Modeling Atrazine in Seven Texas Watersheds

Lake Waxahachie Watershed

Prepared in Cooperation with the

Texas State Soil and Water Conservation Board

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USDA – Natural Resources Conservation Service
Water Resources Assessment Team
Blackland Research Center
808 East Blackland Road
Temple, Texas 76502

EXECUTIVE SUMMARY

The purpose of this study was to simulate atrazine and sediment loadings in the Lake Waxahachie Watershed using the Soil and Water Assessment Tool (SWAT) hydrologic/water quality model. Three scenarios were modeled: (I.) baseline – pre-1999 condition; (II.) §319(h) best management practice (BMP) applications, and (III.) application of BMPs on all cropland. Part one of this report discusses model calibration and validation. Part two discusses the evaluation of the BMPs with the model.

Since 1999, the Texas State Soil and Water Conservation Board has been working through the Environmental Protection Agency (EPA) §319(h) grants program to reduce nonpoint source pollution from agricultural activities in this watershed. Technical and financial assistance was provided through the Ellis-Prairie Soil and Water Conservation District for development and implementation of water quality management plans.

SWAT was calibrated/validated to measured stream flow at a USGS stream gage (08064100). Hydrographic surveys were not available for Lake Waxahachie; the sediment calibration settings developed for a nearby watershed were used. Stream monitoring data was used to calibrate SWAT for atrazine loading. Time series plots and statistical measures were used to verify model predictions.

The validated model was applied to evaluate the effects of various best management practices on three levels: farm level; subbasin level; and watershed level. The analysis was performed for the time period from 1974 through 2003. The major BMPs simulated with SWAT were conservation tillage, conservation crop rotation, conservation buffers, herbicide incorporation, and pasture planting (conversion from cropland to pastureland).

Scenario II showed that BMPs at the farm level where they were implemented reduced atrazine loading by 94 percent, and reduced sediment loading by 92 percent.

Scenario II showed that BMPs at the subbasin level reduced atrazine loading by 2.5 percent, and reduced sediment loading by 2 percent.

Scenario II showed that BMPs at the watershed level reduced atrazine loading into Lake Waxahachie by 2.6 percent and reduced sediment loading by 2 percent.

Scenario III showed that BMPs at the subbasin level reduced atrazine loading by 80 percent, and reduced sediment loading by 86 percent.

Scenario III showed that BMPs at the watershed level reduced atrazine loadings into Lake Waxahachie by 80 percent, and reduced sediment loading by 86 percent.

All simulations assume the effectiveness of BMPs remains constant for the entire modeling period, and do not account for loss of capacity in BMPs due to sediment accumulation.

Given these results, the §319(h) project has been effective in reducing nonpoint source pollution at all levels, but the greatest benefit is at the farm level. There exists good potential for further reducing atrazine and sediment concerns through continued water quality management planning and application.

MODELING ATRAZINE IN SEVEN TEXAS WATERSHEDS
Lake Waxahachie Watershed
Hydrologic Simulation

Carl Amonett, Soil Conservationist, USDA-Natural Resources Conservation Service
Tim Dybala, Civil Engineer, USDA-Natural Resources Conservation Service
Todd Marek, Civil Engineer, USDA-Natural Resources Conservation Service
Water Resources Assessment Team
Blackland Research Center

Watershed Data

Physical Data

The Lake Waxahachie Watershed is located on South Prong Creek in Ellis County in north central Texas (Figure 1). The 279-hectare (690 acres) reservoir controls runoff from 7,955 hectares (30.72 square miles), and deliberate impoundment began in December 1956. A search of USGS records indicate storage extremes: maximum contents, 1,897 hectare-meters (15,380 ac-ft), April 3, 1999; minimum observed, 1,310 hectare-meters (10,620 ac-ft), March 21, 2000.

The climate is sub-humid with an average annual precipitation of about 917 mm (36 inches). The area is subject to high intensity, short duration thunderstorms during the spring and summer months. Typically, summers are hot and winters are mild with intervals of freezing temperatures as cold fronts pass through the region.

The watershed is within the Texas Blackland Prairie Major Land Resource Area. Soils range from well-drained loams to fine-textured montmorillonitic clays. Soil depths vary from shallow to deep. Upland topography ranges from nearly level to steeply sloping.

In 1998 Lake Waxahachie was one of nine Texas water bodies found to be in violation of the finished drinking water criterion for Atrazine. One lake, Aquilla, was listed as impaired on the 1998 §319(h) list. The remaining eight lakes were found to be threatened with a strong potential for violation, with seven of them, including Lake Waxahachie, selected for TMDLs in the spring of 2000.

Partners in this project include the Texas State Soil and Water Conservation Board, the Ellis-Prairie Soil and Water Conservation District (SWCD), USDA-NRCS, and USDA-NRCS Water Resources Assessment Team, Blackland Research Center, Temple, TX.

Project Objectives

The main objectives of this study were to:

- Collect GIS, landuse, management, and measured data for the Lake Waxahachie Watershed.
- Calibrate the watershed model to measured flow, sediment, and atrazine.
- Simulate atrazine load for three scenarios: (I) Baseline - pre-1999 condition, (II) §319(h) BMP applications, (III) Application of BMPs on all cropland (all programs).

This report is organized into two parts. Part 1 describes the calibration of the SWAT model for flow, sediment, and atrazine. Part 2 describes the application of the model to evaluate the impact of best management practices (BMPs) on water quality in the watershed.

PART 1 CALIBRATION

INTRODUCTION

The purpose of this part of the report is to describe the calibration of the SWAT model for flow, sediment and atrazine loading. The SWAT model contains many input parameters that describe the physical, chemical, and biological processes. During the calibration phase, the model is run and the results are compared to observed data. The values of the input parameters are refined within the range of acceptability until the model reproduces the observed data.

The Lake Waxahachie, Bardwell Reservoir, and Richland-Chambers Watersheds were delineated and modeled simultaneously. The watersheds of the former two reservoirs are subsets of the much larger Richland-Chambers Reservoir Watershed (Figure 2). In addition, since stream gages and water quality sampling sites were located downstream from Lakes Waxahachie and Bardwell, modeling all three in one project facilitated model calibration.

METHODOLOGY

Model Inputs

Landuse / Cover

The landuse/land cover map was derived from the USGS National Land Cover Dataset (NLCD) land use. The land use map for the watershed is shown in Figure 3. The area and percentage of each landuse is indicated in Table 1.

Soils

The Soil Survey Geographic (SSURGO) database for Ellis County was downloaded to create the soils database for the Lake Waxahachie Watershed (Figure 3). This database provides a much finer resolution of soils than the previously used CBMS or STATSGO data.

The dominant soil series in the Lake Waxahachie Watershed are Austin (31.5%), Eddy (23.5%), Stephen (17.8%), Houston (13.8%), Gullied Land (6.1%), Lewisville (2.5%), Brackett (0.6%), Sumter (0.3%), and Trinity (0.1) Table 2 shows the major soil series with their relative land areas. A short description of each follows:

Austin. - The Austin series consists of moderately deep, well-drained, moderately slowly permeable soils that formed in chalk and interbedded marl. These soils are on nearly level to sloping erosional uplands. Slopes range from 0 to 8 percent.

Eddy. - The Eddy series consists of shallow to very shallow, well-drained, moderately permeable soils that formed in chalky limestone. These soils are on gently sloping to moderately steep uplands. Slopes range from 1 to 20 percent.

Stephen. - The Stephen series consists of shallow, well-drained, moderately slowly permeable soils formed in interbedded marl and chalky limestone. These soils are on gently sloping to sloping uplands. Slopes are mainly 1 to 5 percent but range from 1 to 8 percent.

Houston. - The Houston Black series consists of very deep, moderately well drained, very slowly permeable soils that formed from weakly consolidated calcareous clays and marls of Cretaceous Age. These soils are on nearly level to moderately sloping uplands. Slopes are mainly 1 to 3 percent, but range from 0 to 8 percent.

Lewisville. - The Lewisville series consists of very deep, well-drained, moderately permeable soils that formed in ancient loamy and calcareous sediments. These upland soils have slopes of 0 to 10 percent.

Brackett. - The Brackett series consists of very shallow to shallow soils over bedrock. These well-drained and moderately permeable soils formed in residuum over chalky limestone bedrock mainly of the Glenrose formation of Cretaceous Age. These soils are on gently sloping to very steep uplands. Slopes range from 1 to 60 percent.

Sumter. - The Sumter series consists of moderately deep, well drained, slowly permeable soils that formed in marly clays and chalk of the Blackland Prairies. They are on gently sloping to steep uplands. Water runs off the surface medium to rapidly. Slope ranges from 1 to 40 percent.

Trinity. - The Trinity series consists of very deep, moderately well drained, very slowly permeable soils on flood plains. They formed in alkaline clayey alluvium. Slopes are typically less than 1 percent, but range from 0 to 3 percent.

Gullied Land. – Gullied land is not a soil series, but land areas so severely eroded and so dissected by gullies that they cannot be farmed. The gullies are typically ten to thirty feet deep and thirty to 150 feet wide.

Topography

Elevations range from about 161 meters (528 ft) on the flood plain above Lake Waxahachie to about 255 meters (837 ft) at the watershed divide.

Climate

Daily precipitation totals and maximum and minimum temperatures were obtained for National Weather Service stations adjacent to the watershed (Figure 5) for input to SWAT. The model uses rainfall and temperature data from the climate station nearest each subbasin. Climate stations outside the watershed, yet close enough to influence input data to the model, were included in the GIS database. Missing precipitation data was patched from neighboring climate stations, while missing temperature data was generated with the SWAT model. Table 3 lists precipitation stations located in or near the Lake Waxahachie Watershed and the time periods for which data is available for each station.

Land Management

Information on typical crops and management practices (e.g. crop rotations, tillage, atrazine application rate and timing) was obtained from the Ellis-Prairie Soil and Water Conservation District (SWCD) office and the USDA – Natural Resources Conservation Service (NRCS) office. In addition, detailed information on the water quality management plans (WQMPs) implemented under the §319(h) program was provided.

Typical crops grown in the watershed are corn, cotton, grain sorghum and wheat. About fifty percent of the cropland is effectively terraced. The remainder is either not terraced, or has worn down, ineffective terraces. Contour farming is not prevalent in the area, although most landowners with terraced cropland periodically re-build terraces to maintain the effective height.

A three-year rotation of grain sorghum-wheat-corn was assumed for the cropland. Appropriate plant growth parameters for each crop were input for all model simulations.

Model Calibration

The Lake Waxahachie watershed is a sub watershed within the larger Richland-Chambers watershed (Figure 1). No stream gage stations or in-stream water quality sampling sites were available within the Lake Waxahachie Watershed. However, a stream gage (8064100) and several water quality sampling sites were located downstream and were used for calibration.

Significant input variables for the SWAT model for the Watershed are shown in Table 4. Input variables were adjusted as needed to calibrate first for flow, then sediment, and finally atrazine concentrations.

Subbasins were delineated using the 30-meter (98.42 ft) DEM and the ArcView interface for SWAT 2000. The subbasin threshold area was set to 2,000 hectares (4,942 ac). Site locations for reservoirs, downstream stream gages and water quality sampling sites were used to define additional subbasin outlets.

Required inputs for each subbasin (e.g. soils, land use/land cover, topography and climate) were extracted and formatted using the AVSWAT 2000 interface. The input interface divided each subbasin into virtual subbasins or hydrologic response units (HRU). A single land use and soil were selected for each HRU. The number of HRU’s within a subbasin was determined by: (1) creating an HRU for each land use that equaled or exceeded two percent of the area of a subbasin; and (2) creating an HRU for each soil type that equaled or exceeded 5 percent of any of the land uses selected in (1). The total number of HRU's (26) was dependent on the variability of the land use and soils within the subbasin. The properties for each of the selected land uses and soils were automatically extracted from model-supported databases.

Flow Calibration

Stream flow was calibrated and validated separately using stream gage 8064100 located on Chambers Creek near Rice, TX (Figure 5). The calibration period was from 1/1/1984 through 12/31/1993 (Figure 7), while the validation period was from 1/1/1994 through 9/30/2003 (Figure 8). A base flow filter (Arnold et al., 1995) was used to determine the portioning of groundwater and surface flow.

Adjustments were made to soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, bank coefficient (fraction of transmission losses returned as base flow), Manning's "n" values for channel roughness and channel transmission loss until the simulated total flow and fraction of base flow were approximately equal to the measured total flow and base flow, respectively.

To measure the accuracy of the SWAT predictions to observed values, the Nash-Suttcliffe coefficient of efficiency (E_{NS}) and root mean square error (RMSE) were used. Significant input variables for the SWAT model are shown in Table 4.

Sediment Calibration

The Lake Waxahachie Watershed is a sub-watershed within the much larger Richland-Chambers Reservoir watershed (Figure 1). The modeling was completed concurrently. The sediment calibration settings were developed based upon TWDB hydrographic survey data for Richland-Chambers Reservoir, and applied to all subbasins in the watershed. For additional details concerning the sediment calibration, see the Richland-Chambers report.

Atrazine Calibration

The Lake Waxahachie Watershed is a sub-watershed within the much larger Richland-Chambers Reservoir watershed (Figure 1). The modeling was completed concurrently. Similarly, the atrazine calibration was developed for the Richland-Chambers watershed and the input settings applied to all subbasins in the watershed. Model calibration was developed using very limited in-stream atrazine concentrations sampled by the Tarrant Regional Water District. Daily in-stream pesticide concentrations simulated by SWAT were compared to grab samples collected at eleven sampling locations (Figure 6). The measured concentrations were obtained from one grab sample collected on a given day. Multiple applications of atrazine were simulated in the HRU's to capture the temporal distribution of the pesticide in the watershed.

Atrazine was calibrated so that the mean of the predicted values was within two standard deviations of the mean of the measured values.

SWAT uses a pesticide database that contains parameters that govern pesticide fate and transport. Table 5 contains the atrazine values and descriptions from the SWAT pesticide database used for the project. In addition, the input variable, PERCOP, in the BSN input file was set to 0.3. PERCOP controls the amount of pesticide removed from the surface layer and lateral flow relative to the amount removed via percolation.

Evaluation of Model Performance

Model prediction performance was evaluated by the mean, standard deviation, root mean square error (RMSE), and Nash-Suttcliffe simulation efficiency (E_{NS}). Nash-Suttcliffe simulation efficiency indicates how well the plot of observed versus simulated values fits the 1:1 line. If the E_{NS} value is less than or close to zero, the model prediction is considered unacceptable or poor. If the E_{NS} value is one, then the model is perfect. Generally, an E_{NS} of 0.6 or higher is considered good.

RMSE is the calculated difference between measured and predicted values expressed as a residual of the means squared. One way to gauge the accuracy of the calibration is to compare the mean measured monthly flow volume with the RMSE. The lower the RMSE compared to the measured values the more precise the comparison.

Results and Discussion

Flow Calibration/Validation:

Stream Gage 8064100 Calibration – Flow calibration results are shown in Figure 7. The low RMSE (6.46) and high E_{NS} (0.89) values indicate that predicted total flow compares well with measured flow. The base flow filter (Arnold et al., 1995) estimated from stream flow records that the groundwater contribution to stream flow was 29 percent. The SWAT predicted base flow was 27 percent.

Stream Gage 8064100 Validation – Flow validation results are shown in Figure 8. Again, low RMSE (8.92) and high E_{NS} (0.79) values indicate that predicted total flow compares reasonably well with the measured flow. Estimated base flow was 29 percent. The SWAT predicted base flow was 29 percent.

The monthly time series shown reveals that SWAT under-predicts flow in some periods and over-predicts in others. This is most likely due to missing precipitation data in the station records or rainfall variability that is not reflected in the measured data. Rainfall variability is caused by localized thunderstorms occurring over climate stations or between stations, and spatial distribution of storms not accurately represented in the precipitation data input in SWAT.

Sediment Calibration: The sediment calibration developed for the Richland-Chambers Watershed was used for the Lake Waxahachie Watershed. The predicted sediment load for Richland-Chambers Reservoir for the 1987 through 1994 period was 36,350,000 metric tons (40,069,016 tons), which was close to the measured sediment of 37,934,000 metric tons (41,815,077 tons), and well within the 15 percent range designated for the project.

Atrazine Calibration: The atrazine calibration developed for the Richland Chambers Watershed was used for the Lake Waxahachie Watershed. Table 6 compares measured and predicted daily in-stream atrazine concentrations for the eleven sampling stations in the Richland-Chambers Watershed. Most sampling sites were represented by only two or three samples. However, RC17 in subbasin 74 had five samples, and RC22 in subbasin 66 had seven samples. Stream flow data was not collected at any of these stations.

The predicted atrazine concentrations fell within two standard deviations of the measured mean concentrations indicating that the model is doing a reasonably good job in simulating the movement and transport of the pesticide in the watershed. Measured atrazine concentrations were assumed accurate.

One should keep in mind that comparing an instantaneous grab sample with the average daily concentration calculated by the SWAT model is a difficult comparison at best.

Conclusions

Part 1 of this report describes the calibration of the SWAT model for flow, sediment and atrazine for the watershed. Since no stream gages were located in the Lake Waxahachie Watershed, the closest downstream gage was used to calibrate flow. In addition, SWAT model parameters developed for the Richland-Chambers Watershed for sediment and atrazine calibration were used for the Waxahachie Watershed.

Monthly simulated flow was compared to measured stream gage values. Sediment yield into Richland-Chambers Reservoir was compared to a sediment survey of the lake. Finally, predicted in-stream atrazine concentrations were compared to measured in-stream atrazine concentrations. The results indicate that the model is calibrated properly and performing well.

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In addition, much appreciated is the stream monitoring data provided by Darrell Andrews at Tarrant Regional Water District.

Also thanks to Dr. Jeffrey Arnold, USDA-ARS, Temple, Texas for assistance with model calibration.

Table 1. Land use/cover in Lake Waxahachie Watershed.

Description	*Hectares*	*Acres*	*Cover (%)*
Cropland	1,818	4,493	22.86%
Pastureland	4,240	10,478	53.30%
Brushy Rangeland	660	1,631	8.30%
Open Rangeland	937	2,316	11.78%
Urban	0	0	0.00%
Water	299	740	3.76%
Total	7,956	19,658	100.00%

Table 2. Soil types in Lake Waxahachie Watershed.

Soil Series / Land Type	*Acres*	*Hectares*	*Percent*
Austin	6,197	2,508	31.52%
Eddy	4,621	1,870	23.50%
Stephen	3,500	1,417	17.81%
Houston	2,707	1,095	13.77%
Gullied land	1,190	482	6.05%
Water	756	306	3.85%
Lewisville	485	196	2.47%
Brackett	107	43	0.55%
Sumter	66	27	0.33%
Pits	21	8	0.11%
Trinity	7	3	0.04%
Dams	2	1	0.01%
Total	19,658	7,956	100.00%

Table 3. Climate stations used in Lake Waxahachie Watershed simulations.

Station Number	*Station Name*	*Data Type*	*Start Date*	*End Date*
480440	Avalon	Precip	1964	2003
480518	Bardwell Dam	Temp & Precip	1965	2005
484761	Kennedale	Precip	1946	1981

Table 4. SWAT Input Variables for Flow and Sediment Calibration.

Variable	***Adjustment Or Value***
Runoff Curve Number Adjustment	-4
Soil Available Water Capacity Adjustment (mm H_2O/mm soil)	None
Soil Crack Volume Factor	None
Soil Saturated Conductivity (mm/hour)	None
Soil Evaporation Compensation Factor	0.55
Minimum Shallow Aquifer Storage for Groundwater Flow (mm)	0.50
Minimum Shallow Aquifer Storage for Re-Evaporation (mm)	2.00
Shallow Aquifer Re-Evaporation Coefficient	0.10
Channel Erodibility Factor	0.85
Channel Cover Factor	0.85
Channel Transmission Loss (mm/hour)	1.00
Subbasin Transmission Loss (mm/hour)	0.55
Bank Coefficient	0.30
Reservoir Seepage Rate (mm/hour)	0.08
Initial Residue (kg/ha)	1000
Residue Decomposition Coefficient	0.10
Re-entrainment of Channel Sediment – Exponent	2.00
Re-entrainment of Channel Sediment – Linear	0.01
Peak Rate Function	2.00
Manning’s “N” Value for the Main Channel	0.06
Manning’s “N” Value for the Tributary Channels	0.06

Table 5. SWAT input variables for atrazine fate and transport.

Input Parameter	***Description***	***Value***
SKOC	Soil adsorption coefficient (mg/kg)/(mg/l)	100
WOF	Wash off fraction (fraction)	0.45
HLIFE_F	Degradation half-life of the chemical on foliage (days)	5.0
HLIFE_S	Degradation half-life of the chemical on the soil (days)	60
AP_EF	Application efficiency (fraction)	0.75
WSOL	Solubility of the chemical in water (mg/l)	33.00
PERCOP	Pesticide percolation coefficient	0.30

Table 6. Measured and predicted atrazine concentrations

Sampling Station		Average	Median	SD	Plus 2 SD	Minus 2 SD
RC01 (Sub 83)	*Meas*	3.41	3.41	2.96	9.32	-2.50
	Pred	1.18				
RC03 (Sub 55)	*Meas*	18.00	18.00	8.49	34.97	1.03
	Pred	32.18				
RC04 (Sub 76)	*Meas*	8.58	8.58	10.35	29.28	-12.12
	Pred	2.33				
RC07 (Sub 36)	*Meas*	9.56	9.56	13.35	36.26	-17.14
	Pred	2.49				
RC08 (Sub 73)	*Meas*	6.00	6.00	8.35	22.70	-10.71
	Pred	19.87				
RC10 (Sub 81)	*Meas*	16.20	16.20	3.96	24.12	8.28
	Pred	7.58				
RC12 (Sub 80)	*Meas*	17.44	17.44	13.52	44.48	-9.60
	Pred	6.22				
RC16 (Sub 37)	*Meas*	0.36	0.36	0.16	0.68	0.03
	Pred	0.93				
RC17 (Sub 74)	*Meas*	4.81	4.74	2.20	9.21	0.42
	Pred	5.65				
RC19 (Sub 69)	*Meas*	135.02	35.00	199.73	534.48	-264.43
	Pred	3.20				
RC21 (Sub 65)	*Meas*	7.96	5.76	9.14	26.24	-10.31
	Pred	4.31				
RC 22 (Sub 66)	*Meas*	4.88	3.26	2.47	9.82	-0.05
	Pred	5.38				

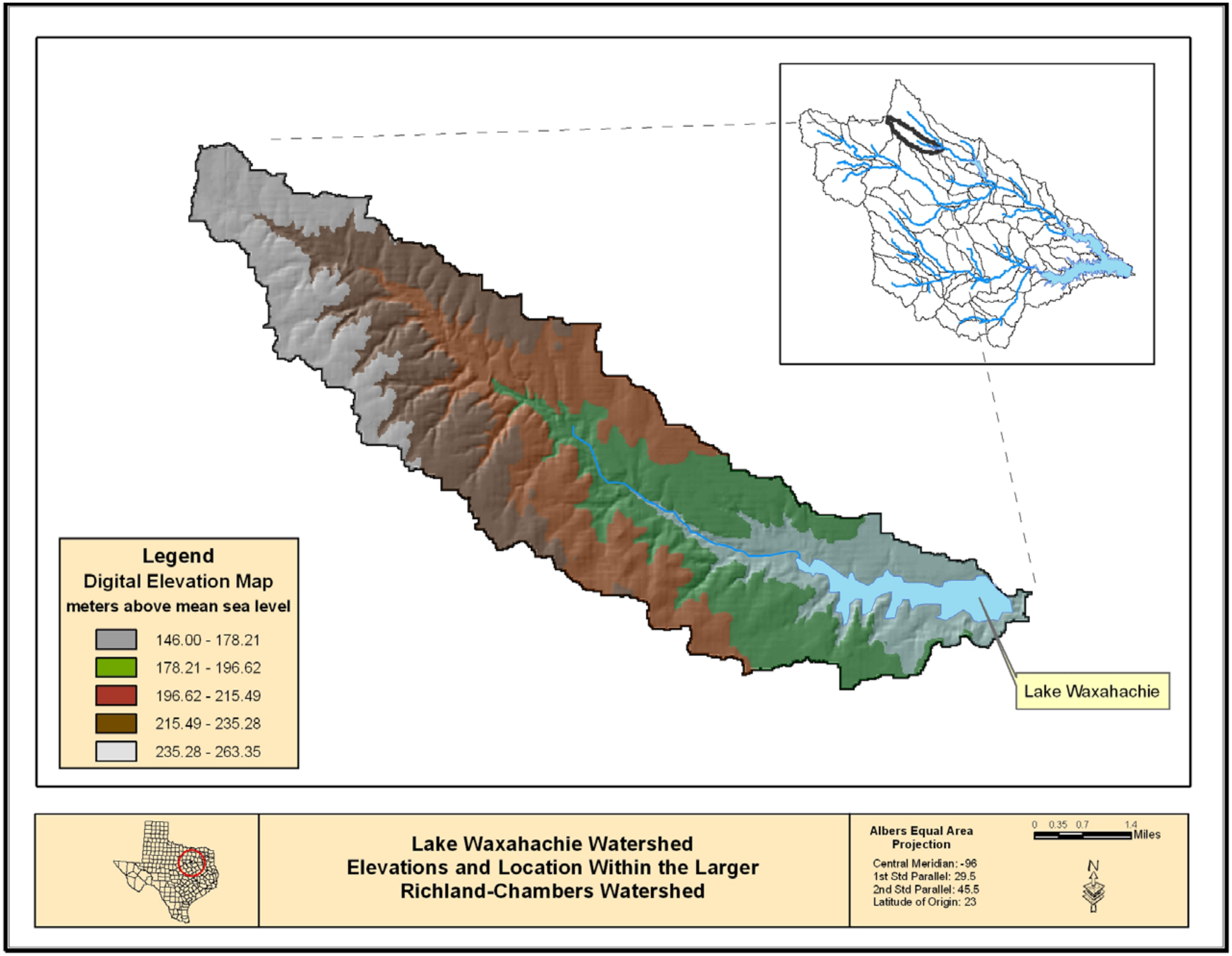

Figure 1. Lake Waxahachie Watershed showing the location within the larger Richland-Chambers Watershed. Elevations above sea level are symbolized by color.

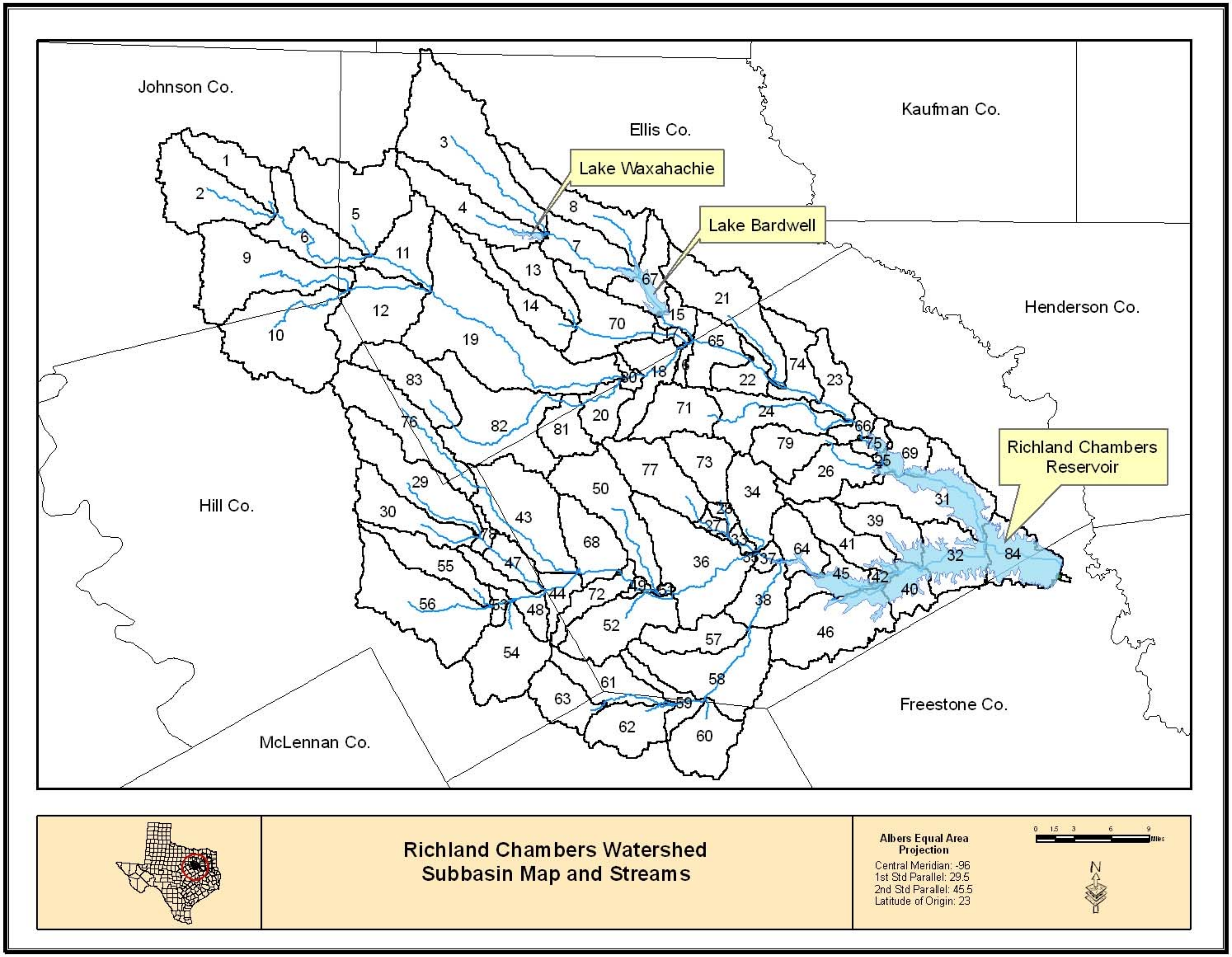

Figure 2. Richland-Chambers Watershed. The Lake Waxahachie Watershed is a subset of this watershed (subbasin 4).

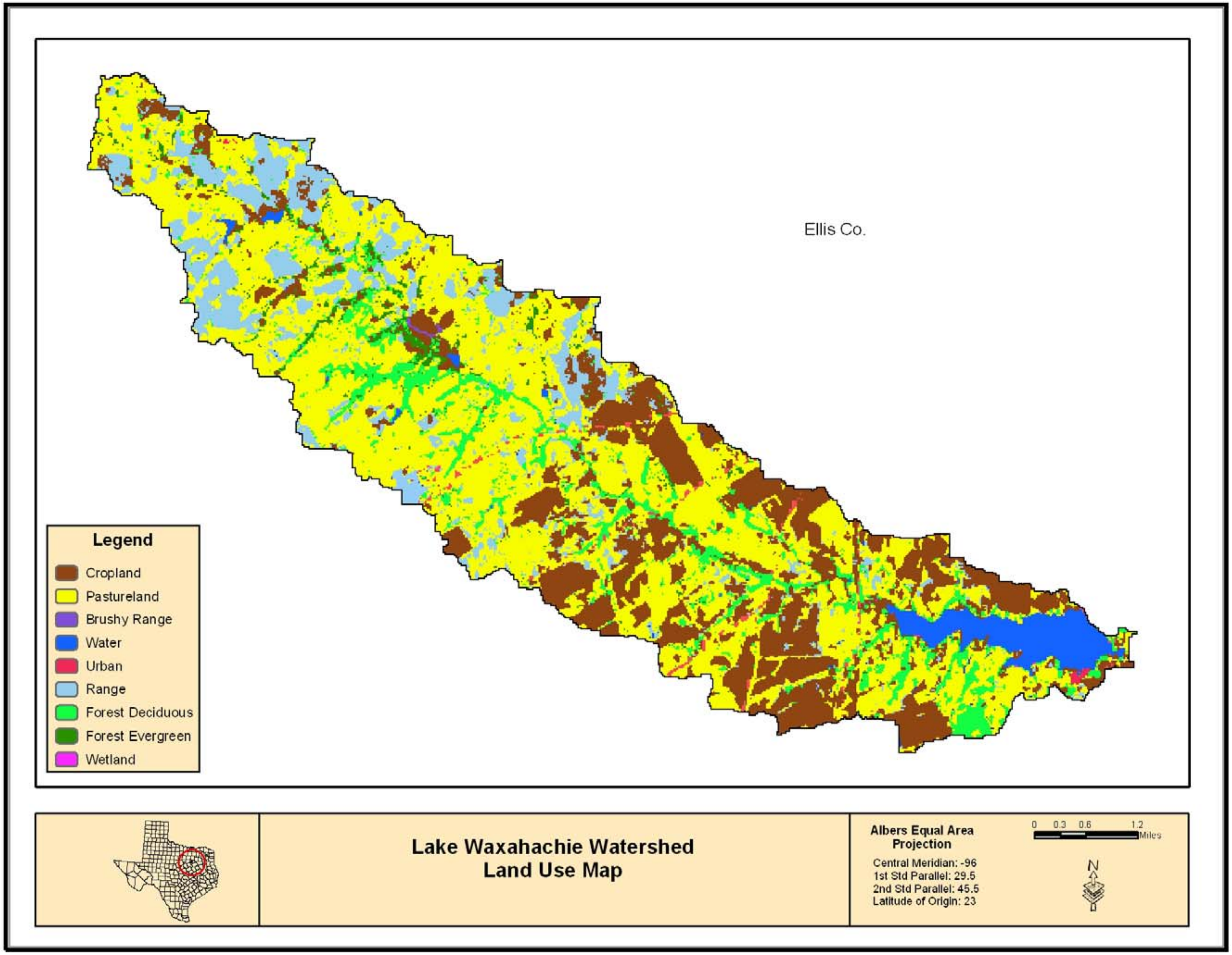

Figure 3. NLCD land use/cover map of the Lake Waxahachie Watershed.

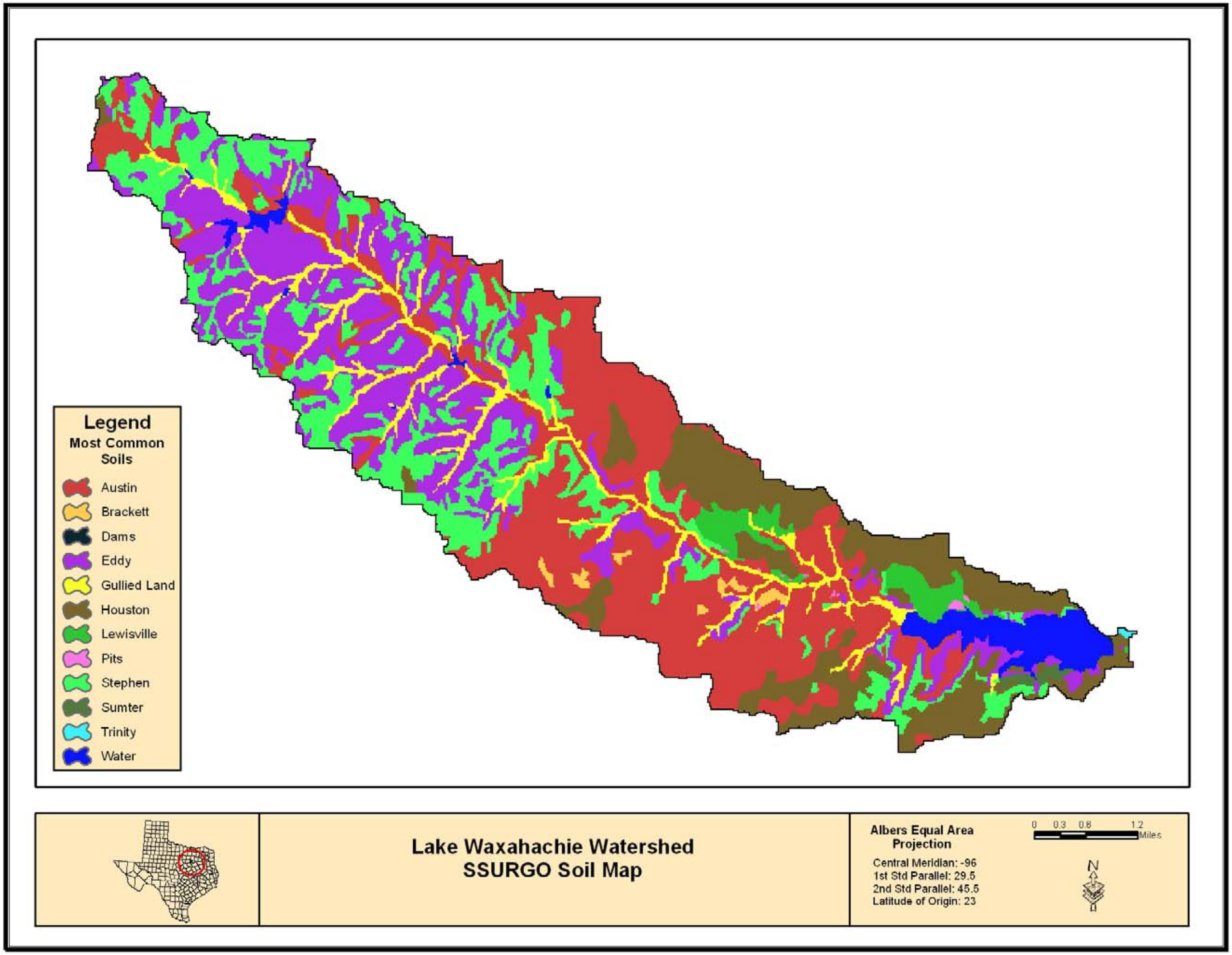

Figure 4. SSURGO soils map of Lake Waxahachie Watershed.

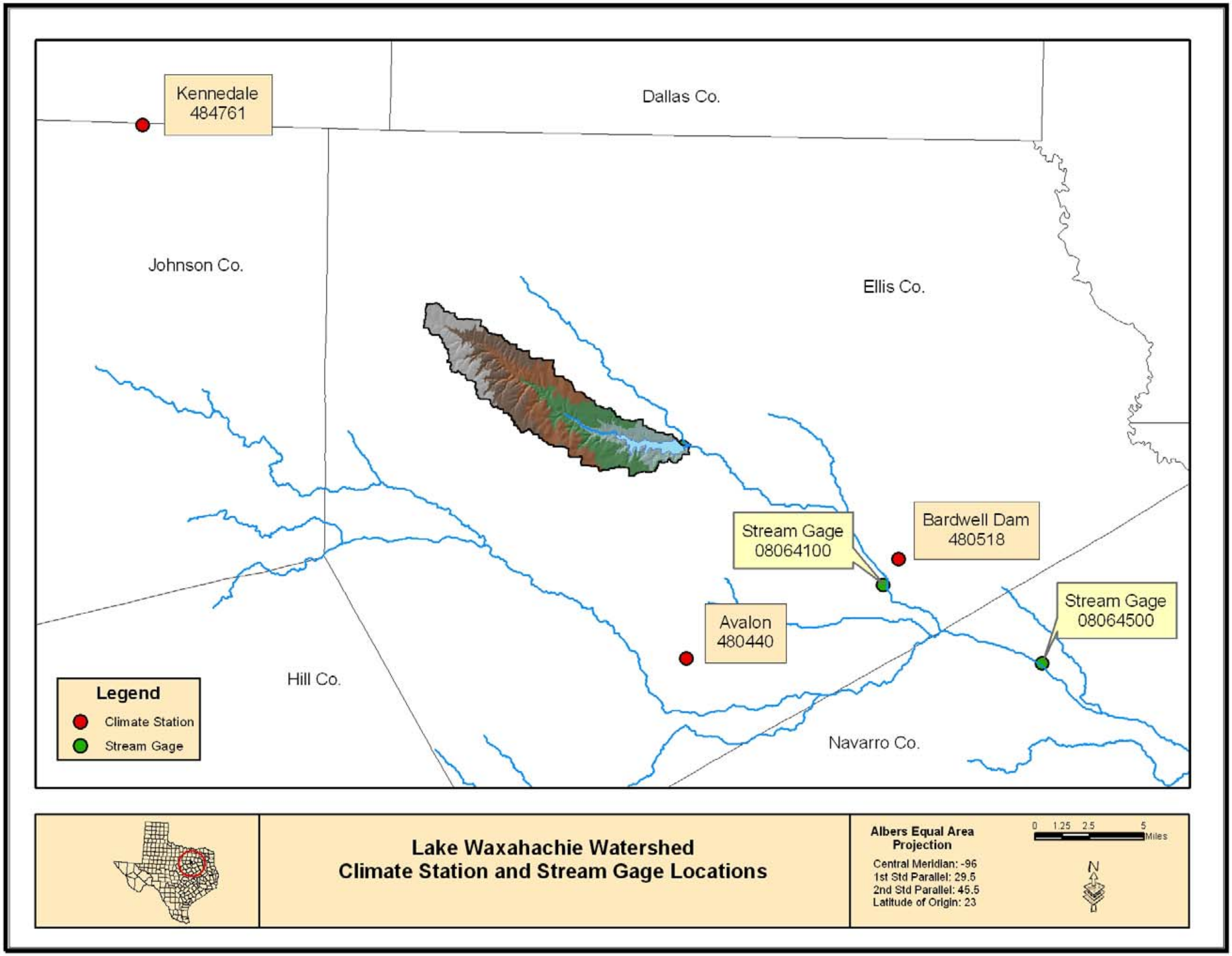

Figure 5. Climate stations and stream gages for Lake Waxahachie Watershed.

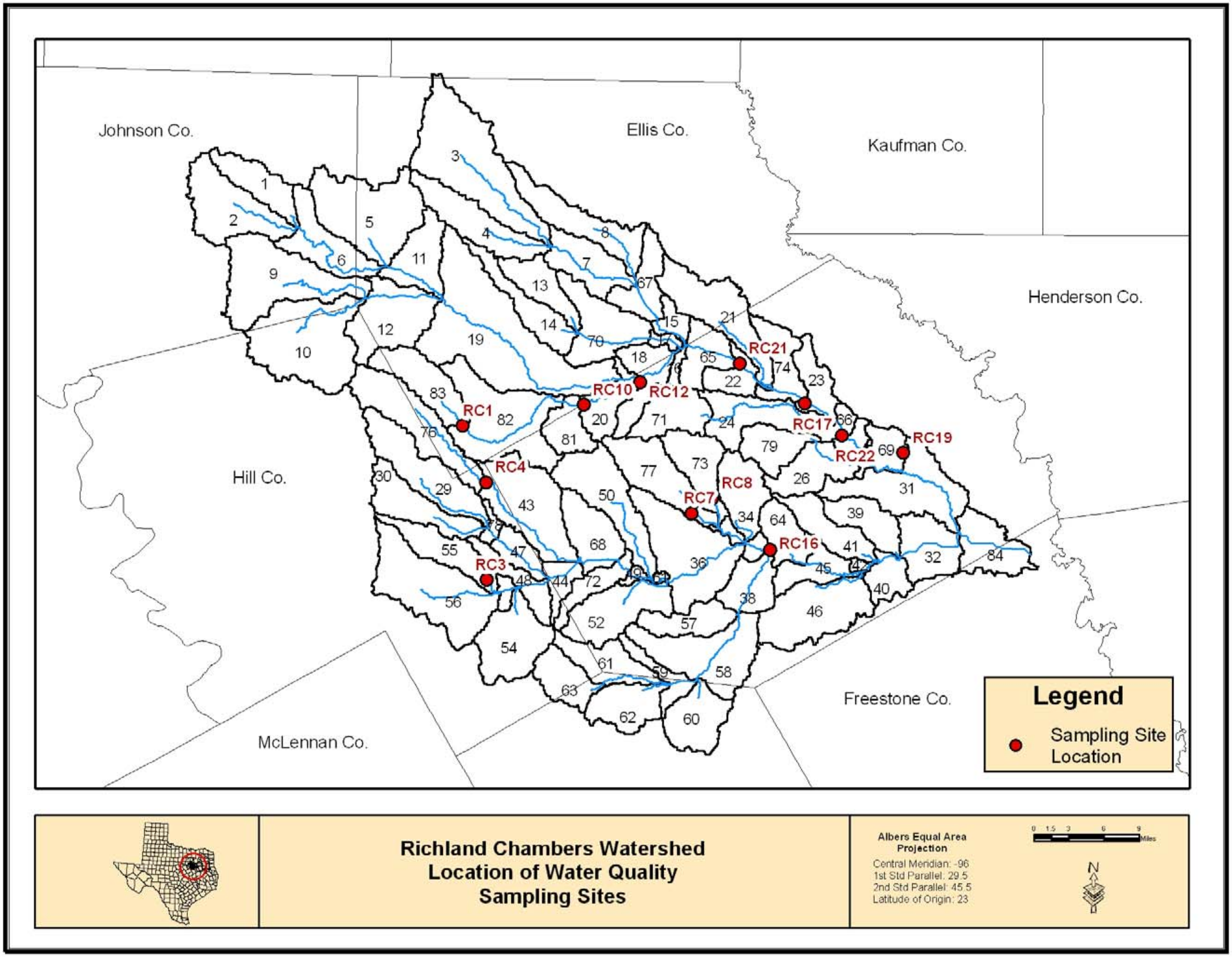

Figure 6. Location of water quality sampling stations in Richland-Chambers Watershed.

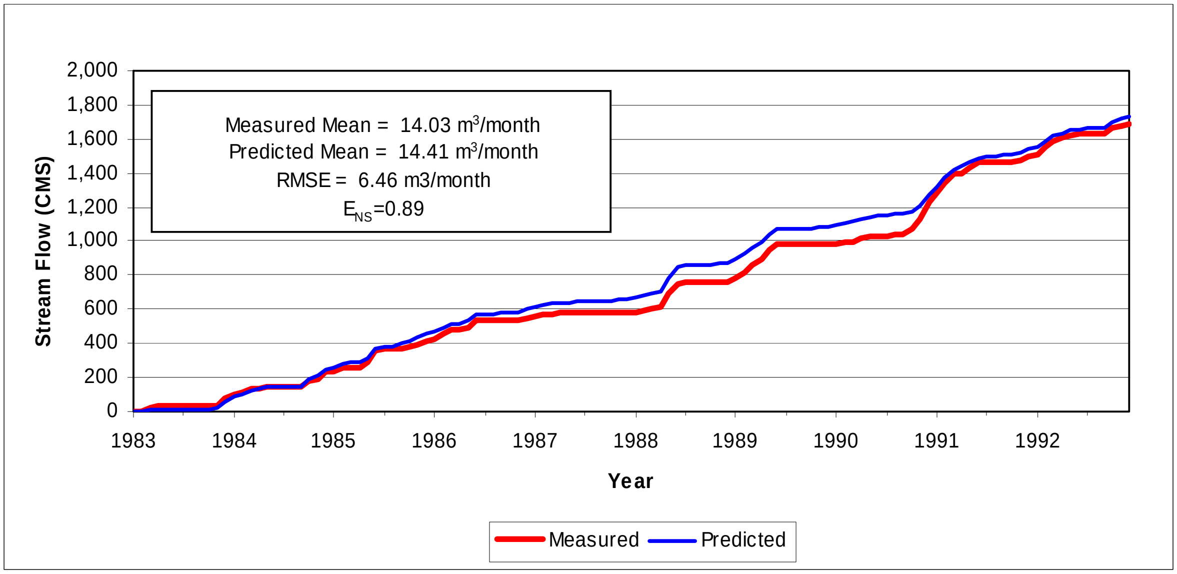

Figure 7. Cumulative monthly measured and predicted stream flow at gage 8064100 (Chambers Creek near Rice, TX), 1984 through 1993. This period was used for flow calibration. Monthly statistics are shown in the box.

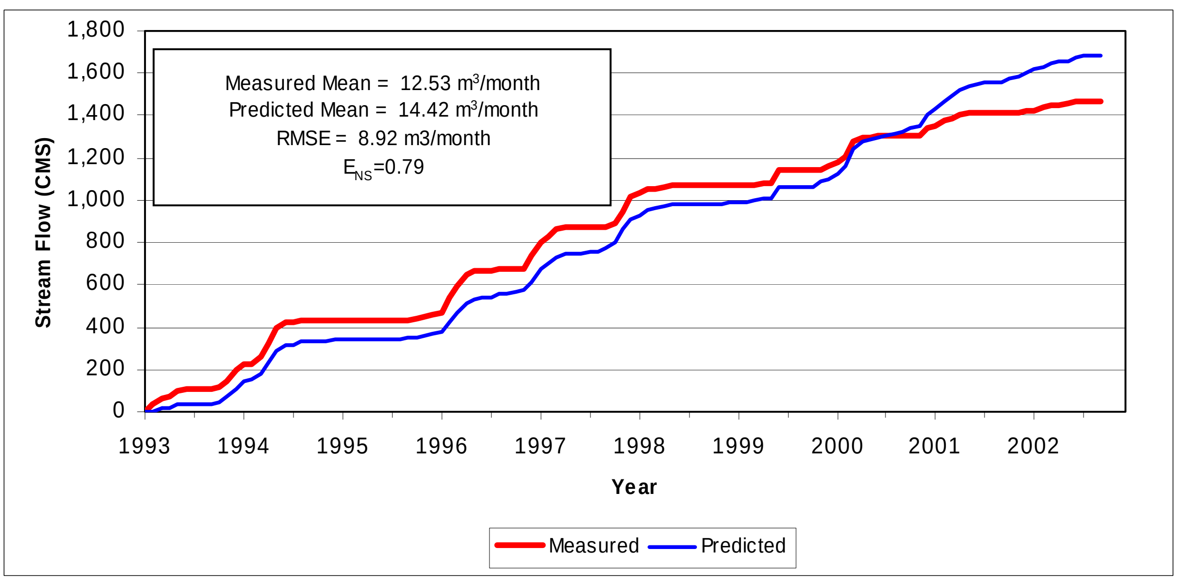

Figure 8. Cumulative monthly measured and predicted stream flow at gage 8064100 (Chambers Creek near Rice, TX), 1994 through 2003. This period was used for flow validation. Monthly statistics are shown in the box.

PART 2: BEST MANAGEMENT PRACTICES

Introduction

The objective of this section of the report is to describe the application of the SWAT model for estimating atrazine loading and sediment yield under the existing conditions of the watershed and analyze the effectiveness of BMPs applied under the §319(h) program.

Methodology

BMP Scenarios

Three scenarios were constructed in order to estimate the reductions in atrazine and sediment due to WQMP implementation under the §319(h) program. Each scenario was run for the 30-year period, 1974 through 2003.

- Scenario I – Current conditions (baseline) scenario representing the conditions in the watershed prior to the implementation of WQMPs under the §319(h) program.
- Scenario II – Post BMP scenario representing the conditions in the watershed after the implementation of funded WQMPs under the §319(h) program.
- Scenario III – All cropland treated scenario representing the ideal condition in which BMPs have been applied to all cropland acres.

Changes in sediment and atrazine loadings between the pre-BMP and the post-BMP scenarios provide the percentage of reduction in the watershed.

Scenario I - Existing Conditions

This scenario was modeled with fifty percent of the cropland effectively terraced with no contouring. Existing ponds and dams were included as well as typical management techniques including tillage, fertilization, and conservation practices. A three-year crop rotation of corn-wheat-sorghum was used.

Scenario II - Post BMP Condition

Table 7 shows the various conservation practices (BMPs) by county that were implemented under the §319(h) project.

Major BMPs simulated with SWAT were:

- Conservation tillage
- Filter strips and field borders
- Conservation crop rotation
- Pasture and hayland planting

- Prescribed grazing
- Nutrient and pest management

These practices were applied only to the farms in the watershed that had implemented WQMPs under the §319(h) program. As a percentage of the total land area in the watershed, these farms constituted a relatively small part – about one percent.

Scenario III - All Cropland Treated

All the BMPs listed above for scenario II were applied to all cropland acres for scenario III. Cropland conversion to pasture/hayland was simulated at 25 percent. This value was chosen since it is similar to the landuse conversion rate implemented in the §319(h) WQMPs and modeled in scenario II.

BMP Analysis

Results are presented as a percentage reduction in atrazine and sediment loadings at three levels:

- Farm level – This included only the areas in each subbasin where BMPs were applied.
- Subbasin level – Included both the BMP areas and the non-BMP areas within the subbasin.
- Watershed level – The watershed outlet on South Prong creek. The effects of reservoir impoundment were ignored for this analysis.

Results and Discussion

The simulation of the watershed hydrology can be separated into two major divisions. The first part is the land phase of the hydrologic cycle that controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each subbasin. The second part is the routing phase, or water phase, of the hydrologic cycle where water, sediment, pesticide, etc. moves through the channel network of the watershed to the outlet.

The following results described under the farm and subbasin levels are from the land phase, while the watershed results are from the routing phase of the simulation.

Reductions at farm level – scenario II

The types of installed practices and extents are listed in Table 7. The farm-level reductions in atrazine and sediment loadings are shown in Figure 9. These include only the areas where §319(h) BMPs were implemented

Atrazine reduction was 94 percent at the farm level. The high percentage atrazine reduction was mostly due to landuse conversion from cropland to permanent pasture. Where the landuse remained as cropland after conservation treatment the combination of conservation practices applied reduced atrazine loading by about 75 percent.

Sediment reduction was 92 percent at the farm level. This high reduction is again associated with the landuse conversion of cropland to pastureland. The treated cropland sediment reduction was about 72 percent.

Reductions at the subbasin level - atrazine

Reductions in subbasin atrazine loadings to the channels are shown in Figure 10. Here all the land in the subbasin is considered.

Scenario II - The percentage reduction was 2.5 percent. Compared to the reduction at the farm level, the percentage reduction is much less, as expected, since the BMP-treated land comprises a relatively small part of the total subbasin area.

Scenario III – In this scenario all cropland in the watershed was treated resulting in a percentage reduction of 80 percent.

Reductions at the subbasin level – sediment

Reductions in subbasin sediment loadings are shown in Figure 11.

Scenario II – The percentage reduction was 2 percent.

Scenario III – The percentage sediment reduction when all cropland was treated was 86 percent.

Reductions at the watershed level – atrazine

Figure 12 shows the percentage of atrazine loading reduction on the main channel at the watershed outlet. Refer to the subbasin map in Figure 1 for location.

Scenario II – The percentage reduction was 2.6.

Scenario III – The percentage reduction was 80.

Reductions at the watershed level – sediment

Figure 12 shows the percentage of sediment loading reduction.

Scenario II – The percentage reduction was 2.

Scenario III – The percentage reduction was 86.

Conclusions

The purpose of this study was to simulate the atrazine and sediment loadings in the Lake Waxahachie Watershed for three scenarios: (I) current conditions (pre 1999), (II) §319(h) BMP applications through WQMPs, and (III) all cropland treated. The study was performed using the SWAT basin scale model.

Scenario II showed that BMPs at the farm level where they were implemented reduced atrazine loading by 94 percent, and reduced sediment loading by 92 percent.

Scenario II showed that BMPs at the subbasin level reduced atrazine loading by 2.5 percent, and reduced sediment loading by 2 percent.

Scenario II showed that BMPs at the watershed level reduced atrazine loadings into Lake Waxahachie by 2.6 percent and reduced sediment loading by 2 percent.

Scenario III showed that BMPs at the subbasin level reduced atrazine loading by 80 percent, and reduced sediment loading by 86 percent.

Scenario III showed that BMPs at the watershed level reduced atrazine loading into Lake Waxahachie by 80 percent, and reduced sediment loading by 86 percent.

Predicted sediment volume to Lake Waxahachie for the 1974 though 2003 modeling period was 438,900 metric tons (1,084,541 tons) for the baseline condition (scenario I), 429,900 metric tons (1,062,302 tons) for the §319(h) BMP condition (scenario II), and 59,850 metric tons (147,892 tons) for the all cropland treated condition (scenario III). In percentages, sediment reduction to the lake for scenario II was two, and for scenario III was 86.

This study modeled only the conservation practices applied through the §319(h) program. There were two contracts in this watershed covering 82 hectares (202 ac), or about one percent of the watershed.

BMPs simulated with SWAT were conservation tillage, conservation crop rotation, conservation buffers, herbicide incorporation, and pasture planting (conversion from cropland to pastureland).

Table 7. Locations and types of conservation practices (BMPs) implemented in the Lake Waxahachie Watershed under the §319(h) project.

Conservation Practice	***Ellis Co.***
328 - Conservation Crop Rotation (ac)	34
511 - Forage Harvest Management (ac)	33
512 - Pasture & Hayland Planting (ac)	121
512 - Pasture & Hayland Planting (no)	2
528A - Prescribed Grazing (ac)	156
590 - Nutrient Management (ac)	188
595 - Pest Management (ac)	188

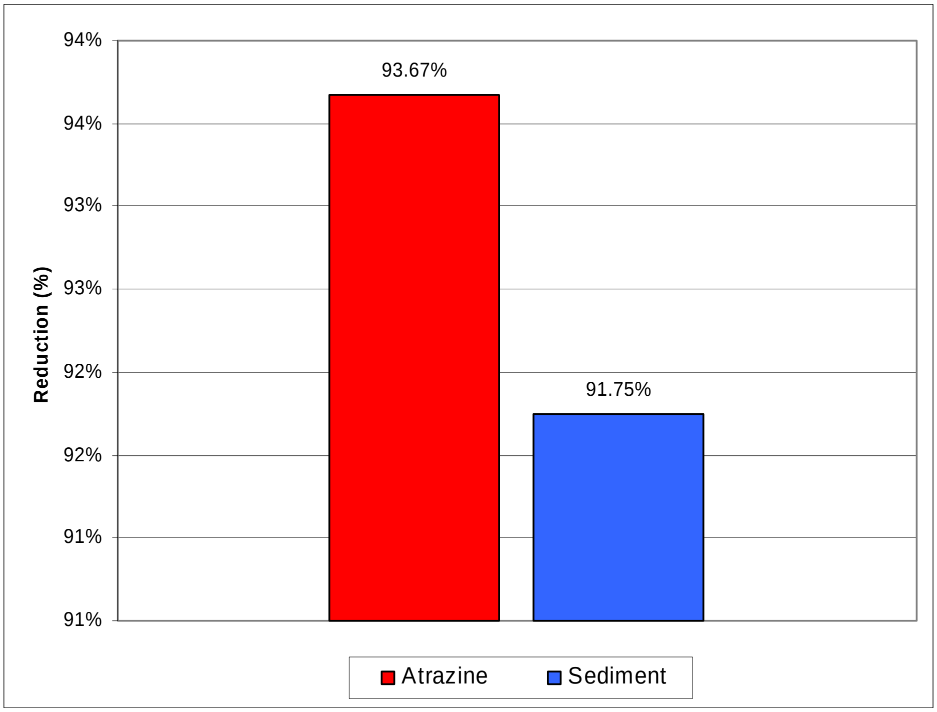

Figure 9. Percentage reductions in atrazine and sediment loading at the farm level where conservation practices were implemented in the Lake Waxahachie Watershed.

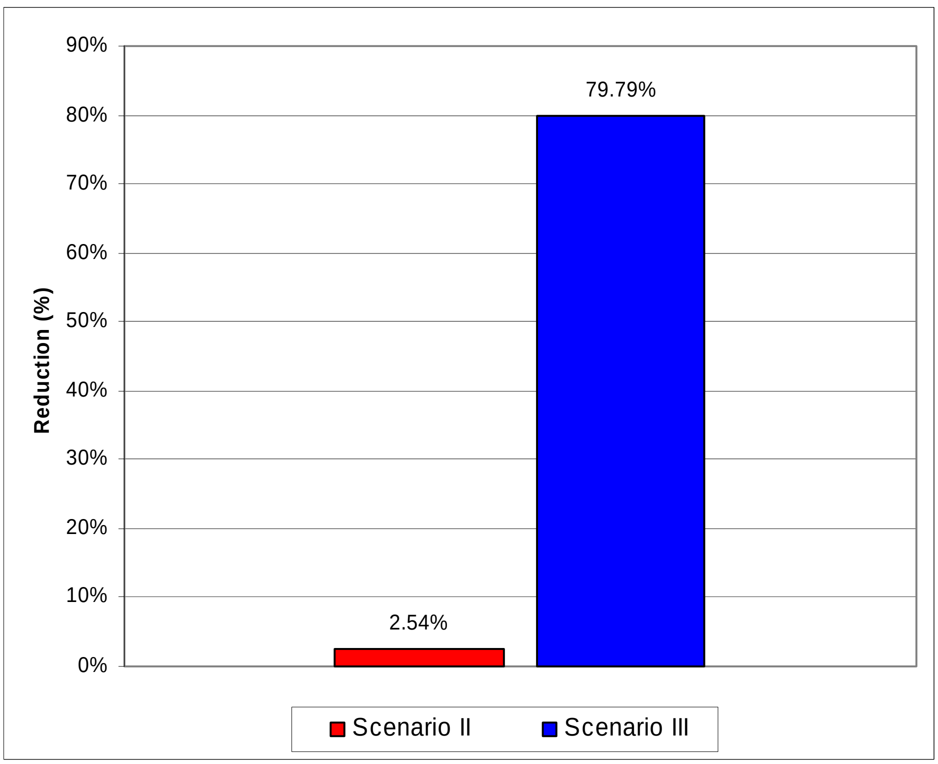

Figure 10. Percentage reductions in atrazine loading at the subbasin level, Lake Waxahachie Watershed.

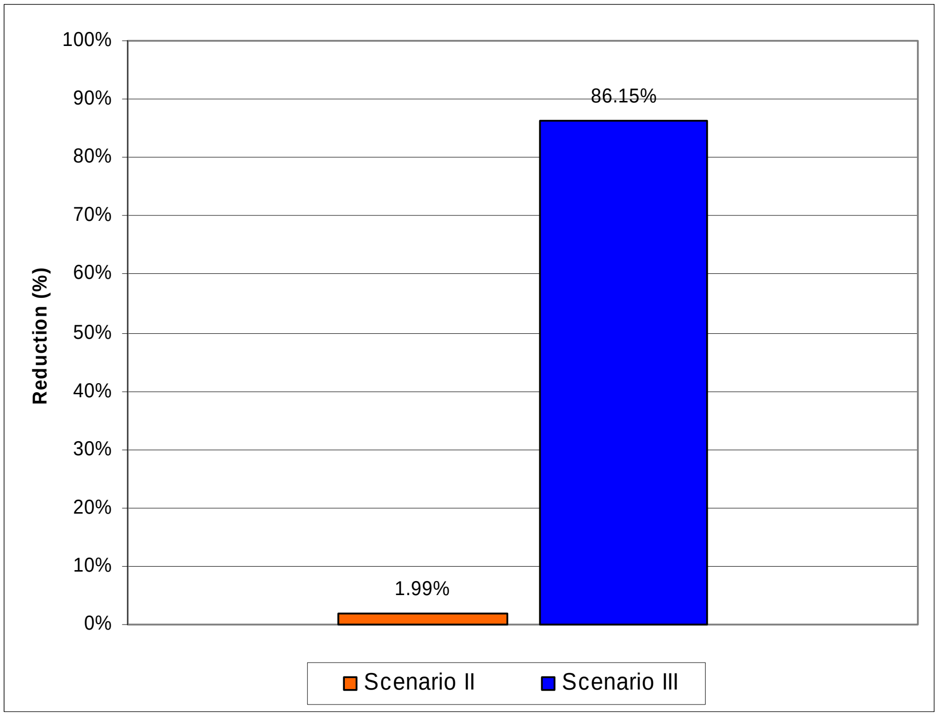

Figure 11. Percentage reductions in sediment loading at the subbasin level, Lake Waxahachie Watershed.

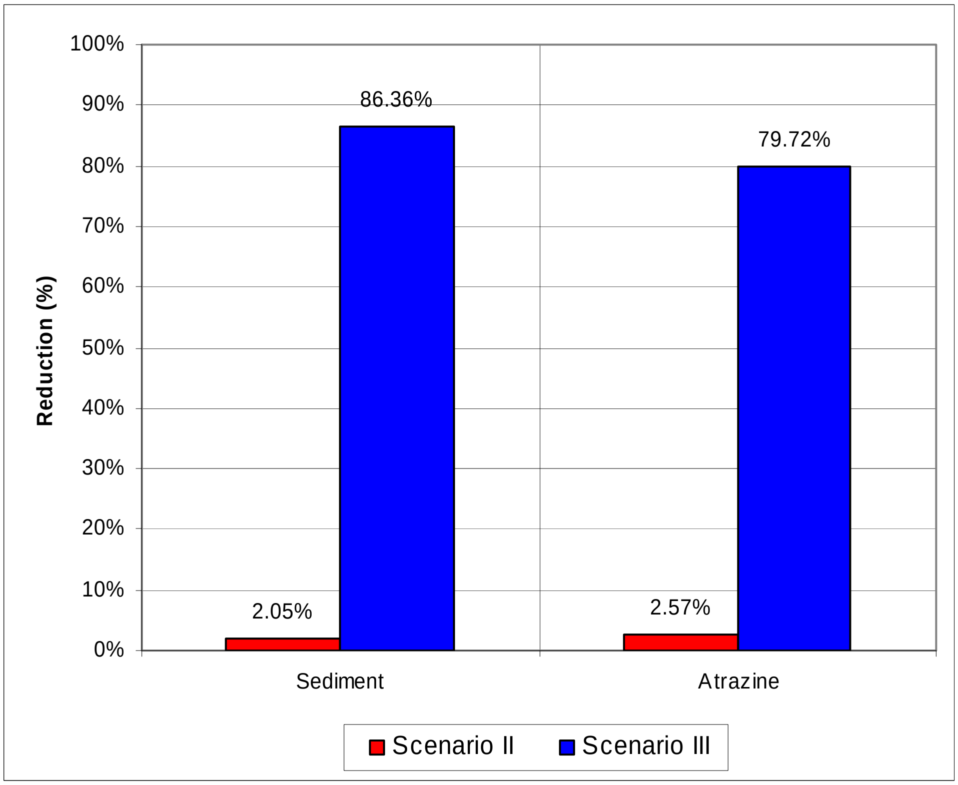

Figure 12. Percentage reductions in sediment and atrazine loading at the watershed level, Lake Waxahachie Watershed.

APPENDIX

Notes for Table 8 – Appendix

In Table 8, the fraction of landuse in each subbasin is based on actual input into SWAT and will not agree exactly with landuse percentages in Table 1. We set the landuse filter in SWAT at 2 percent, which means that any landuse comprising less than 2 percent of a subbasin was ignored in the model input. In addition, SWAT re-allocates areas to the other landuses when a landuse of less than 2 percent is ignored and dropped out of the model. The result is usually a small adjustment in area for each category of landuse in SWAT input.

Table 8. Landuse/Cover, Lake Waxahachie Watershed---------------------------

Detailed LANDUSE/SOIL distribution SWAT model class Wed Jul 13 15:12:05 2005

		Area [ha]	Area [acres]
Watershed		7955.5408	19658.5391
LANDUSE:			
	Residential-High Density --> URHD	0.1801	0.4450
	Range-Brush --> RNGB	15.3057	37.8211
	Pasture --> PAST	4088.9618	10104.0290
	Range-Grasses --> RNGE	906.8175	2240.7914
	Water --> WATR	289.6378	715.7095
	Wetlands-Mixed --> WETL	3.5113	8.6766
	Commercial --> UCOM	50.2387	124.1423
	RC 319 Row Crop --> RCAG	15.7559	38.9335
	RC 319 Crop2Past --> RCAP	28.9008	71.4152
	Forest-Deciduous --> FRSD	638.6077	1578.0315
	Forest-Evergreen --> FRSE	122.1755	301.9017
	RC 319 Past --> RCPA	13.0549	32.2592
	Forest-Mixed --> FRST	31.2416	77.1996
	Agricultural Land-Close-grown --> AGRC	29.1709	72.0826
	Residential-Low Density --> URLD	7.4728	18.4656
	Agricultural Land-Row Crops --> AGRR	1714.5081	4236.6352
SOIL:			
	TRINITY	2.9711	7.3418
	DAMS	0.6302	1.5573
	HOUSTON	1095.3477	2706.6588
	STEPHEN	1416.5872	3500.4578
	AUSTIN	2507.7033	6196.6602
	PITS	8.3731	20.6904
	WATER	306.1139	756.4228
	SUMTER	26.5599	65.6308
	LEWISVILLE	196.1830	484.7780
	GULLIED LAND	481.6793	1190.2535
	BRACKETT	43.4862	107.4565
	EDDY	1869.9059	4620.6310

Appendix Table 9. Predicted mean annual atrazine and sediment loading at the farm level where conservation practices were implemented, Lake Waxahachie watershed, 1974 through 2003. See Figure 10 for a chart of this data.

Atrazine Loading (mg)			Sediment Loading (m. tons)		
Scenario I Current Conditions	Scenario II Treated Conditions	AT reduction % I vs. II	Scenario I Current Conditions	Scenario II Treated Conditions	Sediment reduction % I vs. II
1,673,705	105,987	94%	330.76	27.28	92%

Appendix Table 10. Predicted mean annual atrazine loading at the subbasin level for each modeling scenario, Lake Waxahachie watershed, 1974 through 2003. See Figure 11 for a chart of part of this data.

		Atrazine Loading (mg)				
Area (ha)	Cropland Fraction	Scenario I Current Cond.	Scenario II 319(h) BMP Treated	Scenario III All Treated	Reduction (%) I vs. II	Reduction (%) I vs. III
7,955.60	0.23	61,765,001	60,197,283	12,482,105	3%	80%

Appendix Table 11. Predicted mean annual sediment loading at the subbasin level for each modeling scenario, Lake Waxahachie watershed, 1974 through 2003. See Figure 12 for a chart of part of this data.

		Sediment Loading (m. tons/ha)				
Area (ha)	Cropland Fraction	Scenario I Current Cond.	Scenario II 319(h) BMP Treated	Scenario III All Treated	Reduction (%) I vs. II	Reduction (%) I vs. III
7,955.60	0.23	1.92	1.88	0.27	2%	86%

(Appendix Table 12. Predicted mean annual atrazine loading at the watershed level for each modeling scenario, Lake Waxahachie watershed, 1974 through 2003. See Figure 13 for a chart of part of this data.

		Atrazine Loading (mg)				
Area (ha)	Cropland Fraction	Scenario I Current Cond.	Scenario II 319(h) BMP Treated	Scenario III All Treated	Reduction (%) I vs. II	Reduction (%) I vs. III
7,955.60	0.23	56,710,000	55,250,000	11,500,000	3%	80%

Appendix Table 13. Predicted mean annual sediment loading at the watershed level for each modeling scenario, Lake Waxahachie watershed, 1974 through 2003. See Figure 14 for a chart of part of this data.

Area (ha)	Cropland Fraction	Sediment Loading (m. tons)			Reduction (%)	Reduction (%)
		Scenario I Current Cond.	Scenario II 319(h) BMP Treated	Scenario III All Treated	I vs. II	I vs. III
7,955.60	0.23	14,630	14,330	1,995	2%	86%