36.37	-94.81	2	Britwater	0.10	18.29	WPAS	0	0.00	w/o N rep	127
952	60	36.37	-94.81	2	Clarksville	0.10	18.29	OPAS	1	0.00	w/o N rep	114
953	60	36.37	-94.81	0	Clarksville	0.10	18.29	OPAS	1	0.00	w/o N rep	23
954	60	36.37	-94.81	0	Water	0.10	18.29	OPAS	0	0.00	w/o N rep	-13
956	60	36.37	-94.81	6	Clarksville	0.10	18.29	HAY	0	4.80	w alum;	847
957	60	36.37	-94.81	2	Clarksville	0.10	18.29	HAY	0	4.80	w alum;	208
961	61	36.35	-94.79	5	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	298
962	61	36.35	-94.79	1	Elsah	0.06	24.39	WPAS	0	1.00	w/o N rep	63
963	61	36.35	-94.79	3	Healing	0.06	24.39	WPAS	0	0.00	w/o N rep	186
966	61	36.35	-94.79	2	Clarksville	0.06	24.39	HAY	0	4.80	w alum;	295
967	61	36.35	-94.79	2	Doniphan	0.06	24.39	HAY	0	4.80	w alum;	213
968	62	36.33	-94.8	80	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	4675
969	62	36.33	-94.8	99	Clarksville	0.05	36.58	WPAS	0	0.00	w/o N rep	5678
970	62	36.33	-94.8	47	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	2505
971	62	36.33	-94.8	19	Clarksville	0.05	36.58	OPAS	1	0.54	w/o N rep	1102
972	62	36.33	-94.8	35	Clarksville	0.05	36.58	OPAS	1	0.00	w/o N rep	1975

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973	62	36.33	-94.8	45	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	2427
974	62	36.33	-94.8	18	Jay	0.05	36.58	OPAS	1	0.00	w/o N rep	1153
978	62	36.33	-94.8	50	Clarksville	0.05	36.58	HAY	0	4.80		6683
979	62	36.33	-94.8	113	Clarksville	0.05	36.58	HAY	0	4.80		13971
980	62	36.33	-94.8	99	Doniphan	0.05	36.58	HAY	0	4.80		13311
981	62	36.33	-94.8	5	Clarksville	0.03	36.58	WWHT	0	0.65	w/o N rep	807
982	62	36.33	-94.8	10	Clarksville	0.03	36.58	WWHT	0	0.98	w/o N rep	1526
983	62	36.33	-94.8	13	Doniphan	0.03	36.58	WWHT	0	0.33	w/o N rep	1993
984	62	36.33	-94.8	17	Jay	0.03	36.58	WWHT	1	1.30	w alum;	2308
985	63	36.32	-94.89	5	Razort	0.08	18.29	WPAS	0	0.00	w/o N rep	341
986	63	36.32	-94.89	6	Clarksville	0.08	18.29	WPAS	0	0.00	w/o N rep	348
987	63	36.32	-94.89	3	Britwater	0.08	18.29	WPAS	0	0.00	w/o N rep	165
990	63	36.32	-94.89	4	Razort	0.08	18.29	HAY	0	4.00	w N rep	551
991	63	36.32	-94.89	5	Clarksville	0.08	18.29	HAY	0	4.80		657
992	63	36.32	-94.89	5	Britwater	0.08	18.29	HAY	0	4.80	w alum;	610
995	64	36.37	-94.91	7	Razort	0.11	36.58	WPAS	0	0.00	w/o N rep	497
996	64	36.37	-94.91	16	Clarksville	0.11	36.58	WPAS	0	0.00	w/o N rep	878
997	64	36.37	-94.91	17	Britwater	0.11	36.58	WPAS	0	0.00	w/o N rep	936
1000	64	36.37	-94.91	6	Razort	0.11	36.58	HAY	0	4.00	w N rep	798
1001	64	36.37	-94.91	9	Clarksville	0.11	36.58	HAY	0	4.00	w alum;	1054
1002	64	36.37	-94.91	5	Britwater	0.11	36.58	HAY	0	4.00	w alum;	631
1003	64	36.37	-94.91	2	Water	0.11	36.58	HAY	0	0.00	w/o N rep	-86
1007	66	36.36	-95.02	19	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	1032
1008	66	36.36	-95.02	26	Clarksville	0.07	18.29	WPAS	0	1.00	w/o N rep	1304
1009	66	36.36	-95.02	35	Nixa	0.07	18.29	WPAS	0	1.00	w alum; w/o N rep	1510
1010	66	36.36	-95.02	10	Parsons	0.07	18.29	WPAS	0	0.00	w/o N rep	577
1013	66	36.36	-95.02	8	Clarksville	0.07	18.29	HAY	0	3.40	w/o N rep	806
1014	66	36.36	-95.02	11	Clarksville	0.07	18.29	HAY	0	3.40	w/o N rep	1041
1015	66	36.36	-95.02	7	Nixa	0.07	18.29	HAY	0	3.40	w alum; w/o N rep	531
1016	67	36.37	-94.98	4	Razort	0.13	15.24	WPAS	0	0.00	w/o N rep	292
1017	67	36.37	-94.98	28	Clarksville	0.13	15.24	WPAS	0	1.00	w/o N rep	1528
1021	68	36.33	-94.61	278	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	16130
1022	68	36.33	-94.61	216	Clarksville	0.05	36.58	WPAS	0	1.00	w/o N rep	11391
1023	68	36.33	-94.61	198	Captina	0.05	36.58	WPAS	0	0.00	w/o N rep	11874
1024	68	36.33	-94.61	198	Doniphan	0.05	36.58	WPAS	0	1.00	w/o N rep	10555
1025	68	36.33	-94.61	39	Clarksville	0.05	36.58	OPAS	1	0.54	w/o N rep	2061
1026	68	36.33	-94.61	33	Captina	0.05	36.58	OPAS	1	0.00	w/o N rep	1965
1027	68	36.33	-94.61	29	Doniphan	0.05	36.58	OPAS	1	0.54	w/o N rep	1532
1028	68	36.33	-94.61	23	Tonti	0.05	36.58	OPAS	1	0.54	w/o N rep	1502
1032	68	36.33	-94.61	102	Clarksville	0.05	36.58	HAY	0	4.00	w alum;	11277
1033	68	36.33	-94.61	136	Clarksville	0.05	36.58	HAY	0	4.00	w alum;	13932
1034	68	36.33	-94.61	76	Captina	0.05	36.58	HAY	0	4.00	w alum;	9028
1035	68	36.33	-94.61	73	Tonti	0.05	36.58	HAY	0	6.00	w alum;	8339
1036	68	36.33	-94.61	13	Clarksville	0.04	36.58	WWHT	0	1.30	w N rep	2052
1037	68	36.33	-94.61	24	Captina	0.04	36.58	WWHT	0	0.00	w N rep	3310
1038	68	36.33	-94.61	33	Tonti	0.04	36.59	WWHT	0	1.95	w alum;	12497
1039	69	36.35	-95.01	13	Clarksville	0.06	24.39	WPAS	0	0.00	w/o N rep	667
1040	69	36.35	-95.01	8	Captina	0.06	24.39	WPAS	0	0.00	w/o N rep	454
1041	69	36.35	-95.01	16	Britwater	0.06	24.39	WPAS	0	0.00	w/o N rep	889
1042	69	36.35	-95.01	25	Peridge	0.06	24.39	WPAS	0	0.00	w/o N rep	1487
1043	69	36.35	-95.01	7	Captina	0.06	24.39	OPAS	1	0.00	w/o N rep	394
1044	69	36.35	-95.01	4	Nixa	0.06	24.39	OPAS	1	0.00	w/o N rep	227
1045	69	36.35	-95.01	3	Peridge	0.06	24.39	OPAS	1	0.00	w/o N rep	206
1048	69	36.35	-95.01	7	Captina	0.06	24.39	HAY	0	3.40	w alum; w/o N rep	832
1049	69	36.35	-95.01	3	Britwater	0.06	24.39	HAY	0	4.00	w alum;	290
1050	69	36.35	-95.01	3	Nixa	0.06	24.39	HAY	0	3.40	w alum; w/o N rep	182
1051	69	36.35	-95.01	2	Healing	0.06	24.39	HAY	0	3.40	w/o N rep	302
1052	69	36.35	-95.01	4	Peridge	0.06	24.39	HAY	0	4.00	w alum;	490

Information Transfer Program

Activities for the efficient transfer and retrieval of information are an important part of the Environmental Institute/OWRRI program mandate. The Institute maintains a web site on the Internet at URL http://environ.okstate.edu/ that provides information on the OWRRI and supported research. The site provides links to information on publications of the Institute, grant opportunities and deadlines and any upcoming events. A listing of technical reports and other publications generated by OWRRI and other Environmental Institute sponsored research is updated regularly and is accessible on the Institute web site. Abstracts of each publication are available.

The publication of the bi-monthly newsletter of the Institute, Prism, has continued. Prism is a valuable source of information on research activities sponsored by the Institute and research opportunities in water resources and environmental research. Current and past issues of the newsletter are made available on the web site.

USGS Summer Intern Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	5	0	0	0	5
Ph.D.	4	0	0	0	4
Post-Doc.	0	0	0	0	0
Total	15	0	0	0	15

Notable Awards and Achievements

Publications from Prior Projects

None