CHAPTER 1

BRUSH / WATER YIELD FEASIBILITY STUDIES

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Abstract*:* The Soil and Water Assessment Tool (SWAT) model was used to simulate the effects of brush removal on water yield in 8 watersheds in Texas for 1960 through 1998. Landsat7 satellite imagery was used to classify land use, and the 1:24,000 scale digital elevation model (DEM) was used to delineate the watershed boundaries and subbasins. After calibration of SWAT to existing stream gauges, brush removal was simulated by converting all heavy and moderate categories of brush (except oak) to open range (native grass). Treatment or removal of light brush was not simulated. Results of brush treatment in all watersheds are presented. Water yield (surface runoff and base flow) varied by subbasin, but all subbasins showed an increase in water yield as a result of removing brush. Economic and wildlife habitat considerations will impact actual amounts of brush removed.

BACKGROUND

Recent droughts in Texas have brought attention to the critical need for increasing water supplies in some water-short locations, especially the western portion of the state. Increases in brush area and density may contribute to a decrease in stream flow, possibly due to increased evapotranspiration (ET) (Thurow, 1998; Dugas et al., 1998). A modeling study of the North Concho River watershed (Upper Colorado River Authority, 1998) indicates that removing brush may result in a significant increase in water yield.

During the 1998-99 legislative session, the Texas Legislature appropriated funds to study the effects of brush removal on water yield in eight watersheds in Texas. These watersheds are: Canadian River above Lake Meredith, Wichita River above Lake Kemp, Upper Colorado River above Lake Ivie, Concho River, Pedernales River, watersheds above the Edwards Aquifer, Frio River above Choke Canyon Reservoir, and Nueces River above Choke Canyon. The feasibility studies were conducted by a team from the Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX), U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), and the Texas State Soil and Water Conservation Board (TSSWCB). The goals of the study were:

1. Predict the effects of brush removal or treatment on water yield in each watershed.
2. Prioritize areas within each watershed relative to their potential for increasing water yield.
3. Determine the benefit/cost of applying brush management practices in each watershed.
4. Determine effects of brush management on livestock production and wildlife habitat.

This report will only address the first two.

METHODS

SWAT Model Description

The Soil and Water Assessment Tool (SWAT) model (Arnold et al., 1998) is the continuation of a long-term effort of nonpoint source pollution modeling by the USDA-Agricultural Research Service (ARS), including development of CREAMS (Knisel, 1980), SWRRB (Williams et al., 1985; Arnold et al., 1990), and ROTO (Arnold et al., 1995).

SWAT was developed to predict the impact of climate and management (e.g. vegetative changes, reservoir management, groundwater withdrawals, and water transfer) on water, sediment, and agricultural chemical yields in large un-gauged basins. To satisfy the objective, the model (a) is physically based; (b) uses readily available inputs; (c) is computationally efficient to operate on large basins in a reasonable time; and (d) is continuous time and capable of simulating long periods for computing the effects of management changes. SWAT allows a basin to be divided into hundreds or thousands of grid cells or sub-watersheds.

Geographic Information System (GIS)

In recent years, there has been considerable effort devoted to utilizing GIS to extract inputs (e.g., soils, land use, and topography) for comprehensive simulation models and spatially display model outputs. Much of the initial research was devoted to linking single-event, grid models with raster-based GIS (Srinivasan and Engel, 1991; Rewerts and Engel, 1991). An interface was developed for SWAT (Srinivasan and Arnold, 1993) using the Graphical Resources Analysis Support System (GRASS), (U.S. Army, 1988). The input interface extracts model input data from map layers and associated relational databases for each subbasin. Soils, land use, weather, management, and topographic data are collected and written to appropriate model input files. The output interface allows the user to display output maps and graph output data by selecting a subbasin from a GIS map. The study was performed using GRASS GIS integrated with the SWAT model, both of which operate in the UNIX operating system.

GIS Data

Development of databases and GIS layers was an integral part of the feasibility study. The data was assembled at the highest level of detail possible in order to accurately define the physical characteristics of each watershed.

Topography. The United States Geological Survey (USGS) database known as Digital Elevation Model (DEM) describes the surface of a watershed as a topographical database. The DEM available for the project area is the 1:24,000 scale map (U.S. Geological Survey, 1999). The resolution of the DEM is 30 meters, allowing detailed delineation of subbasins within each watershed. Some of the 8 watersheds designated for study were further sub-divided for ease of simulation. The location and boundaries of the watersheds are shown in Figure 1.

The number of subbasins delineated in each watershed varied because of size and methods used for delineation, and ranged from 5 to 312 (Table 1).

Table 1. Subbasin Delineation

WATERSHED	NUMBER OF SUBBASINS
Canadian River	312
Edwards-Frio	23
Edwards-Medina	25
Edwards-Hondo	5
Edwards-Sabinal	11
Edwards-Seco	13
Frio (Below Edwards)	70
Main Concho	37
Nueces (Above Edwards)	18
Nueces (Below Edwards)	95
Pedernales	35
Twin Buttes/Nasworthy	82
Upper Colorado	71
Wichita	48

Climate. Daily precipitation totals were obtained for National Weather Service (NWS) stations within and adjacent to the watersheds. Data from nearby stations were substituted for missing precipitation data in each station record. Daily maximum and minimum temperatures were obtained for the same NWS stations. A weather generator was used to generate missing temperature data and all solar radiation for each climate station. The average annual precipitation for each watershed for the 1960 through 1998 period is shown in Figure 2.

Soils. The soils database describes the surface and upper subsurface of a watershed and is used to determine a water budget for the soil profile, daily runoff, and erosion. The SWAT model uses information about each soil horizon (e.g., thickness, depth, texture, water holding capacity, dispersion, albedo, etc.).

The soils database used for this project was developed from three major sources from the NRCS (USDA-Natural Resources Conservation Service):

1. The majority of the information was a grid cell digital map created from 1:24,000 scale soil sheets with a cell resolution of 250 meters. This database was known as the Computer Based Mapping System (CBMS) or Map Information Assembly Display

System (MIADS) (Nichols, 1975) soils data. The CBMS database differs from some grid GIS databases in that the attribute of each cell was determined by the soil that occurs under the center point of the cell instead of the soil that makes up the largest percentage of the cell. This method of cell attribute labeling had the advantage of a more accurate measurement of the various soils in an area. The disadvantage was for any given cell the attribute of that cell may not reflect the soil that actually makes up the largest percentage of that cell.

2. The Soil Survey Geographic (SSURGO) was the most detailed soil database available. This 1:24,000-scale soils database was available as printed county soil surveys for over 90% of Texas counties. It was only currently available as a vector or high resolution cell data base at the inception of this project for a few counties in the project area. In the SSURGO database, each soil delineation (mapping unit) was described as a single soil series.

3. The soils data base currently available for all of the counties of Texas is the State Soil Geographic (STATSGO) 1:250,000-scale soils data base. The STATSGO database covers the entire United States and all STATSGO soils were defined in the same way. In the STATSGO database, each soil delineation of a STATSGO soil was a mapping unit made up of more than one soil series. Some STATSGO soils were made up of as many as twenty SSURGO soil series. The dominant SSURGO soil series within an individual STATSGO polygon was selected to represent that area.

The GIS layer representing the soils within the project area was a compilation of CBMS, SSURGO, and STATSGO information. The most detailed information was selected for each individual county and patched together to create the final soils layer. In the project area, approximately 2/3 of the soil data was derived from CBMS and the remainder was largely STATSGO data. Only a very small percentage was represented by SSURGO.

SWAT used the soils series name as the data link between the soils GIS layer and the soils properties tabular database. County soil surveys were used to verify data for selected dominant soils within each watershed.

<u>Land Use/Land Cover</u>. Land use and cover affect surface erosion, water runoff, and ET in a watershed. The NRCS 1:24,000 scale CBMS land use/land cover database was the most detailed data presently available. However, for this project much more detail was needed in the rangeland category of land uses. The CBMS data did not identify varying densities of brush or species of brush – only the categories of open range versus brushy range.

Development of more detailed land use/land cover information for the watersheds in the project area was accomplished by classifying Landsat-7 Enhanced Thematic Mapper Plus ETM+ data. The satellite carries an ETM+ instrument, which is an eight-band multi-spectral scanning radiometer capable of providing high-resolution image information of the Earth's surface. It detects spectrally-filtered radiation at visible, near-infrared, short-wave, and thermal infrared frequency bands (Table 2).

Table 2. Characteristics of Landsat-7

Band Number	**Spectral Range**(microns)	**Ground Resolution**(meters)
1	.45 to .515	30
2	.525 to .605	30
3	.63 to .690	30
4	.75 to .90	30
5	1.55 to 1.75	30
6	10.40 to 12.5	60
7	2.09 to 2.35	30
Pan	.52 to .90	15

Swath width:	185 kilometers
Repeat coverage interval:	16 days (233 orbits)
Altitude:	705 kilometers

Portions of eighteen Landsat-7 scenes were classified using ground truth points collected by NRCS field personnel. The Landsat-7 satellite images used a spectral resolution of six channels (the thermal band (6) and panchromatic band (Pan) were not used in the classification). The imagery was taken from July 5, 1999 through December 14, 1999 in order to obtain relatively cloud-free scenes during the growing season for the project areas. These images were radiometrically and precision terrain corrected (personal communication with Gordon Wells, TNRIS).

Over 1,100 ground control points (GCP) were located and described by NRCS field personnel in November and December 1999. Rockwell precision lightweight Global positioning System (GPS) receivers were utilized to locate the latitude and longitude of the control points. A database was developed from the GCP's with information including the land cover, estimated canopy coverage, areal extent, and other pertinent information about each point. This database was converted into an ArcInfo™ point coverage.

ERDAS's Imagine™ was used for imagery classification. The Landsat-7 images were imported into Imagine (GIS software). Adjoining scenes in each watershed were histogram matched or regression corrected to the scene containing the highest number of GCP's (this was done in order to adjust for the differences in scenes because of dates, time of day, atmospheric conditions, etc.). These adjoining scenes were then mosaiced and trimmed into one image that covered an individual watershed.

The ArcInfo coverage of ground points was then employed to instruct the software to recognize differing land uses based on their spectral properties. Individual ground control points were "grown" into areas approximating the areal extent as reported by the data collector. Spectral signatures were collected by overlaying these areas over the imagery and collecting pixel values from the six imagery layers. A supervised maximum likelihood classification of the image was then performed with the spectral signatures for various land use classes. The ground data was used to perform an accuracy assessment of the resulting image. A sampling of the initial classification was further verified by NRCS field personnel.

The use of remote sensed data and the process of classifying it with ground truthing resulted in a current land use/land cover GIS map that includes more detailed divisions of land use/land cover. Although the vegetation classes varied slightly among all watersheds, the land use and cover was generally classified as follows:

Heavy Cedar, Mesquite, Oak, Mixed	Mostly pure stands of cedar (juniper), mesquite, oak and mixed brush with average canopy cover greater than 30 percent.
Moderate Cedar, Mesquite, Oak, Mixed	Mostly pure stands of cedar, mesquite, oak and mixed brush with average canopy cover 10 to 30 percent.
Light Brush	Either pure stands or mixed with average canopy cover less than 10 percent.
Open Range	Various species of native grasses or improved pasture.
Cropland	All cultivated cropland.
Water	Ponds, reservoirs and large perennial streams.
Barren	Bare Ground
Urban	Developed residential or industrial land.
Other	Other small insignificant categories

The accuracy of the classified image was 70% - 80%. Table 3 summarizes land use/land cover categories for each watershed in the project area.

A small area of the USGS land use/land cover GIS layer was patched to the detailed land use/land cover map developed using remotely sensed data for the western-most (New Mexico) portion of the Upper Colorado River and Canadian River watersheds, which were not included in the satellite scenes for this study.

Table 3. Land Use and Percent Cover

	Percent Cover					
Watershed	Heavy & Mod. Brush (no oak)	Oak	Light Brush (no oak)	Open Range & Pastureland	Cropland	Other (Water Urban,Barren,etc)
Canadian *	69	0	4	5	18	4
Edwards-Frio	60	22	17	1	< 1	< 1
Edwards-Medina	56	24	18	1	1	< 1
Edwards-Hondo	59	24	15	1	1	< 1
Edwards-Sabinal	60	22	16	1	1	< 1
Edwards-Seco	65	24	10	1	< 1	< 1
Frio (Below Edwards)	58	17	18	1	5	1
Main Concho	40	5	19	10	26	< 1
Nueces (Above Edwards)	60	23	17	< 1	< 1	< 1
Nueces (Below Edwards)	62	17	19	< 1	1	< 1
Pedernales	25	50	7	16	1	1
Twin Buttes/Nasworthy *	57	2	31	5	3	2
Upper Colorado *	41	3	21	14	20	1
Wichita	63	4	15	9	7	2

* Percentage of watershed where brush removal was planned

Model Inputs

Required inputs for each subbasin (e.g. soils, land use/land cover, topography, and climate) were extracted and formatted using the SWAT/GRASS input interface. The input interface divided each subbasin into a maximum of 30 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 5 percent of the area of a subbasin; and (2) creating an HRU for each soil type that equaled or exceeded 10 percent of any of the land uses selected in (1). The total number of HRU's for each watershed was dependent on the number of subbasins and the variability of the land use and soils within the watershed. The soil properties for each of the selected soils were automatically extracted from the model-supported soils database.

Surface runoff was predicted using the SCS curve number equation (USDA-SCS, 1972). Higher curve numbers represent greater runoff potential. Curve numbers were selected assuming existing brush sites were fair hydrologic condition and existing open range and pasture sites with no brush were good hydrologic condition. The precipitation intercepted by canopy was based on field experimental work (Thurow and Taylor, 1995) and calibration of SWAT to measured stream flows. The soil evaporation compensation factor adjusts the depth distribution for evaporation from the soil to account for the effect of capillary action, crusting, and cracks. A factor of 0.85 is normally used, but lower values were used in dry climates to account for moisture loss from deeper soil layers.

Shallow aquifer storage is water stored below the root zone. Ground water flow is not allowed until the depth of water in the shallow aquifer is equal to or greater than the input value. Shallow aquifer re-evaporation coefficient controls the amount of water which will move from the shallow aquifer to the root zone as a result of soil moisture depletion, and the amount of direct water uptake by deep rooted trees and shrubs. Higher values represent higher potential water loss. The amount of re-evaporation is also controlled by setting the minimum depth of water in the shallow aquifer before re-evaporation is allowed. Shallow aquifer storage and re-evaporation inputs affect base flow.

Potential heat units (PHU) is the number of growing degree days needed to bring a plant to maturity and varies by latitude. PHU decreases as latitude increases. PHU was obtained from published data (NOAA, 1980).

Channel transmission loss is the effective hydraulic conductivity of channel alluvium, or water loss in the stream channel. The fraction of transmission loss that returns to the stream channel as base flow can also be adjusted.

The leaf area index (LAI) specifies the projected vegetation area (in units of square meters) per ground surface area (square meters). Plant rooting depth, canopy height, albedo, and LAI were based on observed values and modeling experience.

Model Calibration

The calibration period was based on the available period of record for stream gauges within each watershed. Measured stream flow was obtained from USGS. A base flow filter (Arnold et al., 1999) was used to determine the fraction of base flow and surface runoff at selected gauging stations.

Appropriate plant growth parameters for brush and native grass were input for each model simulation. Adjustments were made to runoff curve number, soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, 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.

Brush Removal Simulations

T.L. Thurow (Thurow, 1998) suggested that brush control is most likely to increase water yields in areas that receive at least 18 inches of average annual rainfall. Therefore, brush treatment was not planned in areas generally west of the 18 inch rainfall isohyet (Figure 3). One exception is the Canadian River watershed. Most of this watershed is west of the 18 inch isohyet, and also extends into New Mexico. Brush treatment was simulated in the portion of the Canadian River watershed that lies within Texas.

Some areas in the Upper Colorado and Twin Buttes/Nasworthy watersheds do not contribute to stream flow at downstream gauging stations (USGS, 1999). These areas have little or no defined stream channel, and considerable natural surface storage (e.g. playa lakes) that capture surface runoff. We used available GIS and stream gauge data to estimate the location of these areas, most of which are west of the 18 inch isohyet. Brush treatment was not planned in these areas (Figure 3).

In order to simulate the "treated" or "no-brush" condition, the input files for all areas of heavy and moderate brush (except oak) were converted to native grass rangeland. Appropriate adjustments were made in growth parameters to simulate the replacement of brush with grass. We assumed the shallow aquifer re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. All other calibration parameters and inputs were held constant.

It was assumed all categories of oak would not be treated. In the Pedernales and Edwards watersheds, oak and juniper were mixed together in one classification. We assumed the category was 50 % oak and 50 % juniper and modeled only the removal of juniper.

After calibration of flow, each watershed was simulated for the brush and no-brush conditions for the years 1960 through 1998.

RESULTS

The results of flow calibration and brush treatment simulations for individual watersheds are presented in the subchapters of this report.

Watershed Calibration

The comparisons of measured and predicted flow were, in most cases, reasonable. Deviations of predicted flow from measured were generally attributed to precipitation variability which was not reflected in measured climate data.

Brush Treatment Simulations

Total area of each watershed is shown in Figure 4. For watersheds that lie across the 18 inch isohyet, the area shown represents only the portion of those watersheds where brush treatment was planned.

The fraction of heavy and moderate brush planned for treatment or removal in each watershed is shown in Figure 5. For watersheds that lie across the 18 inch isohyet, this is the fraction of the portion of the watershed where brush treatment was planned.

Average annual water yield increase per treated acre varied by watershed and ranged from 13,000 gallons per treated acre in the Canadian to about 172,000 gallons per treated acre in the Medina watershed (Figure 6).

The average annual stream flow (acre-feet) for the brush and no-brush conditions is shown for each watershed outlet in Figure 7. Average annual stream flow increase varied by watershed and ranged from 6,650 gallons per treated acre in the Upper Colorado to about 172,000 gallons per treated acre in the Medina watershed (Figure 8). In some cases, the increase in stream flow was less than the increase in water yield because of the capture of runoff by upstream reservoirs, as well as stream channel transmission losses that occurred between each subbasin and the watershed outlet.

There was a high correlation between stream flow increase and precipitation (Figure 9). The amount of stream flow increase was greater in watersheds with higher average annual precipitation.

Variations in the amount of increased water yield and stream flow were expected and were influenced by brush type, brush density, soil type, and average annual rainfall, with watersheds receiving higher average annual rainfall generally producing higher increases. The larger water yields and stream flows were most likely due to greater rainfall volumes as well as increased density and canopy of brush.

SUMMARY

The Soil and Water Assessment Tool (SWAT) model was used to simulate the effects of brush removal on water yield in 8 watersheds in Texas for 1960 through 1998. Landsat7 satellite imagery from 1999 was used to classify current land use and cover for all watersheds. Brush cover was separated by species (cedar, mesquite, oak, and mixed) and by density (heavy, moderate, light). After calibration of SWAT to existing stream gauge data, brush removal was simulated by converting all heavy and moderate categories of brush (except oak) to open range (native grass). Removal of light brush was not simulated.

Simulated changes in water yield resulting from brush treatment varied by subbasin, with all subbasins showing increased water yield as a result of removing brush. Average annual water yield increases ranged from about 13,000 gallons per treated acre in the Canadian watershed to about 172,000 gallons per treated acre in the Medina watershed.

For this study, we assumed removal of 100 % of heavy and moderate categories of brush (except oak). Removal of all brush in a specific category is an efficient modeling scenario. However, other factors must be considered in planning brush treatment. Economics and wildlife habitat considerations will impact the specific amounts and locations of actual brush removal.

The hydrologic response of each watershed is directly dependent on receiving precipitation events that provide the opportunity for surface runoff and ground water flow.

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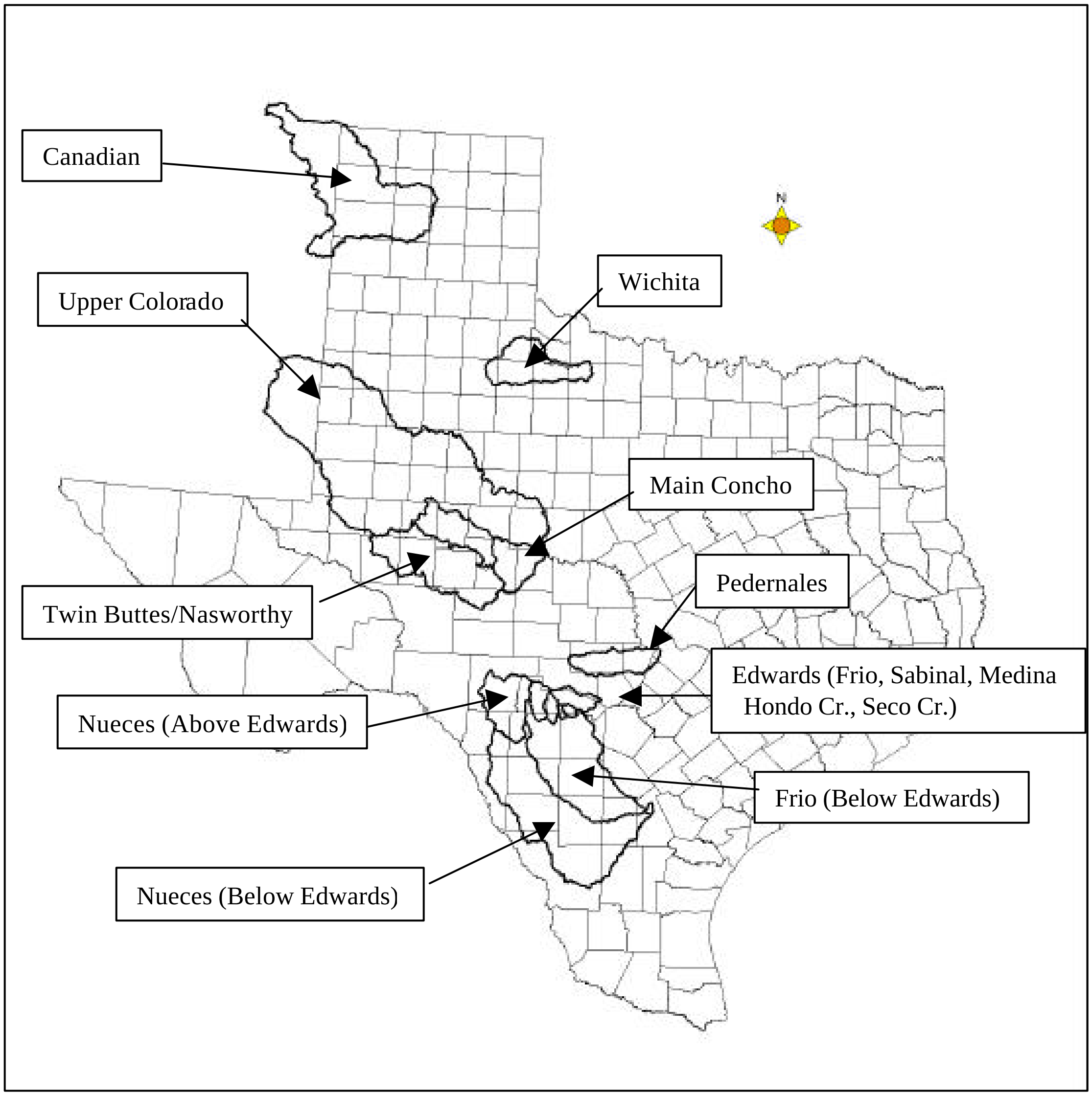

Figure 1. Watersheds included in the study area.

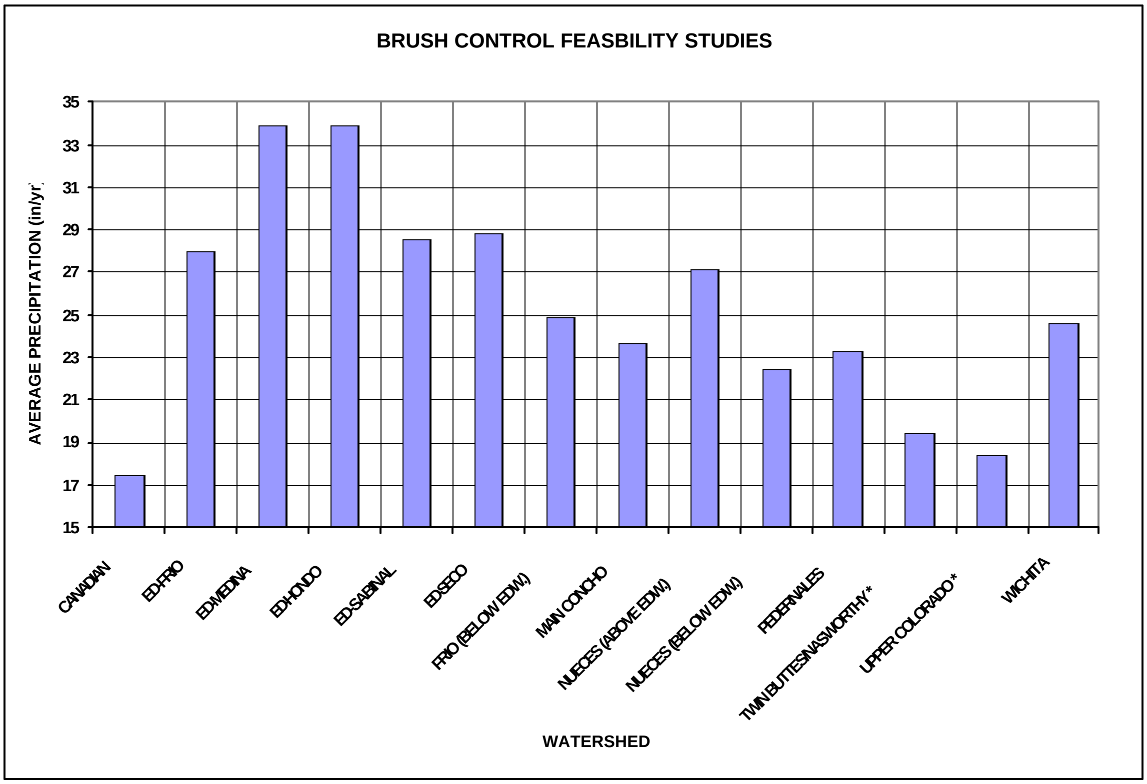

Figure 2. Average annual precipitation. Averages are for all climate stations in each watershed.

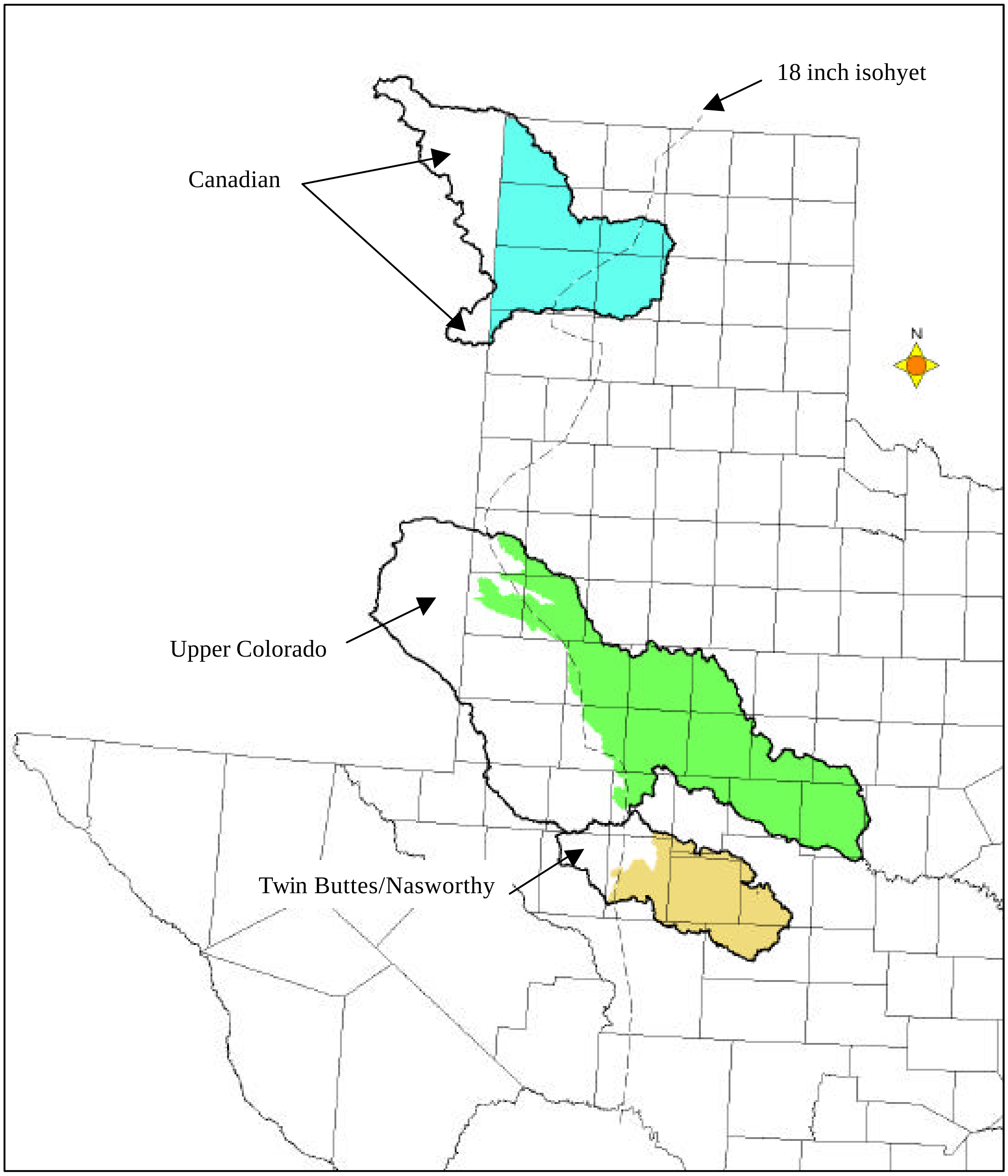

Figure 3. Areas where brush treatment was not planned (non-shaded portions of each watershed).

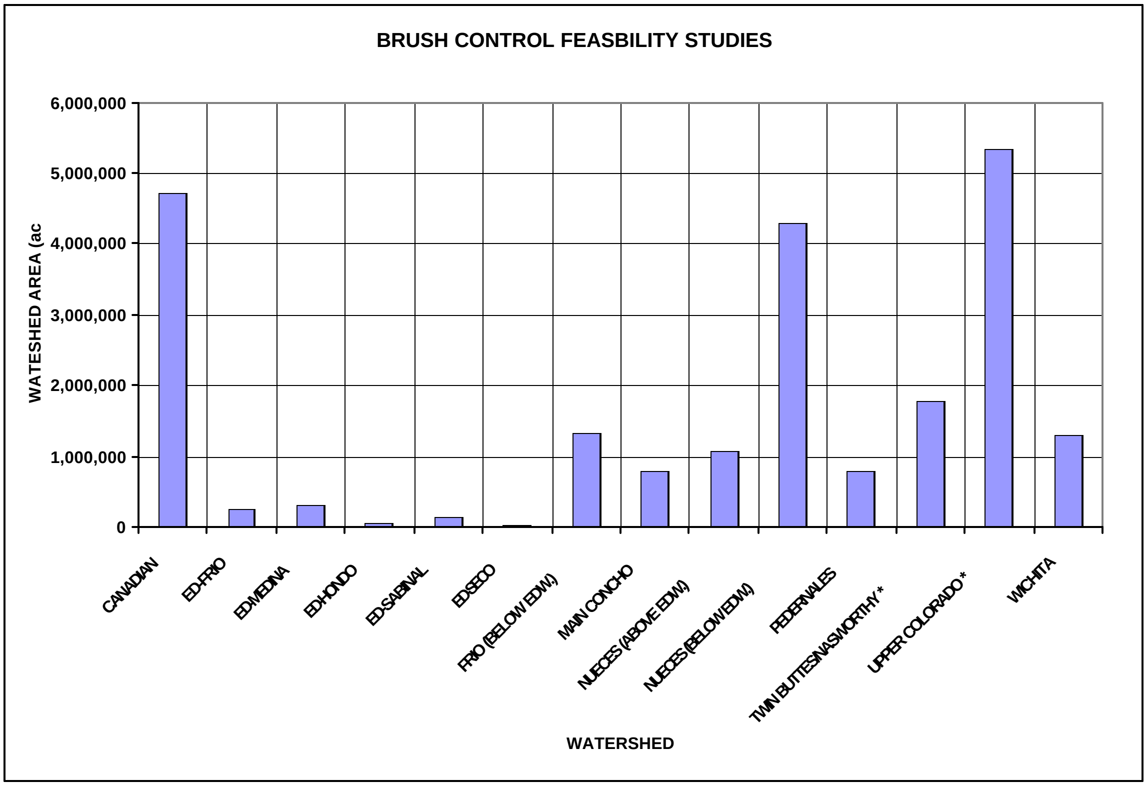

Figure 4. Watershed area. For watersheds that lie across the 18 inch isohyet, the area shown represents only the portion of those watersheds where brush treatment was planned and simulated.

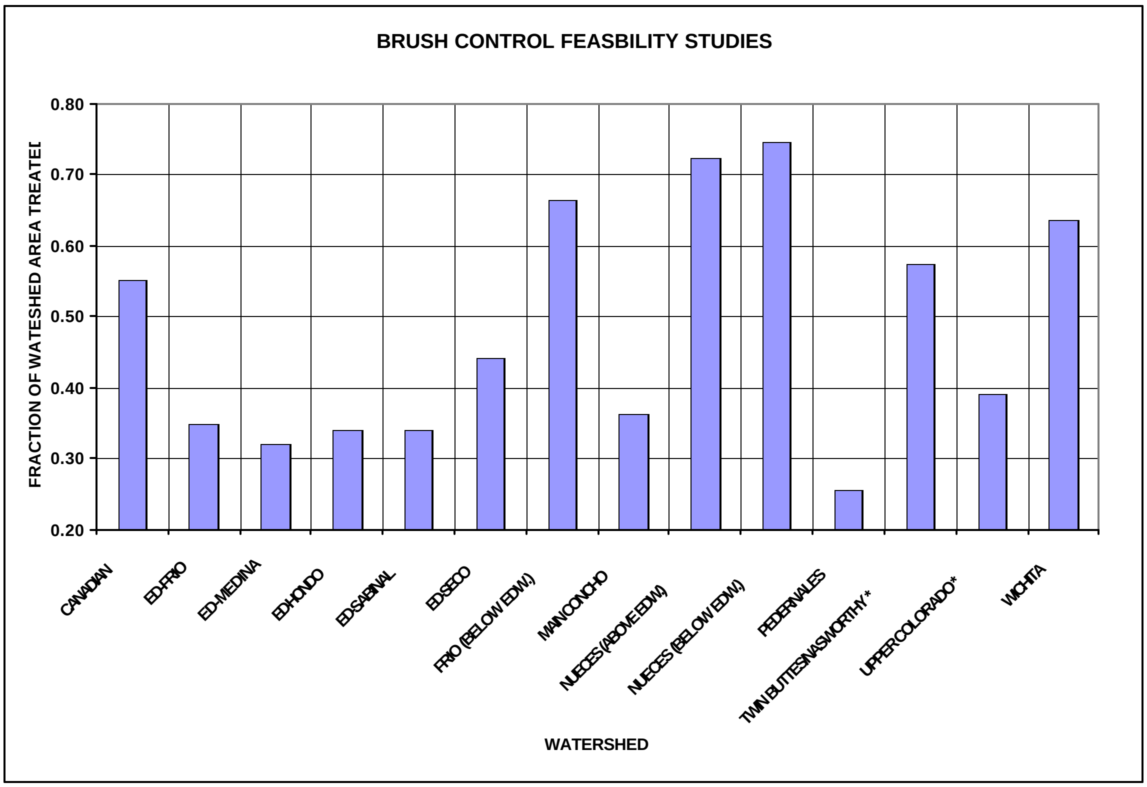

Figure 5. Fraction of watershed containing heavy and moderate brush that was treated. For watersheds that lie across the 18 inch isohyet, this is the fraction of the portion of the watershed where brush treatment was planned and simulated.

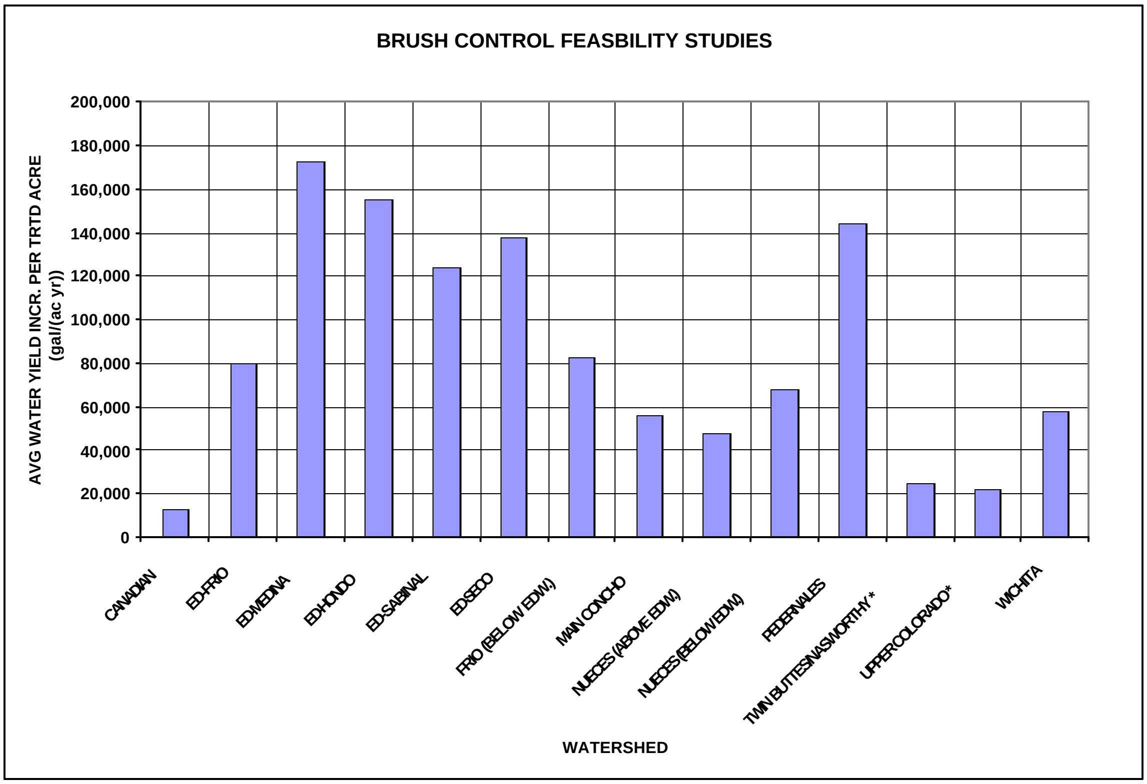

Figure 6. Average annual water yield increase, 1960 through 1998.

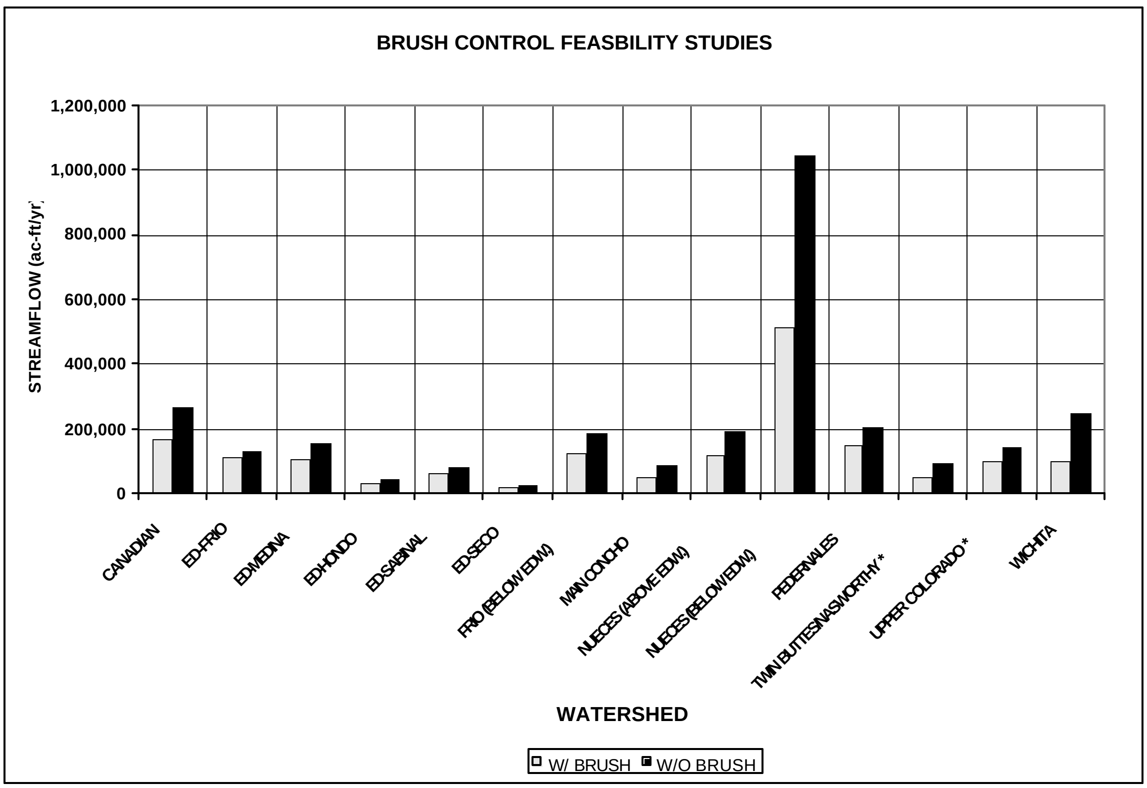

Figure 7. Average annual stream flow at watershed outlet, 1960 through 1998.

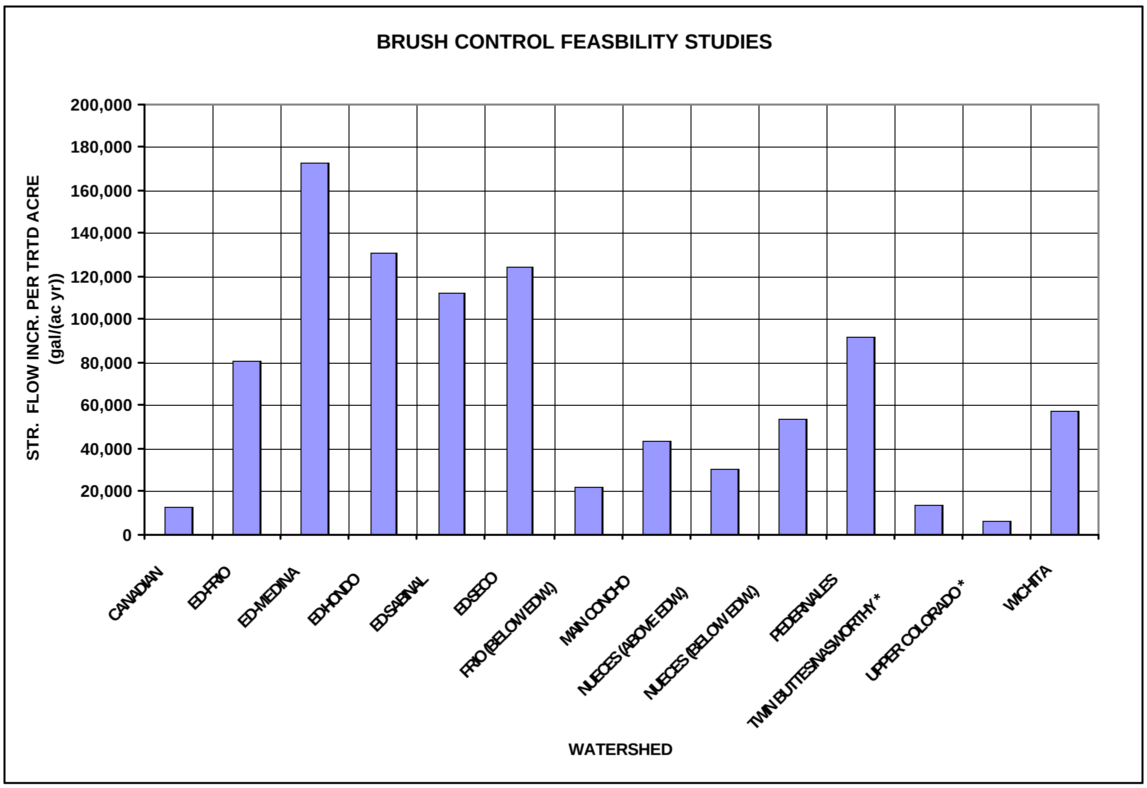

Figure 8. Average annual stream flow increase at watershed outlet, 1960 through 1998.

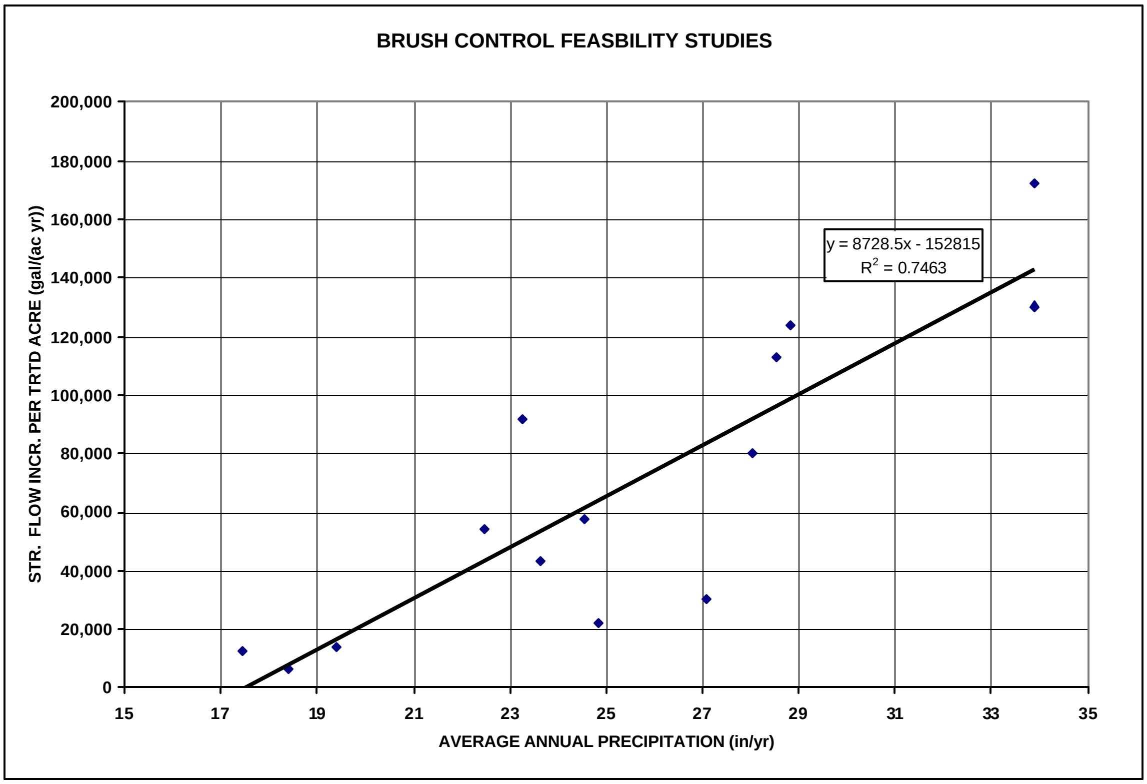

Figure 9. Average annual stream flow increase versus average annual precipitation, 1960 through 1998. Each point represents one watershed.

CHAPTER 2

ASSESSING THE ECONOMIC FEASIBILITY OF BRUSH CONTROL TO ENHANCE OFF-SITE WATER YIELD

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Abstract: A feasibility study of brush control for off-site water yield was undertaken in 1998 on the North Concho River near San Angelo, Texas. Subsequently, studies were conducted on eight additional Texas watersheds. Economic analysis was based on estimated control costs of the different options compared to the estimated rancher benefits of brush control. Control costs included initial and follow-up treatments required to reduce brush canopy to between 8% and 3% and maintain it at the reduced level for 10 years. The state cost share was estimated by subtracting the present value of rancher benefits from the present value of the total cost of the control program. The total cost of additional water was determined by dividing the total state cost share if all eligible acreage were enrolled by the total added water estimated to result from the brush control program This procedure resulted in present values of total control costs per acre ranging from $33.75 to $159.45. Rancher benefits, based on the present value of the improved net returns to typical cattle, sheep, goat and wildlife enterprises, ranged from $52.12 per acre to $8.95. Present values of the state cost share per acre ranged from $138.85 to $21.70. The cost of added water estimated for the eight watersheds ranged from $16.41 to $204.05 per acre-foot averaged over each watershed.

INTRODUCTION

As was reported in Chapter 1 of this report, a feasibility study of brush control for water yield on the North Concho River near San Angelo, Texas was conducted in 1998 Results indicated estimated cost of added water at $49.75 per acre-foot averaged over the entire North Concho basin (Bach and Conner).

In response to this study, the Texas Legislature, in 1999, appropriated approximately $6 million to begin implementing the brush control program on the North Concho Watershed. A companion Bill authorized feasibility studies on eight additional watersheds across Texas.

The Eight watersheds ranged from the Canadian, located in the northwestern Texas Panhandle to the Nueces which encompasses a large portion of the South Texas Plains (Chapter 1, Figure 1). In addition to including a wide variety of soils, topography and plant communities, the 8 watersheds included average annual precipitation zones from 15 to 26 inches and growing seasons from 178 to 291days. The studies were conducted primarily between February and September of 2000.

Objectives

This Chapter reports the assumptions and methods for estimating the economic feasibility of a program to encourage rangeland owners to engage in brush control for purposes of enhancing off-site (downstream) water availability. Vegetative cover determination and categorization through use of Landsat imagery and the estimation of increased water yield from control of the different brush type-density categories using the SWAT simulation model for the watersheds are described in Chapter 1. The data created by these efforts (along with primary data gathered from landowners and federal and state agency personnel) were used as the basis for the economic analysis.

This Chapter provides details on how brush control costs and benefits were calculated for the different brush type-densities and illustrates their use in determining cost-share amounts for participating private landowners-ranchers and the State of Texas. SWAT model estimates of additional off-site water yield resulting from the brush control program are used with the cost estimates to obtain estimates of per acre-foot costs of added water gained through the program.

BRUSH CONTROL

It should be noted that public benefit in the form of additional water depends on landowner participation and proper implementation and maintenance of the appropriate brush control practices. It is also important to understand that rancher participation in a brush control program primarily depends on the rancher's expected economic consequences resulting from participation. With this in mind, the analyses described in this report are predicated on the objective of limiting rancher costs associated with participation in the program to no more than the benefits that would be expected to accrue to the rancher as a result of participation.

It is explicitly assumed that the difference between the total cost of the brush control practices and the value of the practice to the participating landowner would have to be contributed by the state in order to encourage landowner participation. Thus, the state (public) must determine whether the benefits, in the form of additional water for public use, are equal to or greater than the state's share of the costs of the brush control program. Administrative costs (state costs) which would be incurred in implementing, administering and monitoring a brush control project or program are not included in this analysis.

Brush Type-density Categories

Land cover categories identified and quantified for the eight watersheds in Chapter 1 included four brush types: cedar (juniper), mesquite, oaks, and mixed brush. Landowners statewide indicated they were not interested in controlling oaks, so the type category was not considered eligible for inclusion in a brush control program. Two density categories, heavy and moderate, were used. These six type-density categories were used to estimate total costs, landowner benefits and the amount of cost-share that would be required of the state.

Brush control practices include initial and follow-up treatments required to reduce the current canopies of all categories of brush types and densities to 3-8 percent and maintain it at the reduced level for at least 10 years. These practices, or brush control treatments, differed among watersheds due to differences in terrain, soils, amount and distribution of cropland in close proximity to the rangeland, etc. An example of the alternative control practices, the time (year) of application and costs for the Wichita Watershed are outlined in Table 1. Year 0 in Table 1 is the year that the initial practice is applied while years 1 - 9 refer to follow-up treatments in specific years following the initial practice.

The appropriate brush control practices, or treatments, for each brush type-density category and their estimated costs were obtained from focus groups of landowners and NRCS and Extension personnel in each watershed. In the larger watersheds two focus groups were used where it was deemed necessary because of significant climatic and/or terrestrial differences.

Control Costs

Yearly costs for the brush control treatments and the present value of those costs (assuming an 8% discount rate as opportunity cost for rancher investment capital) are also displayed in Table 1. Present values of control programs are used for comparison since some of the treatments will be required in the first year to initiate the program while others will not be needed until later years. Present values of total per acre control costs

range from $33.75 for moderate mesquite that can be initially controlled with herbicide treatments to $159.45 for heavy mesquite that cannot be controlled with herbicide but must be initially controlled with mechanical tree bulldozing or rootplowing.

Landowner Benefits From Brush Control

As was mentioned earlier, one objective of the analysis is to equate rancher benefits with rancher costs. Therefore, the task of discovering the rancher cost (and thus, the rancher cost share) for brush control was reduced to estimating the 10 year stream of region-specific benefits that would be expected to accrue to any rancher participating in the program. These benefits are based on the present value of increased net returns made available to the ranching operation through increases or expansions of the typical livestock (cattle, sheep, or goats) and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program.

Rancher benefits were calculated for changes in existing wildlife operations. Most of these operations were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. For control of heavy mesquite, mixed brush and cedar, wildlife revenues are expected to increase from $0.50 to $1.50 per acre due principally to the resulting improvement in quail habitat and hunter access to quail. Increased wildlife revenues were included only for the heavy brush categories because no changes in wildlife revenues were expected with control for the moderate brush type-density categories.

Table 1 Wichita Water Yield Brush Control Program Methods and Costs by Type-Density Category

Heavy Mesquite Aerial Chemical			
Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
4	Aerial Spray Herbicide	25.00	18.38
7	Choice Type IPT or Burn	15.00	8.75
			$ 52.13

Heavy Mesquite Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze or Root Plow, Rake and Burn	150.00	150.00
6	Choice Type IPT or Burn	15.00	9.45
			$159.45

Heavy Cedar Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 128.86

Heavy Cedar Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 46.36

Heavy Mixed Brush Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 128.86

Table 1 (Continued) Wichita Water Yield Brush Control Program Methods and Costs by Type-Density Category

Heavy Mixed Brush Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 46.36

Moderate Mesquite Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 33.75

Moderate Cedar Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 53.75

Moderate Mixed Brush Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 53.75

For the livestock enterprises, increased net returns would result from increased amounts of usable forage (grazing capacity) produced by removal of the brush and thus eliminating much of the competition for light, water and nutrients within the plant communities on which the enterprise is based. For the wildlife enterprises, improvements in net returns are based on an increased ability to access wildlife for use by paying sportsmen.

As with the brush control methods and costs, estimates of vegetation (forage production/grazing capacity) responses used in the studies were obtained from landowner focus groups, Experiment Station and Extension Service scientists and USDA-NRCS Range Specialists with brush control experience in the respective watersheds. Because of differences in soils and climate, livestock grazing capacities differ by location; in some cases significant differences were noted between sub-basins of a watershed. Grazing capacity estimates were collected for both pre- and post-control states of the brush type-density categories. The carrying capacities range from 70 acres per animal unit year (Ac/AUY) for land infested with heavy cedar to about 15 Ac/AUY for land on which mesquite is controlled to levels of brush less than 8% canopy cover (Table 2.).

Livestock production practices, revenues, and costs representative of the watersheds, or portions thereof, were also obtained from focus groups of local landowners. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into production-based investment analysis budgets.

<u>Table 2</u> Grazing Capacity in Acres per AUY Before and After Brush Control by Brush Type-Density Category

	Brush Type-density Category & Brush Control State											
	Heavy Cedar		Heavy Mesquite		Heavy Mixed Brush		Moderate Cedar		Moderate Mesquite		Moderate Mixed Brush	
Watershed	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Canadian	-	-	30	20	37	23	-	-	25	20	30	23
Edwards Aquifer	60	30	35	20	45	25	45	30	25	20	35	25
Frio – North	50	30	36	24	36	24	40	30	32	24	32	24
Frio – South	-	-	38	23	35	23	-	-	30	23	30	23
Mid Concho	70	35	38	25	50	30	52	35	32	25	40	30
Nueces – North	50	30	39	27	39	27	40	30	35	27	35	27
Nueces – South	-	-	41	26	38	26	-	-	33	26	33	26
Pedernalis	45	28	28	15	40	22	38	28	24	15	34	22
Upper Colorado – East	56	24	32	18	48	21	44	24	28	18	36	21
Upper Colorado – West	70	35	38	25	50	30	52	30	32	25	40	30
Wichita	50	25	32.5	20	38.5	20	40	25	25	20	32.5	20

For ranchers to benefit from the improved forage production resulting from brush control, livestock numbers must be changed as grazing capacity changes. In this study, it was assumed that ranchers would adjust livestock numbers to match grazing capacity changes on an annual basis. Annual benefits that result from brush control were measured as the net differences in annual revenue (added annual revenues minus added annualized costs) that would be expected with brush control as compared to without brush control. It is notable that many ranches preferred to maintain current levels of livestock, therefore realizing benefit in the form of reduced feeding and production risk. No change in perception of value was noted for either type of projected benefit.

The analysis of rancher benefits was done assuming a hypothetical 1,000 acre management unit for facilitating calculations. The investment analysis budget information, carrying capacity information, and brush control methods and costs comprised the data sets that were entered into the investment analysis model ECON (Conner). The ECON model yields net present values for rancher benefits accruing to the management unit over the 10 year life of the projects being considered in the feasibility studies. An example of this process is shown in Table 3 for the control of moderate cedar in the Upper Colorado – West watershed.

Table 3 Net Present Value Report - Upper Colorado – West Watershed, Moderate Cedar Control

Year	Animal Units	Total Increase In Sales	Total Added Investment	Increased Variable Costs	Additional Revenues	Cash Flow	Annual NPV	Accumulated NPV
0	0.0	0	0	0	0	0	0	-
1	4.2	1423	2800	520	0	-1897	-1757	-1757
2	9.8	3557	3500	1171	0	-1113	-955	-2711
3	10.1	3557	0	1171	0	2387	1895	-817
4	10.3	3557	0	1171	0	2387	1754	937
5	10.6	3557	0	1171	0	2387	1624	2562
6	10.8	3913	0	1171	0	2742	1728	4290
7	11.1	3913	0	1171	0	2742	1600	5890
8	11.4	3913	0	1171	0	2742	1482	7371
9	11.6	3913	0	1171	0	2742	1372	8743
				Salvage Value:		6300	3152	11895

Since a 1,000 acre management unit was used, benefits needed to be converted to a per acre basis. To get per acre benefits, the accumulated net present value of $11,895 shown in Table 3 must be divided by 1,000, which results in $11.90 as the estimated present value of the per acre net benefit to a rancher. The resulting net benefit estimates for all of the type-density categories for all watersheds are shown in Table 4. Present values of landowner benefits differ by location within and across watersheds. They range from a low of $8.95 per acre for control of moderate mesquite in the Canadian Watershed to $52.12 per acre for control of heavy mesquite in the Edwards Aquifer Watershed.

Table 4 Landowner and State Shares of Brush Control Costs by Brush Type-Density Category by Watershed

	Brush Type-density Category											
	Heavy Cedar		Heavy Mesquite		Heavy Mixed Brush		Moderate Cedar		Moderate Mesquite		Moderate Mixed Brush	
Watershed	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs
Canadian	-	-	10.37	40.33	10.44	54.93	-	-	8.95	26.10	10.48	23.43
Edwards Aquifer	43.52	138.5	52.12	98.49	45.61	105.00	23.27	93.75	20.81	43.71	23.88	40.64
Frio – North	30.69	79.81	39.76	90.18	39.76	84.57	10.44	92.29	23.43	60.56	23.43	60.56
Frio – South	-	-	38.71	75.95	41.6	72.32	-	-	21.07	55.57	21.07	62.92
Mid Concho	16.59	78.30	15.66	57.46	16.35	78.54	11.79	53.10	10.49	41.76	9.91	54.98
Nueces – North	30.69	79.81	34.49	95.45	34.49	89.84	10.44	92.29	19.73	64.26	19.73	64.26
Nueces – South	-	-	35.69	79.02	36.53	77.40	-	-	17.14	59.50	17.14	66.85
Pedernalis	31.86	108.56	40.61	88.77	33.31	96.07	25.74	54.68	21.22	49.20	21.22	49.20
Upper Colorado – East	14.90	69.99	17.22	60.62	16.35	83.54	11.32	58.57	12.07	42.68	10.92	58.97
Upper Colorado – West	16.76	42.14	15.89	57.23	15.07	64.82	11.90	32.99	10.55	29.84	10.25	34.64
Wichita	18.79	68.82	18.70	87.09	21.80	65.81	15.13	38.62	12.05	21.70	19.09	34.65

Note: Rancher Benefits and State Costs are in $ / Acre.

State Cost Share

If ranchers are not to benefit from the state's portion of the control cost, they must invest in the implementation of the brush control program an amount equal to their total net benefits. The total benefits that are expected to accrue to the rancher from implementation of a brush control program are equal to the maximum amount that a profit maximizing rancher could be expected to spend on a brush control program (for a specific brush density category).

Using this logic, the state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher participation. Present values of the state cost share per acre of brush controlled are also shown in Table 4. The State's cost share ranges from a low of $21.70 for control of moderate mesquite in the Wichita Watershed to $138.85 for control of heavy cedar in the Edwards Aquifer Watershed.

The costs to the state include only the cost for the state's cost share for brush control. Costs that are not accounted for, but which must be incurred, include costs for administering the program. Under current law, this task will be the responsibility of the Texas State Soil and Water Conservation Board.

COSTS OF ADDED WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see Chapter 1). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate). Table 5 provides a detailed example for the Wichita Watershed. The cost of added water from brush control for the Wichita is estimated to average $36.59 per acre-foot for the entire watershed. Sub-basin cost per added acre-foot within the Wichita range from $17.56 to $91.76.

As might be expected, there is a great deal of variation in the cost of added water between sub-basins in the watersheds. Likewise, there is a great deal of variation from watershed to watershed in the average cost of added water for the entire watershed. For an example that contrasts dramatically with the results shown for the Wichita in Table 5, the Middle Concho analysis resulted in an estimated average cost across all its sub-basins of $204.05 per acre-foot. Most of the watershed analyses, however, resulted in estimates of costs in the $40 to $100 per acre-foot range. Although the cost of added water from alternative sources are not currently known for the watersheds in the study, a high degree of

Table 5 Cost Per Acre-Foot of Added Water From Brush Control by Sub-Basin – Wichita Watershed

Sub-Basin #	Total State Cost ($)	Added Gallons/Acre	Added Acre/Feet/Year	Total Acre/Feet/ 10-Years	Cost Per Acre/Foot ($)
1	457182.65	216078212.22	663.12	5173.66	88.37
2	1772111.33	806617084.67	2475.42	19313.20	91.76
3	344487.78	351071562.48	1077.40	8405.87	40.98
4	270611.17	307249619.41	942.91	7356.62	36.78
5	405303.9	244374185.73	749.96	5851.16	69.27
6	551815.58	321549997.08	986.80	7699.02	71.67
7	1829171.16	1767009344.68	5422.75	42308.32	43.23
8	1620183.78	1949004323.95	5981.27	46665.90	34.72
9	1338434.24	1365709430.82	4191.21	32699.81	40.93
10	590024.3	439341539.12	1348.29	10519.36	56.09
11	343140.75	175512983.29	538.63	4202.39	81.65
12	440716.1	337140645.01	1034.65	8072.31	54.60
13	262233	175936587.60	539.93	4212.53	62.25
14	299909.61	323150451.65	991.71	7737.34	38.76
15	354443.07	369339368.84	1133.46	8843.26	40.08
16	187848	230953440.19	708.77	5529.82	33.97
17	84634.43	88598612.82	271.90	2121.36	39.90
18	522247.77	662499062.28	2033.13	15862.52	32.92
19	124871.5	139554413.54	428.28	3341.42	37.37
20	246020.32	290468000.94	891.41	6954.81	35.37
21	2730475.37	1642473500.85	5040.57	39326.50	69.43
22	110738.33	67570294.84	207.37	1617.87	68.45
23	1369643.8	926200497.94	2842.40	22176.44	61.76
24	1563106.99	1414807304.26	4341.88	33875.38	46.14
25	971017.42	992524276.72	3045.95	23764.46	40.86
26	771619.1	1834810250.24	5630.83	43931.70	17.56
27	1478568.35	2291114837.65	7031.17	54857.21	26.95
28	1801533.32	1678434945.84	5150.93	40187.54	44.83
29	1948506.76	1790375041.38	5494.46	42867.77	45.45
30	3769655.99	3613101057.14	11088.20	86510.14	43.57
31	439757.96	589436154.61	1808.91	14113.14	31.16
32	613063.06	867628625.83	2662.65	20774.03	29.51
33	260808.4	318809382.14	978.39	7633.40	34.17
34	722243.11	1057274449.79	3244.66	25314.81	28.53
35	801913.88	1601922140.98	4916.12	38355.56	20.91
36	472961.33	534304493.17	1639.72	12793.10	36.97
37	522081.31	783102254.46	2403.25	18750.18	27.84
38	293231.45	413705742.62	1269.62	9905.55	29.60
39	3111539.76	4332844817.46	13297.01	103743.29	29.99
40	2006939.15	3063451744.60	9401.39	73349.63	27.36
41	307258.55	350869992.59	1076.78	8401.04	36.57
42	424456.46	732734077.37	2248.68	17544.19	24.19
43	493711.42	637433871.96	1956.21	15262.37	32.35
44	452996.05	793219617.91	2434.30	18992.42	23.85
45	272492.79	501654318.26	1539.52	12011.34	22.69
46	243926.57	353972454.43	1086.30	8475.32	28.78
47	24499.3	39919320.98	122.51	955.81	25.63
48	3371088.17	5745904234.60	17633.53	137576.82	24.50
Total	43,395,224.5		152004.32	1185937.68	
				Average	36.59

Note: Total Acre/Feet are adjusted for time-supply availability of water.

variation is likely, based mostly on population and demand. Since few alternatives exist for increasing the supply of water, these values are likely to compare well.

ADDITIONAL CONSIDERATIONS

Total state costs and total possible added water discussed above are based on the assumption that 100% of the eligible acres in each type-density category would enroll in the program. There are several reasons why this will not likely occur. Foremost, there are wildlife considerations. Most wildlife managers recommend maintaining more than 10% brush canopy cover for wildlife habitat, especially white tailed deer. Since deer hunting is an important enterprise on almost all ranches in these eight watersheds it is expected that ranchers will want to leave varying, but significant amounts of brush in strategic locations to provide escape cover and travel lanes for wildlife. The program has consistently encouraged landowners to work with technical specialists from the NRCS and Texas Parks and Wildlife Department to determine how the program can be used with brush sculpting methods to create a balance of benefits.

Another reason that less than 100% of the brush will be enrolled is that many of the tracts where a particular type-density category are located will be so small that it will be infeasible to enroll them in the control program. An additional consideration is found in research work by Thurow, et. al. (2001) that indicated that only about 66% of ranchers surveyed were willing to enroll their land in a similarly characterized program. Also, some landowners will not be financially able to incur the costs expected of them in the beginning of the program due to current debt load.

Based on these considerations, it is reasonable to expect that less than 100% of the eligible land will be enrolled, and, therefore, less water will be added each year than is projected. However, it is likewise reasonable that participation can be encouraged by designing the project to include the concerns of the eligible landowners-ranchers.

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CHAPTER 3

CANADIAN RIVER WATERSHED - HYDROLOGIC SIMULATION

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Watershed Data

Location

The modeled Canadian river basin covers a total drainage area of about 19,000 km^2 (4.7 million acres) ranging from the headwaters at Punta de Agua to final outflow at lake Meredith. The average annual precipitation within the Texas portion of the Canadian basin varies from about 350 mm (14 inches) in the West to about 460 mm (18 inches) in the East. Physiographically the Canadian basin occupies the arid to semi-arid regions of the great plains characterized with breaks on either side of the Canadian river. The geology on the upper reaches of the Canadian within Texas is composed primarily of quaternary period rock, while formations closer to the main river vary from the quaternary to the Jurassic periods. The quaternary period resource type is either made of recharge sand or wind blown (eolian) sand. The Jurassic formation especially in Oldham, and Potter counties is composed of sandstone, mudstone, dissected red beds (mud and sand), or severely eroded lands (Kier et al., 1977). A unique hydrologic feature are the playa lakes with intermittent water holding which dot the landscape. The soils range from fine sandy loam along recharge areas to thin to moderate silt loam in the upper reaches of the Canadian within Texas. The counties within the study area from North to South (clockwise) were: Dallam, Hartle, Moore, Hutchinson, Oldham, Potter, and Garson.

Topography

Figure C-1 shows the sub-basins, and sub-basin numbers that were used for hydrology modeling. Economic analysis is also reported by sub-basin numbers. Generally, the lower the number, the closer the sub-basin is to the outlet of the watershed. The numbers starting with 1 represent sub-watersheds within the 11090101 USGS Hydrologic Cataloging Unit (HCU) called the Middle Canadian-Trujillo, sub-basins beginning with the number 2 are located within the 11090102 (Punta De Agua) HCU, sub-basins beginning with the number 3 are located within HCU 11090103 (Rita Blanca), sub-basins beginning with number 4 are located within HCU 11090104 (Carrizo), and sub-basins beginning with number 5 are located within HCU 11090105 (Lake Meredith).There were a total of 312 sub-basins modeled. Most of the sub-basins ranged in area from 10,000 – 40,000 acres.

Weather Stations

Figure C-2 shows the weather stations used to model the hydrology of the Canadian basin. Weather data was collected from 1960 to 1998 and included daily precipitation, maximum and minimum temperatures, and solar radiation. If data were missing for any weather station, then the closest weather station was used to replace missing data. Each sub-basin was assigned its closest weather station.

Soils

The following soils along with lesser soils were used to model the Canadian:

Mobeetie (*thermic Aridic Ustochrepts*):
Deep, well drained, moderate to rapidly permeable soils formed in calcareous loamy alluvial materials. Slopes generally range from 0-15%. Mobeetie consisted of 10.2% of the study area.

Dallam (*mesic Aridic Paleustalfs*):
Deep, well drainged, moderately permeable soils formed in loamy calcareous materials. Soils are on nearly level and gently sloping uplands. Slopes range from 0-5%. Dallam soils consisted of about 15.5 % of the study area.

Gruver (mesic Aridic Paleustaffs):
Deep, well drained moderately permeable soils formed in calcareous eolian sediments. The soils are on nearly level and gently rolling uplands. Slope range from 0-3%. Gruver consisted of 6% of the Canadian basin.

Berda (thermic Aridic Ustochrepts):
Deep well drained, moderately permeable soils formed in calcareous loam materials. These soils are found on nearly level to steep erosion prone uplands. Slopes can range from 0-50%. The Berda soil series consisted 3% of the Canadian.

Land Use/Land Cover:

Figure C-3 shows areas with heavy and moderate brush cover that were removed and assumed converted to open grasslands (brush control simulation). The land use/cover map was based on classification of 1999 Landsat-7 satellite imagery (see earlier project description for classification details).

Ponds & Reservoirs:

The major reservoir in the watershed was Lake Meredith. Information on normal pool levels, and emergency spillway height were input into the SWAT model. No detail reservoir operation was modeled. Water was assumed controlled when levels reached principle spillway. Lake Meredith water level data were obtained from the nation wide Dam inventory of the Army Corp of Engineers.

Model Input Variables:

The important inputs and their values before and after calibration of the SWAT model are shown in Table C-1. The SWAT model calibration was based on matching predicted and observed flow at a gage near Lake Meredith on the Canadian mainstem (see Figure C-4). The curve number is used in a runoff rating curve developed by the USDA-NRCS to specify fraction of rainfall that runoffs surfaces based on vegetation and surface soil. The higher the curve number, the more the runoff. The curve numbers shown are for the most common soils which had a B type well drained soil. Based on field experience of NRCS range specialists, vegetation was assumed with same curve number before and after brush control in mixed land cover types. The soil evaporation compensation factor (esco) specifies whether the deeper soil layers should be weighted to control soil water evaporation. Generally, the value of esco is near 0.85, but is adjusted in dry climates to reflect more moisture storage in deeper soil layers. The shallow aquifer re-evaporation coefficient (Revap) specifies the fraction of water stored in aquifers lost back to the atmosphere. The soils in SWAT range in depths from 6-8 feet, while the shallow aquifer is assumed down to 150 feet. The shallow aquifer conveys water by base flow back into streams. The potential heat units (PHU) specifies the cumulative temperature above a base temperature at which there will be full canopy. As seen the PHU varies by type of vegetation on the Canadian. The PHUs are a function of latitude: PHUs decrease with increasing latitude. The precipitation intercepted by canopy was based on field experimental work (Thurow and Taylor, 1995) and calibration of SWAT to measured stream flows. Plant rooting depth, and leaf area indices (LAI) were based on observed values, and modeling experience. The LAI specifies the projected vegetation area (in units of m^2) per ground surface area (m^2).

Results

Calibration

Figure C-5 shows the SWAT predicted flows plotted against observed flows. The r^2 which indicates how well predictions match against observations was estimated at r^2 = 0.95. Since USGS measured flows were available for 37 years, the SWAT model predictions were compared over the same time period. If r^2 were 1.0, then there would be a perfect match between prediction and observation.

Brush Removal Simulation

Figure G-5 also shows the flows into Lake Meredith after brush control. Averaged over the 37 years of SWAT simulation, the expected water savings from brush control is nearly 98,000 acre-feet/year. There are several reasons for the increased stream flows from brush control: a). there is about 10% less direct evaporation to the atmosphere from reduced canopy interception and shallower rooting systems of grasses, b). there is more surface runoff from grassed surfaces, and c). less shallow aquifer water re-evaporation from grasslands.

Table C-2 shows the water savings from brush control in each sub-basin within the Canadian watershed. The water savings in gallons/treated acre/year represents the amount of water increase (decrease) leaving the sub-basin taking into account cleared area, agriculture, urban and other land uses in the sub-basin.

References

Kier R.S., L.E. Garner, and L.F. Brown Jr. 1977. Land Resources of Texas. Bureau of Economic Geology, University of Texas, Austin, Texas.

Thurow T.L., and C.A. Taylor Jr. Juniper Effects on the Water Yield of Central Texas Rangeland. Proc. 24^{th} Water for Texas Conference, Texas Water Resources Institute, Austin, Texas January 26-27, 1995; Ed. Ric Jensen.

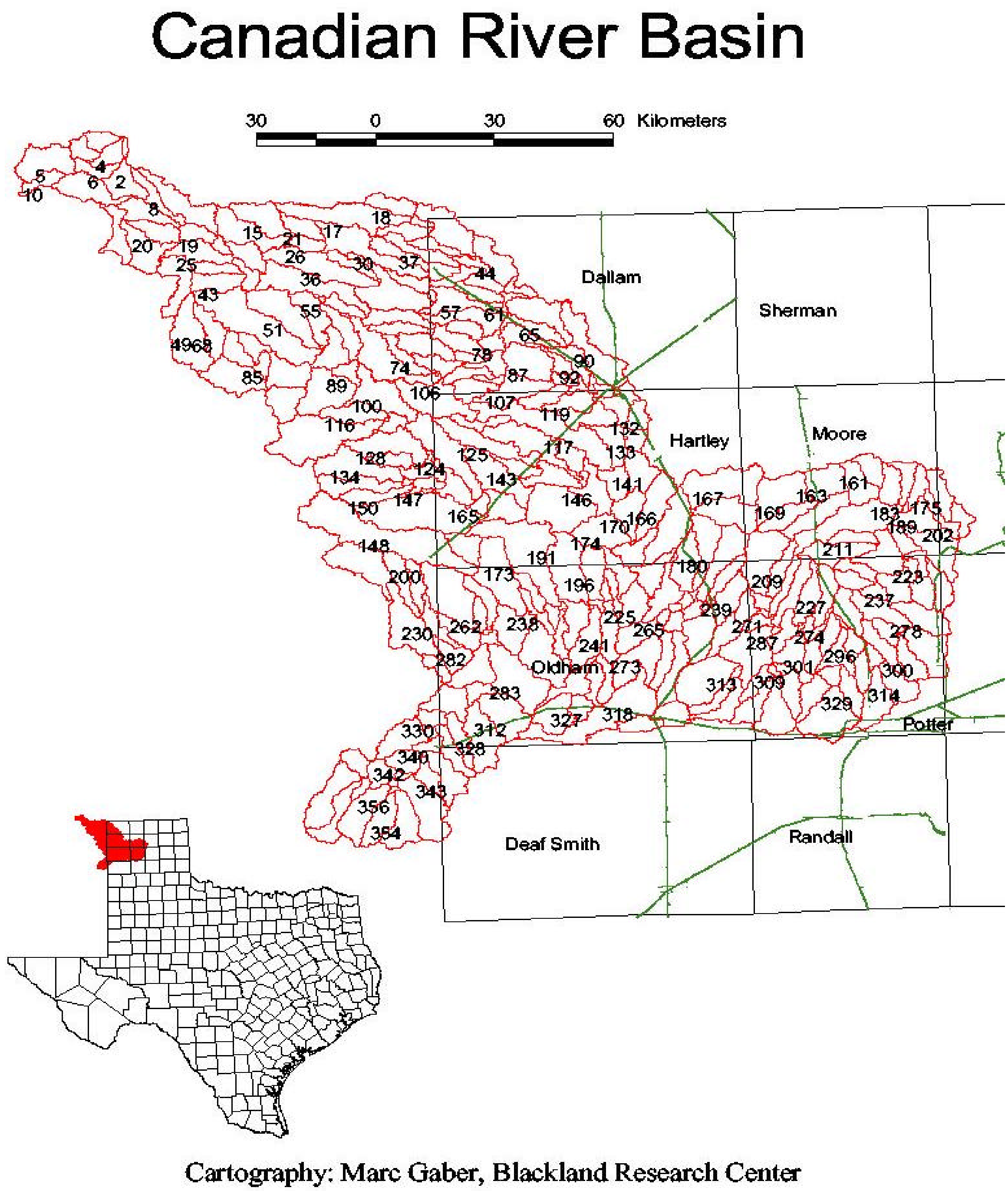

Figure C-1. Canadian watershed.

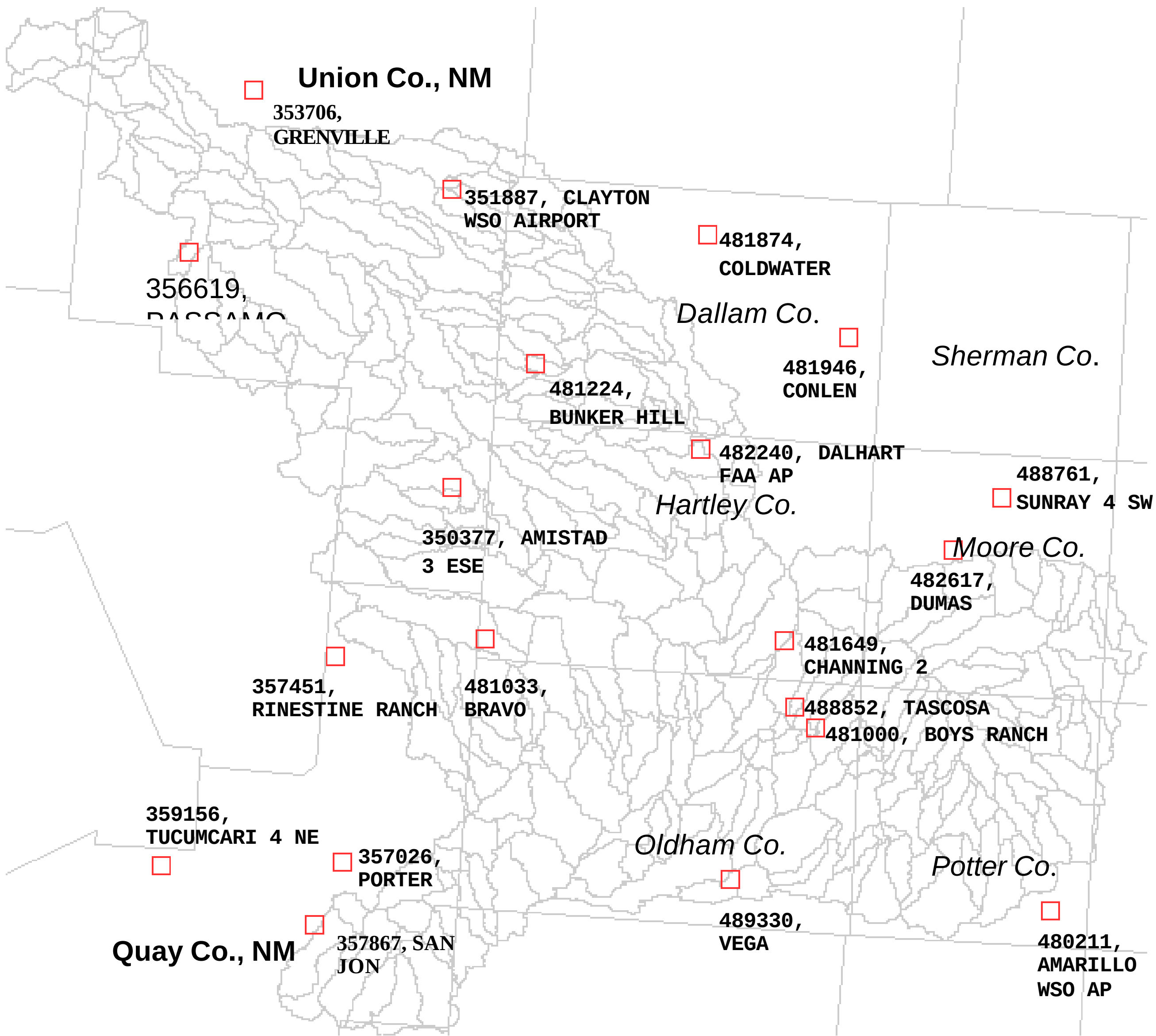

Figure C-2. Weather stations in the Canadian watershed.

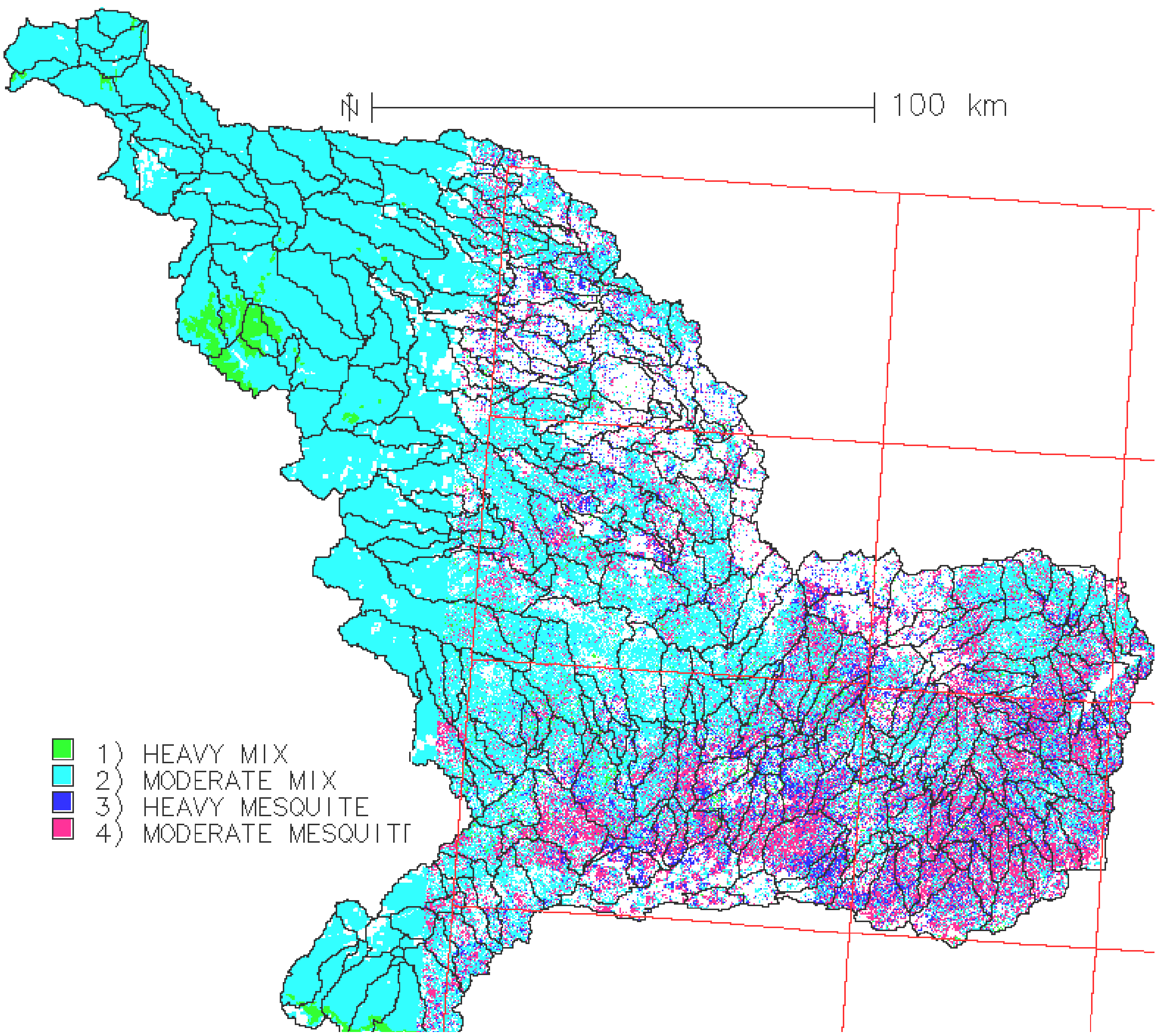

Figure C-3. Major brush types in the Canadian subject to brush removal.

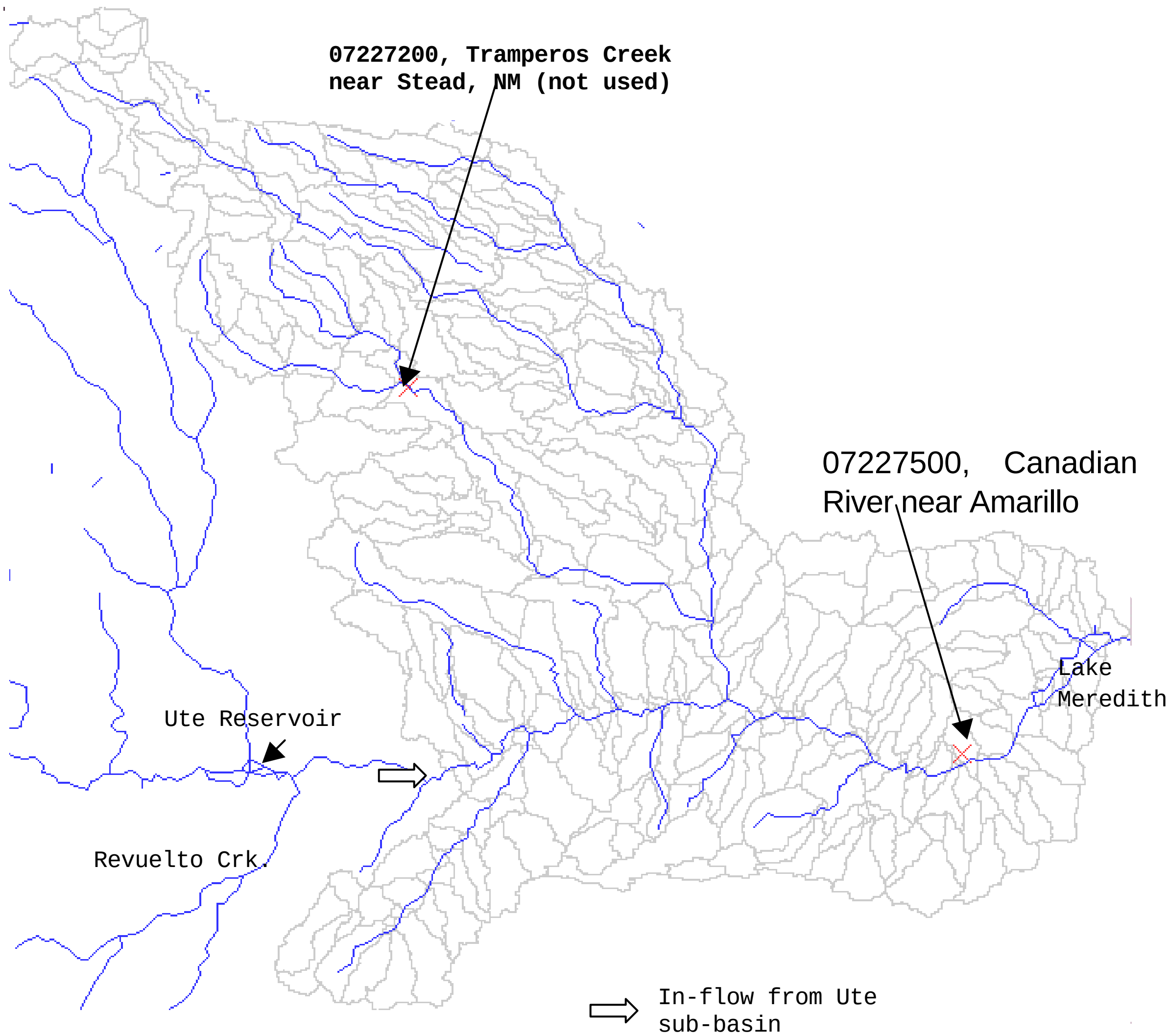

Figure C-4. Stream gages on the Canadian. Tamperos Creek gage was not used for calibration since very limited data from 1967 to 1973 was available. Measured flows at Revuelto and Ute were input into an independent SWAT run for the Ute watershed. Outflows from Ute watershed were used as external flows into the SWAT Canadian model.

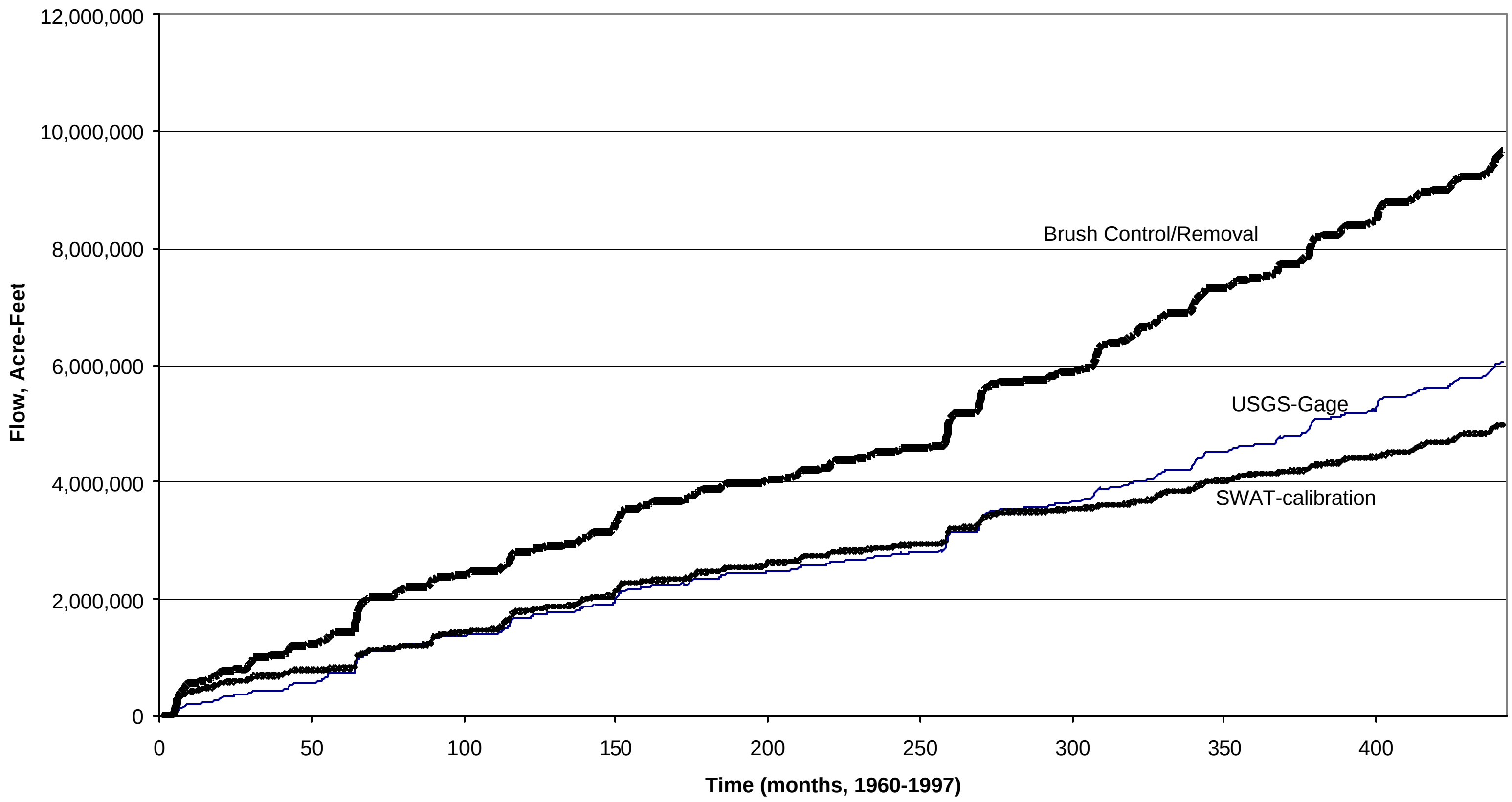

Figure C-5. Comparison between SWAT predicted and USGS measured flows. Flows after brush removal is also shown.

Table C-1. Relevant SWAT input variables for the Canadian watershed.

	Before Calibration	After Calibration	After brush Control
Curve number			
Heavy Mesquite	77	58	61
Heavy mixed	77	62	62
Moderate mesquite	77	83	86
Moderate mixed	77	82	82
Soil evaporation compensation	0.95	0.95	0.95
Shallow aquifer re-evaporation	0.12	0.12	0.03
Potential Heat Units			
Heavy Mesquite	3000	N/A	
Heavy mixed brush	3000	N/A	
Moderate Mesquite	3000	N/A	
Moderate mixed	3000	N/A	
Open grassland	2600	N/A	
Canopy interception (inches)		N/A	
Heavy Mesquite	0.4	N/A	0
Heavy mixed	0	N/A	0
Moderate mesquite	0.2	N/A	0
Moderate mixed	0	N/A	0
Open grassland	0	N/A	0
Rooting depth (feet)		N/A	
Heavy/Moderate brush	6.5	N/A	3.3
Open grassland	3.3	N/A	3.3
Maximum Leaf Area Index		N/A	
Heavy Mesquite	4	N/A	1
Heavy mixed	4	N/A	1
Moderate mesquite	2	N/A	1
Moderate mixed	3	N/A	1
Open grassland	1	N/A	1

Table C-2. Water savings by sub-basin number.

SUB	Area, acres	Trt. Acres	% treated	Savings, gal/tr.ac/yr	Savings, Gallons/year
1001	84,289	84,289	100	7,105	598,900,926
1002	57,057	37,772	66.2	6,510	245,911,111
1003	13,231	13,231	100	4,691	62,070,873
1004	31,045	31,045	100	4,242	131,705,370
1005	37,529	37,529	100	4,576	171,712,910
1006	35,707	23,852	66.8	6,418	153,091,455
1007	15,252	15,252	100	5,027	76,679,841
1008	10,899	10,899	100	5,684	61,950,106
1009	17,723	17,723	100	8,215	145,590,026
1010	12,165	12,165	100	5,383	65,484,259
1011	39,566	39,566	100	6,705	265,284,921
1012	32,650	32,650	100	4,976	162,472,328
1013	11,578	11,578	100	6,055	70,100,238
1014	8,475	6,517	76.9	4,411	28,747,646
1015	6,576	6,576	100	7,150	47,021,614
1016	10,883	10,883	100	5,582	60,754,286
1017	3,057	3,057	100	6,169	18,857,143
1018	7,441	7,441	100	3,187	23,716,667
1019	16,781	16,781	100	1,749	29,350,370
1020	6,329	6,329	100	7,747	49,033,228
1021	15,330	15,330	100	7,738	118,631,429
1022	19,652	19,652	100	4,204	82,616,058
1023	4,369	4,369	100	5,286	23,091,349
1024	13,940	13,940	100	5,685	79,250,661
1025	1,961	1,961	100	8,843	17,337,513
1026	865	865	100	3,231	2,794,312
1027	15,329	15,329	100	21,811	334,346,746
1028	2,439	2,439	100	6,660	16,242,460
1029	370	185	50	2,485	459,101
1030	19,930	19,930	100	15,143	301,782,698
1031	7,796	7,796	100	10,929	85,200,688
1032	34,009	34,009	100	13,082	444,899,788
1033	772	772	100	7,860	6,064,233
1034	12,659	12,659	100	10,531	133,301,640
1035	3,597	2,766	76.9	549	1,518,042
1036	19,436	15,044	77.4	505	7,598,280
1037	39,580	39,580	100	2,697	106,742,566
1038	7,055	7,055	100	638	4,503,598
1039	9,000	9,000	100	15,619	140,567,778
1040	14,155	14,155	100	21,350	302,211,032
1041	9,016	9,016	100	22,152	199,716,799
1042	6,824	6,824	100	10,506	71,688,757
1043	17,753	17,753	100	12,917	229,309,074
1044	26,878	26,878	100	6,432	172,867,751
1045	28,992	18,468	63.7	3,800	70,177,196
1046	20,223	13,711	67.8	28,310	388,169,815
1047	7,904	5,185	65.6	29,787	154,451,376

Table C-2 (continued).

SUB	Area	Trt. Acres	% treated	Gallons/tr.ac/year	Gallons/year
1048	7,086	5,704	80.5	10,539	60,113,677
1049	12,412	7,484	60.3	3,158	23,636,138
1050	20,161	20,161	100	4,651	93,760,794
1051	2,517	1,877	74.6	324	609,206
1052	12,396	8,219	66.3	5,452	44,809,815
1053	5,651	4,588	81.2	3,181	14,597,698
1054	8,645	6,968	80.6	6,489	45,214,259
1055	11,100	11,100	100	230	2,556,005
1056	19,681	15,588	79.2	8,854	138,008,333
1057	26,056	26,056	100	6,335	165,073,836
1058	9,016	7,005	77.7	9,921	69,494,841
1059	10,436	7,649	73.3	871	6,661,481
1060	2,007	1,616	80.5	161	260,106
1061	3,751	3,166	84.4	8,110	25,678,968
1062	16,595	13,226	79.7	11,309	149,571,005
1063	31,091	25,371	81.6	454	11,521,984
1064	1,081	1,081	100	180	194,444
1065	24,700	24,700	100	8,967	221,483,730
1066	803	803	100	196	157,275
1067	22,122	22,122	100	5,708	126,263,439
1068	18,248	18,248	100	12,893	235,272,857
2001	20,022	20,022	100	881	17,649,206
2002	59,929	59,929	100	300	17,972,275
2003	33,175	33,175	100	900	29,847,328
2004	33,700	33,700	100	1,090	36,744,101
2005	18,062	18,062	100	860	15,534,656
2006	16,441	16,441	100	526	8,645,899
2007	7,549	5,986	79.3	1,719	10,292,778
2008	14,712	12,093	82.2	2,309	27,922,116
2009	11,038	11,038	100	56	614,762
2010	15,453	15,453	100	643	9,930,476
2011	8,583	8,583	100	592	5,083,942
2012	5,048	5,048	100	2,033	10,261,772
2013	324	324	100	628	203,571
2014	25,749	25,749	100	1,248	32,129,365
2015	19,328	19,328	100	2,642	51,069,524
2016	6,762	6,762	100	1,215	8,212,196
2017	28,853	28,853	100	3,254	93,883,042
2018	31,153	31,153	100	892	27,794,444
2019	17,337	17,337	100	2,506	43,449,735
2020	33,052	23,169	70.1	4,347	100,713,757
2021	16,179	16,179	100	2,953	47,773,413
2022	56,424	56,424	100	1,924	108,538,307
2023	6,499	5,375	82.7	3,498	18,801,958
2024	37,220	37,220	100	2,717	101,136,376
2025	8,568	8,568	100	4,008	34,339,286
2026	26,074	20,494	78.6	4,370	89,561,005

Table C-2 (continued).

SUB	Area	Trt. Acres	% Treated	Gallons/tr.ac/year	Gallons/year
2027	27,262	20,583	75.5	2,546	52,412,566
2028	31,427	25,959	82.6	9,011	233,905,556
2029	30,829	30,829	100	3,341	102,987,222
2030	9,772	7,876	80.6	1,021	8,038,175
2031	10,111	10,111	100	2,654	26,836,481
2032	30,397	30,397	100	5,933	180,329,603
2033	10,420	6,544	62.8	10,540	68,970,767
2034	9,077	3,477	38.3	5,162	17,947,222
2035	14,450	14,450	100	3,521	50,870,238
2036	18,972	18,972	100	3,881	73,641,005
2037	14,820	9,974	67.3	12,135	121,031,746
2038	17,136	17,136	100	5,255	90,041,984
2039	1,158	1,158	100	4,750	5,500,344
2040	6,607	6,607	100	2,746	18,144,709
2041	13,277	13,277	100	4,595	61,003,122
2042	1,776	1,014	57.1	15,427	15,642,751
2043	62,182	62,182	100	10,593	658,679,233
2044	41,646	30,443	73.1	4,627	140,863,519
2045	16,719	13,241	79.2	7,334	97,107,540
2046	4,878	4,878	100	12,160	59,317,910
2047	31,076	22,095	71.1	8,358	184,658,862
2048	24,391	24,391	100	6,251	152,461,640
2049	13,616	13,616	100	6,950	94,631,270
2050	14,372	14,372	100	10,693	153,687,540
3001	21,057	21,057	100	72	1,511,032
3002	25,920	25,920	100	1,156	29,954,815
3003	12,442	12,442	100	181	2,252,169
3004	38,378	38,378	100	101	3,863,836
3005	11,254	11,254	100	139	1,566,984
3006	27,094	16,311	60.2	3,051	49,768,598
3008	35,441	35,441	100	3,104	110,006,720
3009	2,656	1,742	65.6	4,611	8,032,698
3010	10,389	10,389	100	4,279	44,454,418
3011	7,796	7,796	100	3,242	25,274,656
3012	13,230	13,230	100	3,422	45,272,646
3014	12,119	9,634	79.5	1,529	14,731,878
3016	34,738	34,738	100	2,727	94,726,032
3017	8,228	5,891	71.6	3,087	18,189,418
3018	18,772	12,634	67.3	231	2,915,344
3019	8,460	8,460	100	4,292	36,305,741
3020	34,333	28,805	83.9	2,824	81,340,159
3021	5,434	1,109	20.4	16	17,460
3022	6,916	6,916	100	3,512	24,288,889
3023	9,726	6,273	64.5	1,832	11,489,894
3024	8,691	6,458	74.3	1,682	10,863,598
3025	7,950	7,950	100	2,125	16,893,386
3026	9,664	4,958	51.3	2,649	13,135,132
3027	5,187	5,187	100	4,727	24,516,667
3028	18,558	8,147	43.9	6,021	49,054,444
3030	4,199	1,747	41.6	2,557	4,465,608
3031	23,944	16,737	69.9	3,910	65,446,640

Table C-2 (continued).

SUB	Area	Trt. Acres	% Treated	Gallons/tr.ac/year	Gallons/year
3033	19,343	4,526	23.4	3,552	16,076,958
3034	34,241	11,334	33.1	6,177	70,010,291
3035	11,964	3,338	27.9	3,290	10,981,614
3036	12,088	3,095	25.6	3,255	10,072,619
3037	11,378	0	0	0	0
3038	16	16	100	46	714
3040	48,041	32,284	67.2	6,740	217,603,307
3042	2,902	0	0	0	0
3043	2,038	450	22.1	252	113,492
3044	14,079	6,490	46.1	4,753	30,852,381
3045	4,060	2,075	51.1	5,368	11,136,958
3046	12,458	2,915	23.4	4,577	13,343,122
3048	16,534	5,125	31	5,500	28,191,481
3049	9,215	0	0	0	0
3050	14,788	7,512	50.8	4,164	31,281,296
3051	7,626	0	0	0	0
3053	17,149	0	0	0	0
3054	12,536	12,536	100	3,096	38,815,106
3055	24,129	8,155	33.8	4,820	39,307,381
3056	16,843	16,843	100	9,400	158,318,545
3061	170	170	100	9,965	1,690,979
4001	8,120	8,120	100	752	6,105,370
4002	8,089	8,089	100	40	320,582
4003	25,781	25,781	100	70	1,794,788
4004	18,155	18,155	100	41	738,889
4005	9,293	9,293	100	28	258,810
4007	8,552	8,552	100	28	238,148
4008	8,630	8,630	100	108	933,519
4009	22,354	22,354	100	225	5,027,831
4010	11,563	11,563	100	20	235,317
4011	26,306	26,306	100	164	4,310,714
4014	14,804	14,804	100	208	3,076,138
4015	14,959	14,959	100	669	10,013,889
4016	22,833	18,061	79.1	70	1,271,667
4017	12,983	12,983	100	71	917,751
4018	8,815	8,815	100	19	169,921
4020	3,705	3,705	100	443	1,642,751
4021	17,568	17,568	100	160	2,803,545
4022	12,273	12,273	100	771	9,464,206
4023	7,225	7,225	100	385	2,777,963
4024	8,784	8,784	100	227	1,994,471
4025	36,432	36,432	100	1,350	49,166,349
4027	15,175	15,175	100	170	2,584,286
4029	726	726	100	1,675	1,215,635
4030	14,573	10,959	75.2	3,737	40,956,614
4031	35,723	23,577	66	3,492	82,338,492
4032	10,050	2,291	22.8	4,528	10,376,508
4033	8,491	0	0	0	0
4034	13,770	2,837	20.6	3,426	9,719,365
4035	10,914	3,285	30.1	3,903	12,823,862
4036	17,491	0	0	0	0

Table C-2 (continued).

SUB	Area	Trt. Acres	% Treated	Gallons/tr.ac/year	Gallons/year
4037	6,546	2,062	31.5	3,706	7,641,534
4038	24,962	0	0	0	0
4039	8,165	0	0	0	0
4040	10,405	2,466	23.7	2,481	6,118,175
4041	4,631	0	0	0	0
4042	8,661	6,158	71.1	3,620	22,290,688
4043	386	294	76.2	4,826	1,419,524
4045	8,552	4,823	56.4	3,792	18,291,561
4046	22,848	6,032	26.4	3,590	21,656,958
4047	2,887	1,423	49.3	3,743	5,327,169
4048	12,783	9,715	76	3,729	36,225,714
4050	2,176	988	45.4	1,420	1,403,228
4051	1,976	0	0	0	0
4057	11,331	2,187	19.3	4,556	9,963,651
5001	39,879	0	0	0	42,698
5002	11,378	9,114	80.1	14,259	129,951,296
5003	16,765	16,765	100	13,051	218,794,894
5004	19,899	19,899	100	11,579	230,411,561
5005	12,519	12,519	100	10,495	131,392,143
5006	9,648	6,541	67.8	11,546	75,528,280
5007	29,671	0	0	0	0
5008	8,938	8,938	100	13,457	120,278,704
5009	13,245	13,245	100	20,235	268,015,714
5010	25,521	7,299	28.6	25,675	187,406,376
5011	19,976	19,976	100	14,190	283,468,995
5012	8,182	6,284	76.8	17,651	110,916,164
5013	14,635	5,429	37.1	17,050	92,574,233
5014	39,737	39,737	100	16,903	671,682,751
5015	21,320	21,320	100	9,258	197,382,778
5016	15,345	15,345	100	13,181	202,267,804
5017	803	803	100	8,585	6,889,947
5018	926	926	100	11,227	10,397,037
5019	8,074	8,074	100	20,347	164,268,757
5020	20,316	20,316	100	6,977	141,744,974
5021	24,870	24,870	100	17,266	429,415,741
5022	32,465	22,953	70.7	20,144	462,362,672
5023	8,676	8,676	100	23,046	199,954,418
5024	8,846	8,846	100	18,077	159,903,413
5025	25,842	19,588	75.8	27,221	533,222,487
5026	21,472	21,472	100	17,699	380,035,608
5027	12,244	8,154	66.6	18,755	152,932,619
5028	17,475	17,475	100	3,848	67,248,968
5029	19,698	19,698	100	17,915	352,899,921
5030	10,127	10,127	100	15,905	161,071,429
5031	15,144	15,144	100	16,692	252,782,090
5032	9,602	9,602	100	11,112	106,697,804
5033	5,589	3,795	67.9	30,228	114,709,312
5034	15,917	15,917	100	12,794	203,633,836
5035	8,366	8,366	100	8,095	67,724,074
5037	17,043	17,043	100	17,912	305,279,365
5038	15,376	15,376	100	18,558	285,340,899

Table C-2 (continued).

SUB	Area	Trt. Acres	% Treated	Gallons/tr.ac/year	Gallons/year
5039	4,261	4,261	100	22,129	94,290,899
5040	12,967	12,967	100	27,602	357,923,730
5041	10,683	10,683	100	33,393	356,724,153
5042	8,954	8,954	100	11,624	104,079,683
5043	14,404	14,404	100	24,398	351,417,302
5044	2,702	2,702	100	10,607	28,658,439
5045	864	654	75.7	14,711	9,620,450
5046	8,398	6,215	74	14,454	89,823,810
5047	4,369	3,229	73.9	14,287	46,131,799
5048	4,848	4,848	100	8,829	42,798,175
5049	864	864	100	19,570	16,914,603
5050	14,789	14,789	100	13,451	198,937,222
5051	5,342	5,342	100	14,101	75,321,376
5052	1,035	1,035	100	15,891	16,439,577
5053	1,591	1,165	73.2	9,680	11,273,466
5054	17,954	17,954	100	21,509	386,169,418
5055	21,366	21,366	100	4,381	93,593,942
5056	2,686	2,686	100	3,034	8,149,762
5057	5,480	4,455	81.3	3,458	15,406,958
5058	12,458	12,458	100	10,524	131,112,116
5059	14,928	14,928	100	8,200	122,410,926
5060	1,158	864	74.6	20,483	17,692,857
5061	11,547	11,547	100	18,168	209,793,704
5062	18,571	14,764	79.5	3,740	55,216,693
5063	3,103	3,103	100	23,811	73,894,947
5064	5,758	5,758	100	16,797	96,720,132
5065	18,942	18,942	100	22,378	423,868,042
5066	9,186	9,186	100	18,149	166,711,005
5067	3,427	3,427	100	18,703	64,096,614
5068	1,096	846	77.2	19,834	16,784,577
5069	12,228	12,228	100	8,772	107,260,847
5070	18,402	14,078	76.5	21,309	299,978,915
5071	31,184	23,450	75.2	13,791	323,407,090
5072	571	571	100	15,210	8,687,831
5073	972	972	100	15,518	15,086,958
5074	8,352	8,352	100	15,112	126,212,090
5075	13,616	13,616	100	11,776	160,343,730
5076	13,029	13,029	100	31,682	412,781,905
5077	7,209	7,209	100	13,916	100,317,646
5078	16,025	16,025	100	10,558	169,197,698
5079	8,969	8,969	100	22,593	202,636,323
5080	24,762	24,762	100	22,889	566,789,418
5081	13,354	13,354	100	23,314	311,325,688
5082	54,911	32,727	59.6	35,994	1,177,964,815
5083	9,433	9,433	100	13,058	123,174,683
5084	35,769	35,769	100	15,297	547,147,989
5085	5,079	5,079	100	12,691	64,457,937
5086	9,201	9,201	100	14,737	135,595,291
5087	2,424	2,424	100	7,219	17,497,249

Table C-2 (continued).

SUB	Area		% Treated	Gallons/tr.ac/year	Gallons/year
5088	1,513	1,513	100	4,378	6,622,434
5089	1,606	1,606	100	14,301	22,968,677
5090	8,304	5,024	60.5	15,455	77,648,519
5091	12,874	12,874	100	14,502	186,697,963
5092	11,685	11,685	100	21,969	256,720,159
5093	16,025	16,025	100	39,753	637,020,582
5094	5,775	5,775	100	28,495	164,549,841
5095	22,338	22,338	100	27,721	619,237,063
5096	13,338	10,350	77.6	14,233	147,311,561
5097	21,612	21,612	100	16,003	345,848,598
5098	14,266	14,266	100	11,201	159,791,614
5099	8,723	6,062	69.5	18,411	111,612,804
5100	13,230	13,230	100	15,060	199,249,577
5101	33,330	33,330	100	46,896	1,563,020,238
5102	12,196	0	0	0	0
5103	9,416	2,505	26.6	39,033	97,765,794
Totals	4,712,811	3,949,960			33,504,018,598
Weighted					
Average			83.81324	8,482	

CHAPTER 4

CANADIAN RIVER WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Lake Meredith watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs in the project area (per acre) range from $35.95 for moderate mesquite that can be initially controlled with herbicide treatments to $72.71 for heavy mixed brush. The costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Table 1.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite - Chemical

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	26.50	26.50
6	Aerial Spray Herbicide	26.50	16.70
9	Chemical IPT or Prescribed.Burn	15.00	7.50
		Total:	$ 50.70

Heavy Mixed Brush - Chemical

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	34.00 - 40.00	34.00 - 40.00
6	Aerial Spray Herbicide	34.00 - 40.00	21.43 - 25.21
9	Chemical IPT or Prescribed Burn	15.00	7.50
		Total:	$ 62.93 - 72.71

Moderate Mesquite - Chemical

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	26.50	26.50
6	Chemical IPT or Prescribed Burn	15.00	9.45
		Total:	$ 35.95

Moderate Mixed Brush - Chemical

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	34.00 - 40.00	34.00 - 40.00
6	Chemical IPT or Prescribed Burn	15.00	9.45
		Total:	$ 43.45 - 49.45

*Canadian River watershed.

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the watershed draining to Lake Meredith are shown in Table 2. Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type-Density Classification	Brush Control (Or) No Control	Program Year 0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Brush Control	30.0	28.0	25.0	25.0	23.0	20.0	20.0	20.0	20.0	20.0
	No Control	30.0	30.0	30.0	30.1	30.1	30.1	30.1	30.3	30.3	30.3
Heavy Mixed Brush (Sand Sage & Snakeweed)	Brush Control	40.0	37.0	33.0	33.0	30.0	25.0	25.0	25.0	25.0	25.0
	No Control	40.0	40.0	40.1	40.1	40.2	40.2	40.3	40.3	40.4	40.4
Heavy Mixed Brush (Cholla & Pear Cactus)	Brush Control	35.0	32.0	29.0	29.0	26.0	22.0	22.0	22.0	22.0	22.0
	No Control	35.0	35.0	35.1	35.1	35.2	35.2	35.3	35.3	35.4	35.4
Moderate Mesquite	Brush Control	25.0	23.0	22.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	25.0	25.1	25.3	25.4	25.6	25.7	25.8	25.9	26.1	26.3
Moderate Mixed Brush (Sand Sage & Snakeweed)	Brush Control	33.0	30.0	27.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	33.0	33.2	33.4	33.6	33.8	34.0	34.2	34.4	34.6	34.7
Moderate Mixed Brush (Cholla & Pear Cactus)	Brush Control	29.0	26.0	24.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
	No Control	29.0	29.1	29.3	29.4	29.6	29.7	29.9	30.1	30.3	30.5

*Canadian River watershed.

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. Livestock grazing capacities range from about 20 acres per AUY for land on which mesquite is controlled to 40 acres per animal unit year (AUY) for land infested with heavy mixed brush.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle and stocker calves) in the project areas is shown in Tables 3a and 3b. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Ranchers in the Canadian watershed felt that the brush control program would not have an impact on net returns to wildlife related enterprises.

Table 3a. Investment Analysis Budget, Cow-Calf Production*

Revenues

Production Item	Marketed Percentage	Quantity	Unit	$ Per Unit	$ Return
Beef Cull Bull	0.01 (Head)	19.50	Cwt	50.00	0.00
Beef Cull Cow	0.105 (Head)	11.00	Cwt	40.00	0.00
Calves	0.84 (Head)	5.55	Cwt	75.00	416.25
				Total:	$416.25

Partial Variable Costs

Variable Cost Description	Quantity	Unit	$ per Unit	$ Cost
Supplemental Feed	-	-	-	50.00
Cattle Marketing - All Cattle	-----	Head of Cow	-----	18.16
Vitamin / Salt / Mineral	60.0	Pound	0.183	11.00
Veterinary and Medicine	1.0	Head	14.50	14.50
Net Cost for Purchased Cows	-----	Head	700.00	37.80
Net Cost for Purchased Bulls	-----	Head	1500.00	3.50
			Total:	$134.96

*Canadian River Watershed

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3b. Investment Analysis Budget, Stocker Calf Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	$ Revenue
Net Gain on Stockers	1.0	Head	87.50	87.50
			Total:	$87.50

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	$ Cost
Stocker delivery	1.0	Head	5.00	5.00
Interest	400.0	Dollars	.05	20.00
Vitamin / Salt / Mineral	15.0	Pound	0.233	3.50
Veterinary and Medicine	1.0	Head	10.00	10.00
Labor	1.2	Hour	7.00	8.40
			Total:	$46.90

* Canadian River Watershed

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $9.59 per acre for control of moderate mixed brush to $11.37 per acre for the control of heavy mesquite (Table 4).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the project area range from $26.10 for control of moderate mesquite with chemical treatments to $62.84 for control of heavy mixed brush. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Table 4.

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush Category by Type & Density	PV Total Cost ($/Acre)	Landowner Share ($/Acre)	Landowner Share (Percent)	State Share ($/Acre)	State Share (Percent)
Heavy Mesquite	50.7	10.37	20.45	40.33	79.55
Heavy Mixed (Sand Sage & Snakeweed)	62.93 - 72.71	9.87	15.68 - 13.57	53.06 - 62.84	84.32 - 86.43
Heavy Mixed (Cholla & Pear Cactus)	62.93	11.02	17.51	51.91	82.49
Moderate Mesquite	35.95	9.85	27.4	26.1	72.6
Moderate Mixed (Sand Sage & Snakeweed)	77.93 – 49.45	9.59	22.07 - 19.39	33.86 – 39.86	70.37 - 80.61
Moderate Mixed (Cholla & Pear Cactus)	43.45	11.36	26.14	32.09	73.86
Average[1]	$54.09	$10.34	21.14%	$40.87	78.23%

* Canadian River Watershed

[1] Average is calculated as simple average, not relative average. The averages are based on the Heavy Mesquite Chemical comprising 50% of the cost for Heavy Mesquite control and Heavy Mesquite Mechanical comprising the other 50% of the cost for Heavy Mesquite. Also, it is assumed that Mechanical and Chemical comprise 50% each of cost for Moderate Mesquite control. Actual averages may change depending on relative amounts of each Type- Density Category of brush in each control category.

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water was determined to average $111.37 per acre-foot for the entire watershed and ranges from $26.16 per acre foot for Subbasin 5101 to $91,399.96 per acre foot for Subbasin 3021. Details of the costs of added water for each Subbasin of the Canadian are shown in Table 5. Subbasins in the Canadian Watershed outside the State were excluded from the analysis and added water yields and costs for subbasins partially outside the State were prorated based on the proportion of the total area in the subbasin lying inside the state boundary.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1001	564,979.10	356.77	2,783.55	202.97
1002	1,301,980.00	753.56	5,879.31	221.45
1003	456,212.10	190.21	1,484.01	307.42
1005	1,293,985.00	526.19	4,105.36	315.19
1006	821,929.40	469.13	3,660.15	224.56
1009	611,072.50	446.14	3,480.80	175.55
1010	419,438.90	200.67	1,565.61	267.91
1011	1,061,113.00	632.30	4,933.20	215.10
1012	75,089.80	33.21	259.09	289.82
1013	399,208.10	214.81	1,675.97	238.19
1014	224,750.30	88.09	687.31	327.00
1015	226,749.10	144.09	1,124.21	201.70
1016	300,204.70	148.94	1,162.02	258.35
1017	105,395.70	57.79	450.84	233.78
1018	256,551.20	72.68	567.02	452.45
1019	530,581.50	89.94	701.72	756.12
1020	205,569.10	150.26	1,172.30	175.36
1021	501,014.20	363.53	2,836.27	176.65
1022	634,792.80	253.17	1,975.21	321.38
1023	142,408.50	70.76	552.07	257.95
1024	480,651.90	242.85	1,894.75	253.68
1025	64,313.54	53.13	414.51	155.16
1026	29,818.30	8.56	66.81	446.33
1027	455,232.70	1,024.56	7,993.65	56.95
1028	79,341.20	49.77	388.33	204.31
1029	6,370.18	1.41	10.98	580.36
1030	630,935.60	924.78	7,215.10	87.45
1031	268,803.70	261.09	2,037.00	131.96
1032	1,067,469.00	1,363.34	10,636.78	100.36
1033	24,985.65	18.58	144.99	172.33
1034	436,468.90	408.49	3,187.01	136.95
1035	95,402.37	4.65	36.29	2,628.62
1036	518,968.80	23.28	181.66	2,856.79
1037	1,157,597.00	327.10	2,552.03	453.60
1038	145,955.50	8.28	64.60	2,259.24
1039	288,545.00	430.75	3,360.73	85.86
1040	470,225.20	926.09	7,225.34	65.08
1041	262,680.30	612.01	4,774.88	55.01
1042	210,075.80	219.68	1,713.95	122.57
1043	496,248.90	614.85	4,797.08	103.45
1044	838,780.50	529.73	4,132.97	202.95
1045	636,666.00	215.05	1,677.81	379.46
1046	411,452.80	1,189.50	9,280.47	44.34
1047	167,773.40	473.30	3,692.66	45.43
1048	$93,711.78	92.11	718.61	$130.41

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)* (Continued)

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1049	258,176.60	72.43	565.10	456.87
1052	265,353.30	137.31	1,071.32	247.69
1056	492,143.80	422.91	3,299.54	149.16
1058	96,627.58	286.71	2,236.91	43.20
1063	295,546.70	12.61	98.37	3,004.42
2020	513,897.10	198.41	1,548.03	331.97
2024	905,910.70	218.77	1,706.86	530.75
2025	295,420.80	105.23	820.99	359.83
2026	666,332.50	274.45	2,141.25	311.19
2028	843,069.50	716.77	5,592.28	150.76
2031	139,455.50	32.89	256.65	543.38
2032	978,103.30	552.60	4,311.37	226.87
2033	203,664.00	211.35	1,648.97	123.51
2035	618,027.50	155.89	1,216.22	508.15
2037	310,215.10	370.89	2,893.66	107.21
2038	590,841.70	275.92	2,152.75	274.46
2040	75,864.65	18.52	144.46	525.17
2042	30,451.99	47.94	373.99	81.42
2043	2144,043.00	874.59	6,823.55	314.21
2044	1050,076.00	431.66	3,367.80	311.80
2045	456,667.30	297.57	2,321.67	196.70
2046	168,201.40	181.77	1,418.19	118.60
2047	761,723.90	565.86	4,414.87	172.54
2048	841,006.90	467.20	3,645.09	230.72
2049	469,472.10	289.99	2,262.47	207.50
2050	467,516.50	470.96	3,674.40	127.24
3006	460,052.90	124.78	973.56	472.55
3009	27,506.66	12.31	96.02	286.46
3010	89,556.54	34.06	265.71	337.05
3012	260,651.80	79.27	618.48	421.44
3017	135,450.00	37.18	290.06	466.97
3018	435,867.50	8.93	69.70	6,253.41
3021	38,154.53	0.05	0.42	91,399.96
3022	238,465.40	74.43	580.71	410.65
3023	216,300.60	7.04	54.94	3,936.98
3024	222,573.20	33.29	259.73	856.94
3025	274,117.40	51.77	403.89	678.69
3026	170,980.10	40.25	314.04	544.46
3027	178,845.00	75.13	586.15	305.12
3028	264,991.60	131.53	1,026.21	258.22
3030	60,189.32	13.68	106.76	563.76
3031	576,996.60	200.55	1,564.72	368.75
3033	$138566.50	43.79	341.67	$405.56

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)* (Continued)

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
3034	390,563.20	214.54	1,673.82	233.34
3035	115,048.40	33.65	262.55	438.19
3036	106,533.50	30.87	240.82	442.38
3038	536.16	0.00	0.02	31,396.24
3040	1,041,884.00	666.82	5,202.52	200.27
3043	15,551.17	0.35	2.71	5731.25
3044	200,683.20	94.54	737.63	272.07
3045	71,482.56	34.13	266.27	268.46
3046	100,472.30	40.89	319.01	314.95
3048	176,440.00	86.39	674.01	261.78
3050	258,842.40	95.86	747.88	346.10
3054	432,227.50	118.94	928.00	465.76
3055	281,202.30	120.45	939.77	299.22
3056	545,502.30	485.15	3,785.12	144.12
3061	5,494.74	5.18	40.43	135.91
4031	58,017.46	18.02	140.56	412.77
4032	19,727.21	7.95	62.02	318.07
4034	97,758.73	29.78	232.37	420.70
4035	18,869.74	6.55	51.11	369.20
4037	71,027.77	23.42	182.70	388.78
4040	67,910.98	15.00	117.02	580.34
4042	212,286.80	68.31	532.93	398.34
4043	10,139.88	4.35	33.94	298.77
4045	166,365.30	56.05	437.32	380.42
4046	207,899.60	66.37	517.78	401.52
4047	49,106.76	16.32	127.36	385.56
4048	335,053.90	111.01	866.09	386.86
4050	34,059.69	4.30	33.55	1,015.23
4057	75,399.14	30.53	238.21	316.52
5002	291,927.00	398.22	3,106.91	93.96
5003	543,986.10	670.47	5,231.01	103.99
5004	643,358.00	706.07	5,508.74	116.79
5005	401,813.80	402.63	3,141.36	127.91
5006	225,611.90	231.45	1,805.75	124.94
5008	290,922.50	368.58	2,875.65	101.17
5009	425,740.40	821.30	6,407.79	66.44
5010	190,755.00	574.28	4,480.56	42.57
5011	622,386.70	868.66	6,777.25	91.83
5012	196,878.00	339.89	2,651.81	74.24
5013	165,666.10	283.68	2,213.29	74.85
5014	1,269,218.00	2058.29	16,058.77	79.04
5015	$664,461.30	604.86	4,719.08	$140.80

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)* (Continued)

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
5016	470,610.70	619.82	4835.87	97.32
5017	27,335.56	21.11	164.73	165.94
5018	28,155.02	31.86	248.58	113.27
5019	261,788.20	503.38	3,927.38	66.66
5020	634,470.40	434.36	3,388.88	187.22
5021	770,421.90	1,315.89	10,266.58	75.04
5022	705,136.00	1,416.85	11,054.29	63.79
5023	260,506.10	612.74	4,780.56	54.49
5024	280,596.80	490.00	3,823.01	73.40
5025	586,534.70	1,633.99	12,748.42	46.01
5026	688,933.20	1,164.57	9,085.99	75.82
5027	248,627.10	468.64	3,656.35	68.00
5028	570,375.80	206.08	1,607.81	354.75
5029	590,979.20	1,081.42	8,437.22	70.04
5030	330,431.20	493.58	3,850.94	85.81
5031	473,766.40	774.62	6,043.58	78.39
5032	303,182.60	326.96	2,550.96	118.85
5033	126,694.20	351.51	2,742.50	46.20
5034	489,721.70	624.01	4,868.53	100.59
5035	265,614.50	207.53	1,619.16	164.04
5037	532,184.00	935.49	7,298.70	72.91
5038	474,241.50	874.39	6,822.01	69.52
5039	128,632.60	288.94	2,254.33	57.06
5040	424,312.70	1,096.81	8,557.33	49.58
5041	305,448.10	1,093.14	8528.65	35.81
5042	268,572.30	318.94	2488.36	107.93
5043	466,448.70	1,076.87	8401.78	55.52
5044	83,871.24	87.82	685.17	122.41
5045	24,605.93	29.48	230.01	106.98
5046	198,792.80	275.25	2,147.53	92.57
5047	100,894.40	141.37	1,102.93	91.48
5048	157,066.10	131.15	1,023.23	153.50
5049	28,877.84	51.83	404.40	71.41
5050	451,511.50	609.62	4,756.24	94.93
5051	167,649.20	230.81	1,800.80	93.10
5053	35,473.21	34.55	269.53	131.61
5054	538,575.60	1,183.37	9,232.64	58.33
5055	707,385.70	286.81	2,237.67	316.13
5056	81,723.06	24.97	194.85	419.42
5057	154,274.20	47.21	368.35	418.82
5058	405,931.30	401.78	3,134.66	129.50
5059	480,345.60	375.11	2,926.63	164.13
5060	$27,471.59	54.22	423.01	$64.94

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)* (Continued)

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
5061	372,978.20	642.89	5,015.80	74.36
5062	476,487.40	169.20	1,320.14	360.94
5063	96,651.97	226.44	1,766.70	54.71
5064	189,319.50	296.39	2,312.41	81.87
5065	579,506.80	1,298.89	10,133.95	57.18
5066	265,781.80	510.87	3,985.77	66.68
5067	102,702.20	196.42	1,532.44	67.02
5068	25,787.44	51.43	401.29	64.26
5069	385,276.20	328.69	2,564.42	150.24
5070	405,549.70	919.25	7,171.97	56.55
5071	716,347.90	991.04	7,732.10	92.65
5072	18,791.30	26.62	207.71	90.47
5073	32,173.54	46.23	360.70	89.20
5074	263,128.80	386.76	3,017.51	87.20
5075	434,394.50	491.35	3,833.54	113.31
5076	414,508.20	1,264.92	9,868.90	42.00
5077	224,899.70	307.41	2,398.42	93.77
5078	480,354.70	518.49	4,045.22	118.75
5079	276,418.20	620.95	4,844.68	57.06
5080	740,413.70	1,736.86	13,550.95	54.64
5081	386,268.80	954.02	7,443.26	51.90
5082	982,999.50	3,609.73	28,163.09	34.90
5083	272,910.80	377.45	2,944.89	92.67
5084	1,106,133.00	1,676.67	13,081.36	84.56
5085	158,177.50	197.52	1,541.08	102.64
5086	259,785.50	415.51	3,241.85	80.14
5087	74,812.67	53.62	418.33	178.84
5088	48,504.07	20.29	158.33	306.35
5089	49,534.05	70.38	549.14	90.20
5090	153,968.80	237.94	1,856.44	82.94
5091	406,820.10	572.11	4,463.62	91.14
5092	334,510.40	786.69	6,137.73	54.50
5093	468,569.80	1,952.07	15,230.06	30.77
5094	179,880.00	504.24	3,934.10	45.72
5095	698,821.20	1,897.58	14,804.88	47.20
5096	349,341.70	451.42	3,521.96	99.19
5097	633,727.60	1,059.81	8,268.64	76.64
5098	463,062.10	489.66	3,820.34	121.21
5099	208,087.50	342.02	2,668.47	77.98
5100	408,577.40	610.58	4,763.71	85.77
5101	977,652.50	4,789.68	3,7369.1	26.16
5103	65,327.78.00	299.59	2,337.41	27.95
Totals:	$77,844,501.00	----------	698,958.66	Average: $111.37

*Canadian River watershed.

CHAPTER 5

EDWARDS RECHARGE ZONE WATERSHEDS– HYDROLOGIC SIMULATION
(Drainage Areas above USGS Gauging Stations)

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The Edwards recharge area was assumed to consist of the Upper Nueces watershed and the five river basins: Upper Frio, Sabinal, Seco, Hondo, and Medina. The hydrologic modeling for Nueces and the five river basins was done separately since the Upper Nueces was modeled in the context of the rest of the Nueces river basin described in Chapter 11. Therefore, Chapter 5 consists of two sections. Outflows from the Upper Nueces were used as inflow into the rest of the Nueces below the recharge fault zone. The general methodology for modeling followed those described in the introductory chapter.

SECTION 1- UPPER FRIO, SABINAL, SECO, HONDO, AND MEDINA

WATERSHED DATA

Location

The primary recharge zones of the Edwards aquifer are the located on the Great Plain and Coastal Plains provinces. The two provinces are separated by the highly fractured Balcones Fault Zone. The Edwards aquifer recharge areas are underlain by limestone of cretaceous age and marl (sedimentary rock). The Edwards recharge zone watersheds as defined in this report consists of the natural drainage areas defined above the U.S. Geological Survey (USGS) gauging stations West to East on the Frio, Sabinal, Seco, Hondo, and Medina rivers. Therefore, drainage areas near and around Lake Medina were not defined in this report. The drainage areas are located within Uvalde, Bandera, and Medina counties capturing most of the recharge area of the Edwards Plateau. The river flows from the Edwards Plateau contributes to the significant spring flows in the Edwards aquifer which moves laterally eastward to San Antonio. The average annual precipitation within the study area varies generally from about 560 mm (22 inches) to 760 mm (30 inches) West to East. The Edwards aquifer and the Edwards Plateau are intensely studies sites (Petitt and George, 1956;Garza, 1962; Puente, 1971; Rose, 1972).

Topography

Figure E-1 shows the location of the five river basins on the Edwards recharge zone, and Figures E-2 through E-6 show the individual river basins, and the sub-basin numbers. There were a total of 23 sub-basins within Frio, 11 within Sabinal, 13 within Seco, 5 within Hondo, and 25 within Medina.

Weather Stations

Figure E-7 shows the weather stations used for study of brush control on the Edwards. The nearest station to each sub-basin was used. Daily weather data (1960-1998) on precipitation, temperature, and solar radiation were collected from National Weather Service (NWS) stations. Missing data for any weather station was filled using the nearest station. Daily relative humidity was generated from monthly measurements.

Soils

Tarrant series (*thermic Lithic Calciustolls); Clayey-Skeletal, Smectitic*

The Tarrant series consists of very shallow and shallow, well drained, moderately slowly permeable soils on uplands. They formed in residuum from limestone, and includes interbedded marls, chalks, and marly materials. Soils are found mainly on 1-8% slopes and consist of less than 35% clay fraction. Tarrant soils consisted of 32.6% of the entire studied Edwards watershed.

Eckrant series (*thermic lithic Haplustolls*); *Clayey-Skeletal, montmorillonitic*

This soil series consists of shallow to very shallow, well drained, moderately slow permeable soils formed in interbedded limestone, marls, chalks and marly earths. Slopes generally range from 0-40%. Eckrant series soils consisted of 30.2% of the entire study area.

Brackett series (*thermic Udic Ustochrepts*); *Fine-loamy, carbonatic*

The Brackett series consists of very deep, well drained moderately permeable soils that formed in marly loamy earth interbedded with chalky limestone. These soils are on uplands with slopes ranging from 1 to 40 percent. This soil series consisted of 8.13% of the Edwards watershed.

Speck series (thermic Lithic Argiustolls); *Clayey, mixed, superactive*

The Speck series consists of shallow, well drained, slowly permeable soils formed in residuum and colluvium derived from indurated limestone. These soils are on nearly level to sloping uplands. Slopes range from 0 to 8 percent. The speck soils consisted of 7.7% of the Edwards.

Krum series (*thermic Vertic Haplustolls); Fine, montmorillonitic*

The Krum series consists of very deep, well drained, moderately slowly permeable soils that formed in calcareous clayey sediments. These soils are on nearly level to moderately sloping terraces and lower slopes of valleys. Slopes range from 0 to 8 percent. The Krum soils consisted of 4.16% of the Edwards.

Land Use/Cover:

Figure E-8 shows brush areas on which brush control was simulated. The brush areas after removal was assumed converted to open range conditions (grassland). Details of Landsat-7 (ETM+) 1999 image classification is given earlier in general project description.

Ponds & Reservoirs:

The major reservoir in the Edwards recharge zone study area was Lake Medina. Since drainage to the U.S. Geological Survey (USGS) gauging points only were considered, Lake Medina and sub-basins draining into Lake Medina were not considered for this project.

Model Input Variables:

The important SWAT model parameters and parameter input values before and after calibration are shown on Tables E-1 through E-5. The SWAT model calibration was based on matching observed and predicted stream flows at the USGS gauging station. The curve numbers specify runoff rate depending on vegetation cover and soils, and is given for the most common soils in each river basin. West to East there is a general trend for higher transmission losses in the river basins, the curve numbers are reduced compared to default values after the calibration stage except for Frio. The Potential Heat Units (PHUs) which specify maximum canopy maturity as function of cumulated air temperature above a base temperature was obtained from the Climatography of the United States No.20 (NOAA, 1980). The amount of precipitation intercepted by brush canopy was based on field experiments (Thurow and Taylor, 1995) and calibration of SWAT stream flows to USGS measured flows.

Results

Calibration

Figures E-9 through E-13 show the SWAT and USGS measured flows for each of the Edwards recharge river basins. The r^2 measure was high over 0.9 for all comparisons.

Brush Removal Simulation

The dashed line graph shows cumulative stream flows after brush removal. For the Frio river basin, based on 39 years of simulation it is predicted that there will be an increase in flow at outlet of 20,561 Acre-Feet/year due to brush removal; for Sabinal there will be an increased flow at outlet of 15,535 Acre-Feet/year due to brush removal; for Hondo there will be an increased flow of 7,665 Acre-Feet/year due to brush removal; for Seco SWAT predicts an increased flow of 5,300 Acre-Feet/year; and for Medina there will be an increased flow at outlet of river basin of nearly 50,000 Acre-Feet/year. Table E-6 shows the water savings within each sub-basin of the Edwards Plateau recharge watersheds after brush removal. The water savings within sub-basins are much higher than predicted stream flows at outlet of river basins since the stream flows account for all the transmission losses in the stream segments. There is a significant water loss in streams in the Edwards river basins. The sub-basin water yields given in Gallons/treated acre/year can be compared against some field measurements. Thruow and Taylor (1995) made water savings estimates of close to 85,000 gallons/treated acre/year in Sonora, Texas. Dugas et al. (1998) observed water savings of nearly 130,000 gallons/treated acre/year in a sub-basin in Seco river basin.

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Rose P.R. 1972. Edwards group, surface and subsurface, Central Texas. Bureau of Economic Geology, University of Texas. Report Inv. 73. 198 Pp.

Thurow T.L., and C.A. Taylor. 1995. Juniper effects on the water yield of Central Texas rangeland. Proc. 24th Water for Texas Conference, Texas Water Resources Institute, College Station, Texas. Pp. 657-666.

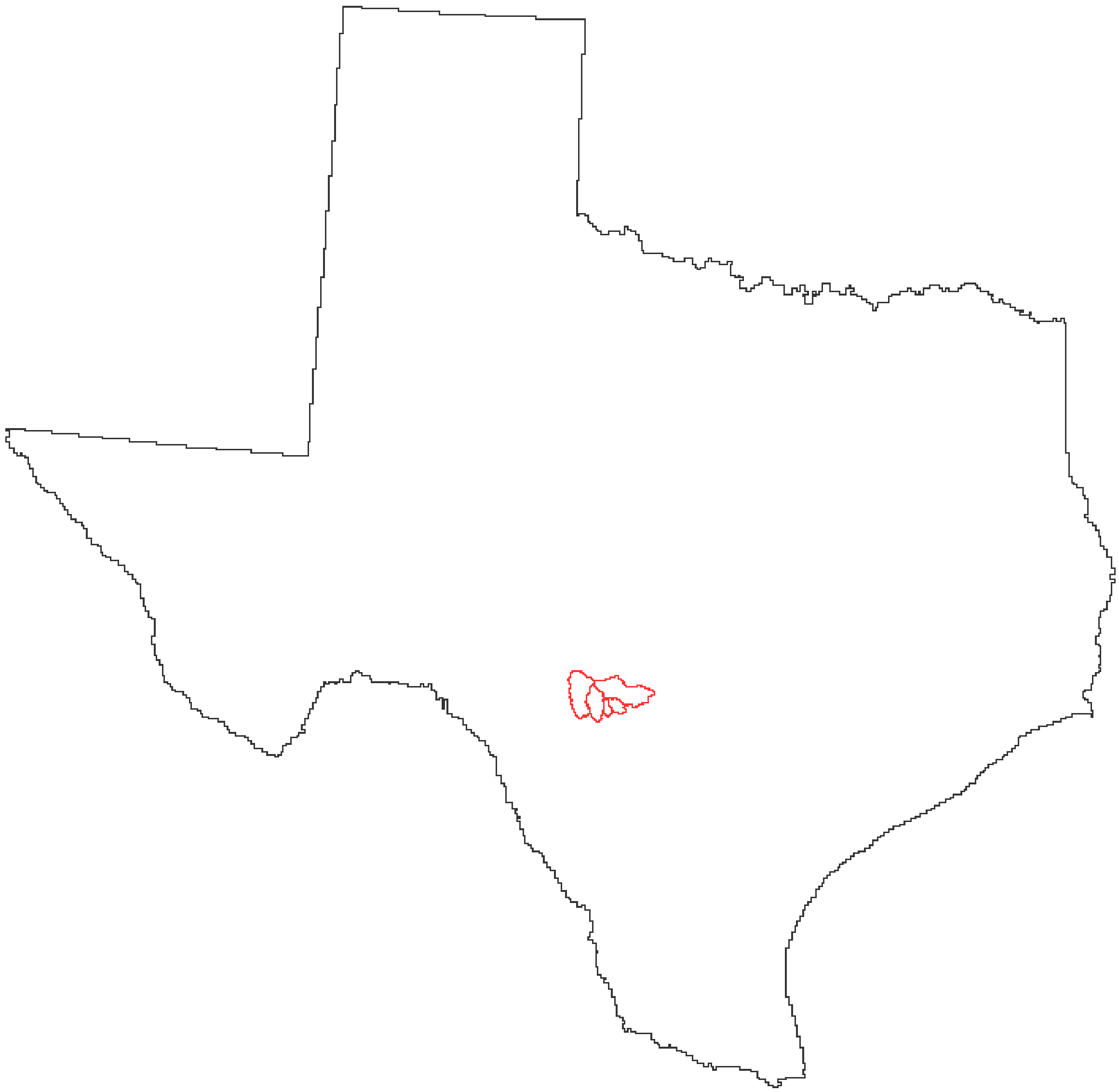

Figure E-1. Loci of Edwards Plateau recharge river basins in Texas.

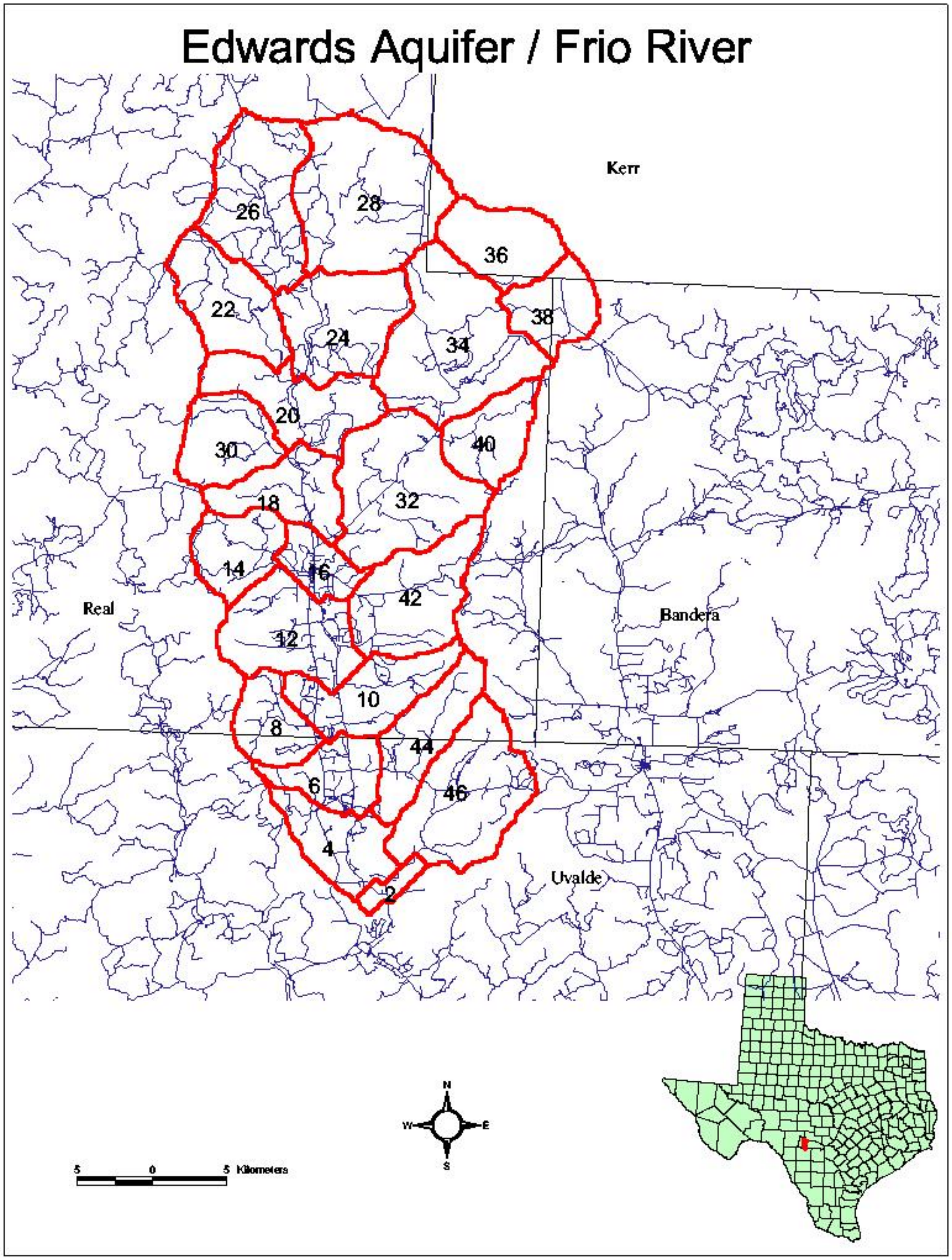

Figure E-2. Sub-basin numbers for Frio river basin.

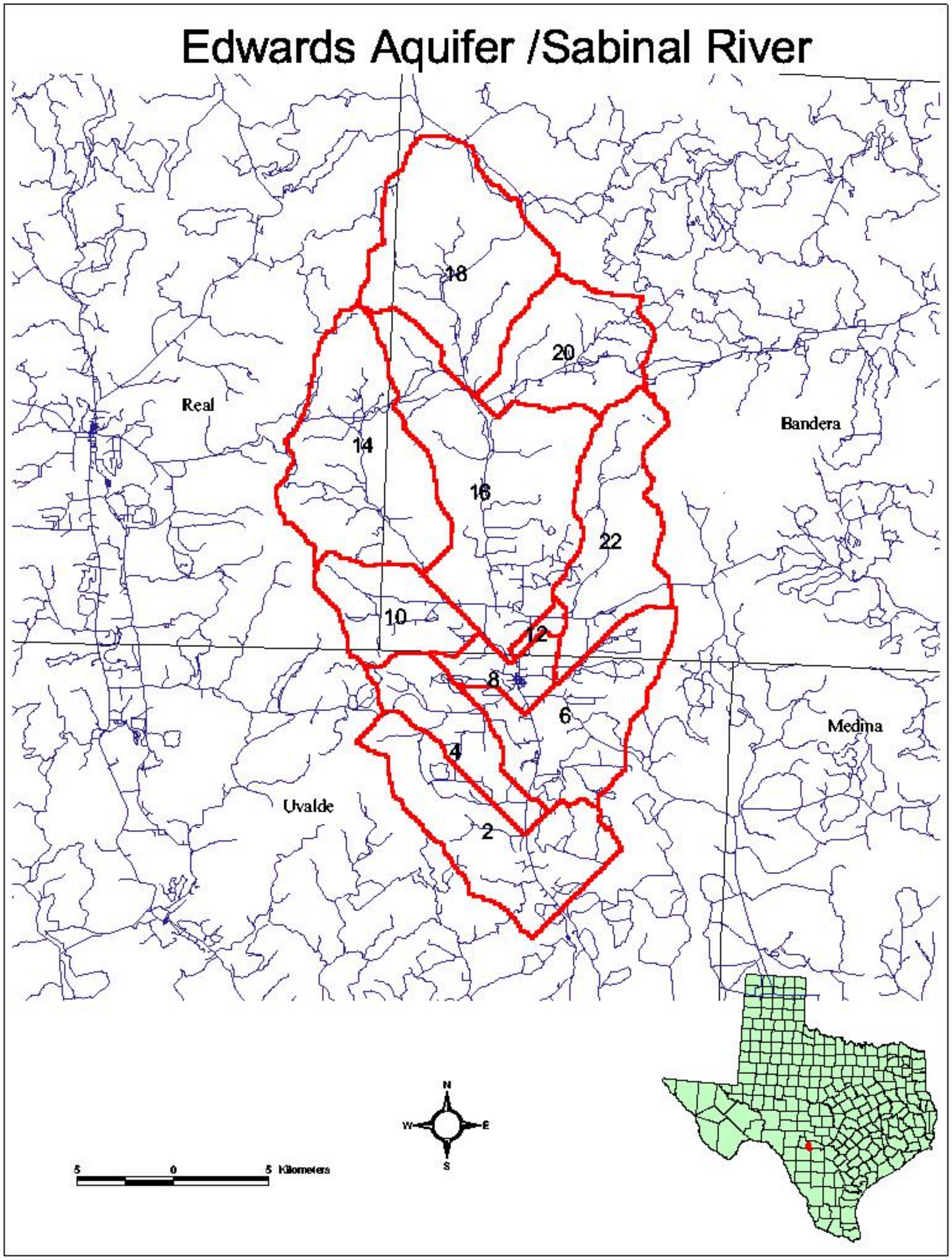

Figure E-3. Sabinal river basin with associated sub-basin numbers.

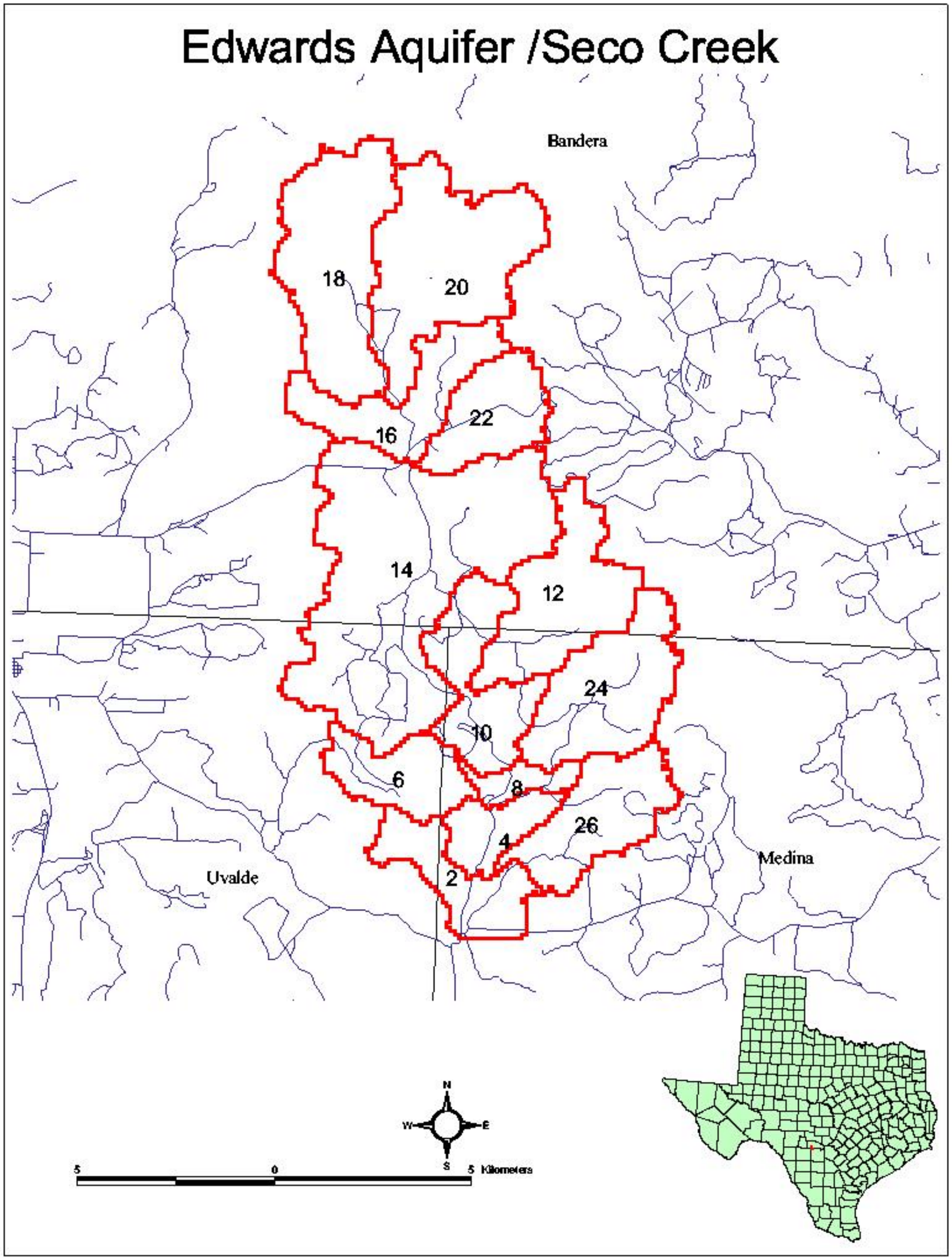

Figure E-4. Seco river basin and associated sub-basin numbers.

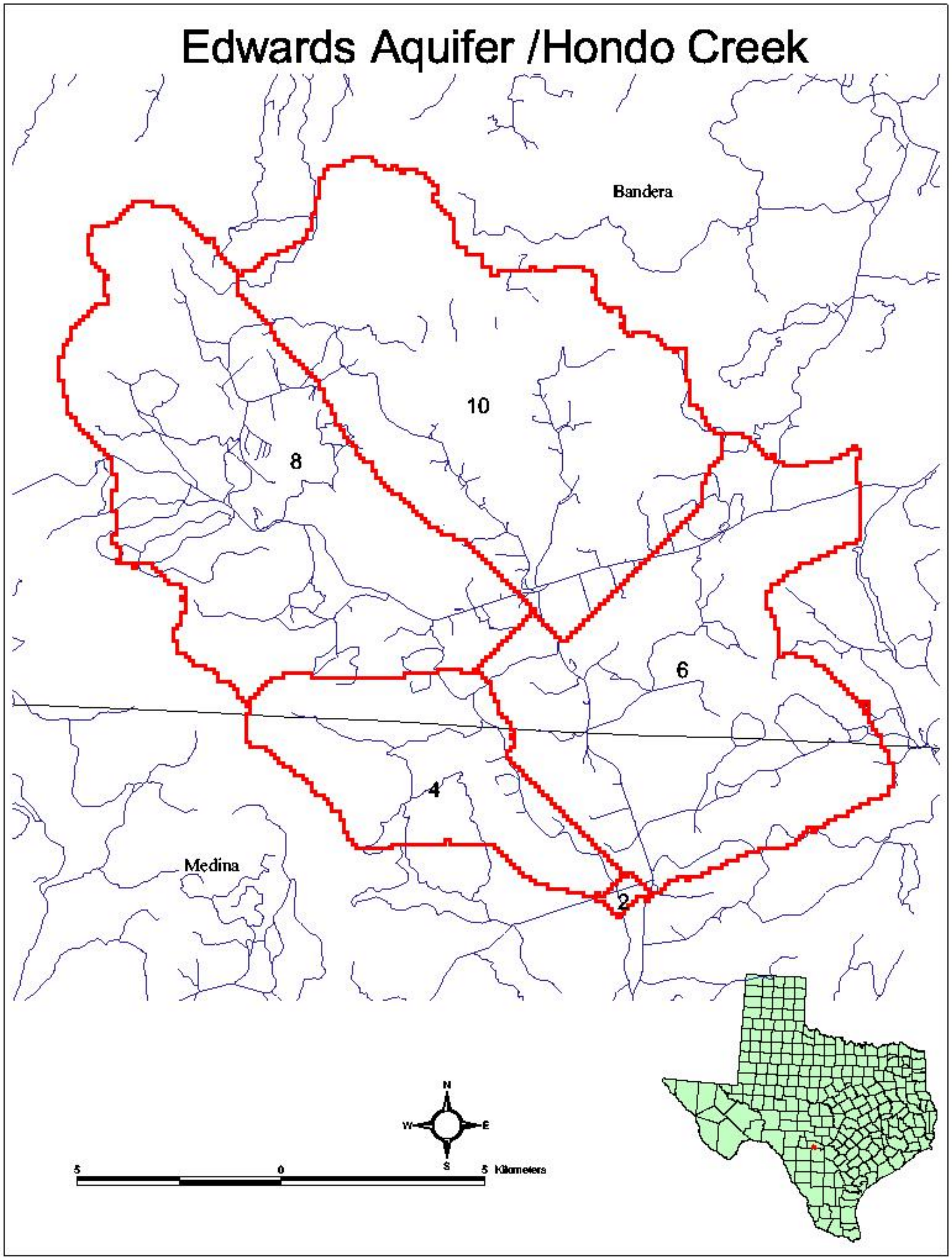

Figure E-5. Hondo river basin and associated sub-basin numbers.

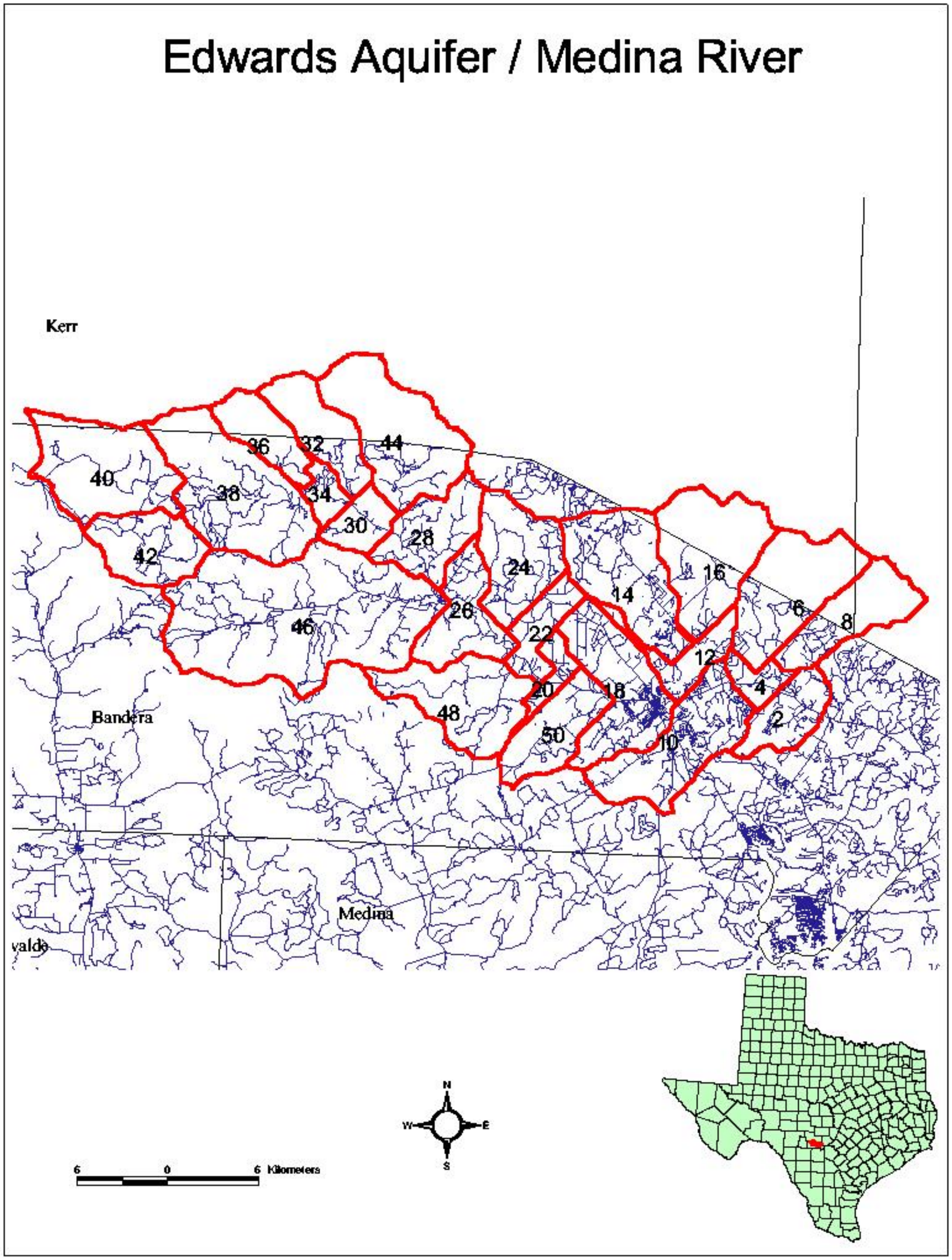

Figure E-6. Medina river basin and associated sub-basin numbers.

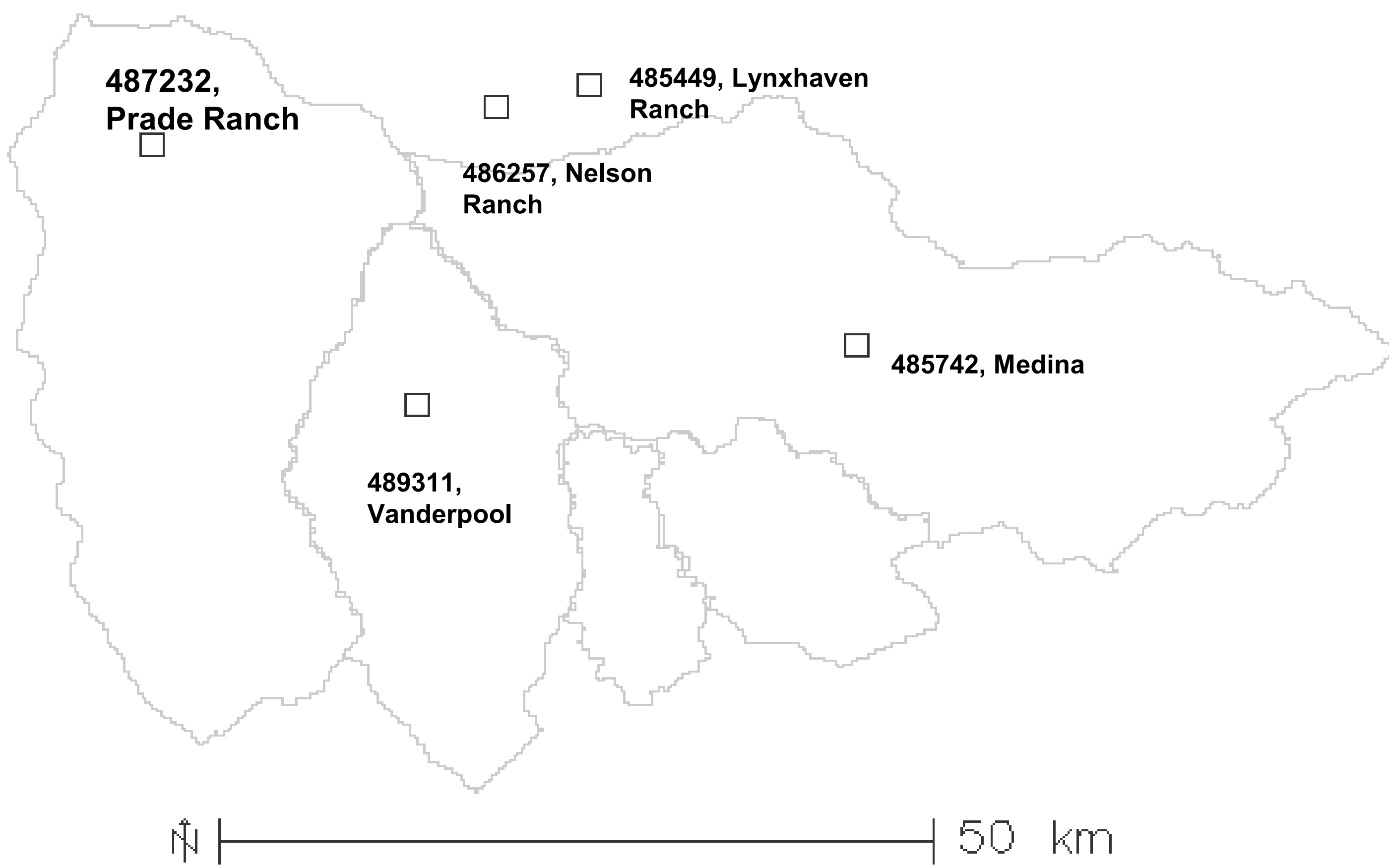

Figure E-7. Weather stations used for modeling hydrology of Edwards recharge watersheds.

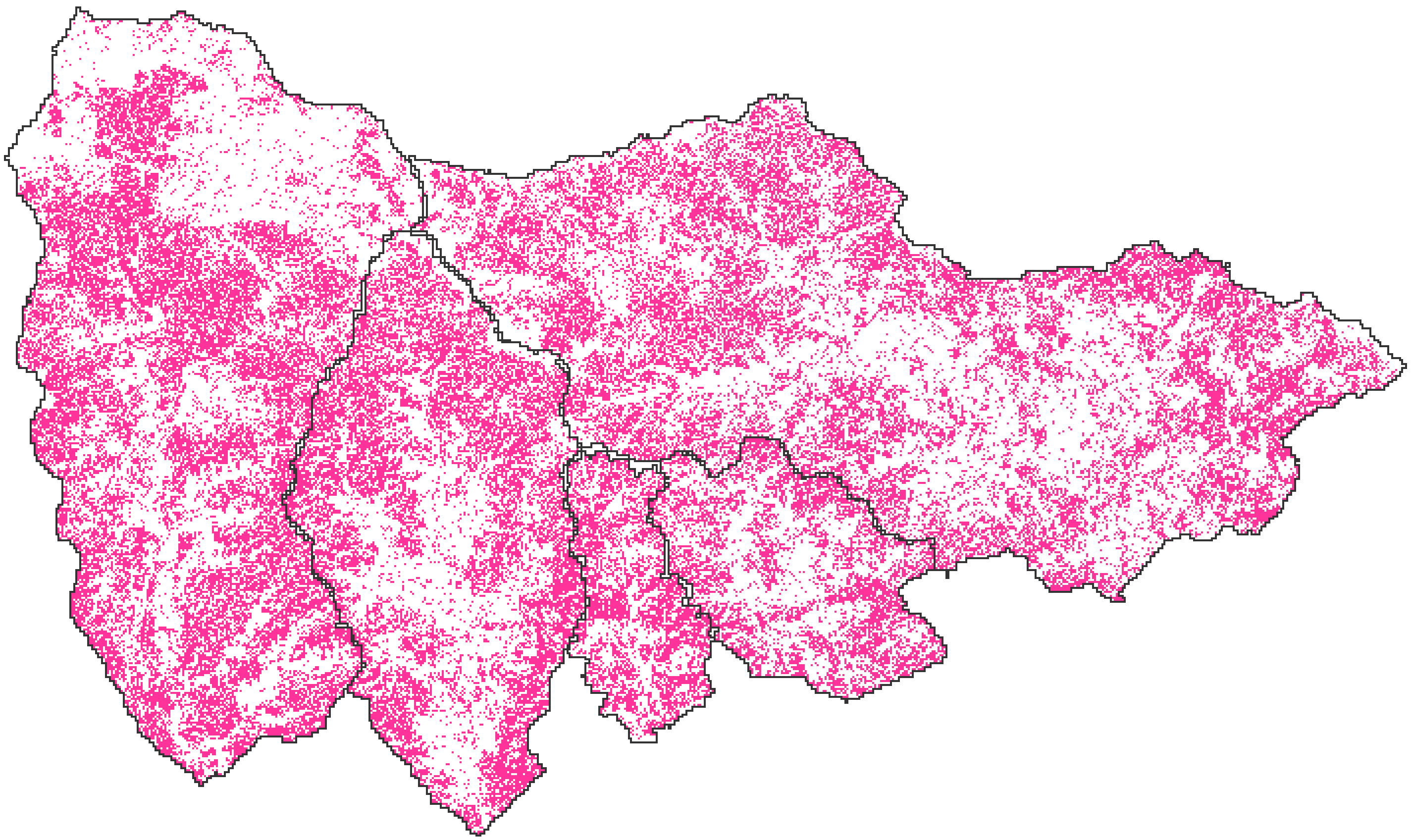

Figure E-8. Areas proposed controlled for brush on the Edwards Plateau.

Table E-1. The SWAT input variables for the Frio river basin.

Parameter	*Before Calibration*	*After Calibration*	*After Brush Control*
Curve number			
Heavy Cedar	77	87	90
Heavy Oak	77	87	87
Open range/grass	85	69	69
Soil evaporation Compensation	0.85	0.98	0.98
Shallow aquifer re-evaporation	0.40	0.30	0.10
Potential Heat Units			
Heavy Cedar	4300	4300	4300
Heavy Oak	3750	3750	3750
Open range/grass	2900	2900	2900
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range/grass	0.0	N/A	
Maximum Leaf Area Index (m^2 canopy/m^2 ground)			
Heavy Cedar	8.0		
Heavy Oak	8.0		
Open range	1.0		
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range	0.0	N/A	
Plant rooting depth (feet)			
Heavy Cedar	6.5	N/A	
Heavy Oak	6.5	N/A	
Open range	3.3	3.3	
Transmission Loss (in/hr)	0.04	0.04	
Sub-basin transmission (in/hr)	0.02	0.02	

Table E-2. The SWAT input variables for the Sabinal river basin.

Parameter	*Before Calibration*	*After Calibration*	*After Brush Control*
Curve number			
Heavy Cedar	77	69	72
Heavy Oak	77	69	69
Open range/grass	85	72	72
Soil evaporation Compensation	0.85	0.95	0.95
Shallow aquifer re-evaporation	0.40	0.15	0.10
Potential Heat Units			
Heavy Cedar	4300	4300	4300
Heavy Oak	3750	3750	3750
Open range/grass	2900	2900	2900
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range/grass	0.0	N/A	
Maximum Leaf Area Index (m^2 canopy/m^2 ground)			
Heavy Cedar	8.0		
Heavy Oak	8.0		
Open range	1.0		
Soil Evaporation Compensation Factor (esco)	0.98	0.98	0.98
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range	0.0	N/A	
Plant rooting depth (feet)			
Heavy Cedar	6.5	N/A	
Heavy Oak	6.5	N/A	
Open range	3.3	3.3	
Transmission Loss (in/hr)	0.04	0.04	
Sub-basin transmission (in/hr)	0.04	0.04	

Table E-3. The SWAT input variables for the Hondo river basin.

Parameter	*Before Calibration*	*After Calibration*	*After Brush Control*
Curve number			
Heavy Cedar	77	52	56
Heavy Oak	77	59	59
Open range/grass	72	61	61
Soil evaporation Compensation	0.85	0.95	0.95
Shallow aquifer re-evaporation	0.40	0.40	0.10
Potential Heat Units			
Heavy Cedar	4300	4300	4300
Heavy Oak	3750	3750	3750
Open range/grass	2900	2900	2900
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range/grass	0.0	N/A	
Maximum Leaf Area Index (m^2 canopy/m^2 ground)			
Heavy Cedar	8.0		
Heavy Oak	8.0		
Open range	1.0		
Soil Evaporation Compensation Factor (esco)	0.98	0.98	0.98
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range	0.0	N/A	
Plant rooting depth (feet)			
Heavy Cedar	6.5	N/A	
Heavy Oak	6.5	N/A	
Open range	3.3	3.3	
Transmission Loss (in/hr)	0.4	0.4	
Sub-basin transmission (in/hr)	0.7	0.7	

Table E-4. The SWAT input variables for the Seco river basin.

Parameter	*Before Calibration*	*After Calibration*	*After Brush Control*
Curve number			
Heavy Cedar	77	63	60
Heavy Oak	77	63	63
Open range/grass	72	65	65
Soil evaporation Compensation	0.85	0.95	0.95
Shallow aquifer re-evaporation	0.40	0.40	0.10
Potential Heat Units			
Heavy Cedar	4300	4300	4300
Heavy Oak	3750	3750	3750
Open range/grass	2900	2900	2900
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range/grass	0.0	N/A	
Maximum Leaf Area Index (m^2 canopy/m^2 ground)			
Heavy Cedar	8.0		
Heavy Oak	8.0		
Open range	1.0		
Soil Evaporation Compensation Factor (esco)	0.98	0.98	0.98
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range	0.0	N/A	
Plant rooting depth (feet)			
Heavy Cedar	6.5	N/A	
Heavy Oak	6.5	N/A	
Open range	3.3	3.3	
Transmission Loss (in/hr)	0.2	0.2	
Sub-basin transmission (in/hr)	0.2	0.2	

Table E-5. The SWAT input variables for the Medina river basin.

Parameter	*Before Calibration*	*After Calibration*	*After Brush Control*
Curve number			
Heavy Cedar	77	61	64
Heavy Oak	77	61	61
Open range/grass	72	58	58
Soil evaporation Compensation	0.85	0.95	0.95
Shallow aquifer re-evaporation	0.40	0.40	0.10
Potential Heat Units			
Heavy Cedar	4300	4300	4300
Heavy Oak	3750	3750	3750
Open range/grass	2900	2900	2900
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range/grass	0.0	N/A	
Maximum Leaf Area Index (m^2 canopy/m^2 ground)			
Heavy Cedar	8.0		
Heavy Oak	8.0		
Open range	1.0		
Soil Evaporation Compensation Factor (esco)	0.98	0.98	0.98
Canopy Interception (inches)			
Heavy Cedar	0.8	N/A	
Heavy Oak	0.8	N/A	
Open range	0.0	N/A	
Plant rooting depth (feet)			
Heavy Cedar	6.5	N/A	
Heavy Oak	6.5	N/A	
Open range	3.3	3.3	
Transmission Loss (in/hr)	0.78	0.78	
Sub-basin transmission (in/hr)	0.98	0.98	

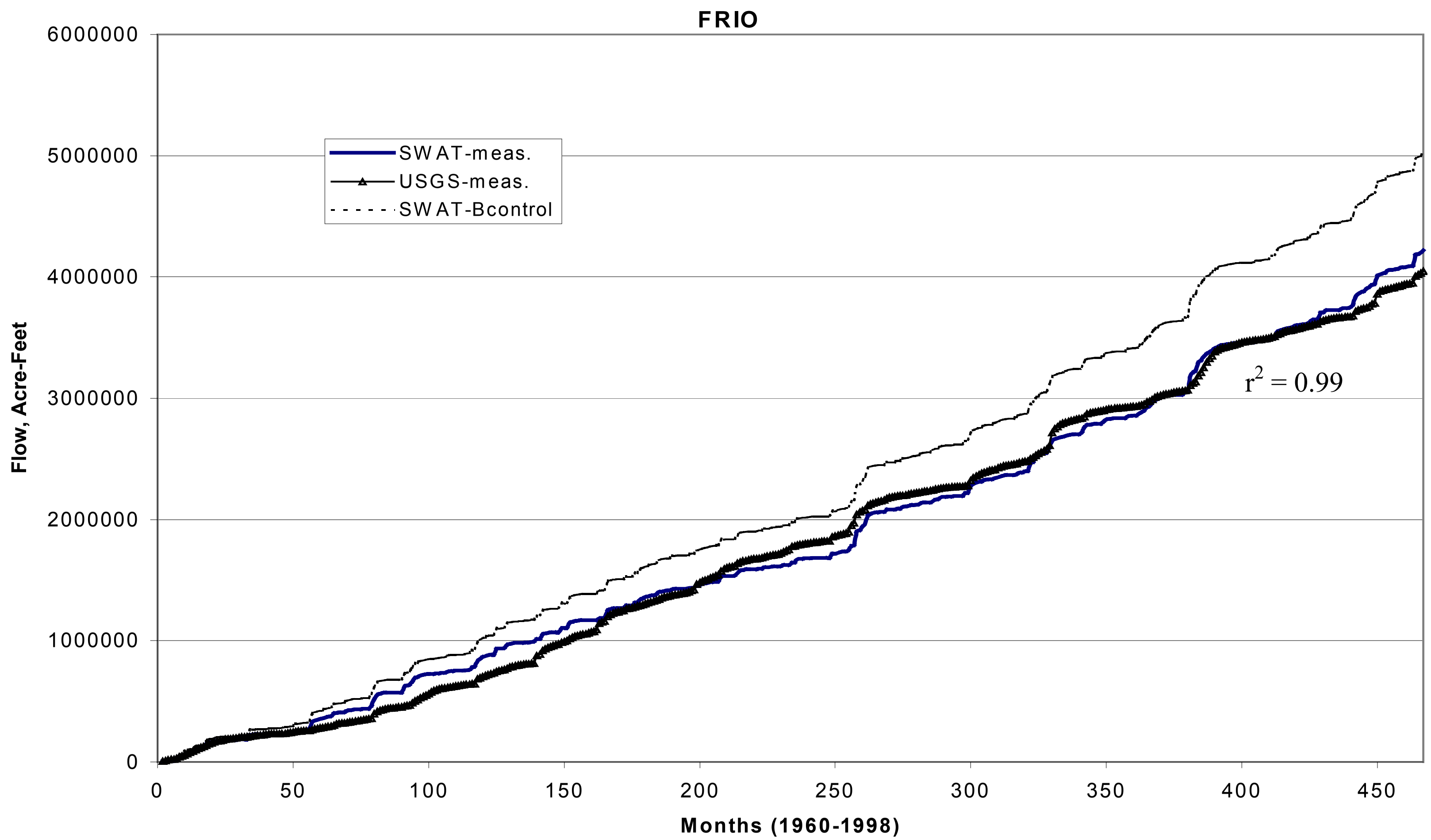

Figure E-9. Comparison of SWAT predicted and USGS measured flows, 1960-1998. The dotted line above the comparisons is stream flows after brush removal. The USGS estimated drainage area above stream gage was 389 mi^2. The SWAT modeled drainage area was 383 mi^2 (gage 08195000 at Concan, Texas).

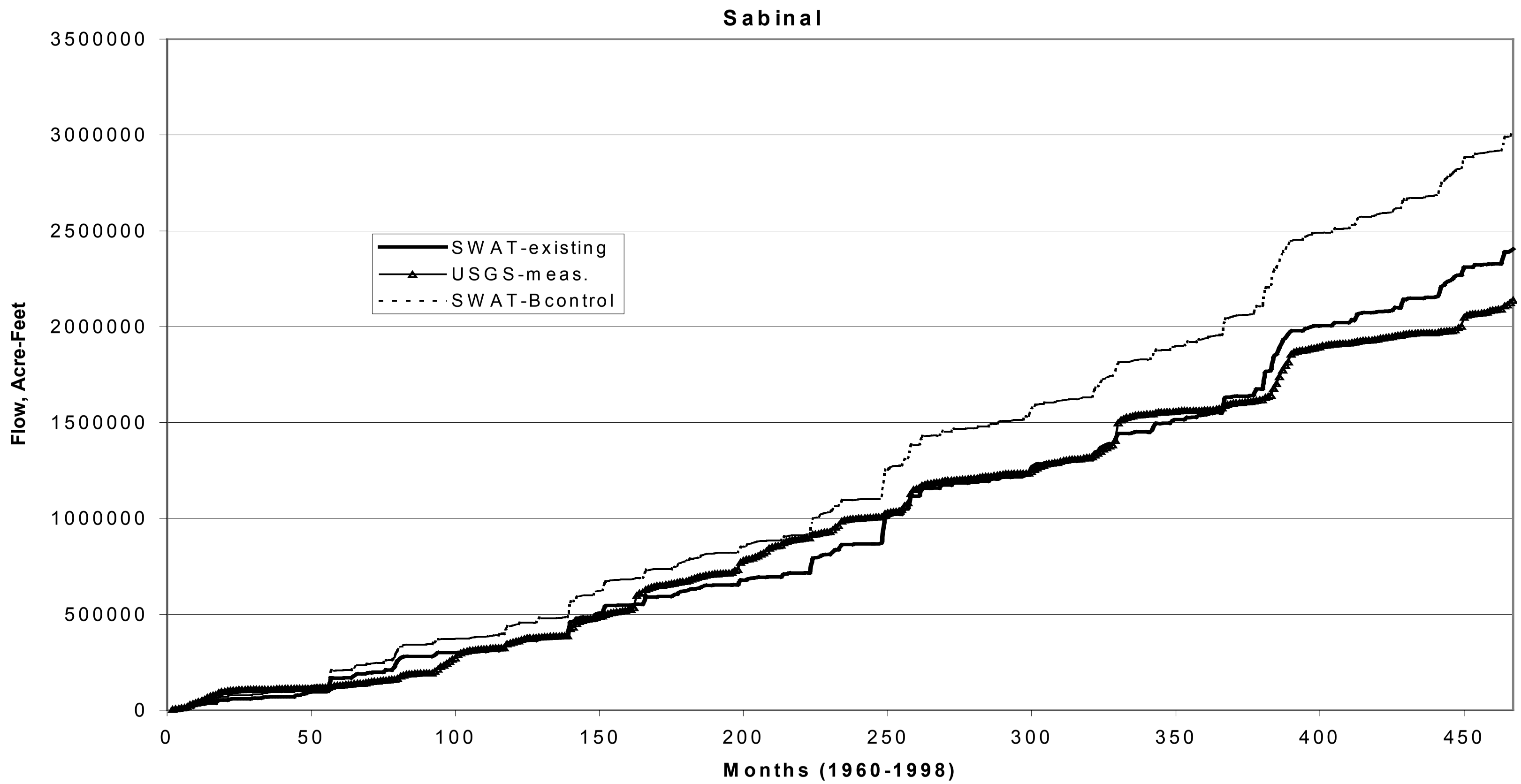

Figure E-10. The SWAT modeled and USGS measured flows for Sabinal river basin. The drainage area above the USGS gage was estimated by USGS to be 206 mi^2. The SWAT modeled drainage area was 212 mi^2 (gage 08198000 near Sabinal, Texas).

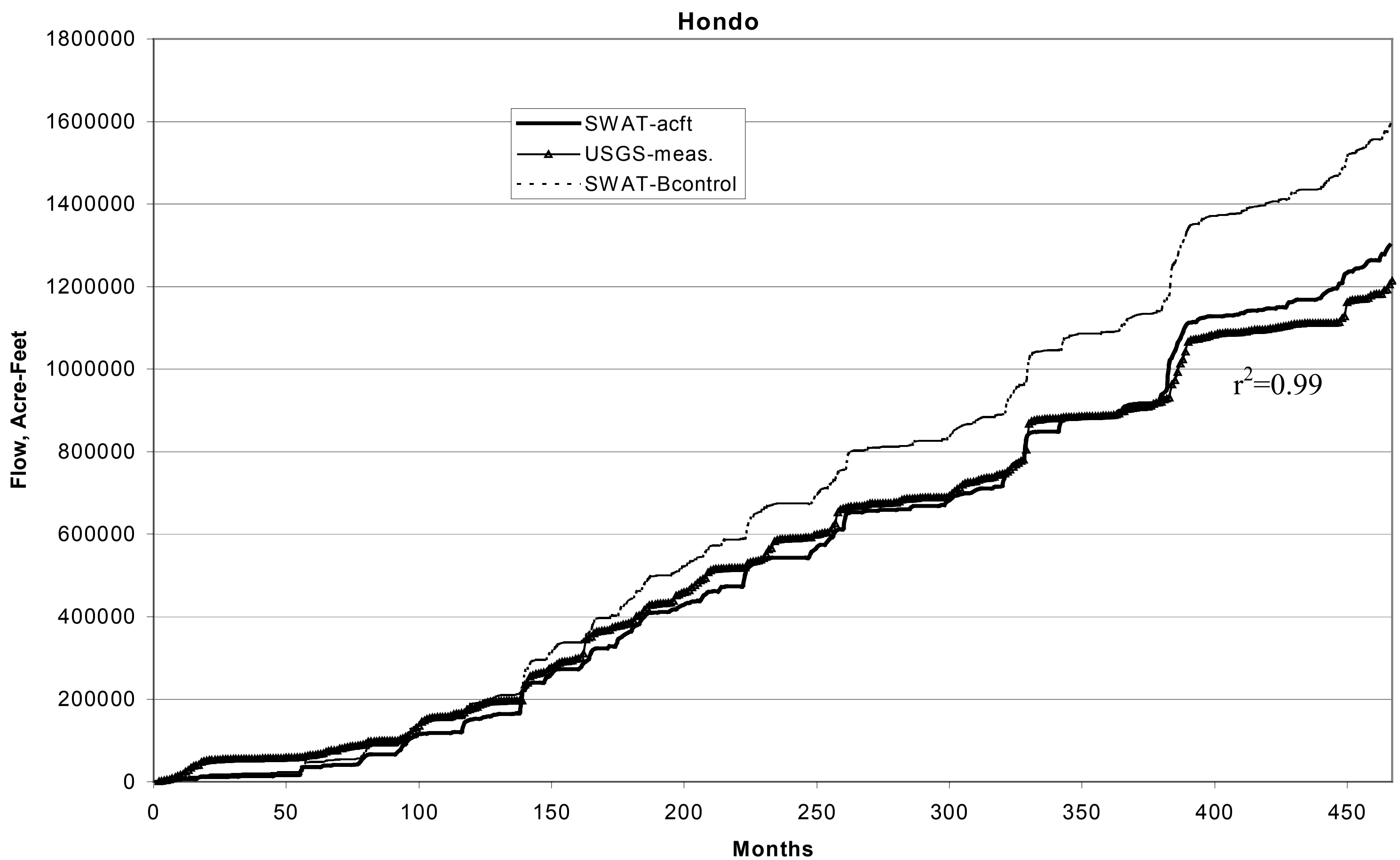

Figure E-11. The SWAT modeled and USGS measured stream flows in Hondo river basin. The upper line is for SWAT modeled flows after brush removal and conversion of brush land to open range conditions. The USGS drainage area above the gage was 95.6 mi^2. The SWAT modeled drainage area was 90 mi^2 (gage 08200000 near Tarpley, Texas).

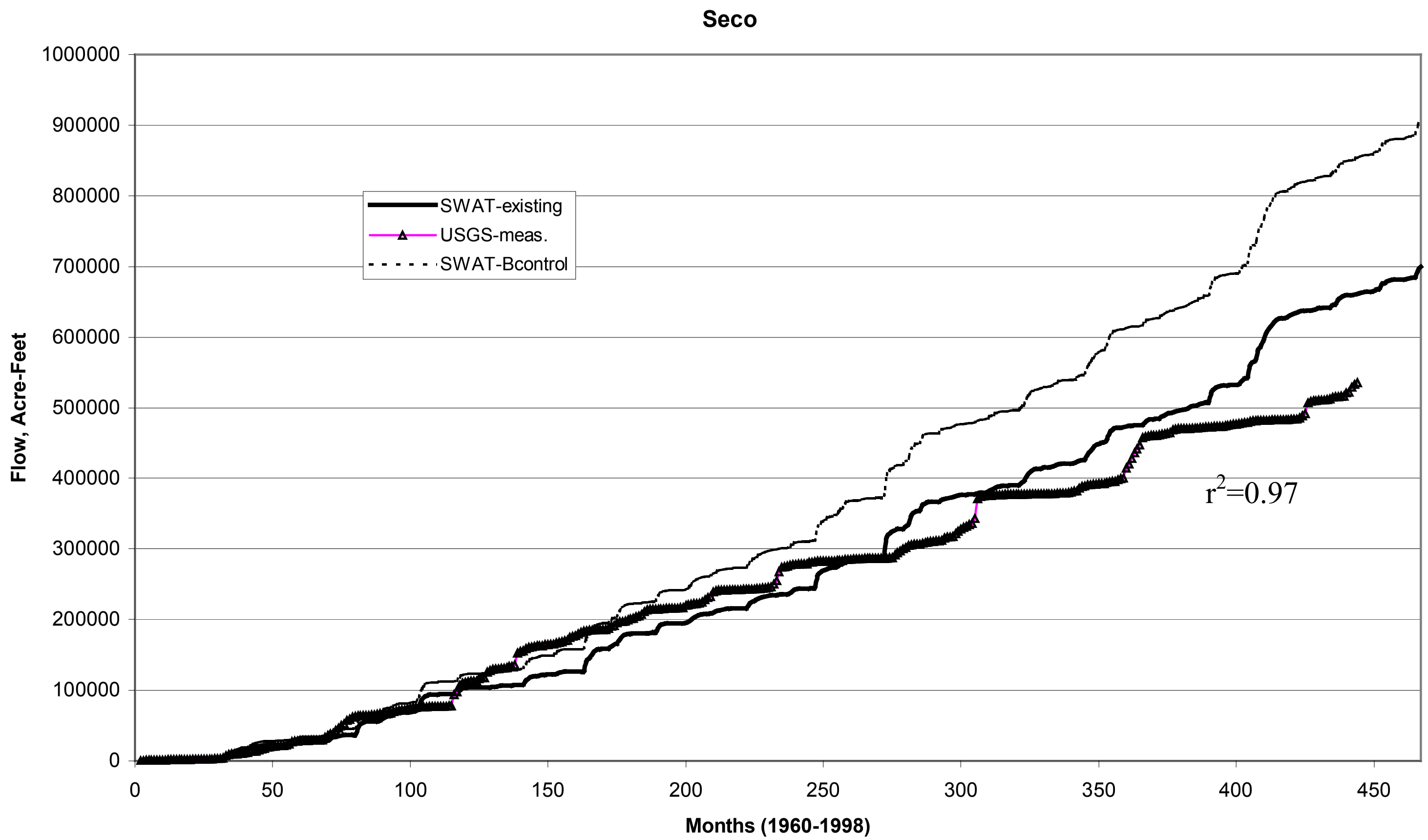

Figure E-12. The SWAT predicted and USGS measured flows at gage 08201500 near Utopia, Texas. The Upper dotted line is stream flows after brush removal. The USGS estimated drainage area above the gage was 45 mi^2, and the SWAT modeled drainage area was 51 mi^2.

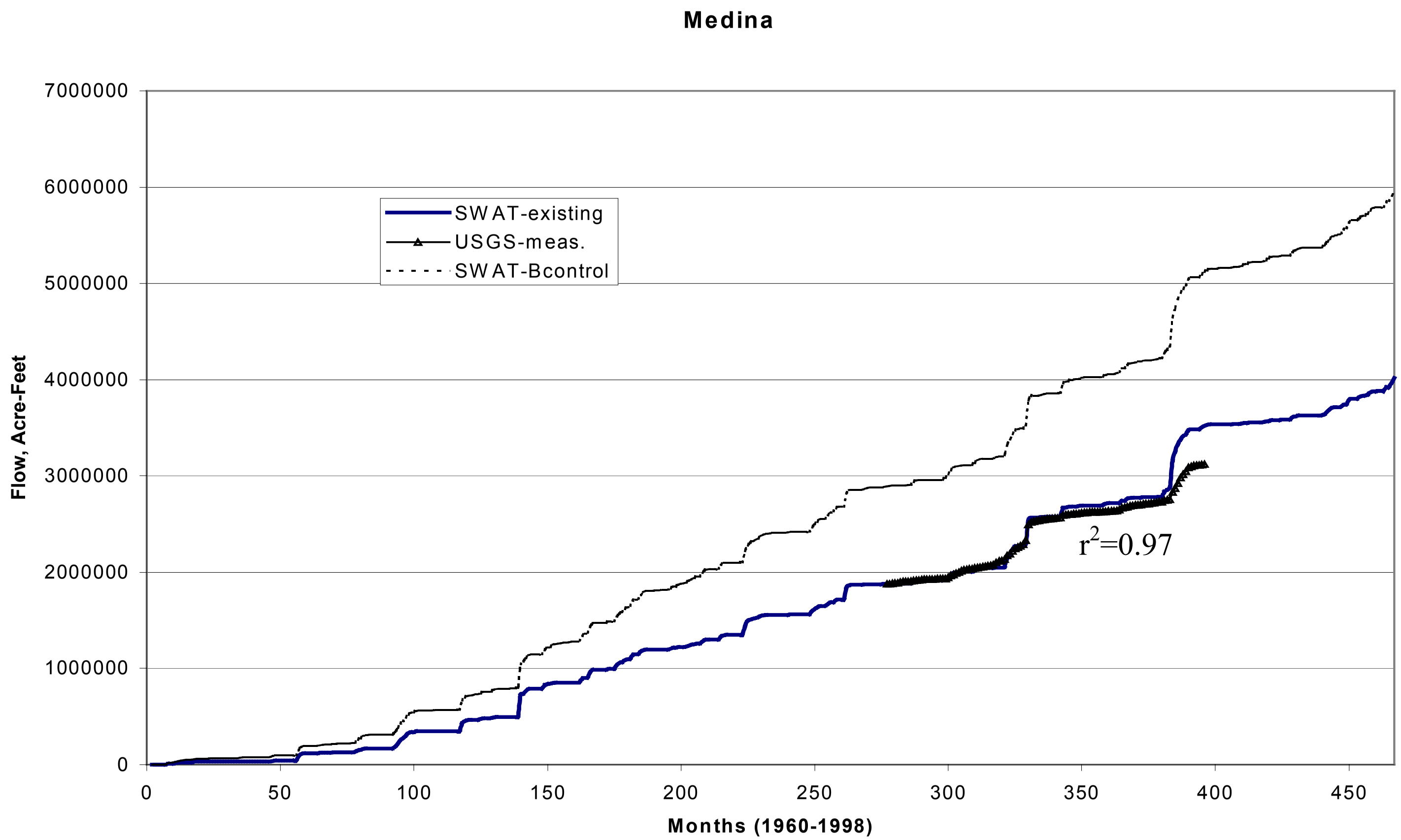

Figure E-13. The SWAT model predicted and USGS measured flows. Measurements by USGS were available for a limited time period post-1982. USGS estimated drainage area was 427 mi^2, and the SWAT modeled area was 472 mi^2.

Table E-6. Water yield savings Gallons/treated acre/year for Edwards recharge sub-basins.

FRIO				Savings	Savings
Sub-basin	Acres	Trt. Acres	%treated	Gal/tr.ac/yr	Gal/yr
2	1,678	753	44.9	109,324	82,366,931
4	8,183	4,108	50.2	52,967	217,585,026
6	6,786	2,572	37.9	112,867	290,298,360
8	6,357	3,153	49.6	64,010	201,826,587
10	9,903	3,704	37.4	43,320	160,450,000
12	12,524	4,221	33.7	54,697	230,854,683
14	7,245	3,565	49.2	84,185	300,097,619
16	4,565	1,055	23.1	303,675	320,257,540
18	8,225	3,043	37	123,274	375,157,672
20	11,194	6,325	56.5	65,512	414,334,709
22	10,765	2,928	27.2	177,901	520,884,259
24	12,833	3,439	26.8	22,722	78,143,571
26	15,147	1,999	13.2	32,156	64,294,788
28	21,536	2,843	13.2	104,121	295,995,503
30	8,368	3,188	38.1	124,316	396,360,132
32	17,827	7,077	39.7	65,136	460,996,825
34	20,675	4,590	22.2	45,335	208,081,217
36	8,734	594	6.8	712,718	423,272,487
38	6,737	916	13.6	642,870	589,018,519
40	7,312	3,071	42	63,408	194,730,556
42	12,889	4,937	38.3	32,543	160,651,323
44	9,146	4,820	52.7	116,848	563,170,899
46	16,221	8,240	50.8	28,174	232,153,439
Totals	244,851	81,141			6,780,982,646
Weighted Avg.			33.13874	83,571	
SABINAL				Savings	Savings
Sub-basin	Acres	Trt. Acres	% treated	Gal/tr.ac/yr	Gal/yr
2	14,805	7,017	47.4	94,627	664,043,519
4	7,198	1,807	25.1	90,893	164,204,153
6	13,603	6,026	44.3	96,152	579,418,386
8	3,572	786	22	112,311	88,248,889
10	7,731	2,049	26.5	107,447	220,118,783
12	1,153	106	9.2	115,281	12,225,397
14	19,055	9,852	51.7	102,805	1,012,788,889
16	24,550	6,088	24.8	118,045	718,692,857
18	19,697	8,194	41.6	115,198	943,926,720
20	11,169	4,680	41.9	154,459	722,837,831
22	13,072	4,719	36.1	116,691	550,669,577
Totals	135,603	51,323			5,677,175,000
Weighted Avg.			37.8481	110,616	

Figure E-6 (continued). Water yield savings for Edwards recharge watersheds.

SECO				Savings	Savings
Sub-basin	Acres	Trt. Acres	% treated	gal/tr.ac/yr	gal/yr
2	1,514	448	29.6	95,963	43,005,185
4	937	469	50	98,793	46,289,497
6	1,442	721	50	106,308	76,626,772
8	504	252	50	107,113	26,992,460
10	2,064	586	28.4	133,991	78,534,709
12	2,645	1,013	38.3	198,902	201,456,190
14	7,680	3,840	50	127,986	491,484,656
16	1,968	667	33.9	134,660	89,857,011
18	3,477	1,739	50	138,385	240,610,450
20	3,847	1,923	50	137,554	264,563,836
22	1,577	593	37.6	138,495	82,141,429
24	2,657	1,329	50	138,894	184,541,984
26	2,094	1,047	50	135,662	142,024,815
Totals	32,406	14,627			1,968,128,995
Weighted Avg.			45.13504	134,558	
HONDO					
				Savings	Savings
Sub	Acres	Trt. Acres	% treated	Gal/tr.ac/yr	Gal/yr
2	170	51	30	185,882	9,496,720
4	6,691	2,369	35.4	134,414	318,375,132
6	15,554	5,693	36.6	171,199	974,591,534
8	17,459	5,901	33.8	142,441	840,581,481
10	17,677	5,992	33.9	149,264	894,437,566
Totals	57,551	20,006			3,037,482,434
Weighted Avg.			34.76223	151,829	
MEDINA					
				Savings	Savings
Sub-basin	Acres	Trt. Acres	% treated	Gal/tr.ac/yr	Gal/yr
2	6,901	2,084	30.2	168,571	351,298,942
4	2,969	888	29.9	159,803	141,862,328
6	15,388	4,832	31.4	143,876	695,193,651
8	10,161	5,080	50	147,483	749,280,688
10	15,452	3,554	23	169,544	602,563,624
12	5,449	1,319	24.2	136,799	180,404,153
14	16,314	3,540	21.7	166,424	589,154,101
16	16,691	5,007	30	138,847	695,266,138
18	14,922	3,059	20.5	146,493	448,114,550
20	2,981	0	0	0	0
22	5,501	1,188	21.6	148,963	177,013,254
24	12,029	3,152	26.2	173,678	547,375,926

Figure E-6 (continued). Water yield savings for Medina watershed.

				Savings	Savings
Sub-basin	Acres	Trt. Acres	% treated	Gal/tr.ac/yr	Gal/yr
26	9,660	2,212	22.9	172,397	381,366,402
28	9,852	2,246	22.8	170,566	383,149,339
30	4,519	1,487	32.9	174,737	259,784,444
32	8,818	4,409	50	170,107	750,028,439
34	2,902	1,451	50	181,845	263,893,201
36	6,681	3,341	50	170,802	570,563,280
38	21,963	8,192	37.3	183,071	1,499,760,317
40	17,076	4,867	28.5	162,825	792,434,788
42	9,813	4,906	50	183,540	900,527,910
44	18,681	9,340	50	170,016	1,588,003,968
46	43,702	16,301	37.3	183,492	2,991,050,265
48	14,157	4,162	29.4	174,478	726,184,392
50	9,250	2,488	26.9	160,288	398,840,344
Totals	301,834	99,106			16,683,114,444
Weighted Avg.			32.83468	168,336	

SECTION 2-UPPER NUECES RIVER WATERSHED-EDWARDS AQUIFER

METHODS

Watershed Characteristics

The Upper Nueces watershed covers a large area of South Texas north and east of the Rio Grande River basin. It is within a semiarid climatic region with soils that are primarily Usterts and Ustalfs that generally have large cracks that persist for more than 3 months during the summer. This allows for deep infiltration of any significant rainfall during the summer months. The watershed generally runs northwest to southeast and is above the gauging station at Uvalde. Based on the digital elevation map (DEM), the derived subbasins are shown in Figure UN-1. Due to the fact that part of the watershed lies over the western part of the Edwards Aquifer recharge zone, the entire Nueces watershed was divided into the upper (Edwards) and lower Nueces. The upper Nueces corresponds to the 8-digit hydrologic response units (HRU) 12110101 and 121102. The stream flow gauge near Uvalde was used to calibrate the flows for the Upper Nueces.

Climate

For the simulations actual weather data from 1960-1998 were used. The model used daily maximum and minimum air temperatures, precipitation and solar radiation. Solar radiation was generated using the WGEN model based on parameters for the specific climate station. Climate stations are shown in Figure UN-2. For each subbasin, precipitation and temperature data are retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin.

Topography

The outlet or "catchment" for the portion of the upper Nueces River simulated in this study is at Uvalde of subbasin number 102_1. The subbasin delineation and numbers are shown in Figure UN-1. Roads (obtained from the Census Bureau) are overlaid in Figure UN-3.

Soils

The dominant soil series in the Nueces River watershed are Uvalde, Aguilares, Duval, Maverick, and Montell. These six soil series represent over 50 percent of the watershed area. A short description of each follows:

Uvalde. The Uvalde series consists of a deep, well-drained, moderately permeable soils formed in alluvium from limestone. These level to gently sloping or gently undulating soils are on alluvial fans or stream terraces. Slopes range from 0 to 3 percent.

Aguilares. The Aguilares series consists of deep, well drained moderately permeable soils that formed in calcareous, loamy sediments. These soils are on uplands with slopes ranging from 1 to 3 percent.

Duval. The Duval series consists of deep, well drained, moderately permeable soils that formed in sandy clay loams with interbedded sandstone on uplands. Slopes range from 1 to 5 percent.
Maverick. The Maverick series consists of moderately deep, well drained soils formed in ancient clayey marine sediments. These soils are gently rolling. Slopes range from 0 to 10 percent.
Montell. The Montell series consists of deep, moderately well drained,very slowly permeable soils that formed in ancient clayey alluvium. These soils are on nearly level to gently sloping uplands. Slopes range from 0 to about 3 percent.

Land Use/Land Cover

Figure UN-4 show the areas of heavy and moderate brush in the Nueces River Watershed that represent the area of brush removed or treated in the no-brush simulation.. This corresponds to 72% of the total watershed area.

Model Input Variables

Significant input variables for the SWAT model for the upper Nueces River Watershed are shown in Table UN-1. Input variables for the no brush condition were the same as the calibrated condition with one exception:

1. We assumed the re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units is 0.4, and for non-brush units is 0.1..

UPPER NUECES RIVER WATERSHED RESULTS

Calibration

SWAT was calibrated for the flow at stream gauges near Uvalde. The results of calibration are shown on Figures UN-6. Measured and predicted average monthly flows compare reasonably well with a 4% difference between measured and simulated cumulative flow. At Uvalde, the measured monthly mean is 12,830 acre-feet, and predicted monthly mean is 12,284 acre-feet. The coefficient of determination (r^2) was 0.99 between measured and simulated. Average base flow for the entire watershed is 7% of total flow.

Brush Removal Simulation

The average annual rainfall for the Upper Nueces River Watershed is 27.09 inches. Average annual evapotranspiration (ET) in the Upper Nueces is 22.31 inches for the brush condition (calibration) and 19.81 inches for the no-brush condition. This represents 82% and 73% of precipitation for the brush and no-brush conditions, respectively, in the Upper Nueces.

The increases in water yield by subbasin for the Upper Nueces River Watersheds are shown in Figures UN-7 and Table UN-2. The amount of annual increase varies among the subbasins and ranges from 20,130 gallons per acre of brush removed per year in subbasin number 102-1, to 64,123 gallons per acre in subbasin number 101-4. Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. In addition, Table UN-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the Upper Nueces, the average annual water yield increases by 57 % or approximately 112,875acre-feet. The average annual flow at Uvalde could increase by 71,344 acre-feet. The increase in volume of flow is slightly less than the water yield because of stream channel transmission losses that occur after water leaves each subbasin and the shallow soils that allow for percolation.

TABLE UN-1

SWAT INPUT VARIABLES FOR NUECES RIVER WATERSHED		
VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	-15	-15
Soil Available Water Capacity Adjustment (%)	0	0
Soil Evaporation Compensation Factor ($in^3 in^{-3}$)	0.85	0.85
Min. Shallow Aqu. Storage for GW flow (inches)	0	0
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0.3	0.3
Potential Heat Units (degree-days)		
Heavy Cedar	5399	5399
Heavy Mesquite	4697	4697
Heavy Mixed Brush	5021	5021
Moderate Cedar	4697	4697
Moderate Mesquite	4157	4157
Moderate Mixed Brush	4427	4427
Heavy Oak	4697	4697
Moderate Oak	4157	4157
Light Brush & Open Range/Pasture	3617	3617
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.02	0.02
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.07	0.07

Table N-2. Upper Nueces areas and water yield

Subbasin	Subbasin Total Area (acres)	Brush Removal Area (acres)	Fraction of Subbasin Containing Brush	Increase (gal/ac) Water Yield	Ave Ann. Gal. Incr.
101-1	185288	139448	0.75	43964	6130727916
101-2	26787	20104	0.75	47477	954472646
101-3	30591	25268	0.83	48458	1224429007
101-4	55555	33594	0.60	64123	2154144354
101-5	59790	45607	0.76	60097	2740863615
101-6	42803	31357	0.73	49777	1560845886
101-7	28521	22329	0.78	46209	1031808731
101-8	34786	28834	0.83	55885	1611377433
101-9	48332	33384	0.69	61662	2058534699
102-1	62270	46827	0.75	20130	942640759
102-2	33037	33037	1.00	45628	1507402078
102-3	3839	2879	0.75	27299	78594288
102-4	52055	52055	1.00	30671	1596603565
102-5	101325	80961	0.80	41959	3397009504
102-6	142026	70686	0.50	62142	4392587131
102-7	74993	40773	0.54	62942	2566318159
102-8	68093	49898	0.73	47035	2346937893
102-9	24961	19689	0.79	24924	490735872

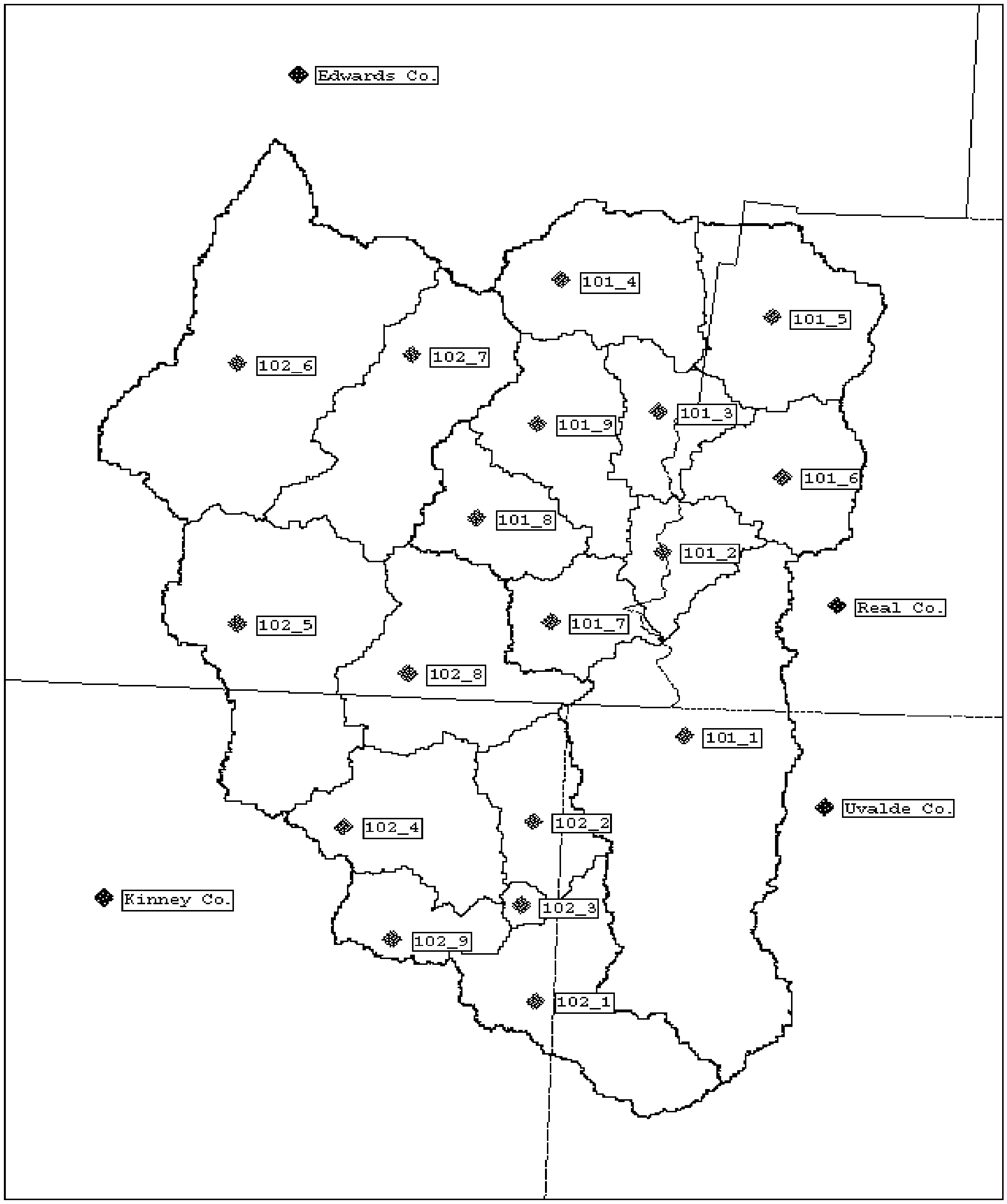

Figure UN-1 Upper Nueces River Watershed subbasin map.

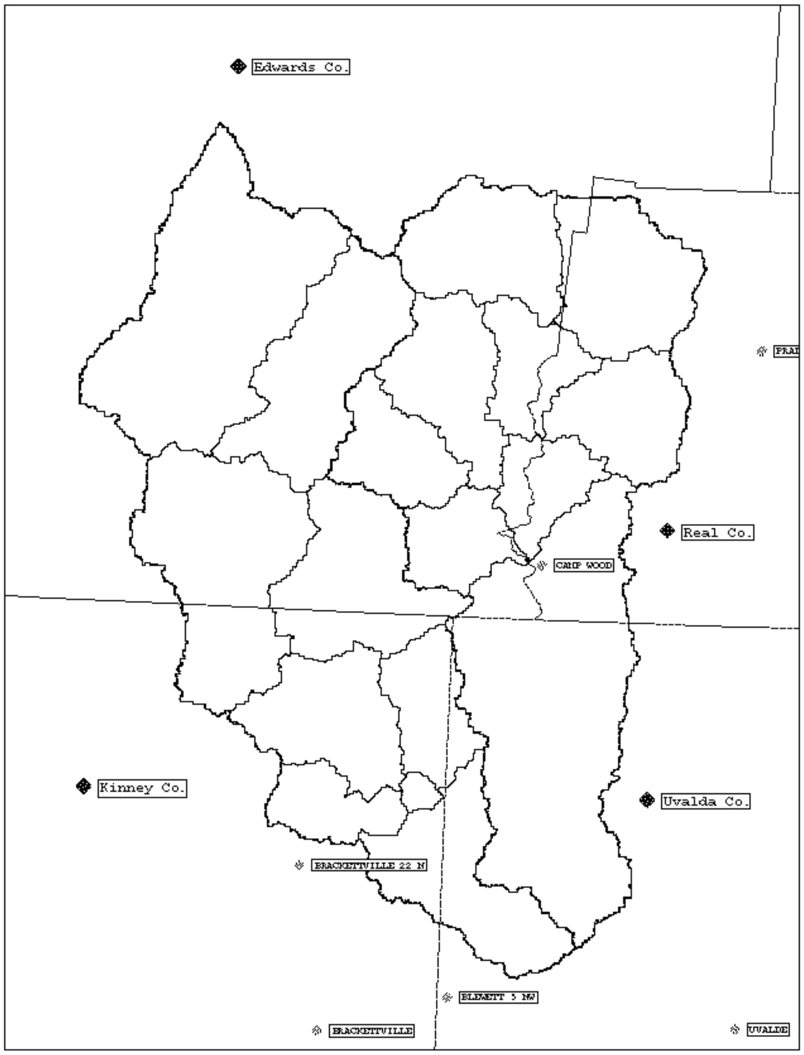

Figure UN-2. Climate Stations in the Upper Nueces Watershed.

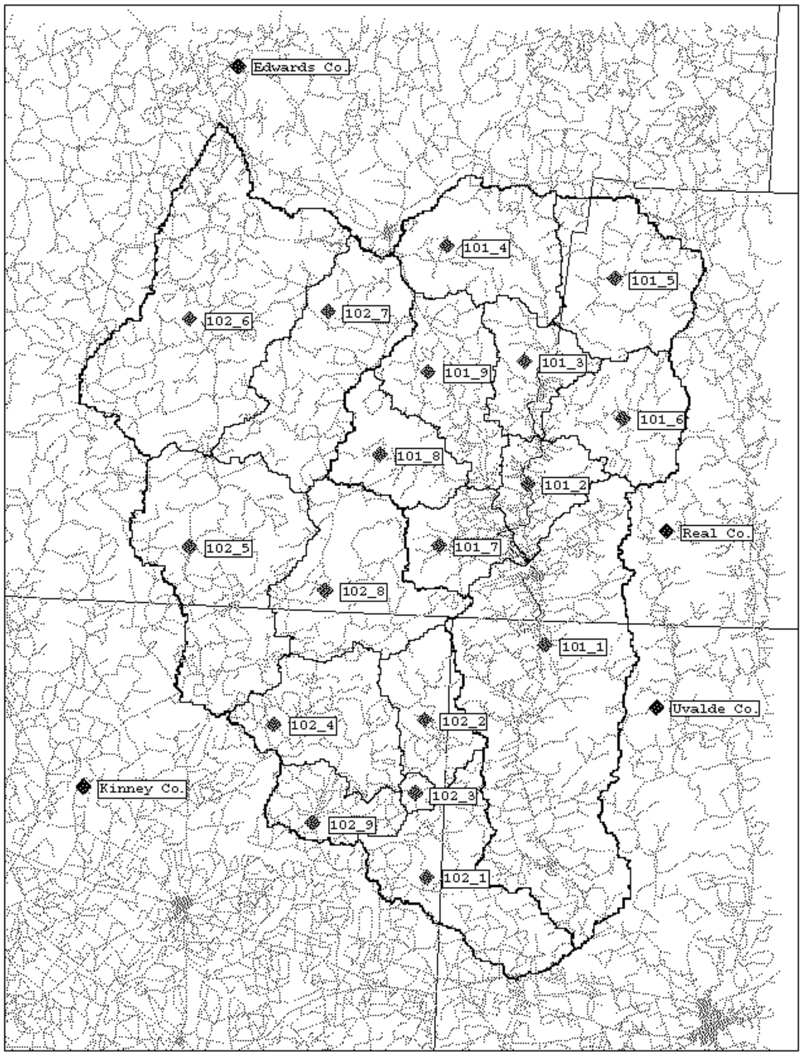

Figure UN-3. Upper Nueces River Watershed roads map.

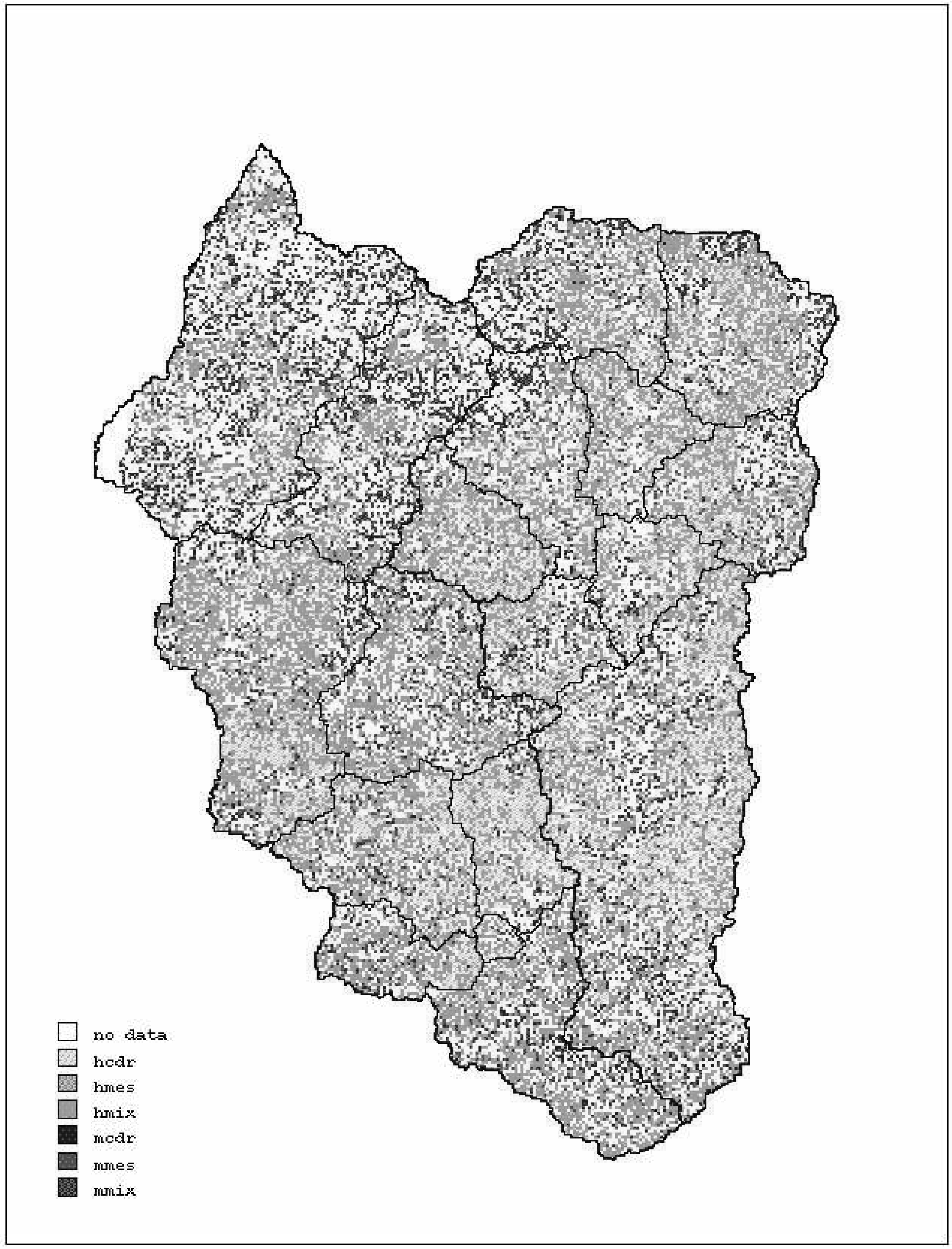

Figure UN-4. Areas of heavy and moderate brush in the Upper Nueces River Watershed.

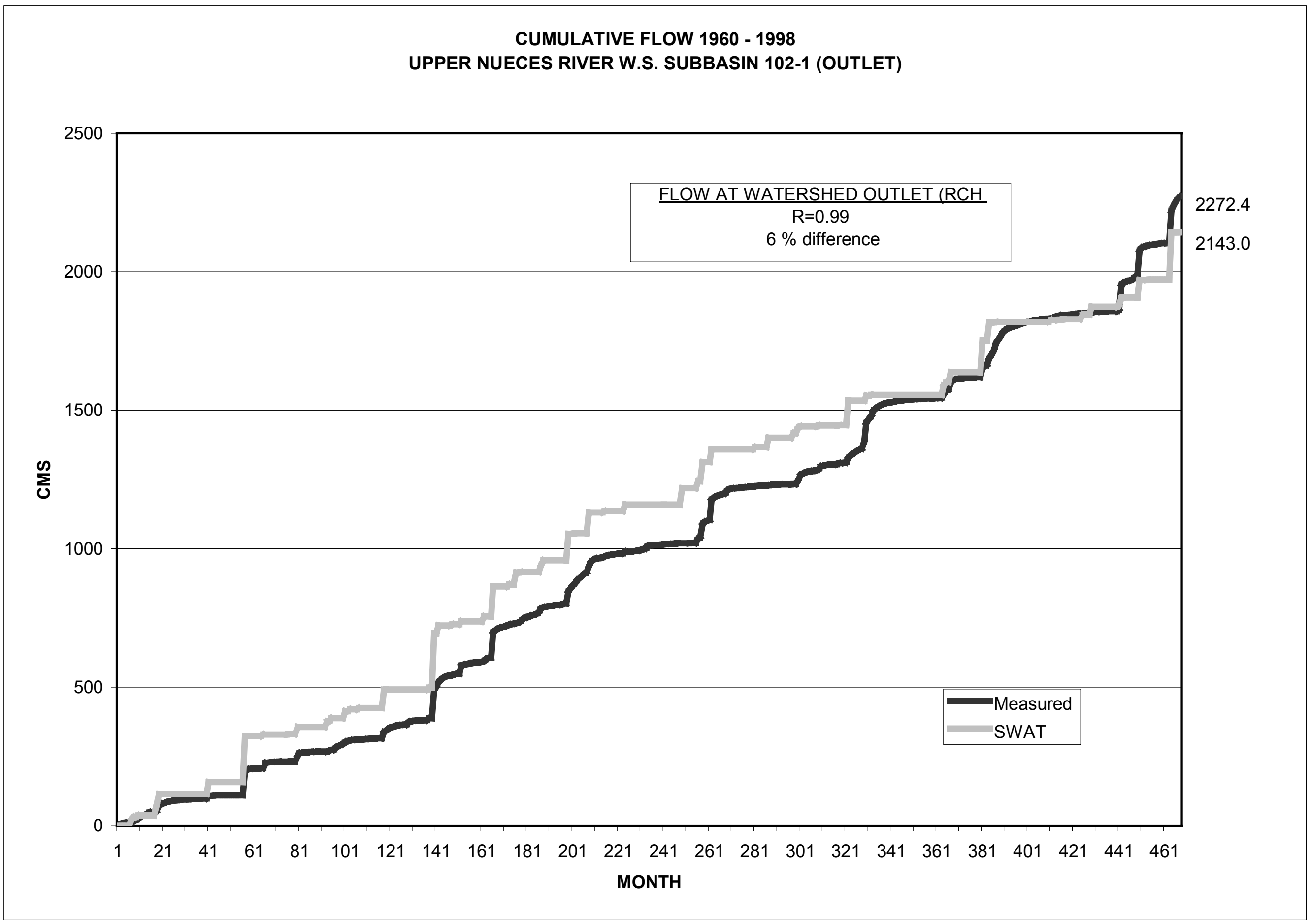

Figure UN-5. Simulated and measured cumulative flow at the outlet of the Upper Nueces (Uvalde).

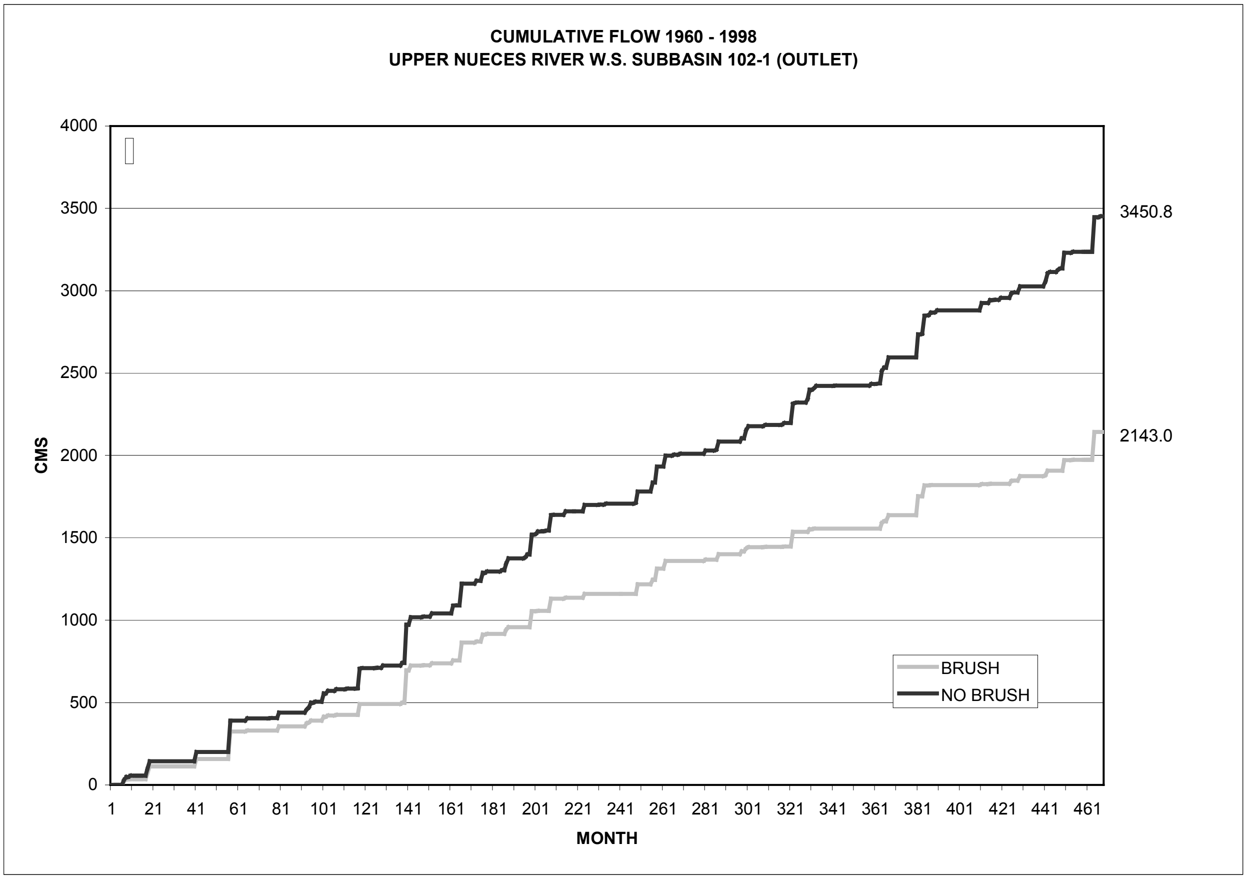

Figure UN-6. Simulated cumulative flow at the outlet for brush and no brush conditions in the Upper Nueces

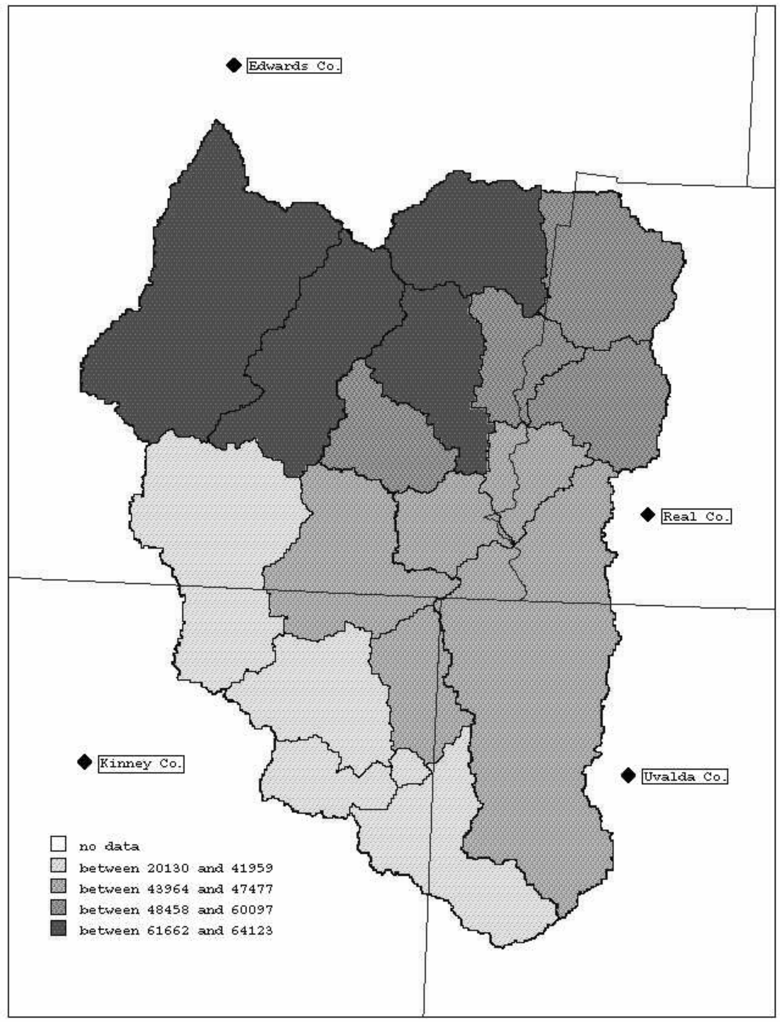

Figure UN-7. Increase in water yield per treated acre (gallons/acre) due to brush removal from 1960 through 1998.

CHAPTER 6

EDWARDS AQUIFER RECHARGE ZONE WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Edwards Aquifer Recharge Zone watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. The Recharge Zone is broken into an eastern and western portion. The eastern portion is comprised of the Hondo, Medina, Sabinal and Seco watersheds. Present values of total costs for that region range from $52.02 per acre for moderate mesquite or mixed brush that can be initially controlled with herbicide treatments to $200.76 per acre for root-plowing with pre-dozing for control of heavy mesquite. Costs of treatments, year those treatments are needed and treatment life for each brush type density category in the eastern portion are detailed in Table 1a.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar - Mechanical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Doze	165.00	165.00
5	IPT or Burn	25.00	17.02
		Total	182.02

[1] Doze or tree shear, stack, and burn.

Heavy Mesquite - Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	35.00	35.00
4	Aerial Herbicide	35.00	25.73
7	Choice IPT or Burn	20.00	14.59
		Total	75.32

[1] Individual chemical application may also be used.

Heavy Mesquite – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	160.00	160.00
6	IPT or Burn	25.00	15.76
		Total	175.76

[1] Rootplow, rake, stack, and burn.

Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	185.00	185.00
6	IPT or Burn	25.00	15.76
		Total	200.76

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	35.00	35.00
4	Aerial Herbicide	35.00	25.73
7	Choice IPT or Burn	20.00	14.59
		Total	75.32

[1] Individual chemical application may also be used.

Heavy Mixed Brush – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	160.00	160.00
6	IPT or Burn	25.00	15.76
		Total	175.76

[1] Rootplow, rake, stack, and burn.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category* (Continued)

Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	185.00	185.00
6	IPT or Burn	25.00	15.76
		Total	200.76

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Moderate Cedar – Mechanical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Doze	100.00	100.00
5	IPT or Burn	25.00	17.02
		Total	117.02

[1] Doze or shear, stack, and burn.

Moderate Mesquite – Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
5	IPT or Burn	25.00	17.02
		Total	52.02

[1] Either aerial or individual chemical application may be used.

Moderate Mesquite – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Mechanical Method	60.00	60.00
5	IPT or Burn	25.00	17.02
		Total	77.02

[1] Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning.

Moderate Mixed Brush – Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
5	IPT or Burn	25.00	17.02
		Total	52.02

[1] Either aerial or individual chemical application may be used.

Moderate Mixed – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Mechanical Method	60.00	60.00
5	IPT or Burn	25.00	17.02
		Total	77.02

[1] Choice of tree dozing, stack, & burn, tree shearing, stump spray and later burn, or low power grubbing and burning

* Eastern portion of Edwards Recharge Zone watershed.

Similar information is presented in Table 1b for the western portions of the region, which consists of the upper portions of the Frio and Nueces watersheds. For this portion of the region, present values of total costs range from $52.02 per acre for moderate mesquite or mixed brush that can be initially controlled with herbicide treatments to $195.76 per acre for root-plowing with pre-dozing for control of heavy mesquite. As in Table 1a, costs of treatments, year those treatments are needed and treatment life for each brush type density category for the western region are detailed in Table 1b.

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar - Two Way Chain[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Two Way Chain	90.00	90.00
5	IPT or Burn	25.00	17.02
		Total	107.02

[1] Two way chain, stack, and burn.

Heavy Cedar - Tree Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Doze	145.00	145.00
5	IPT or Burn	25.00	17.02
		Total	162.02

[1] Doze, stack, and burn.

Heavy Cedar - Tree Shear or Flat Cutting[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Shear/Flat Cutting	130.00	130.00
5	IPT or Burn	25.00	17.02
		Total	147.02

[1] Tree shear or flat cutting by hand, stack, and burn.

Heavy Mesquite - Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	35.00	35.00
4	Aerial Herbicide	35.00	25.73
7	Choice IPT or Burn	20.00	14.59
		Total	75.32

[1] Individual chemical application may also be used.

Heavy Mesquite – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	155.00	155.00
6	IPT or Burn	25.00	15.76
		Total	170.76

[1] Rootplow, rake, stack, and burn.

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category* (Continued)

Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	180.00	180.00
6	IPT or Burn	25.00	15.76
		Total	195.76

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Initial IPT	60.00	60.00
6	IPT or Burn	25.00	15.76
		Total	75.36

[1] Initial IPT for heavy canopies.

Heavy Mixed Brush – Tree Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Doze	145.00	145.00
5	IPT or Burn	25.00	17.02
		Total	162.02

[1] Tree doze, stack, and burn.

Moderate Cedar – Tree Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Doze	95.00	95.00
5	IPT or Burn	25.00	17.02
		Total	112.02

[1] Doze, rake, stack, and burn.

Moderate Cedar – Tree Shear or Flat Cutting[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree Shear/Flat Cutting	75.00	75.00
5	IPT or Burn	25.00	17.02
		Total	92.02

[1] Tree shear or flat cutting by hand, stack, and burn.

Moderate Mesquite – Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
5	IPT or Burn	25.00	17.02
		Total	52.02

[1] Either aerial or individual chemical application may be used.

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category* (Continued)

Moderate Mesquite – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Mechanical Method	60.00	60.00
5	IPT or Burn	25.00	17.02
		Total	77.02

[1] Choice of tree dozing, rake and burn, tree shearing with stump spray and later burn, or grubbing and burning.

Moderate Mixed Brush – Chemical[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	35.00	35.00
5	IPT or Burn	25.00	17.02
		Total	52.02

[1] Either aerial or individual chemical application may be used.

Moderate Mixed – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Mechanical Method	60.00	60.00
5	IPT or Burn	25.00	17.02
		Total	77.02

[1] Choice of tree dozing with rake, burn, tree shearing with stump spray and later burn, or grubbing and burning.

*Western portion of Edwards Recharge Zone watershed.

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the Edwards Recharge Zone watershed are shown in Tables 2a (the Hondo, Medina, Sabinal and Seco watersheds) and 2b (the upper portions of the Frio and Nueces watersheds). Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2a. Grazing Capacity With and Without Brush Control (Acres/AUY)*

		Program Year									
Brush Type / Category	Brush Control	0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Control	60.0	50.0	40.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	60.0	60.1	60.1	60.2	60.3	60.3	60.4	60.5	60.5	60.6
Heavy Mesquite	Control	35.0	30.0	25.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	35.0	35.0	35.1	35.1	35.2	35.2	35.2	35.3	35.3	35.4
Heavy Mixed Brush	Control	45.0	38.2	31.6	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	45.0	45.1	45.1	45.2	45.2	45.3	45.3	45.4	45.4	45.5
Moderate Cedar	Control	45.0	40.0	35.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	45.0	45.3	45.5	45.8	46.0	46.3	46.5	46.8	47.0	47.3
Moderate Mesquite	Control	25.0	23.2	21.6	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	25.0	25.1	25.3	25.4	25.6	25.7	25.8	26.0	26.1	26.3
Moderate Mixed Brush	Control	35.0	31.6	28.3	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	35.0	35.2	35.4	35.6	35.8	36.0	36.2	36.4	36.6	36.8

* Eastern portion of Edwards Recharge Zone watershed.

Table 2b. Grazing Capacity With and Without Brush Control (Acres/AUY)*

		Program Year									
Brush Type / Category	Brush Control	0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Control	50.0	43.3	36.7	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	50.0	50.1	50.1	50.2	50.2	50.3	50.3	50.4	50.4	50.5
Heavy Mesquite	Control	30.0	26.7	23.3	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	30.0	30.0	30.1	30.1	30.2	30.3	30.3	30.4	30.4	30.3
Heavy Mixed Brush	Control	40.0	35.0	30.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	40.0	40.0	40.1	40.2	40.2	40.3	40.3	40.4	40.4	40.4
Moderate Cedar	Control	40.0	36.7	33.3	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	40.0	40.2	40.3	40.3	40.4	40.4	40.5	40.6	40.6	42.0
Moderate Mesquite	Control	25.0	23.3	21.6	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	25.0	25.1	25.2	25.3	25.3	25.4	25.4	25.5	25.5	26.3
Moderate Mixed Brush	Control	35.0	31.7	28.3	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	35.0	35.2	35.3	35.3	35.4	35.4	35.5	35.5	35.6	36.8

* Western portion of Edwards Recharge Zone watershed.

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. In the Eastern portion of the watershed livestock grazing capacities range from about 20 acres per AUY for land on which mesquite is controlled to 60 acres per animal unit year (AUY) for land infested with heavy Cedar. In the Western portion of the watershed livestock grazing capacities range from about 20 acres per AUY for land on which mesquite is controlled to 50 acres per animal unit year (AUY) for land infested with heavy cedar.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle and goats) in the Eastern portion of the project area is shown in Tables 3a and 3b. In the Western portion of the project area the livestock enterprises consist of cattle, sheep and goats (Tables 3c, 3d and 3e). It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Table 3a. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	405.00	Pound	.95	384.75
Cows	111.1	Pound	.40	0.00
Bulls	250.0	Pound	.50	0.00
			Total	384.75

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	480.0	Pound	0.10	48.00
Salt & Minerals	27.0	Pound	0.20	5.40
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	14.00	14.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	127.09

*Eastern portion of Edwards Recharge Zone Watershed.

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3b. Investment Analysis Budget, Meat Goat Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Kid Goats	345.00	Pound	0.85	293.25
Cull Nannies	1.0	Head	20.00	0.00
Cull Bucks	0.045	Head	40.00	0.00
			Total	293.25

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	384.0	Pound	0.10	38.40
Salt & Minerals	73.5	Pound	0.20	14.70
Marketing	1.0	Head	2.55	15.31
Veterinary Medicine	1.0	Head	2.50	15.00
Miscellaneous	1.0	Head	1.17	7.00
Net Replacement Nannies	1.0	Head	6.08	36.48
Net Replacement Bucks	1.0	Head	0.79	4.74
			Total	131.63

* Eastern portion of Edwards Recharge Zone Watershed.

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $1.75 per acre (from $9.00 per acre to $10.75 per acre) due principally to the resulting improvement in habitat and accessibility to hunting. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3c. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	405.00	Pound	0.95	384.75
Cows	111.1	Pound	0.40	0.00
Bulls	250.0	Pound	0.50	0.00
			Total	384.75

Table 3c. Investment Analysis Budget, Cow-Calf Production* (Continued)

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	500.0	Pound	0.10	50.00
Salt & Minerals	50.0	Pound	0.20	10.00
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	14.00	14.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows	1.0	Head	35.28	35.28
Net Replacement Bulls	1.0	Head	3.09	6.09
			Total	133.69

* Western portion of Edwards Recharge Zone Watershed.

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3d. Investment Analysis Budget, Sheep Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Lambs	211.25	Pound	0.85	179.56
Cull Ewes	0.83	Head	20.00	0.00
Cull Rams	0.038	Head	40.00	0.00
Wool	40.00	Pounds	1.00	40.00
			Total	219.56

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	300.0	Pound	0.10	30.00
Salt & Minerals	60.00	Pound	0.30	18.00
Marketing	1.0	Head	1.00	5.00
Veterinary Medicine	1.0	Head	3.00	15.00
Miscellaneous	1.0	Head	1.20	6.00
Shearing	1.0	Head	2.40	12.00
Net Replacement Ewes	1.0	Head	6.83	39.17
Net Replacement Rams	1.0	Head	0.87	8.52
			Total	133.69

* Western portion of Edwards Recharge Zone Watershed.

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3e. Investment Analysis Budget, Meat Goat Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Kid Goats	405.00	Pound	0.85	344.25
Cull Nannies	1.0	Head	20.00	0.00
Cull Bucks	0.045	Head	40.00	0.00
			Total	344.25

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	350.0	Pound	0.10	35.00
Salt & Minerals	73.5	Pound	0.20	14.70
Marketing	1.0	Head	2.55	15.31
Veterinary Medicine	1.0	Head	2.50	15.00
Miscellaneous	1.0	Head	1.17	7.00
Net Replacement Nannies	1.0	Head	6.83	41.00
Net Replacement Bucks	1.0	Head	0.87	5.23
			Total	133.24

* Western portion of Edwards Recharge Zone Watershed.

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. For the Eastern part of the region they range from $52.12 per acre for the control of heavy mesquite to $20.81 per acre for control of moderate mesquite (Table 4a). For the Western portion of the region, present value of landowner benefits range from 33.99 per acre for the control of heavy mesquite to 10.44 per acre for control of moderate cedar (Table 4b).

Table 4a. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control Practice	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Cedar	Doze or Shear	182.02	43.52	0.24	138.5	0.76
Heavy Mesquite	Chemical	75.32	52.12	0.69	23.2	0.31
	Rootplow	175.76		0.30	123.64	0.70
	Doze & Plow[1]	200.76		0.26	148.64	0.74
Heavy Mixed Brush	Chemical	75.32	45.61	0.61	29.71	0.39
	Rootplow	175.76		0.26	130.15	0.74
	Doze & Plow[1]	200.76		0.23	155.15	0.77
Moderate Cedar	Doze or Shear	117.02	23.27	0.20	93.75	0.80
Moderate Mesquite	Chemical	52.02	20.81	0.40	31.21	0.60
	Doze or Grub	77.02		0.27	56.21	0.73
Moderate Mixed Brush	Chemical	52.02	23.88	0.46	28.14	0.54
	Doze or Grub	77.02		0.31	53.14	0.69
Average		121.73	37.45	0.35	84.29	0.65

*Eastern portion of Edwards Recharge Zone watershed.

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise mixture of 80% cattle and 20% meat goats. In this region, 20% of typical ranch resources are assigned to wildlife production.

[1] The (pre)doze & plow category is to be applied to extra heavy densities of this brush type (ie., over 40% canopy cover.)

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. In the eastern part of the region present values of the state cost share per acre of brush control ranges from $23.20 for control of heavy mesquite with herbicide to $155.15 for mechanical control of heavy mixed brush. For the western portion of the region present values of the state cost share per acre of brush control range from $36.67 for control of moderate mixed brush with herbicide to $164.96for mechanical control of heavy mixed brush. Total treatment cost, rancher benefits and state cost share for all brush type-density categories are shown in Tables 4a and 4b.

Table 4b. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control Practice	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Cedar	Chain	107.02	30.69	0.29	76.33	0.71
	Doze	162.02		0.19	131.33	0.81
	Shear or Flat Cut	147.02		0.21	116.33	0.79
Heavy Mesquite	Chemical	75.32	33.99	0.45	41.33	0.55
	Rootplow	170.76		0.20	136.77	0.80
	Doze & Plow[1]	195.76		0.17	161.77	0.83
Heavy Mixed Brush	Chemical	75.32	30.80	0.41	44.52	0.59
	Rootplow	170.76		0.18	139.96	0.82
	Doze & Plow[1]	195.76		0.16	164.96	0.84
Moderate Cedar	Doze	112.02	10.44	0.09	101.58	0.91
	Shear or Flat Cut	92.02		0.11	81.58	0.89
Moderate Mesquite	Chemical	52.02	12.45	0.24	39.57	0.76
	Doze or Grub	77.02		0.16	64.57	0.84
Moderate Mixed Brush	Chemical	52.02	15.35	0.30	36.67	0.70
	Doze or Grub	77.02		0.20	61.67	0.80
Averages		117.46	24.19	0.22	93.26	0.78

*Western portion of Edwards Recharge Zone watershed.

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise mixture of 20% cattle, 30% sheep, and 50% meat goats. In this region, 25% of the typical ranch' resources are assigned to wildlife production.

[1] The (pre)doze and plow category is to be applied to extra heavy densities of this brush type (ie., over 40% canopy cover).

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water thus determined averages $29.92 per acre foot for the Hondo Watershed (Table 5a), $26.68 per acre foot for the Medina Watershed (Table 5b), $42.04 per acre foot for the Sabinal Watershed (Table 5c), $35.33 per acre foot for the Seco Watershed (Table 5d), $51.65 per acre foot for the Upper Frio Watershed (Table 5e) and

$97.51 per acre foot for the upper Nueces Watershed (Table 5f). Sub-basins range from costs per added acre foot of $4.79 to $241.67. For the entire Edwards Recharge Zone Watershed the average costs per added acre foot of added water is $67.41.

Table 5a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
2	5,384.12	29.14	227.38	23.68
4	259,953.00	977.06	7,623.00	34.10
6	630,981.90	2,990.91	23,335.09	27.04
8	631,559.90	2,579.65	20,126.43	31.38
10	647,846.20	2,744.93	21,415.93	30.25
Totals:	$2,175,725.00	----------	72,727.84	Average: $29.92

* Hondo River Watershed

Table 5b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
2	226,441.20	1,078.10	8,411.31	26.92
4	95,490.56	435.36	3,396.68	28.11
6	535,567.20	2,133.47	16,645.34	32.18
8	568,659.80	2,299.46	17,940.37	31.70
10	366,786.50	1,849.20	14,427.46	25.42
12	138,257.60	553.64	4,319.50	32.01
14	359,552.80	1,808.05	14,106.39	25.49
16	546,827.80	2,133.69	16,647.08	32.85
18	305,680.70	1,375.21	10,729.41	28.49
20	0.00	0.00	0.00	0.00
22	120,691.70	543.23	4,238.31	28.48
24	330,420.20	1,679.84	13,106.07	25.21
26	222,265.90	1,170.37	9,131.23	24.34
28	231,829.80	1,175.84	9,173.92	25.27
30	159,110.80	797.25	6,220.14	25.58
32	486,305.00	2,301.75	17,958.28	27.08
34	160,851.00	809.86	6,318.52	25.46
36	381,194.50	1,750.99	13,661.26	27.90
38	876,745.40	4,602.60	35,909.45	24.42
40	507,575.30	2,431.89	18,973.63	26.75
42	506,360.40	2,763.62	21,561.75	23.48
44	1,055,659.00	4,873.41	38,022.31	27.76
46	1,771,201.00	9,179.20	71,616.09	24.73
48	445,427.80	2,228.58	17,387.37	25.62
50	259,512.40	1,224.00	9,549.62	27.18
Totals:	$10,658,415.00	----------	399,451.50	Average: $26.68

* Medina River Watershed

Table 5c. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
2	789,301.05	2,037.88	15,899.50	49.64
4	191,371.13	503.92	3,931.62	48.67
6	671,213.52	1,778.17	13,873.28	48.38
8	80,663.34	270.83	2,112.98	38.18
10	209,190.27	675.52	5,270.41	39.69
12	9,324.73	37.52	292.72	31.86
14	1,134,936.63	3,108.14	24,249.67	46.80
16	634,973.24	2,205.59	17,207.99	36.90
18	926,096.84	2,896.81	22,600.87	40.98
20	544,238.62	2,218.31	17,307.24	31.45
22	523,057.08	1,689.94	13,184.93	39.67
Totals:	$5,714,366.45	----------	135,931.20	Average: $42.04

* Sabinal River Watershed

Table 5d. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) *

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
2	49,916.74	131.98	1,029.69	48.48
4	52,445.27	142.06	1,108.33	47.32
6	83,432.24	235.16	1,834.71	45.47
8	28,481.54	82.84	646.29	44.07
10	61,768.17	241.01	1,880.39	32.85
12	119,446.20	618.25	4,823.56	24.76
14	431,926.60	1,508.31	11,767.84	36.70
16	75,782.18	275.76	2,151.49	35.22
18	199,356.70	738.41	5,761.05	34.60
20	220,528.40	811.92	6,334.57	34.81
22	66,386.54	252.08	1,966.75	33.75
24	153,065.80	566.34	4,418.57	34.64
26	122,320.30	435.86	3,400.57	35.97
Totals:	$1,664,857.00	----------	47,123.82	Average: $35.33

* Seco Creek watershed

Table 5e. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) *

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
2	78,885.85	252.77	1,972.15	40.00
4	431,838.05	667.74	5,209.74	82.89
6	267,148.09	890.89	6,950.75	38.43
8	335,418.12	619.38	4,832.43	69.41
10	381,597.00	492.40	3,841.73	99.33
12	433,077.57	708.47	5,527.46	78.35

Table 5e. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) (Continued)

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
14	385,180.51	920.97	7,185.37	53.61
16	107,771.60	982.83	7,668.07	14.05
18	321,190.94	1,151.32	8,982.57	35.76
20	683,386.98	1,271.55	9,920.61	68.89
22	297,984.18	1,598.54	12,471.77	23.89
24	345,686.96	239.81	1,871.03	184.76
26	180,884.86	197.31	1,539.44	117.50
28	254,801.16	908.38	7,087.16	35.95
30	337,833.04	1,216.38	9,490.23	35.60
32	743,995.16	1,414.75	11,037.86	67.40
34	434,452.52	638.58	4,982.18	87.20
36	48,505.48	1,298.98	10,134.61	4.79
38	82,889.31	1,807.63	14,103.14	5.88
40	326,696.18	597.61	4,662.52	70.07
42	516,879.00	493.02	3,846.55	134.37
44	520,780.72	1,728.31	13,484.26	38.62
46	869,668.39	712.45	5,558.56	156.46
Totals:	$8,386,551.66	----------	162360.18	Average: $51.65

* Upper Frio River Watershed

Table 5f. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) *

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
101-1	16,242,903.00	18,814.51	146,790.83	110.65
101-2	2,297,010.00	2,929.17	22,853.38	100.51
101-3	2,895,235.00	3,757.63	29,317.07	98.76
101-4	3,344,663.00	6,610.83	51,577.67	64.85
101-5	5,312,303.00	8,411.40	65,625.76	80.95
101-6	3,652,463.00	4,790.06	37,372.05	97.73
101-7	2,552,173.00	3,166.50	24,705.07	103.31
101-8	3,303,922.00	4,945.14	38,581.95	85.63
101-9	3,271,623.00	6,317.41	49,288.44	66.38
102-1	5,454,409.00	2,892.86	22,570.08	241.67
102-2	3,694,543.00	4,626.05	36,092.42	102.36
102-3	335,345.90	241.20	1,881.82	178.20
102-4	5,960,334.00	4,899.80	38,228.21	155.91
102-5	9,430,337.00	10,425.04	81,336.16	115.94
102-6	6,355,018.00	13,480.35	105,173.73	60.42
102-7	3,681,164.00	7,875.74	61,446.53	59.91
102-8	5,812,119.00	7,202.49	56,193.81	103.43
102-9	2,293,491.00	1,506.01	11,749.91	195.19
Totals:	$85,889,057.00	----------	880784.88	Average: $97.51

* Upper Nueces River Watershed

CHAPTER 7

FRIO RIVER WATERSHED – HYDROLOGIC SIMULATION

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METHODS

Watershed Characteristics

The Frio watershed covers a large area of South Texas just north and east of the Nueces River basin. It is within a semiarid climatic region with soils that are primarily Usterts and Ustalfs that generally have high infiltration that allows for high percolation. The watershed generally runs northwest to east and drains into Choke Canyon Lake. Based on the digital elevation map (DEM), the derived subbasins are shown in Figure F-1. Due to the fact that part of the watershed lies over the western part of the Edwards Aquifer recharge zone, the watershed was divided into the upper (Edwards) and lower Frio. The upper Frio corresponds to the 8-digit hydrologic response units (HRU) 12110106 and 12110107 and the lower corresponds to the 8-digit HRUs 12110108, and 12110109. The HRU 12110106, 12110107, 12110109 all feed into the HRU 12110108. Actual flow at Derby (outlet of 12110106 and 12110107) served as input into model runs. The stream flow gauge near Choke Canyon (outlet of 1211108; subbasin 1) was used to calibrate the flows for the Frio.

Climate

For the simulations actual weather data from 1960-1998 were used. The model used daily maximum and minimum air temperatures, precipitation and solar radiation. Solar radiation was generated using the WGEN model based on parameters for the specific climate station. Climate stations are shown in Figure F-2. For each subbasin, precipitation and temperature data are retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin.

Topography

The outlet or "catchment" for the Frio River simulated in this study is Choke Canyon Lake, which is located just downstream of subbasin number 108_1. The subbasin delineation and numbers are shown in Figure F-1. Roads (obtained from the Census Bureau) are overlaid in Figure F-3.

Soils

The dominant soil series in the Frio River watershed are Uvalde, Duval, and Monteola. These three soil series represent over 50 percent of the watershed area. A short description of each follows:

Uvalde. The Uvalde series consists of a deep, well-drained, moderately permeable soils formed in alluvium from limestone. These level to gently sloping or gently undulating soils are on alluvial fans or stream terraces. Slopes range from 0 to 3 percent.

Duval. The Duval series consists of deep, well drained, moderately permeable soils that formed in sandy clay loams with interbedded sandstone on uplands. Slopes range from 1 to 5 percent.

Monteola. The Monteola series consists of a deep, moderately well drained veryy slowly permeable soils that formed in clays and shaly clays. These soils are on gently undulating uplands. Slopes range from 0 to 8 percent.

Land Use/Land Cover

Figure F-4 show the areas of heavy and moderate brush in the Frio River Watershed that is the area of brush removed or treated in the no-brush simulation.. This corresponds to 69% of the total watershed area

Model Input Variables

Significant input variables for the SWAT model for the Frio River Watershed are shown in Table F-1. Input variables for all subbasins in the watershed were the same, with these exceptions:

It was necessary to decrease the curve number by 8 in order to calibrate flow at stream gauge flowing into Choke Canyon.

1. The base flow factor was calculated to be 0.0264. Also the amount of heat units for the crops to mature were for mixed brush 4623 degree days, oak 4325, and brushy range 3331 degree days.
2. We assumed the re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units is 0.4, and for non-brush units is 0.1. Also, for the non-brush condition curve number increased by 4 units to account for the change from fair to good hydrologic conditions and from brush to range conditions.

FRIO RIVER WATERSHED RESULTS

Calibration

SWAT was calibrated for the flow at stream gauges near Choke Canyon Lake. The results of calibration are shown on Figures F-5. Measured and predicted average monthly flows compare reasonably well with a 3% difference between measured and simulated cumulative flow. At the outlet, the measured monthly mean is 6,263 acre-feet, and predicted monthly mean is 5,969 acre-feet. The coefficient of determination (r^2) was 0.99 between measured and simulated flows. Average base flow for the entire watershed is 10% of total flow.

Brush Removal Simulation

The average annual rainfall for the Frio River Watershed is 24.85 inches. Average annual evapo-transpiration (ET) in the Frio is 24.20 inches for the brush condition (calibration) and 21.64 inches for the no-brush condition. This represents 98% and 87% of precipitation for the brush and no-brush conditions, respectively.

The increases in water yield by subbasin for the Frio River Watersheds are shown in Figures F-7, 8, and Table F-2. The amount of annual increase varies among the subbasins and ranges from 33,557 gallons per acre of brush removed per year in subbasin number 108-18, to 202,206 gallons per acre in subbasin number 108-2. Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. In addition, Table F-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the Frio, the average annual water yield increases by 125 % or approximately 223,696 acre-feet. The average annual flow to Choke Canyon could increase by 59,806 acre-feet. The increase in volume of flow to the lake is less than the water yield because of stream channel transmission losses that occur after water leaves each subbasin.

TABLE F-1

SWAT INPUT VARIABLES FOR FRIO RIVER WATERSHED		
VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	-8	-8
Soil Available Water Capacity Adjustment (%)	0	0
Soil Evaporation Compensation Factor ($in^3 in^{-3}$)	0.1	0.1
Min. Shallow Aqu. Storage for GW flow (inches)	0	0
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0.3	0.3
Potential Heat Units (degree-days)		
Heavy Cedar	N/A	N/A
Heavy Mesquite	N/A	N/A
Heavy Mixed Brush	4623	4623
Moderate Cedar	N/A	N/A
Moderate Mesquite	N/A	N/A
Moderate Mixed Brush	4076	4076
Heavy Oak	4325	4325
Moderate Oak	N/A	N/A
Light Brush & Open Range/Pasture	3331	3331
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.04	0.04
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.10	0.10

Table F-2. Frio areas and water yield

Subbasin	Ave Ann. Gal. Incr.	Subbasin Total Area (acres)	Brush Removal Area (acres)	Fraction of Subbasin Containing Brush	Increase (gal/ac) Water Yield
108-1	1506088753	25211	15954	0.63	94402
108-2	2283104752	24850	11291	0.45	202206
108-3	1798053066	24741	19385	0.78	92755
108-4	1559115701	27642	18066	0.65	86301
108-5	1415099009	32993	17562	0.53	80577
108-6	3438828182	44913	35086	0.78	98011
108-7	2329136850	45886	29845	0.65	78041
108-8	202848213	4654	3038	0.65	66770
108-9	3617654826	63441	52091	0.82	69449
108-10	1596121887	40167	30702	0.76	51988
108-11	1410685834	28457	18648	0.66	75648
108-12	2581587485	43191	26096	0.60	98927
108-13	434595326	6838	6839	1.00	63547
108-14	2060776742	47339	26505	0.56	77750
108-15	1417183557	36259	18140	0.50	78125
108-16	43827280	909	701	0.77	62521
108-17	7047889265	194816	103020	0.53	68413
108-18	1459411484	53979	43491	0.81	33557
108-19	1415844661	40977	34191	0.83	41410
109-1	3255215997	70615	44558	0.63	73056
109-2	6729221911	109090	71140	0.65	94591
109-3	9712496487	145477	100582	0.69	96563
109-4	5148441909	80492	58750	0.73	87633
109-5	3797156681	50217	34449	0.69	110225
109-6	3058860451	40476	29069	0.72	105228
109-7	4569745200	45464	33684	0.74	135665

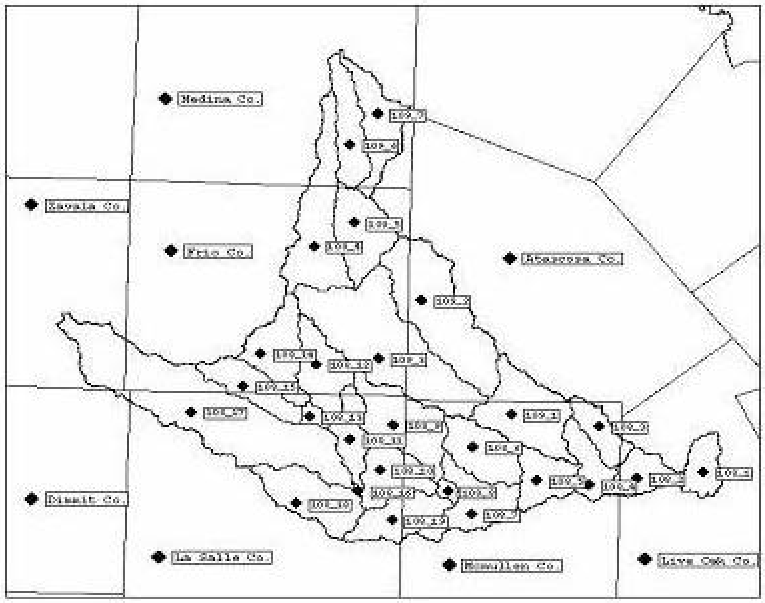
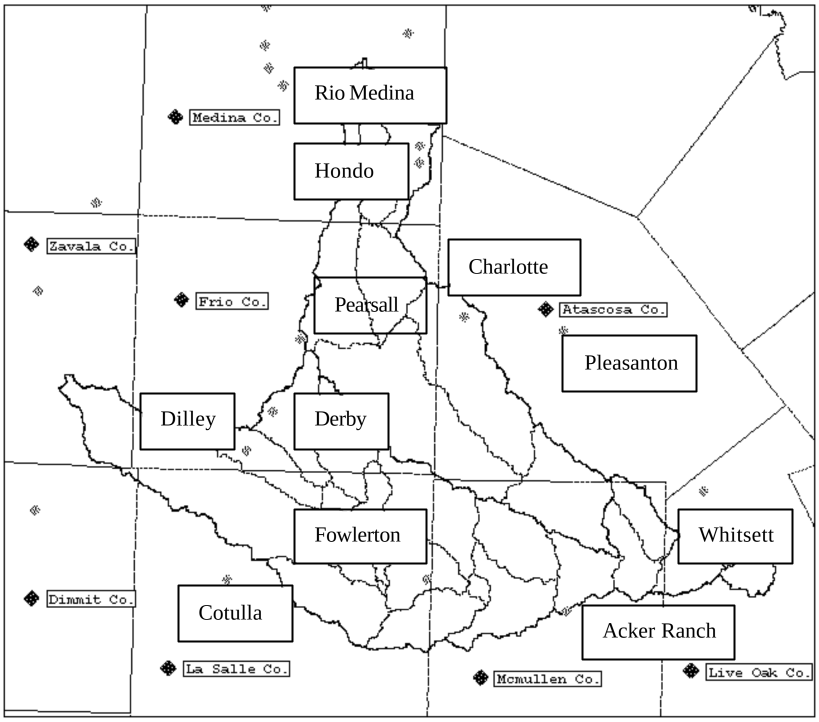


Figure F-1 Frio River Watershed subbasin map.

Figure F-2. Climate Stations in the Frio Watershed.



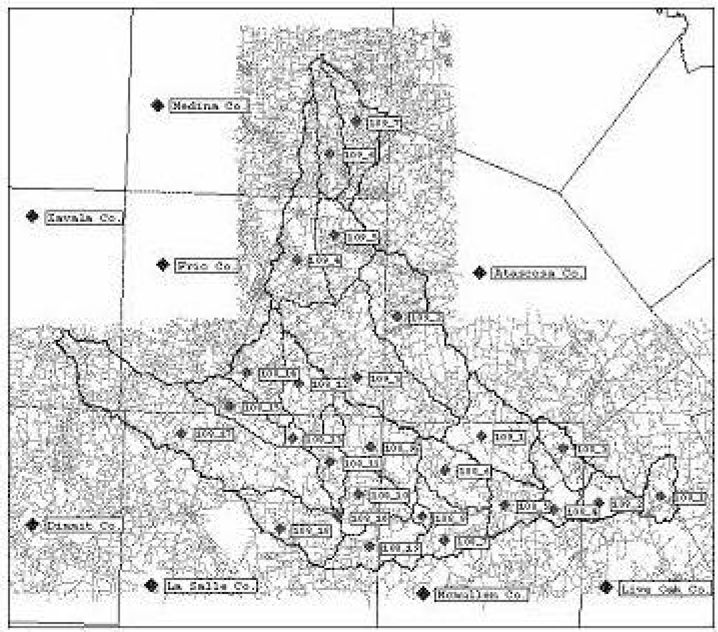


Figure F-3. Frio River Watershed roads map.

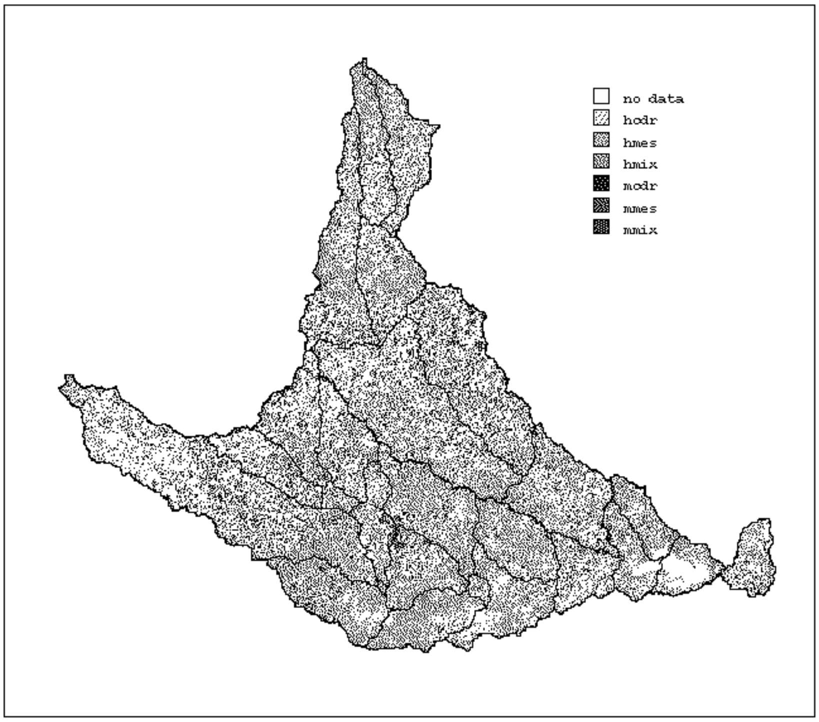


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Figure F-4. Areas of heavy and moderate brush in the Frio River Watershed.

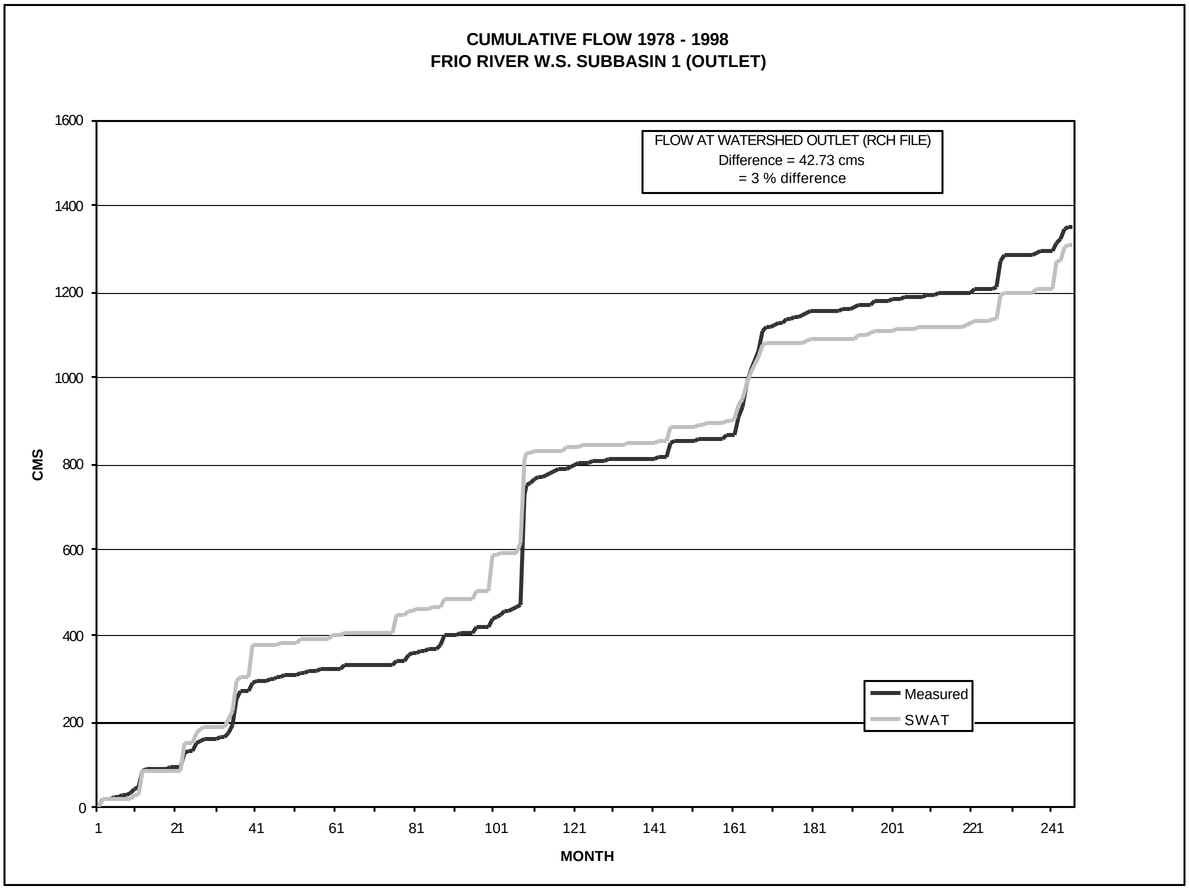

Figure F-5. Simulated and measured cumulative flow at the outlet of the Frio.

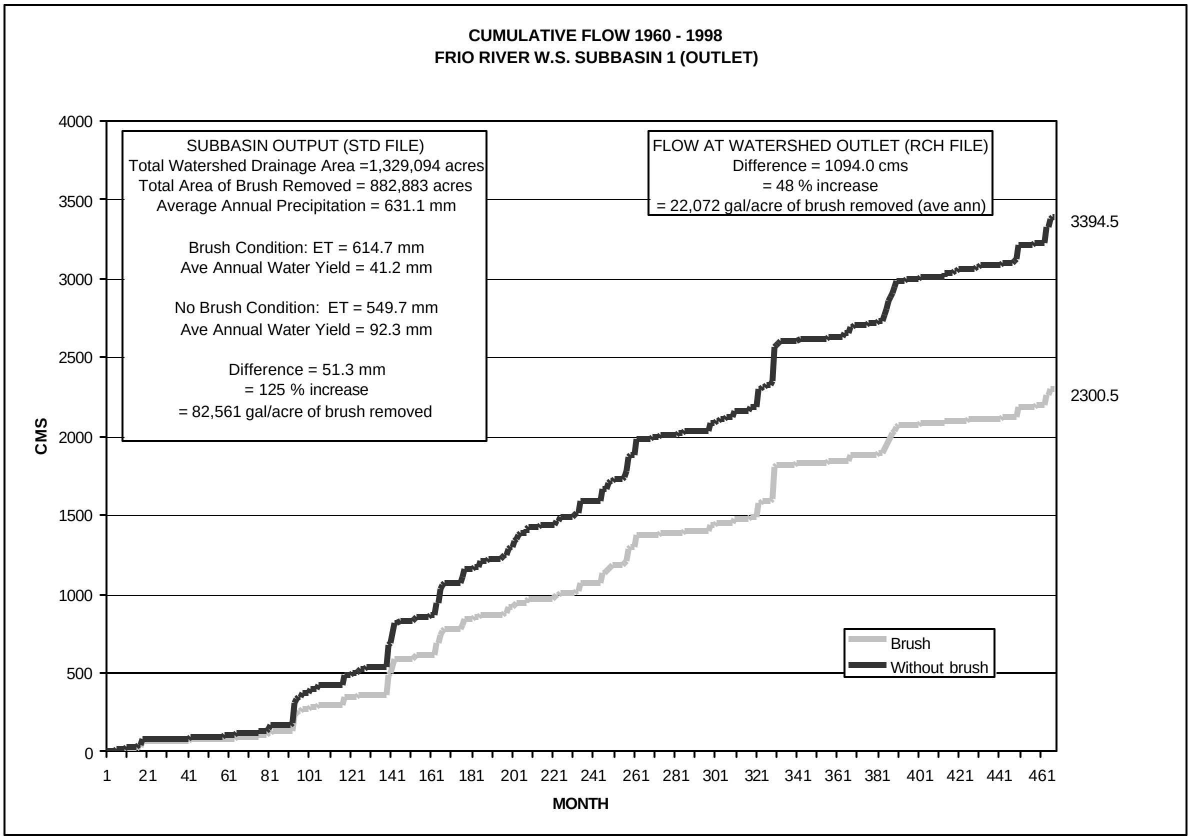

Figure F-6. Simulated cumulative flow at the outlet for brush and no brush conditions in the Frio.

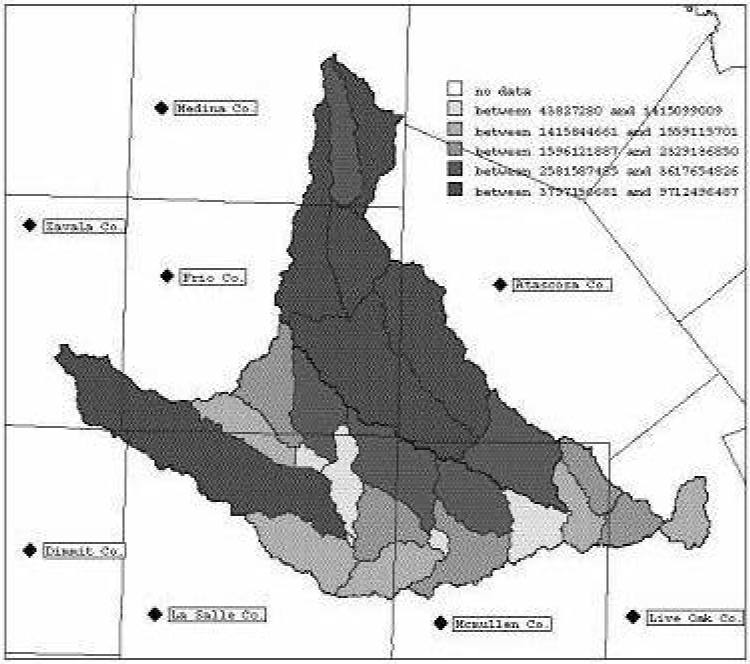

Figure F-7. Increased water yield (gallons) by subbasin.

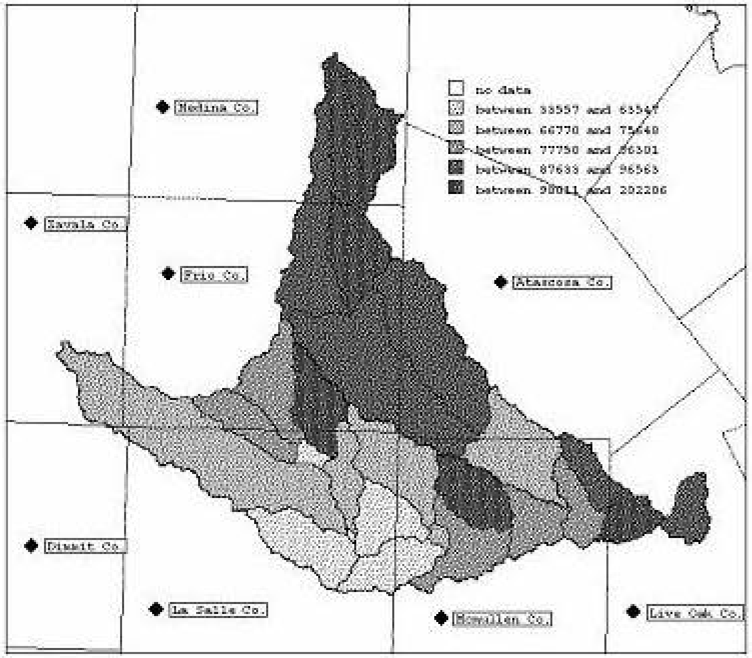

Figure F-8. Increase in water yield per treated acre due to brush removal from 1960 through 1998.

CHAPTER 8

FRIO RIVER WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Frio River watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Table 1a presents present values of total control costs per acre for the Northern portion of the region which consists of sub-basins with the 109 prefix. Present values of total costs range from $170.42 per acre for rootplowing with predozing for control of heavy mesquite or mixed brush to $83.99 per acre for moderate mesquite or mixed brush that can be initially controlled with herbicide treatments. Similar information is presented in Table 1b for the Southern portion of the region consisting of sub-basins with the 108 prefix. For this portion of the region, present values of total costs range from $140.42 per acre for rootplowing with predozing for control of heavy mesquite or mixed brush to $76.64 per acre for moderate mesquite that can be initially controlled with herbicide treatments. Costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Tables 1a and 1b.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	45.00	45.00
4	Chemical Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	88.99

[1] Either aerial or individual chemical application may be used.

Heavy Mesquite – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	110.00	110.00
5	Choice IPT or Burn	30.00	20.42
		Total	130.42

[1] Rootplow, rake, stack, and burn.

Extra Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	150.00	150.00
5	Choice IPT or Burn	30.00	20.42
		Total	170.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	90.00	90.00
5	Choice IPT or Burn	35.00	23.82
		Total	113.82

[1] Aerial or individual chemical application may be used.

Heavy Mixed Brush – Chop Method[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Chop Method	45.00	45.00
4	Choice Chop, IPT or Burn	45.00	33.08
7	Choice IPT or Burn	25.00	14.59
		Total	92.67

1 Choice of roller-chop, aerator method, or deep disking.

Heavy Mixed Brush – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	100.00	100.00
5	IPT or Burn	30.00	20.42
		Total	120.42

[1] Rootplow, rake, stack, and burn.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category* (Continued)

Extra Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	150.00	150.00
5	IPT or Burn	30.00	20.42
		Total	170.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Moderate Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.

Moderate Mixed Brush – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.

* Northern portion of Frio River Watershed

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	45.00	45.00
4	Chemical Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	88.99

[1] Either aerial or individual chemical application may may be used.

Heavy and Extra Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	120.00	120.00
5	Choice IPT or Burn	30.00	20.42
		Total	140.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	50.00	50.00
4	Choice Chop, IPT or Burn	60.00	44.10
7	Choice IPT or Burn	25.00	14.59
		Total	108.69

[1] Aerial or individual chemical application may be used. Year 4 choice includes chemicals, choice or chop method or burning, if effective.

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category* (Continued)

Heavy Mixed Brush – Chop Method[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Chop Method	45.00	45.00
4	Choice Chop, IPT or Burn	45.00	33.08
7	Choice IPT or Burn	25.00	14.59
		Total	92.67

2 Choice of roller-chop, aerator method, or deep disking.

Heavy and Extra Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	120.00	120.00
5	IPT or Burn	30.00	20.42
		Total	140.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Moderate Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	30.00	20.42
7	Choice IPT or Burn	25.00	14.59
		Total	76.64

[1] Either aerial or individual chemical application may be used.

Moderate Mixed Brush – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.

* Southern Portion of Frio River Watershed

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the Frio River watershed are shown in Tables 2a (sub-basins with 109 prefix) and 2b (sub-basins with

108 prefix). Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2a. Grazing Capacity With and Without Brush Control (Acres/AUY)*

		Program Year									
Brush Type / Category	Brush Control	0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Control	36.0	32.0	28.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	36.0	36.0	36.1	36.1	36.2	36.2	36.2	36.3	36.3	36.4
Heavy Mixed Brush	Control	36.0	32.0	28.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	36.0	36.0	36.1	36.1	36.2	36.2	36.2	36.3	36.3	36.4
Moderate Mesquite	Control	32.0	29.3	26.7	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	32.0	32.2	32.4	32.5	32.7	32.9	33.1	33.2	33.4	33.6
Moderate Mixed Brush	Control	32.0	29.3	26.7	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	32.0	32.2	32.4	32.5	32.7	32.9	33.1	33.2	33.4	33.6

*Northern portion of Frio River Watershed

Table 2b. Grazing Capacity With and Without Brush Control (Acres/AUY)*

		Program Year									
Brush Type / Category	Brush Control	0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Control	38.0	33.0	28.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	No Control	38.0	38.0	38.1	38.1	38.2	38.2	38.3	38.3	38.3	38.4
Heavy Mixed Brush	Control	35.0	31.0	27.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	No Control	35.0	35.0	35.1	35.1	35.2	35.2	35.2	35.3	35.3	35.4
Moderate Mesquite	Control	30.0	27.6	25.3	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	No Control	30.0	30.2	30.3	30.5	30.7	30.8	31.0	31.2	31.3	31.5
Moderate Mixed Brush	Control	30.0	27.6	25.3	23.0	23.0	23.0	23.0	23.0	23.0	23.0
	No Control	30.0	30.2	30.3	30.5	30.7	30.8	31.0	31.2	31.3	31.5

* Southern Portion of Frio River Watershed

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. In the Northern portion of the watershed livestock grazing capacities range from about 24 acres per AUY for land on which mesquite is controlled to 36 acres per animal unit year (AUY) for land infested with heavy mixed brush. In the Southern portion of the watershed livestock grazing capacities range from about 23 acres per AUY for land on which mesquite is controlled to 38 acres per animal unit year (AUY) for land infested with heavy mesquite.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle) in the project areas is shown in Table 3. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $1.50 per acre (from $10.00 per acre to $11.50 per acre) due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	425.00	Pound	.85	361.25
Cows	111.1	Pound	.40	0
Bulls	250.0	Pound	.50	0
			Total	361.25

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	400.0	Pound	0.10	40.00
Salt & Minerals	50.0	Pound	0.20	10.00
Marketing	1.0	Head	6.25	6.25
Veterinary Medicine	1.0	Head	12.00	12.00
Miscellaneous	1.0	Head	5.00	5.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	114.62

Note: This budget is for presentation of the information used in the investment analysis only. Values herein are representative of a typical ranch in the Lower Frio and Nueces Watersheds. The budget is based on 1 cow-calf pair per animal unit. Variable costs listed here include only items which change as a result of implementing a brush control program and adjusting livestock numbers to meet changes in grazing capacity. Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included, nor have fixed costs been considered.

* Frio River waterrshed.

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. In the Northern portion of the watershed they range from $23.43 per acre for control of moderate mesquite and mixed brush to $39.76 per acre for the control of heavy mesquite and mixed brush (Table 4a). In the Southern portion of the watershed they range from

$21.07 per acre for control of moderate mesquite and mixed brush to $41.60 per acre for the control of heavy mixed brush (Table 4b).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the Northern portion of the project area range from $49.23 for control of heavy mesquite with chemical treatments to $130.66 for control of heavy mesquite and mixed brush by mechanical method. State per acre cost share of brush control in the Southern portion of the project area range from $50.28 for control of heavy mesquite with chemical treatments to $101.71 for control of heavy mesquite brush by mechanical method. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Tables 4a and 4b.

Table 4a. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control Practice	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Mesquite	Chemical	88.99	39.76	0.45	49.23	0.55
	Rootplow	130.42		0.30	90.66	0.70
	Doze & Plow[1]	170.42		0.23	130.66	0.77
Heavy Mixed Brush	Chemical	113.82	39.76	0.35	74.06	0.65
	Chop[2]	92.67		0.43	52.91	0.57
	Rootplow	120.42		0.33	80.66	0.67
	Doze & Plow[1]	170.42		0.23	130.66	0.77
Moderate Mesquite	Treatment Choice	83.99	23.43	0.28	60.56	0.72
Moderate Mixed Brush	Treatment Choice	83.99		0.28	60.56	0.72
Average		117.24	36.13	0.32	81.11	0.68

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise venture of 100% cow-calf cattle. In this region, 20% of typical ranch resources are assigned to wildlife production, but this budget is based on a 100% assignment of carrying capacity to the livestock operation.

1 The (pre)doze and plow category is for extra heavy brush canopy cover classifications in excess of 40% canopy cover.

2 The "Chop" category is for roller chopping, heavy disking, or for the use of heavy "aerator"-type treatments. This category is not for use in areas where mesquite or other plants which sprout from the root crown, unless additional means for controlling those plants are used.

*Northern Portion of Frio River Watershed

Table 4b. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Mesquite	Chemical	88.99	38.71	.43	50.28	0.57
	Doze & Plow[1]	140.42		.28	101.71	0.72
Heavy Mixed Brush	Chemical (Chop)[2]	108.69	41.60	.38	67.09	0.62
	Chop[3]	92.67		.45	51.07	0.55
	Doze & Plow[1]	140.42		.30	98.82	0.70
Moderate Mesquite	Treatment Choice	76.64	21.07	.27	55.57	0.73
Moderate Mixed Brush	Treatment Choice	83.99		.25	62.92	0.75
	Average	104.55	34.91	0.34	69.64	0.66

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise venture of 100% cow-calf cattle. In this region, 20% of typical ranch resources are assigned to wildlife production, but this budget is based on a 100% assignment of carrying capacity to the livestock operation.

1 The (pre)doze and plow category is for extra heavy brush canopy cover classifications in excess of 40% canopy cover. However, only one category of cost was included for all rootplow treatment options.. A cost average between heavy and extra heavy was used.

2 This chemical treatment can be used in combinations of chemical or mechanical chop methods for retreatments.

3 The "Chop" category is for roller chopping, heavy disking, or for the use of heavy "aerator"-type treatments. This category is not for use in areas where mesquite or other plants which sprout from the root crown, unless additional means for controlling those plants are used.

* Southern Portion of Frio River Watershed

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water was determined to average $36.95per acre foot for the entire Nueces Watershed (Table 5). Sub-basins range from costs per added acre foot of $14.94 to $90.03.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin	Total State Cost ($)	Added Galllons per Year	Added Ac.Ft./Yr.	Total Ac.Ft. 10Yrs. Dsctd.	State Cost/ Ac.Ft. ($)
108-1	1114233	1506088753	4622.016667	36060.97	30.90
108-2	816678	2283104752	7006.591207	54665.42	14.94
108-3	1402045	1798053066	5518.022244	43051.61	32.57
108-4	1306786	1559115701	4784.750394	37330.62	35.01
108-5	1270332	1415099009	4342.779396	33882.36	37.49
108-6	2537843	3438828182	10553.37618	82337.44	30.82
108-7	2158472	2329136850	7147.85853	55767.59	38.70
108-8	219738.5	202848212.9	622.5183071	4856.888	45.24
108-9	3767742	3617654826	11102.175	86619.17	43.50
108-10	2220531	1596121887	4898.318209	38216.68	58.10
108-11	1298359	1410685834	4329.23586	33776.7	38.44
108-12	1797781	2581587485	7922.601083	61812.13	29.08
108-13	482124.3	434595325.6	1333.724081	10405.72	46.33
108-14	1815742	2060776742	6324.291601	49342.12	36.80
108-15	1219501	1417183557	4349.17664	33932.28	35.94
108-16	50703.33	43827280.22	134.5009843	1049.377	48.32
108-17	7055840	7047889265	21629.17795	168750.8	41.81
108-18	3145849	1459411484	4478.76939	34943.36	90.03
108-19	2473107	1415844661	4345.067717	33900.22	72.95
109-1	3538939	3255215997	9989.891076	77941.13	45.41
109-2	5208147	6729221911	20651.22375	161120.8	32.32
109-3	7696637	9712496487	29806.55725	232550.8	33.10
109-4	4550388	5148441909	15799.98806	123271.5	36.91
109-5	2913267	3797156681	11653.04596	90917.06	32.04
109-6	2458281	3058860451	9387.298031	73239.7	33.56
109-7	2848656	4569745200	14024.03307	109415.5	26.04
Total	65367721			1769158	
Average					36.95

*Frio River watershed

MAIN CONCHO RIVER WATERSHED

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WATERSHED DATA

Topography

The outlet or "catchment" for the Main Concho River simulated in this study is the O. H. Ivie Reservoir, which is located in subbasin number 37. The subbasin delineation, numbers, and roads (obtained from the Census Bureau) are shown in Figure CO-1.

Weather Stations

Climate stations are shown in Figure CO-2. For each subbasin, precipitation and temperature data were retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin. USGS stream gauge stations are also shown in this figure.

Soils

The dominant soil series in the Main Concho River watershed are Angelo, Tarrant, Cho, Talpa, Mereta, and Kimbrough. These six soil series represent about 83 percent of the watershed area. A short description of each follows:

Angelo. The Angelo series consists of deep or very deep, well drained, moderately slowly permeable soils formed in calcareous loamy and clayey alluvium. The deep phase is underlain by limestone. These nearly level to gently sloping upland soils have slopes ranging from 0 to 3 percent.

Tarrant. The Tarrant series consists of very shallow and shallow, well drained, moderately slowly permeable soils on uplands. They formed in residuum from limestone, and includes interbedded marls, chalks, and marly materials.

Cho. The Cho series consists of very shallow and shallow to a petrocalcic horizon, well drained, moderately permeable soils that formed in loamy calcareous gravelly alluvium. These soils are on nearly level to moderately sloping stream terraces and alluvial fans. Slopes are from 0 to 8 percent.

Talpa. The Talpa series consists of very shallow and shallow, well drained, moderately permeable soils that formed in dolomitic limestone of Permian age. These soils are on gently sloping to steep uplands of the Central Rolling Red Plains (MLRA-78B,78C) and Rolling Limestone Prairies (MLRA-78D). Slopes are from 1 to 30 percent.

Mereta. The Mereta series consists of soils that are shallow to a petrocalcic horizon. They are well drained, moderately slowly permeable soils that formed in loamy, calcareous, alluvium and colluvium. These nearly level to gently sloping soils are on stream terraces and alluvial fans. Slopes range from 0 to 5 percent.

Kimbrough. The Kimbrough series consists of soils that are very shallow to shallow to a petrocalcic horizon. They are well drained, calcareous, gravelly soils that formed in moderately fine textured eolian sediments of the Blackwater Draw Formation of

Pleistocene age. These soils are typically on gently sloping plains, narrow ridges, and side slopes along draws. Slope ranges from 0 to 3 percent.

Land Use/Land Cover

Figure CO-3 shows the areas of heavy and moderate brush (oak not included) in the Main Concho River Watershed. This is the area of brush removed or treated in the no-brush simulation.

Ponds and Reservoirs

Surface area, storage, and drainage area were obtained from the Texas Natural Resource Conservation Commission (TNRCC) for existing inventory-sized ponds and reservoirs in the watershed (Figure CO-4), and input to the SWAT model. The stream network and O. H. Ivie Reservoir are also shown in this figure.

Model Input Variables

Significant input variables for the SWAT model for the Main Concho River Watershed are shown in Table CO-1. Input variables were adjusted as needed by subbasin in order to calibrate flow at the USGS stream gauge. The calibration simulation represents the current "with brush" condition.

The input variables for the no-brush condition, with one exception, were the same as the calibration variables, with the change in landuse being the only difference between the two simulations. The exception is that we assumed the shallow aquifer re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and the opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units (HRU – combinations of soil and land use/cover) is 0.4, and for non-brush HRU's is 0.1.

RESULTS

Calibration

SWAT was calibrated for flow at stream gauge 08136500 (Main Concho River at Paint Rock) (Figure CO-2). Measured flow was input to SWAT for the area above gauge 08136000 (Main Concho River at San Angelo). The results of calibration are shown for the gauge on Figure CO-5. Measured and predicted total monthly flows compare reasonably well with a R^2 value of 0.67 for this gauge. The measured monthly mean is 3,923 acre-feet, and the predicted monthly mean is 3,688 acre-feet.

The predicted total flow was less than measured. This deviation is probably attributed to not accurately predicting base flow in the channel, as well as spatial variability in the precipitation data.

Brush Removal Simulation

The average annual rainfall for the Main Concho River Watershed varies from 22.2 inches in the western portion of the watershed to 25.5 inches in the eastern portion. The composite average for the entire watershed is 23.6 inches. Average annual evapo-transpiration (ET) is 22.04 inches for the brush condition (calibration) and 20.89 inches for the no-brush condition. This represents 93% and 89% of precipitation for the brush and no-brush conditions, respectively.

Figure CO-6 shows the cumulative monthly total flow to O. H. Ivie Reservoir for the brush and no-brush conditions from 1960 through 1998. The increase in water yield by subbasin for the Main Concho River Watershed is shown in Figure CO-7. The amount of annual increase varies among the subbasins and ranges from 22,527 gallons per acre of brush removed per year in subbasin number 6, to 89,889 gallons per acre in subbasin number 8. Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. Table CO-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the entire simulated watershed, the average annual water yield at the subbasin level increased by 81 % or approximately 48,523 acre-feet. The average annual flow to O. H. Ivie Reservoir increased by 37,636 acre-feet. The increase in volume of flow to O. H. Ivie Reservoir is less because of stream channel transmission losses that occur after water leaves each subbasin.

TABLE CO-1

SWAT INPUT VARIABLES FOR MAIN CONCHO RIVER WATERSHED		
VARIABLE	**BRUSH CONDITION (CALIBRATION)**	**NO BRUSH CONDITION**
Runoff Curve Number Adjustment	-6	-6
Soil Available Water Capacity Adjustment (inches H^2O/in. soil)	N/A	N/A
Soil Evaporation Compensation Factor	0.10	0.10
Min. Shallow Aqu. Storage for GW flow (inches)	0.00	0.00
Ground Water Delay (days)	35	35
Shallow Aqu. Re-Evaporation (Revap) Coefficient	0.40	0.10
Min. Shallow Aqu. Storage for Revap (inches)	0.00	0.00
Potential Heat Units (^oC)		
Heavy Juniper	4150	N/A
Heavy Mesquite	3610	N/A
Heavy Mixed Brush	3860	N/A
Moderate Juniper	3610	N/A
Moderate Mesquite	3195	N/A
Moderate Mixed Brush	3405	N/A
Heavy Oak	3610	3611
Moderate Oak	3195	3195
Light Brush & Open Range/Pasture	2820	2820
Precipitation Interception (Inches)		
Heavy Juniper	0.79	N/A
Heavy Mesquite	0.00	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Juniper	0.59	N/A
Moderate Mesquite	0.00	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0.00	0.00
Moderate Oak	0.00	0.00
Light Brush & Open Range/Pasture	0.00	0.00
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Juniper	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Juniper	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range/Pasture	1	1
Channel Transmission Loss (inches/hour)	0.04	0.04
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.00	0.00

TABLE CO-2

SUBBASIN DATA - MAIN CONCHO RIVER WATERSHED					
Subbasin	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
1	37,007	17,982	0.49	48,988	880,878,840
2	28,687	16,685	0.58	49,101	819,245,753
3	14,122	7,271	0.51	32,281	234,728,938
4	11,152	985	0.09	63,780	62,807,736
5	35,343	7,658	0.22	33,842	259,168,043
6	77,049	27,782	0.36	22,527	625,846,410
7	36,508	19,446	0.53	34,062	662,374,898
8	106,389	52,700	0.50	89,889	4,737,169,485
9	35,153	14,142	0.40	37,152	525,399,570
10	24,824	3,319	0.13	34,858	115,694,472
11	10,415	3,102	0.30	33,613	104,262,699
12	30,090	7,911	0.26	54,106	428,015,948
13	11,164	1,167	0.10	36,814	42,953,426
14	39,933	10,000	0.25	61,711	617,126,183
15	14,001	4,500	0.32	80,907	364,074,534
16	18,274	2,842	0.16	81,130	230,565,739
17	7,243	462	0.06	87,007	40,201,148
18	23,912	3,625	0.15	80,975	293,572,191
19	2,216	1,090	0.49	80,239	87,464,376
20	1,053	388	0.37	80,044	31,057,341
21	5,864	1,248	0.21	81,234	101,415,917
22	14,752	3,582	0.24	63,588	227,760,179
23	23,072	9,730	0.42	69,689	678,042,343
24	14,172	5,797	0.41	69,855	404,960,135
25	15,719	5,703	0.36	62,293	355,282,605
26	2,836	1,022	0.36	63,270	64,670,788
27	11,405	5,843	0.51	56,724	331,458,858
28	5,190	1,274	0.25	70,936	90,401,488
29	22,360	4,193	0.19	69,138	289,867,262
30	7,122	2,967	0.42	52,865	156,836,363
31	21,661	9,267	0.43	36,407	337,372,326
32	18,813	6,835	0.36	55,358	378,385,001
33	35,479	15,231	0.43	45,337	690,537,575
34	4,384	1,387	0.32	46,593	64,610,709
35	1,357	294	0.22	79,545	23,365,274
36	121	18	0.15	77,984	1,435,896
37	18,011	6,769	0.38	66,822	452,294,623
	786,854 Watershed Total	**284,217 Watershed Total**	**0.36 Watershed Average**	**55,631 Watershed Average**	**15,811,305,073 (48,523 Ac-Ft/yr.) Watershed Total**

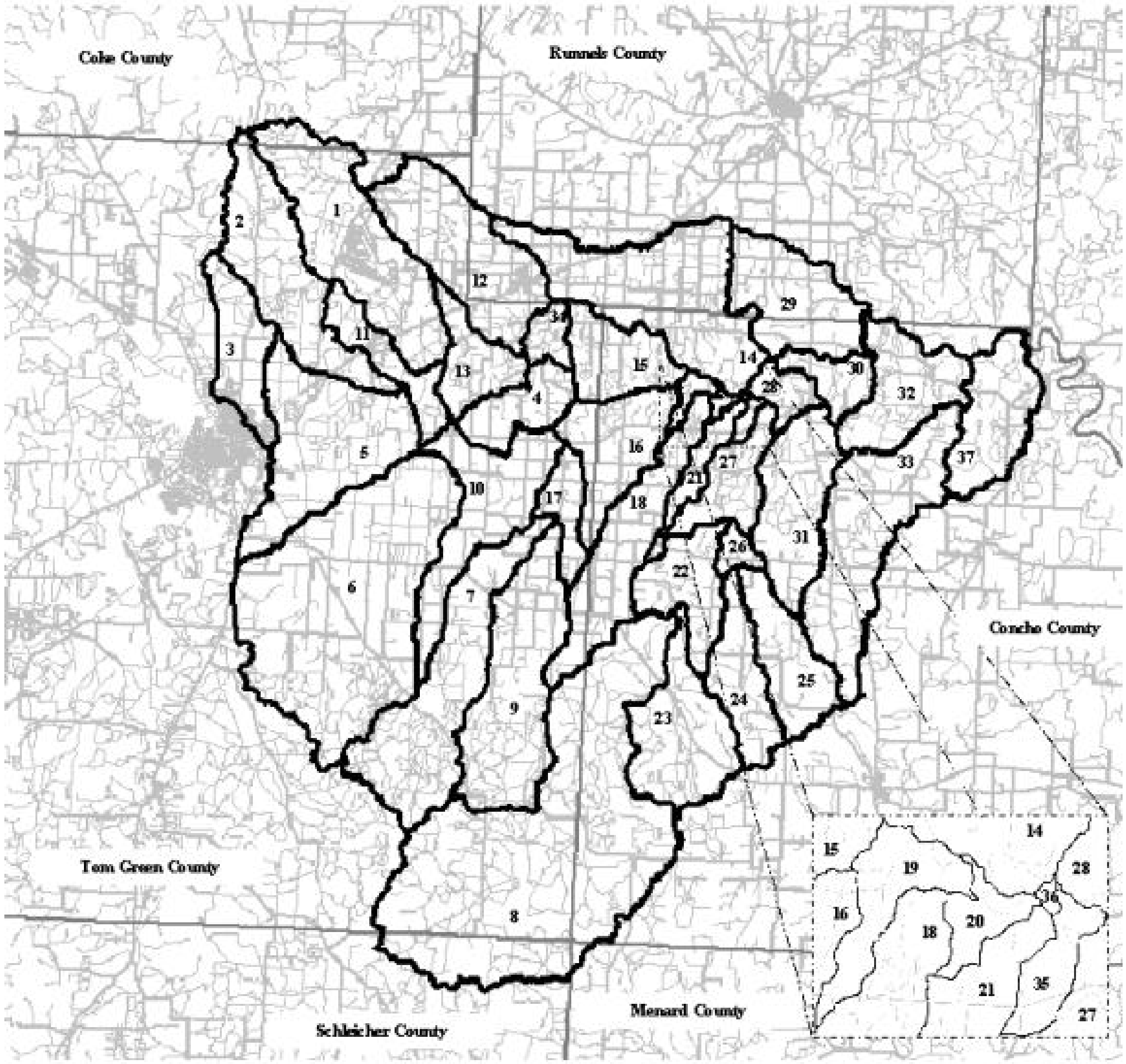


Figure CO-1. Main Concho River Watershed subbasin map.

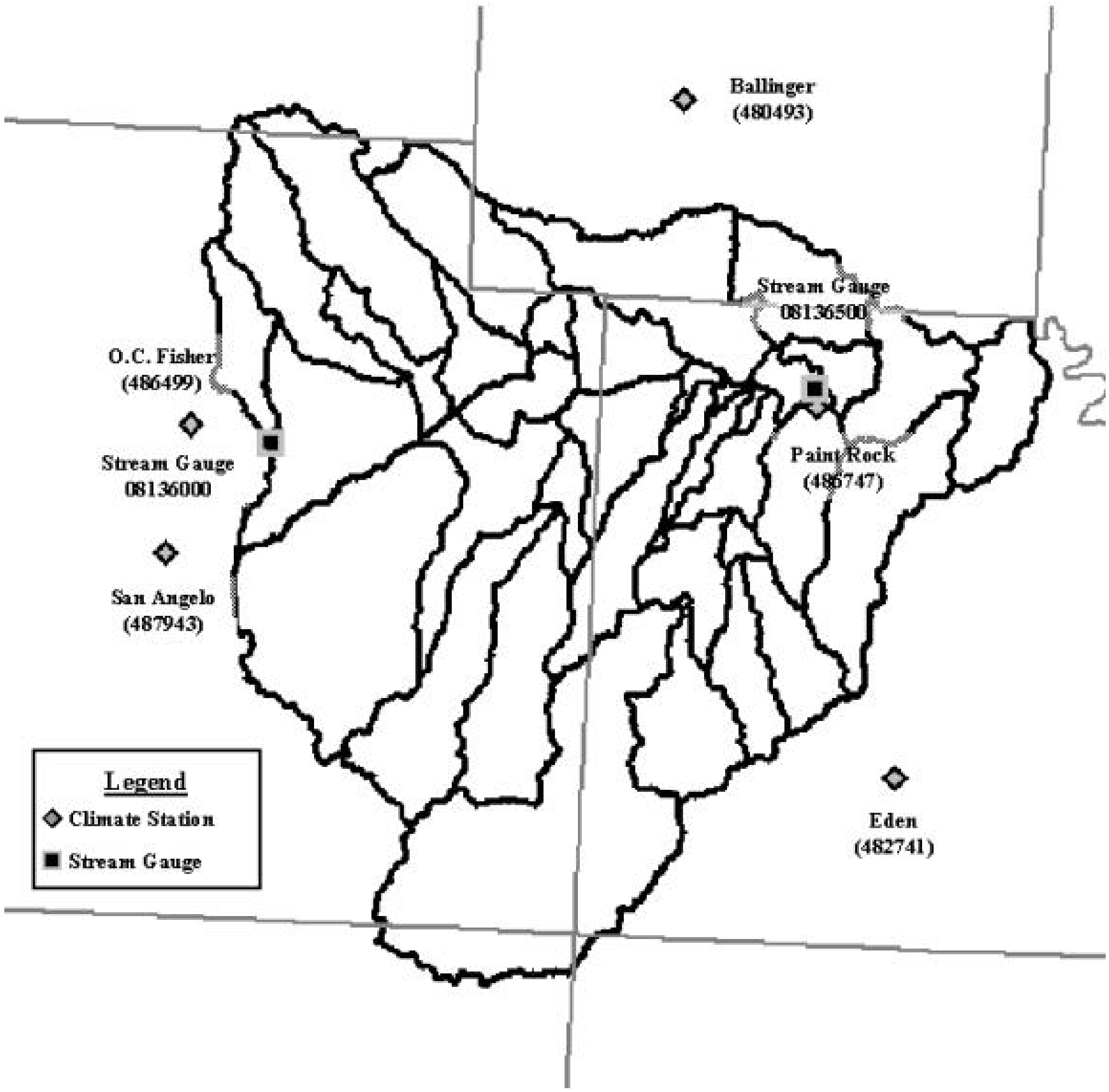


Figure CO-2. Climate and Stream Gauge stations in the Main Concho River Watershed.

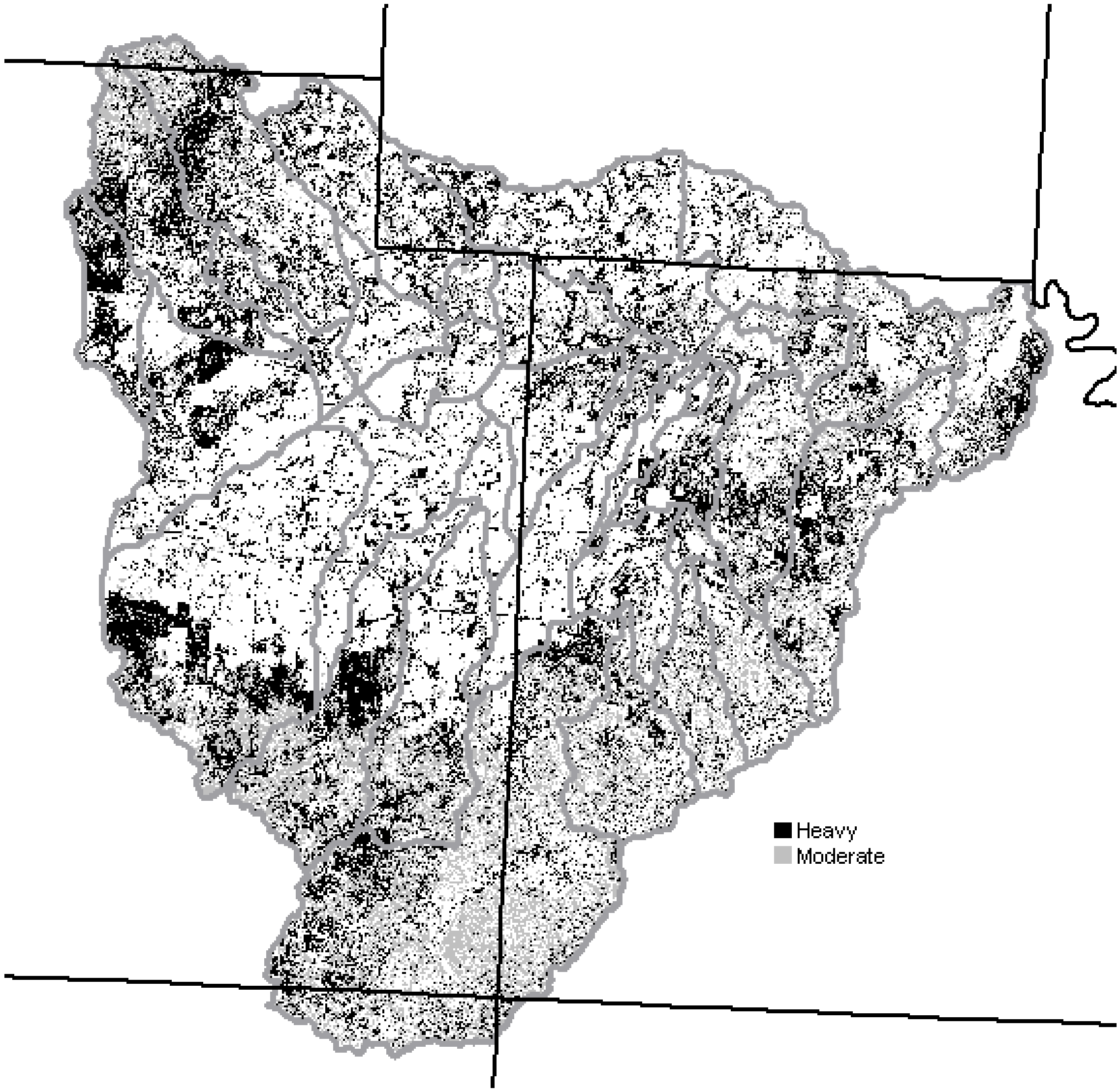


Figure CO-3. Areas of heavy and moderate brush (oak not included) in the Main Concho River Watershed.

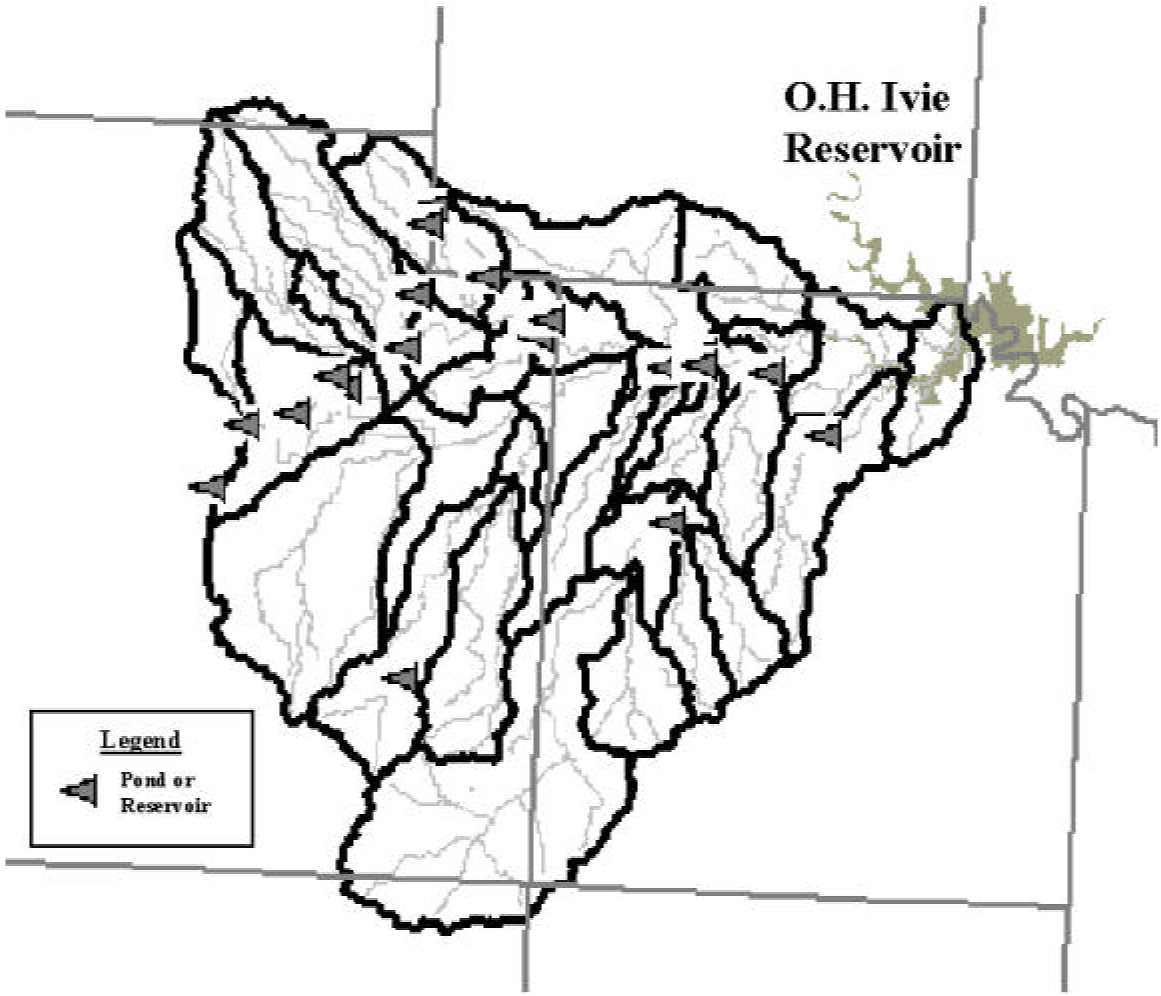


Figure CO-4. Stream network and significant ponds and reservoirs in the Main Concho River Watershed (from Texas Natural Resource Conservation Commission inventory of dams).

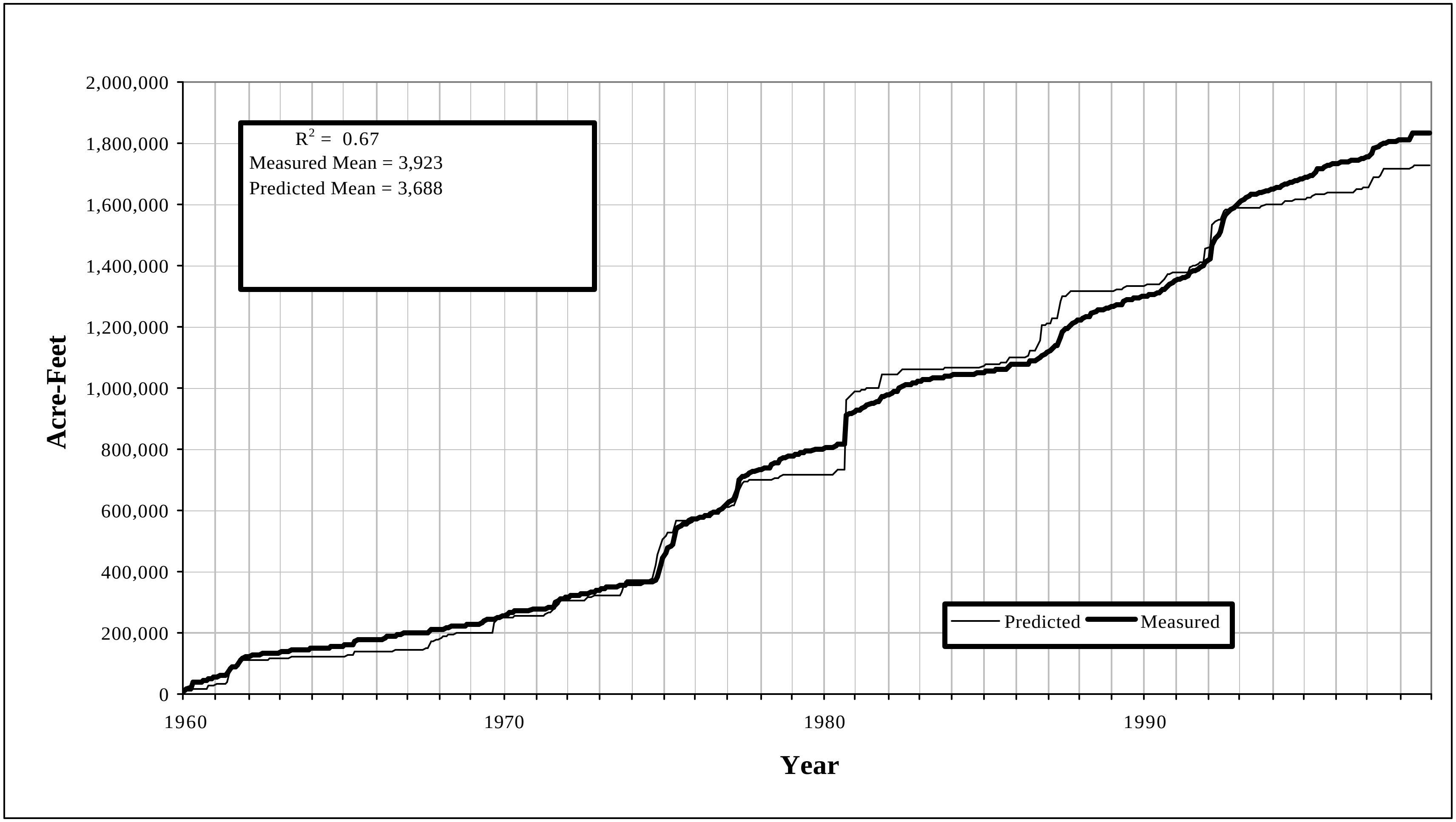


Figure CO-5. Cumulative monthly total measured and predicted stream flow at gauge 08136500 (at Paint Rock), Main Concho River Watershed, 1960 through 1998. Monthly statistics are shown in box.

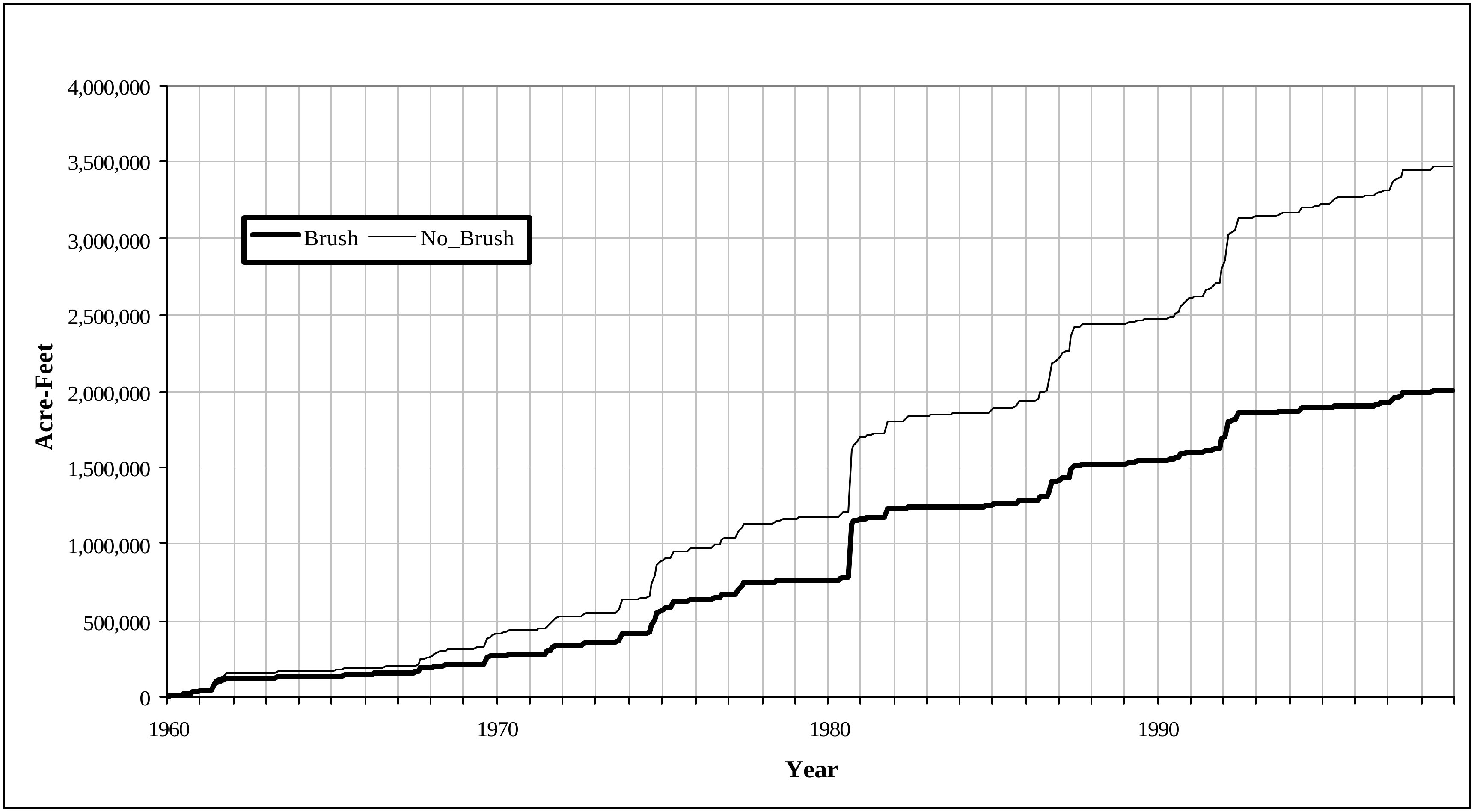


Figure CO-6. Cumulative monthly total predicted flow to O. H. Ivie Reservoir with and without brush, Main Concho River Watershed, 1960 through 1998.

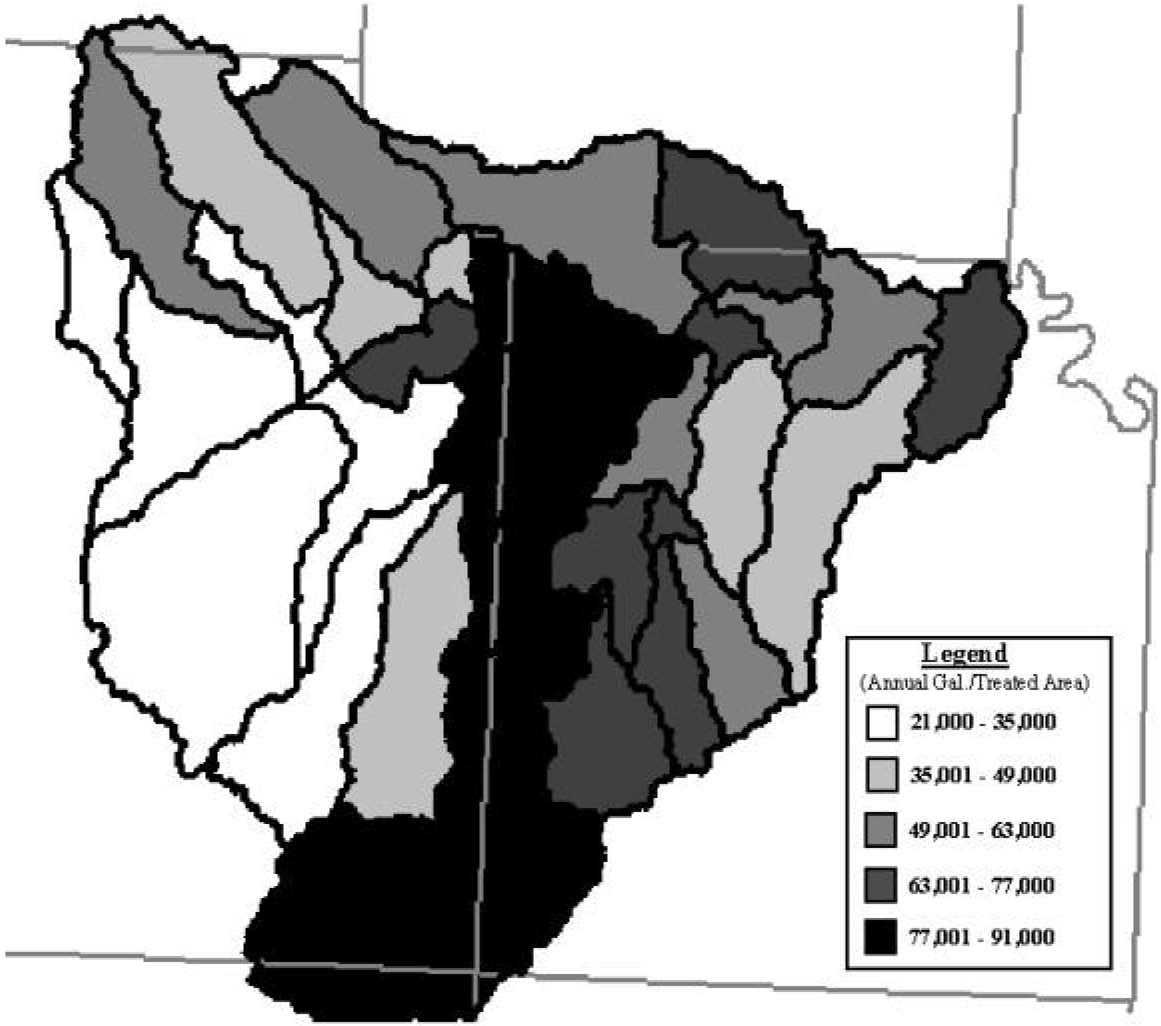
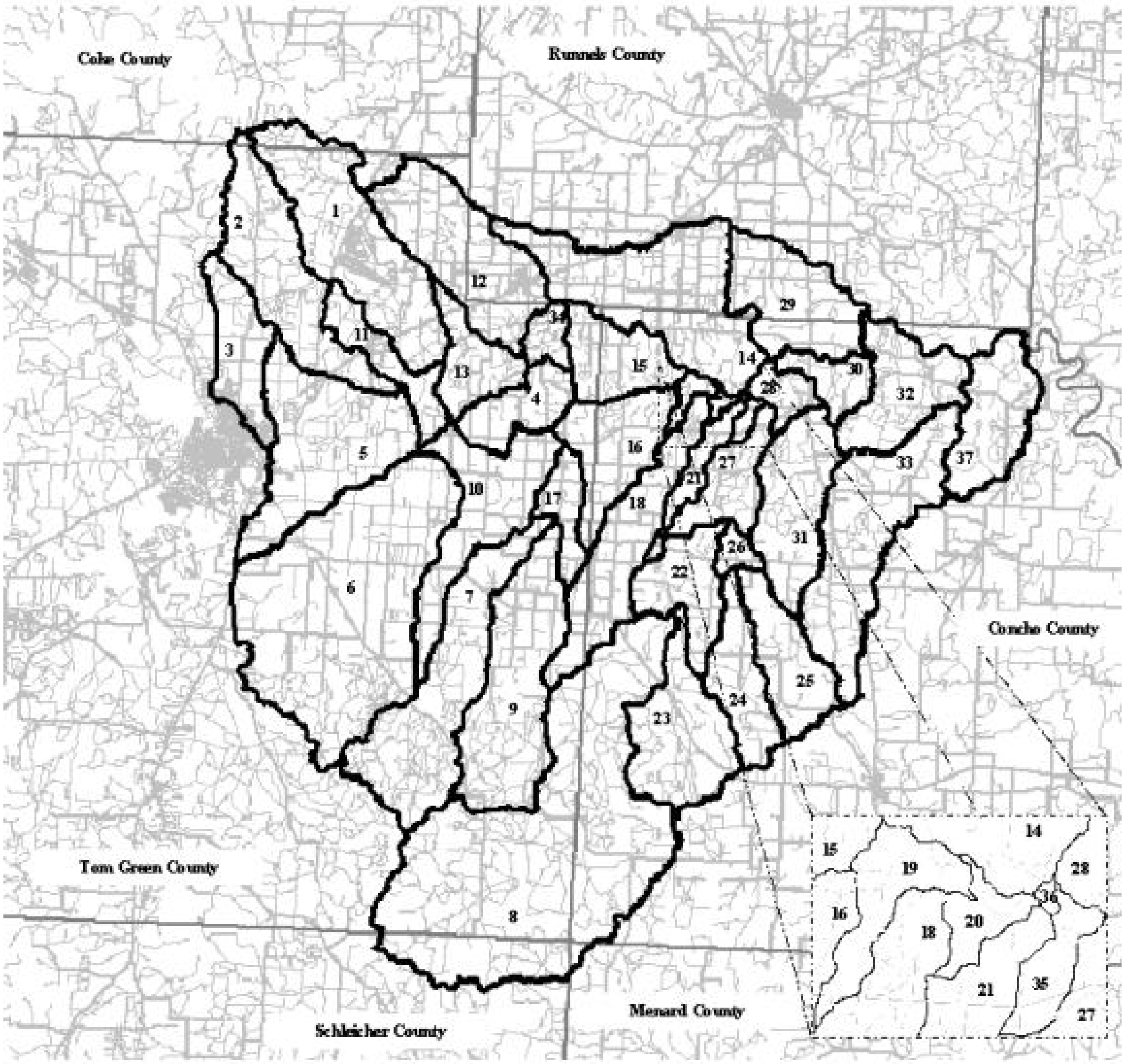


Figure CO-7. Annual increase in water yield per treated acre due to brush removal, Main Concho River Watershed, 1960 through 1998.



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CHAPTER 10

MAIN CONCHO RIVER WATERSHED - ECONOMIC ANALYSIS

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and
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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Main Concho watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs in the project area (per acre) range from $108.75 for mechanical control heavy mesquite to $39.61 for moderate mesquite that can be initially controlled with herbicide treatments. Costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Table 1.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar - Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	75.00	75.00
5	IPT or Burn	15.00	9.89
		Total	84.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Heavy Mesquite – Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	90.00	90.00
5	IPT or Burn	15.00	9.89
		Total	99.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Heavy Mesquite – Rootplow

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mechanical Rootplow	100.00	100.00
7	IPT or Burn	15.00	8.75
		Total	108.75

Heavy Mesquite -Herbicide

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Aerial Herbicide	26.00	26.00
5	Aerial Herbicide	26.00	17.70
8	IPT or Burn	15.00	7.65
		Total	51.35

Heavy Mixed – Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	90.00	90.00
5	IPT or Burn	15.00	9.89
		Total	99.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Moderate Cedar – Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	60.00	60.00
5	IPT or Burn	15.00	9.89
		Total	69.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Moderate Mesquite – Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	60.00	60.00
5	IPT or Burn	15.00	9.89
		Total	69.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Moderate Mesquite – Chemical

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Aerial Herbicide	26.00	26.00
5	IPT or Burn	20.00	13.61
		Total	39.61

Moderate Mixed – Mechanical Choice[1]

Treatment Year	Treatment Description	Treatment Cost ($/Acre)	Present Value ($/Acre)
0	Mech. Choice	60.00	60.00
5	IPT or Burn	15.00	9.89
		Total	69.89

[1] Choice of tree dozing with rake and burn, tree shearing with stump spray and later burn, or excavation and later burn.

* Main Concho River Watershed

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the watersheds draining to Lake Ivey are shown in Table 2. Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type-Density Classification	Brush Control (Or) No Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Brush Control	56.0	45.3	34.7	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	56.0	56.1	56.1	56.2	56.2	56.3	56.4	56.4	56.5	56.6
Heavy Mesquite	Brush Control	32.0	27.3	22.7	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	No Control	32.0	32.0	32.1	32.1	32.1	32.2	32.2	32.2	32.3	32.3
Heavy Mix	Brush Control	48.0	39.0	30.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
	No Control	48.0	48.1	48.1	48.2	48.2	48.3	48.3	48.4	48.4	48.5
Moderate Cedar	Brush Control	44.0	37.3	30.7	24.0	24.0	24.0	24.0	24.0	24.0	24.0
	No Control	44.0	44.2	44.5	44.7	45.0	45.2	45.5	45.7	46.0	46.2
Moderate Mesquite	Brush Control	28.0	24.7	21.3	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	No Control	28.0	28.2	28.3	28.5	28.6	28.8	28.9	29.1	29.2	29.4
Moderate Mix	Brush Control	36.0	31.0	26.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
	No Control	36.0	36.2	36.4	36.6	36.8	37.0	37.2	37.4	37.6	37.8

* Main Concho River Watershed

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. Livestock grazing capacities range from about 18 acres per AUY for land on which mesquite is controlled to 56 acres per animal unit year (AUY) for land infested with heavy cedar.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle, sheep, and goats) in the project areas is shown in Tables 3a, 3b, and 3c. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $0.50 per acre (from $8.00 per acre to $8.50 per acre) due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3a. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	382.5	Pound	.80	306.00
Cows	111.1	Pound	.40	0
Bulls	250.0	Pound	.50	0
			Total	306.00

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	480.0	Pound	0.10	48.00
Salt & Minerals	27.0	Pound	0.20	5.40
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	15.00	15.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	128.09

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
*Main Concho River Watersheds

Table 3b. Investment Analysis Budget, Sheep Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Lambs	350.0	Pound	0.85	297.50
Ewes	0.833	Head	30.00	0
Rams	0.037	Head	50.00	0
Wool	8.0	Pound	1.00	8.00
			Total	305.50

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	480.0	Pound	0.10	35.20
Salt & Minerals	27.0	Pound	0.20	18.00
Marketing	1.0	Head	1.00	5.00
Veterinary Medicine	1.0	Head	3.00	15.00
Shearing	1.2	Head	2.00	12.00
Miscellaneous	1.0	Head	1.00	6.00
Net Replacement Ewes[3]	1.0	Head	34.80	34.80
Net Replacement Rams[4]	1.0	Head	7.08	7.80
			Total	133.80

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
*Main Concho River Watershed

Table 3c. Investment Analysis Budget, Meat Goat Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Kids	0.85	Head	50.00	255.00
Nannies	0.167	Head	25.00	0
Bucks	0.0076	Head	50.00	0
			Total	$255.00

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	384.0	Pound	0.10	38.40
Salt & Minerals	73.5	Pound	0.20	14.70
Marketing	1.0	Head	1.00	6.00
Veterinary Medicine	1.0	Head	2.50	15.00
Miscellaneous	1.0	Head	1.17	7.00
Net Replacement Nannies[3]	1.0	Head	36.48	36.48
Net Replacement Bucks[4]	1.0	Head	4.74	4.74
			Total	$122.32

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
*Main Concho River Watershed

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $10.92 per acre for control of moderate mixed brush to $17.22 per acre for the control of heavy mesquite (Table 4).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the project area range from $27.54 for control of moderate mesquite with chemical treatments to $91.53 for control of heavy mesquite by mechanical method. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Table 4.

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush Category by Type & Density	PV Total Cost ($/Acre)	Landowner Share ($/Acre)	Landowner (Percent)	State Share ($/Acre)	State (Percent)
Heavy Cedar	84.89	14.90	17.6	69.99	82.4
Heavy Mesquite (Mechanical One)	99.89	17.22	17.2	82.67	82.8
Heavy Mesquite (Mechanical Two)	108.75	17.22	15.8	91.53	84.2
Heavy Mesquite (Chemical)	51.35	17.22	33.5	34.13	66.5
Heavy Mixed Brush	99.89	16.35	16.4	83.54	83.6
Moderate Cedar	69.89	11.32	16.2	58.57	83.8
Moderate Mesquite (Mechanical)	69.89	12.07	17.3	57.82	82.7
Moderate Mesquite (Chemical)	39.61	12.07	30.5	27.54	69.5
Moderate Mixed Brush	69.89	10.92	15.6	58.97	84.4
Average[1]	76.19	13.80	20.0	62.39	80.0

[1] Average is based on Heavy Mesquite Mechanical One and Two comprising 25% each and Heavy Mesquite Chemical comprising 50% of the cost for Heavy Mesquite control and Mechanical and Chemical comprising 50% each of cost for Moderate Mesquite control. Actual average may change depending on relative amounts of each Type- Density Category of brush.
*Main Concho River Watershed

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate). The cost of added water was determined to average $42.32 per acre-foot for the entire Main Concho Watershed (Table 5). Sub-basins range from costs per added acre-foot of $24.37 to $87.79.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	1,047,353.70	2,703.32	21,091.29	49.66
2	1,028,869.30	2,514.17	19,615.58	52.45
3	448,642.90	720.36	5,620.22	79.83
4	59,710.70	192.75	1,503.83	39.71
5	464,227.90	795.36	6,205.38	74.81
6	1,315,453.30	1,920.65	14,984.93	87.79
7	1,116,846.60	2,032.75	15,859.55	70.42
8	2,764,145.30	14,537.84	11,3424.20	24.37
9	799,961.90	1,612.39	12,579.88	63.59
10	213,940.90	355.05	2,770.13	77.23
11	210,617.40	319.97	2,496.41	84.37
12	503,224.00	1,313.53	10,248.18	49.10
13	70,743.54	131.82	1,028.45	68.79
14	639,950.70	1,893.89	14,776.14	43.31
15	277,886.30	1,117.30	8,717.20	31.88
16	172,282.00	707.58	5,520.54	31.21
17	28,006.44	123.37	962.55	29.10
18	232,453.20	900.94	7,029.13	33.07
19	66,974.94	268.42	2,094.20	31.98
20	22,065.41	95.31	743.62	29.67
21	79,795.30	311.23	2,428.25	32.86
22	215,347.00	698.97	5,453.37	39.49
23	516,527.40	2,080.84	16,234.68	31.82
24	311,794.10	1,242.78	9,696.15	32.16
25	299,018.90	1,090.32	8,506.69	35.15
26	61,344.79	198.47	1,548.44	39.62
27	345,814.80	1,017.21	7,936.27	43.57
28	76,262.28	277.43	2,164.52	35.23
29	250,709.00	889.57	6,940.43	36.12
30	161,185.60	481.31	3,755.21	42.92
31	518,303.70	1,035.36	8,077.86	64.16
32	375,339.20	1,161.22	9,059.85	41.43
33	841,688.20	2,119.18	16,533.86	50.91
34	81,932.49	198.28	1,547.00	52.96
35	17,822.28	71.71	559.45	31.86
36	0.00	4.41	34.38	0.00
37	385,728.70	1,388.04	10,829.50	35.62
Totals	$16,021,971.40	----------	378,577.30	Average: $42.32

*Main Concho River Watershed

Chapter 11

NUECES RIVER WATERSHED – HYDROLOGIC SIMULATION

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METHODS

Watershed Characteristics

The Nueces watershed covers a large area of South Texas just north of the Rio Grande River basin. It is within a semiarid climatic region with soils that are primarily Usterts and Ustalfs that generally have large cracks that persist for more than 3 months during the summer. This allows for deep infiltration of any significant rainfall during the summer months. The watershed generally runs northwest to east and drains into the junction with the Frio River just below Choke Canyon Lake. Based on the digital elevation map (DEM), the derived subbasins are shown in Figure N-1. Due to the fact part of the watershed that lies over the western part of the Edwards Aquifer recharge zone, the watershed was divided into the upper (Edwards) and lower Nueces. The upper Nueces corresponds to the 8-digit hydrologic response units (HRU) 12110101 and 12110102 and the lower corresponds to the 8-digit HRUs 12110103, 12110104, and 12110105. The stream gauge flows near Uvalde were used to calibrate the flows for the Upper Nueces and the actual flows at Uvalde were input into SWAT for the Lower Nueces.

Climate

For the simulations actual weather data from 1960-1998 were used. The model used daily maximum and minimum air temperatures, precipitation and solar radiation. Solar radiation was generated using the WGEN model based on parameters for the specific climate station. Climate stations are shown in Figure N-2. For each subbasin, precipitation and temperature data are retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin.

Topography

The outlet or "catchment" for the portion of the upper and lower Nueces River simulated in this study is Lake Corpus Christi, which is located just downstream of subbasin number 105_1. The subbasin delineation and numbers are shown in Figure N-1. Roads (obtained from the Census Bureau) are overlaid in Figure N-3.

Soils

The dominant soil series in the Nueces River watershed are Uvalde, Aguilares, Duval, Maverick, and Montell. These six soil series represent over 50 percent of the watershed area. A short description of each follows:

Uvalde. The Uvalde series consists of a deep, well-drained, moderately permeable soils formed in alluvium from limestone. These level to gently sloping or gently undulating soils are on alluvial fans or stream terraces. Slopes range from 0 to 3 percent.

Aguilares. The Aguilares series consists of deep, well drained moderately permeable soils that formed in calcareous, loamy sediments. These soils are on uplands with slopes ranging from 1 to 3 percent.

Duval. The Duval series consists of deep, well drained, moderately permeable soils that formed in sandy clay loams with interbedded sandstone on uplands. Slopes range from 1 to 5 percent.

Maverick. The Maverick series consists of moderately deep, well drained soils formed in ancient clayey marine sediments. These soils are gently rolling. Slopes range from 0 to 10 percent.

Montell. The Montell series consists of deep, moderately well drained,very slowly permeable soils that formed in ancient clayey alluvium. These soils are on nearly level to gently sloping uplands. Slopes range from 0 to about 3 percent.

Land Use/Land Cover

Figure N-4 show the areas of heavy and moderate brush in the Nueces River Watershed that is the area of brush removed or treated in the no-brush simulation.. This corresponds to 74% of the total watershed area

Model Input Variables

Significant input variables for the SWAT model for the lower Nueces River Watershed are shown in Table N-1. Input variables for all subbasins in the watershed were the same, with one exception:

Chapter 11 We assumed the re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units is 0.4, and for non-brush units is 0.1. Also, for the non-brush condition curve number increased by 4 units to account for the change from fair to good hydrologic conditions and from brush to range conditions.

NUECES RIVER WATERSHED RESULTS

Calibration

SWAT was calibrated for the flow at stream gauges near Three Rivers. The results of calibration are shown on Figures N-5. Measured and predicted average monthly flows compare reasonably well with a 4% difference between measured and simulated cumulative flow. Near Three Rivers the measured and predicted monthly mean values are 34,340 and 29,386 acre-feet, respectively. The coefficient of determination (r^2) was 0.99 between measured and simulated the Lower Nueces. Average base flow for the entire watershed is 7% of total flow.

<u>Brush Removal Simulation</u>

The average annual rainfall is 22.47 inches for the Lower Nueces. Average annual evapotranspiration in the Lower Nueces is 21.00 inches for the brush condition and 18.57 inches for the no-brush condition. This represents 93% and 83% of precipitation for the brush and no-brush conditions, respectively in the Lower Nueces.

The increases in water yield by subbasin for the Lower Nueces River Watersheds are shown in Figures N-6 and 7 and Table N-2. The amount of annual increase varies among the subbasins and ranges from 16058 gallons per acre of brush removed per year in subbasin number 103-25 to 123,654 gallons per acre in subbasin number 105-38. Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. In addition, Table N-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the lower Nueces, the increase is 105% or 653,618 acre-feet. The average annual flow to Lake Corpus Christi could increase by 523,141 acre-feet. The increase in volume of flow to Lake Corpus Christi is slightly less than the water yield because of stream channel transmission losses that occur after water leaves each subbasin and the shallow soils that allow for percolation.

TABLE N-1

SWAT INPUT VARIABLES FOR NUECES RIVER WATERSHED		
VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	-15	-15
Soil Available Water Capacity Adjustment (%)	0	0
Soil Evaporation Compensation Factor ($in^3 in^{-3}$)	0.85	0.85
Min. Shallow Aqu. Storage for GW flow (inches)	0	0
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0.3	0.3
Potential Heat Units (degree-days)		
Heavy Cedar	5399	5399
Heavy Mesquite	4697	4697
Heavy Mixed Brush	5021	5021
Moderate Cedar	4697	4697
Moderate Mesquite	4157	4157
Moderate Mixed Brush	4427	4427
Heavy Oak	4697	4697
Moderate Oak	4157	4157
Light Brush & Open Range/Pasture	3617	3617
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.02	0.02
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.07	0.07

Table N-2 Lower Nueces acres and water yield

Subbasin	Subbasin Total Area (acres)	Brush Removal Area (acres)	Fraction of Subbasin Containing Brush	Increase (gal/ac) Water Yield	Water Yield Increase (gallons/yr.)
103-1	63206	16440	0.26	86026	1414267726
103-2	7952	2905	0.37	91684	266342739
103-3	10435	3910	0.37	89360	349396301
103-4	49891	31755	0.64	60416	1918521817
103-5	2320	1959	0.84	96361	188770359
103-6	77461	34494	0.45	90364	3117000052
103-7	2596	2024	0.78	50707	102630322
103-8	81937	66467	0.81	71825	4773980675
103-9	26377	14691	0.56	39080	574126071
103-10	2638	1887	0.72	45539	85931292
103-11	29579	19072	0.64	28137	536623176
103-12	38109	25874	0.68	50970	1318786059
103-13	52121	27671	0.53	74245	2054423493
103-14	14608	8938	0.61	38736	346226694
103-15	30070	16387	0.54	31701	519492019
103-16	47699	29903	0.63	45429	1358462299
103-17	157836	113634	0.72	46968	5337149321
103-18	39715	23948	0.60	45546	1090743834
103-19	1564	1148	0.73	70391	80808611
103-20	64402	38899	0.60	35081	1364605446
103-21	42963	27350	0.64	34343	939273365
103-22	97607	77509	0.79	55359	4290798955
103-23	66803	34210	0.51	22358	764873356
103-24	21043	21043	1.00	16613	349593030
103-25	32783	17089	0.52	16058	274419236
103-26	39488	39488	1.00	16506	651803262
103-27	34124	12007	0.35	67085	805495462
104-1	23402	13619	0.58	75226	1024497674
104-2	42361	25611	0.60	74850	1916984352
104-3	1650	1041	0.63	86486	90032375
104-4	212	127	0.60	88515	11241432
104-5	287	287	1.00	90753	26046089
104-6	21708	16102	0.74	70564	1136227556
104-7	89867	89867	1.00	90165	8102852553
104-8	26547	18771	0.71	64559	1211845963
104-9	9657	7453	0.77	70867	528173810
104-10	73755	50372	0.68	65478	3298248909
104-11	120046	96431	0.80	52969	5107811496
104-12	18968	10916	0.58	62082	677691568
104-13	12335	7476	0.61	68298	510597399
104-14	37234	26098	0.70	62824	1639591212
104-15	37398	19570	0.52	63026	1233410500
104-16	76277	53800	0.71	72269	3888068842

104-17	27565	18268	0.66	60815	1110972842
104-18	27847	21759	0.78	77330	1682614641
104-19	43527	34290	0.79	61311	2102369549
104-20	31995	24694	0.77	63744	1574101832
104-21	55686	44098	0.79	64921	2862891543
104-22	134439	103047	0.77	47854	4931171272
104-23	53735	25029	0.47	96260	2409293865
105-1	109371	82739	0.76	87052	7202561755
105-2	48203	34224	0.71	89004	3046064695
105-3	107943	86808	0.80	84134	7303544423
105-4	41983	34774	0.83	74744	2599148716
105-5	1929	1632	0.85	85383	139344632
105-6	11213	11213	1.00	75080	841876886
105-7	75519	75521	1.00	80595	6086590297
105-8	8639	8639	1.00	72258	624237732
105-9	2705	2298	0.85	65399	150287923
105-10	6477	5370	0.83	73357	393925347
105-11	50691	50692	1.00	66719	3382120967
105-12	15675	12302	0.78	55455	682201622
105-13	85277	85277	1.00	72098	6148279055
105-14	81569	65835	0.81	82838	5453648088
105-15	41116	41116	1.00	46130	1896687373
105-16	35149	35150	1.00	64570	2269624484
105-17	47969	47969	1.00	65705	3151790312
105-18	4553	4552	1.00	57400	261284865
105-19	37543	37543	1.00	71071	2668235019
105-20	2290	2291	1.00	70720	162019147
105-21	175846	95449	0.54	96980	9256666848
105-22	147144	102589	0.70	92845	9524908246
105-23	33094	23046	0.70	79614	1834787913
105-24	119471	90822	0.76	99326	9021023218
105-25	45795	37941	0.83	60957	2312767883
105-26	62181	62181	1.00	56137	3490629992
105-27	26283	26283	1.00	50768	1334325721
105-28	37437	37437	1.00	58788	2200841945
105-29	60783	39211	0.65	87816	3443341892
105-30	43329	43330	1.00	90954	3941034554
105-31	9277	7552	0.81	150985	1140239767
105-32	25423	13721	0.54	129783	1780757498
105-33	27684	18744	0.68	108253	2029101374
105-34	90967	72018	0.79	109176	7862632769
105-35	35258	28171	0.80	90717	2555591663
105-36	26392	17036	0.65	97566	1662131655
105-37	27975	27975	1.00	100503	2811565745
105-38	19082	14508	0.76	123654	1793966993
105-39	36866	36866	1.00	80169	2955517041
105-40	30285	30285	1.00	83890	2540594339
105-41	31636	25103	0.79	102475	2572420628
105-42	87664	71314	0.81	56299	4014900999
105-43	60634	44439	0.73	48209	2142356683
105-44	48690	40817	0.84	59198	2416289720

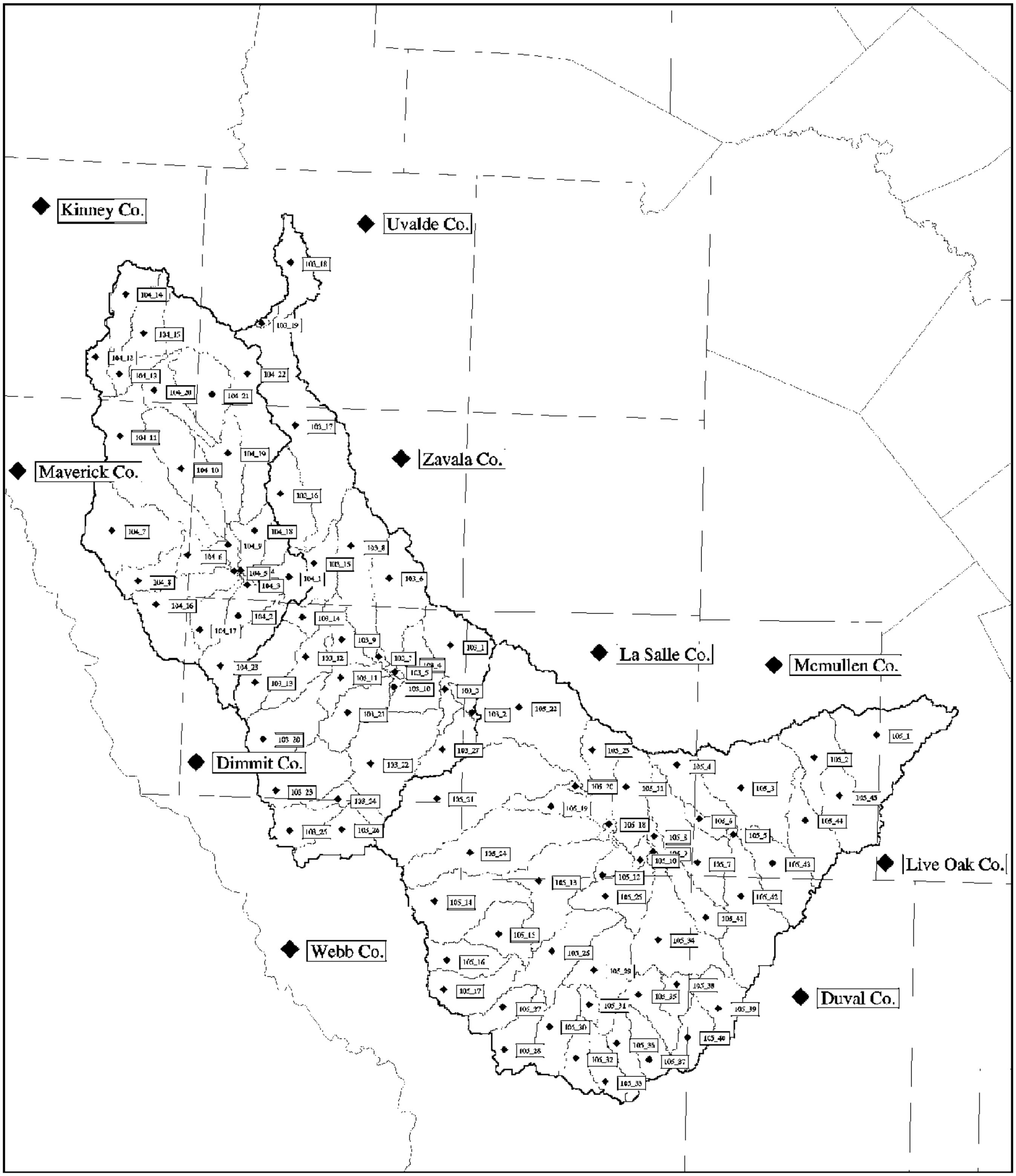

Figure N-1 Nueces River Watershed subbasin map.

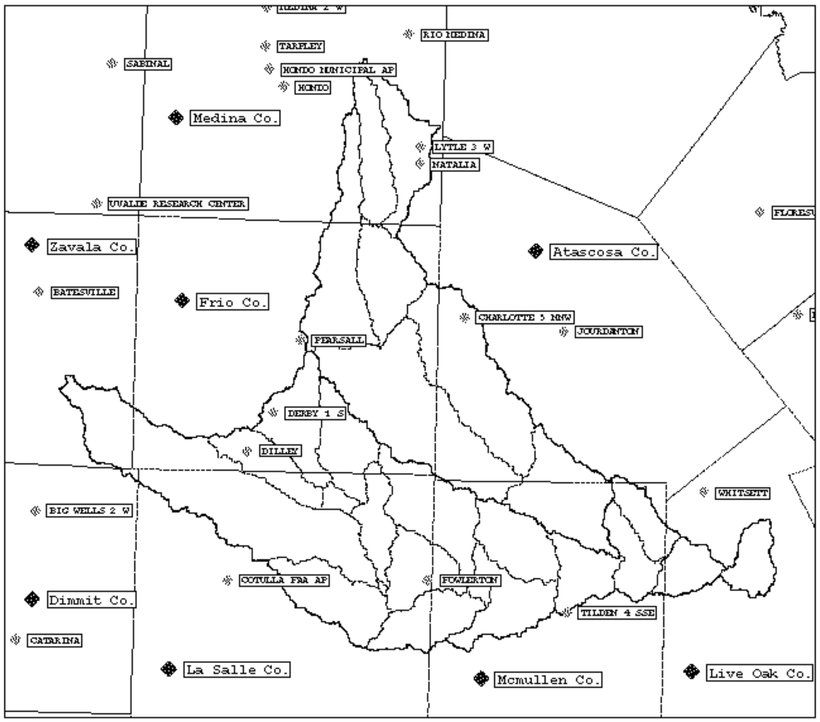

Figure N-2. Climate Stations in the Upper Nueces Watershed.

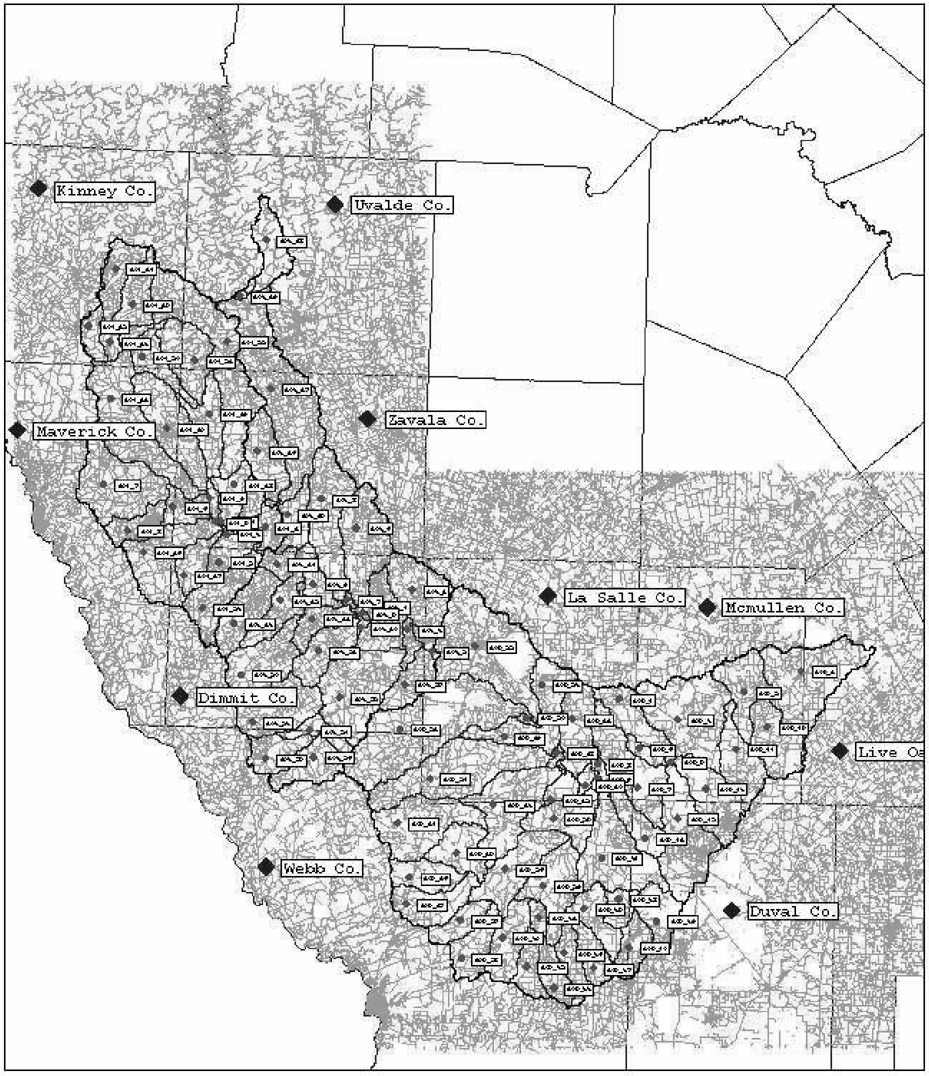

Figure N-3. Nueces River Watershed roads map.

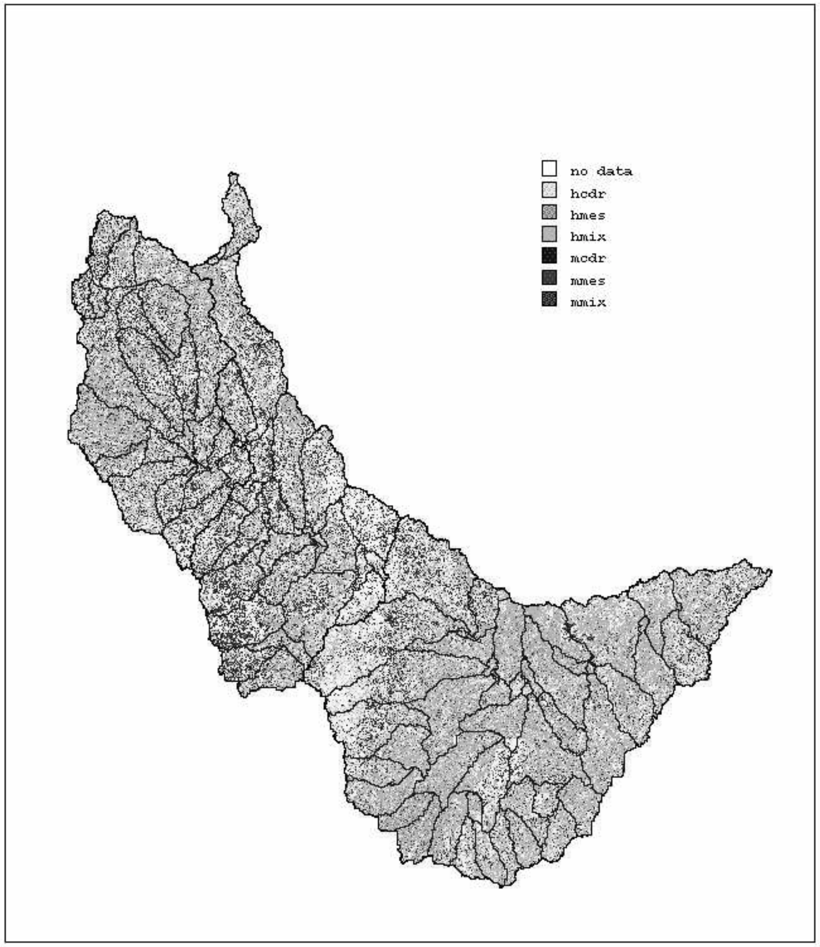

Figure N-4. Areas of heavy and moderate brush in the Nueces River Watershed.

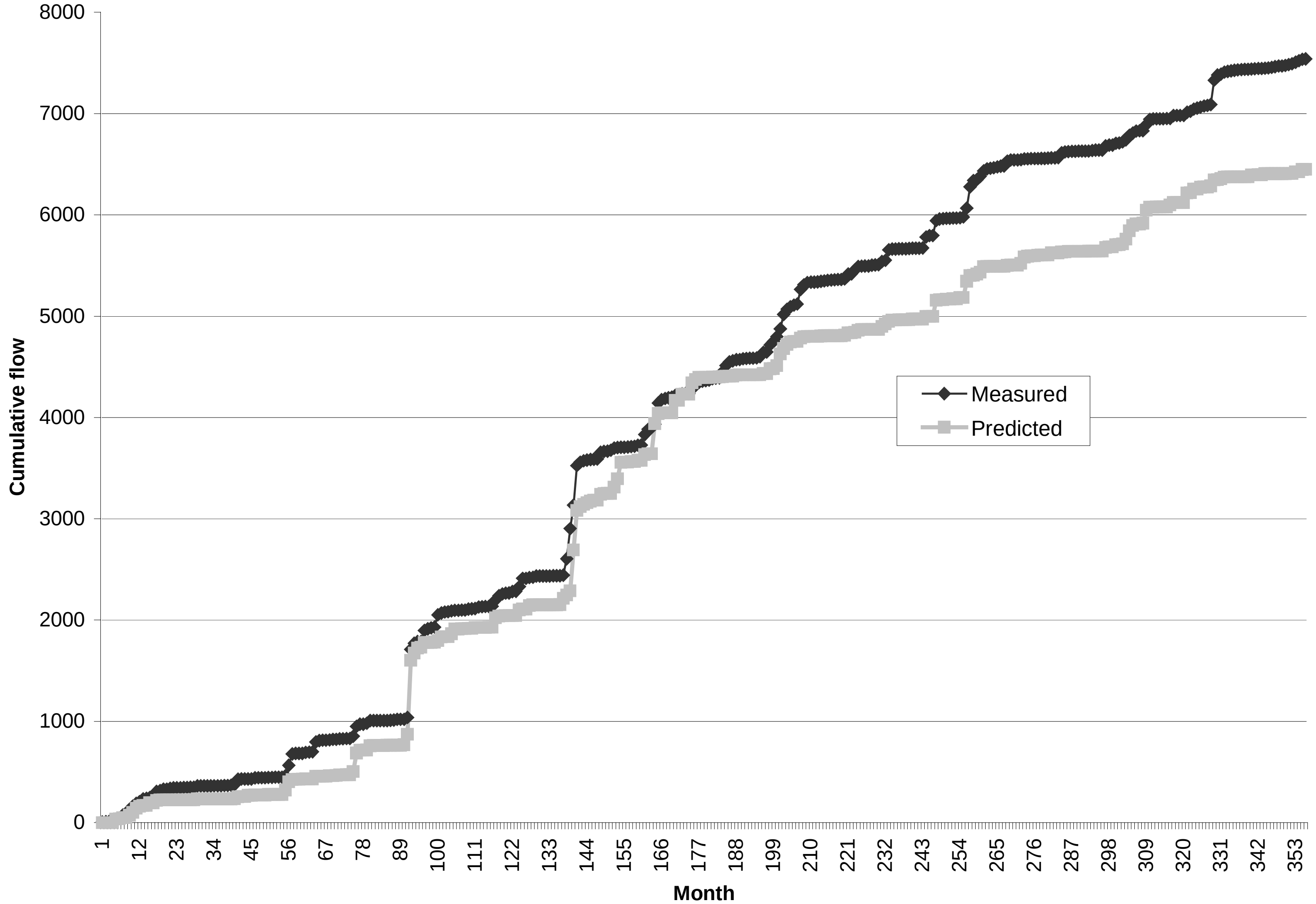

Figure N-5. Simulated and measured cumulative flow at the outlet of the Lower Nueces (Three Rivers).

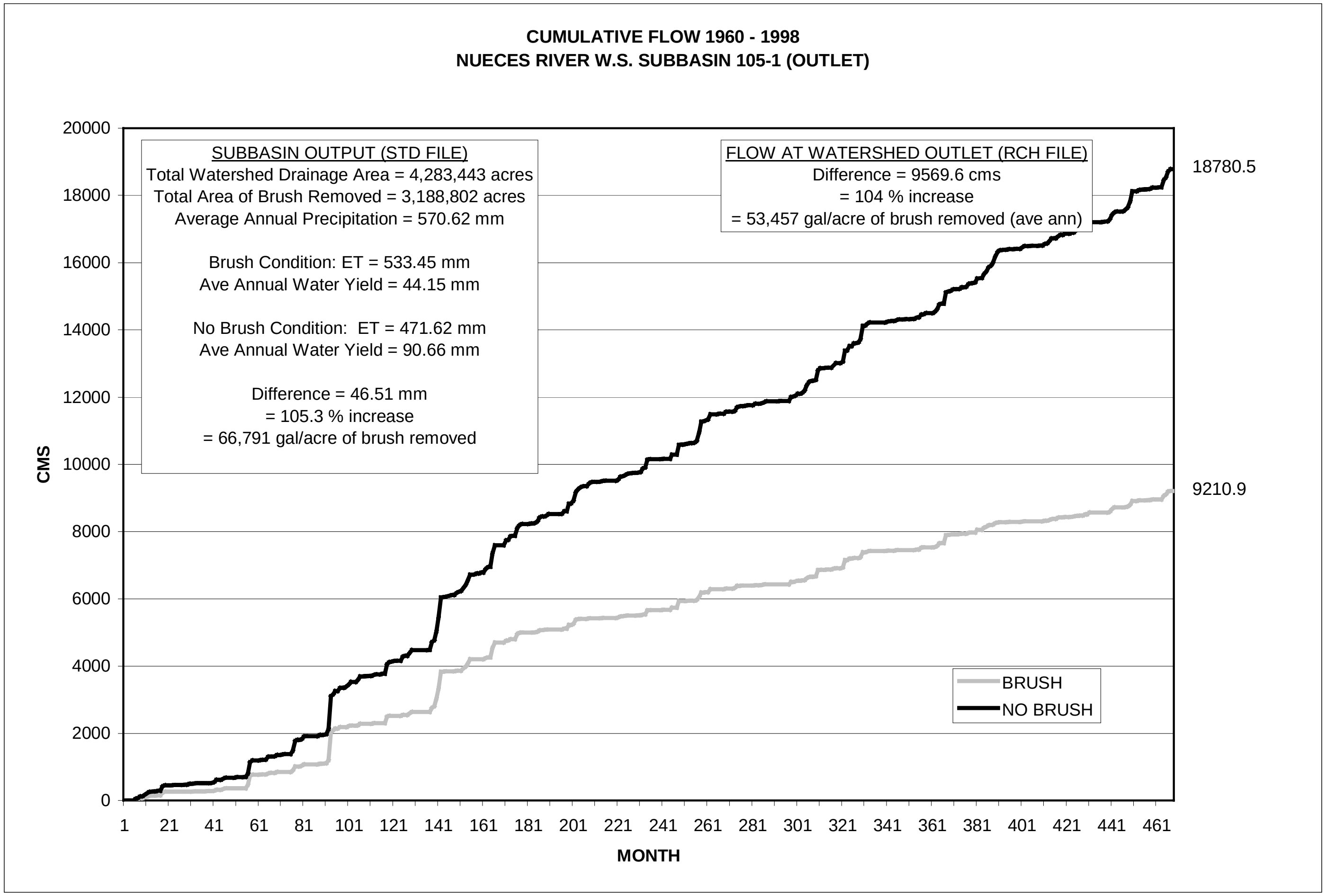

Figure N-6. Simulated cumulative flow at the outlet for brush and no brush conditions in the Lower Nueces.

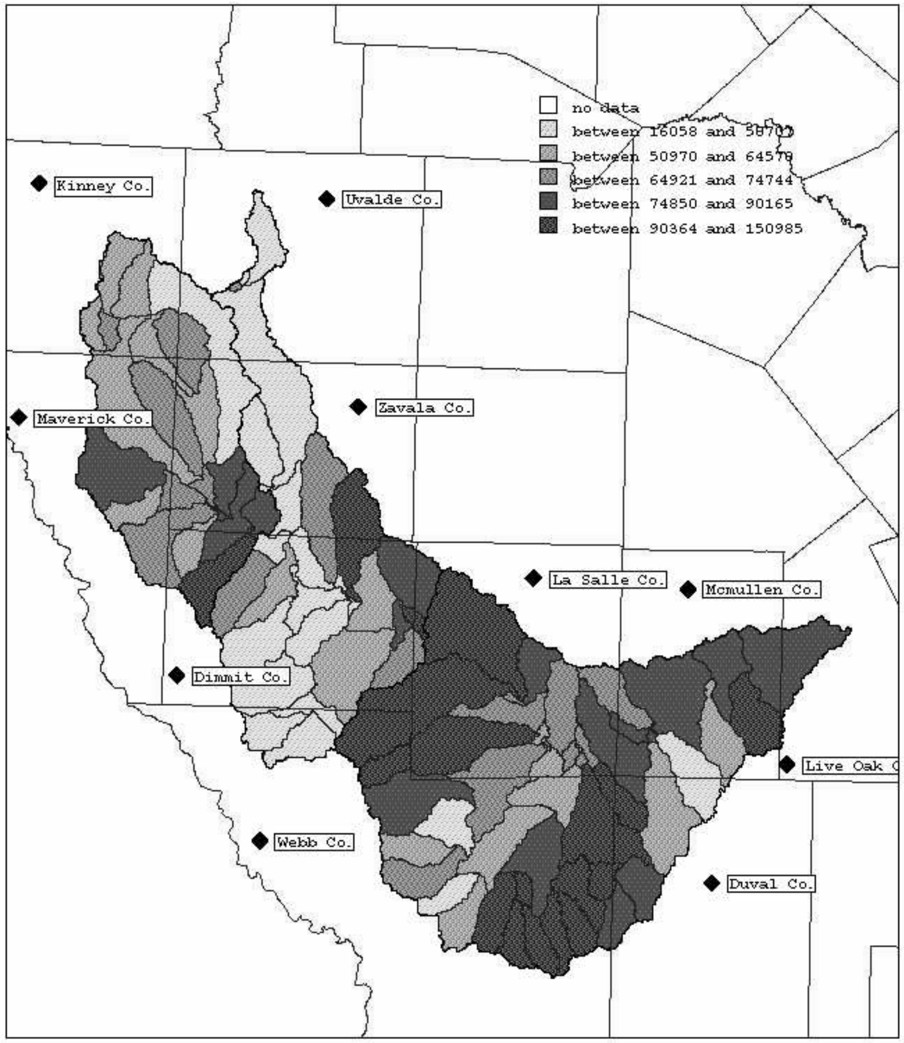

Figure N-7. Increase in water yield per treated acre (gallons/acre) due to brush removal from 1960 through 1998.

CHAPTER 12

NUECES RIVER WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the portion of the Nueces river watershed down stream of the Edwards Aquifer recharge zone.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs will vary with brush type-density categories. Present values of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Table 1a presents present values of total control costs per acre for the Northern portion of the region which consists of sub-basins with the 103 and 104 prefix . Present values of total costs range from $170.42 per acre for rootplowing with predozing for control of heavy mesquite or mixed brush to $83.99 per acre for moderate mesquite or mixed brush that can be initially controlled with herbicide treatments. Similar information is presented in Table 1b for the Southern portions of the region consisting of sub-basins with the 105 prefix. For this portion of the region, present values of total costs range from $140.42 per acre for rootplowing with predozing for control of heavy mesquite or mixed brush to $76.64 per acre for moderate mesquite that can be initially controlled with herbicide treatments. Costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Tables 1a and 1b.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	45.00	45.00
4	Chemical Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	88.99

[1] Either aerial or individual chemical application may be used.

Heavy Mesquite – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	110.00	110.00
5	Choice IPT or Burn	30.00	20.42
		Total	130.42

[1] Rootplow, rake, stack, and burn.

Extra Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	150.00	150.00
5	Choice IPT or Burn	30.00	20.42
		Total	170.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	90.00	90.00
5	Choice IPT or Burn	35.00	23.82
		Total	113.82

[1] Aerial or individual chemical application may be used.

Heavy Mixed Brush – Chop Method[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Chop Method	45.00	45.00
4	Choice Chop, IPT or Burn	45.00	33.08
7	Choice IPT or Burn	25.00	14.59
		Total	92.67

1 Choice of roller-chop, aerator method, or deep disking.

Heavy Mixed Brush – Rootplow[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Rootplow	100.00	100.00
5	IPT or Burn	30.00	20.42
		Total	120.42

[1] Rootplow, rake, stack, and burn.

Extra Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	150.00	150.00
5	IPT or Burn	30.00	20.42
		Total	170.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Table 1a. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Moderate Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.

Moderate Mixed Brush – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.

*Northern portion of Nueces River Watershed

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	45.00	45.00
4	Chemical Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	88.99

[1] Either aerial or individual chemical application may may be used.

Heavy and Extra Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	120.00	120.00
5	Choice IPT or Burn	30.00	20.42
		Total	140.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Chemical Herbicide	50.00	50.00
4	Choice Chop, IPT or Burn	60.00	44.10
7	Choice IPT or Burn	25.00	14.59
		Total	108.69

[1] Aerial or individual chemical application may be used. Year 4 choice includes chemicals, choice or chop method or burning, if effective.

Heavy Mixed Brush – Chop Method[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Choice of Chop Method	45.00	45.00
4	Choice Chop, IPT or Burn	45.00	33.08
7	Choice IPT or Burn	25.00	14.59
		Total	92.67

2 Choice of roller-chop, aerator method, or deep disking.

Table 1b. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Heavy and Extra Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Pre-doze and Rootplow	120.00	120.00
5	IPT or Burn	30.00	20.42
Note: Canopy Cover for this practice is 40% or greater		Total	140.42

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Moderate Mesquite – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	30.00	20.42
7	Choice IPT or Burn	25.00	14.59
		Total	76.64

[1] Either aerial or individual chemical application may be used.

Moderate Mixed Brush – Chemical Herbicide[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial or IPT Herbicide	40.00	40.00
4	Aerial or IPT Herbicide	40.00	29.40
7	Choice IPT or Burn	25.00	14.59
		Total	83.99

[1] Either aerial or individual chemical application may be used.
*Southern portion of Nueces River Watershed

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the Nueces River watershed are shown in Tables 2a (sub-basins 103 & 104) and 2b (sub-basin 105). Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2a. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type / Category	Brush Control	Program Year 0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Control	39.0	35.0	31.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
	No Control	39.0	39.0	39.1	39.1	39.2	39.2	39.2	39.3	39.3	39.4
Heavy Mixed Brush	Control	39.0	35.0	31.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0
	No Control	39.0	39.0	39.1	39.1	39.2	39.2	39.2	39.3	39.3	39.4
Moderate Mesquite	Control	35.0	32.3	29.7	27.0	27.0	27.0	27.0	27.0	27.0	27.0
	No Control	35.0	35.2	35.4	35.5	35.7	35.9	36.1	36.2	36.4	36.6
Moderate Mixed Brush	Control	35.0	32.3	29.7	27.0	27.0	27.0	27.0	27.0	27.0	27.0
	No Control	35.0	35.2	35.4	35.5	35.7	35.9	36.1	36.2	36.4	36.6

*Northern portion of Nueces River Watershed

Table 2b. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type / Category	Brush Control	Program Year 0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Control	41.0	36.0	31.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
	No Control	41.0	41.0	41.1	41.1	41.2	41.2	41.3	41.3	41.3	41.4
Heavy Mixed Brush	Control	38.0	34.0	30.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
	No Control	38.0	38.0	38.1	38.1	38.2	38.2	38.2	38.3	38.3	38.4
Moderate Mesquite	Control	33.0	30.6	28.3	26.0	26.0	26.0	26.0	26.0	26.0	26.0
	No Control	33.0	33.2	33.3	33.5	33.7	33.8	34.0	34.2	34.3	34.5
Moderate Mixed Brush	Control	33.0	30.6	28.3	26.0	26.0	26.0	26.0	26.0	26.0	26.0
	No Control	33.0	33.2	33.3	33.5	33.7	33.8	34.0	34.2	34.3	34.5

*Southern portion of Nueces River Watershed

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. In the Northern portion of the watershed livestock grazing capacities range from about 27 acres per AUY for land on which mesquite is controlled to 39 acres per animal unit year (AUY) for land infested with heavy mixed brush. In the Southern portion of the watershed livestock grazing capacities range from about 26 acres per AUY for land on which mesquite is controlled to 41 acres per animal unit year (AUY) for land infested with heavy mesquite.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle) in the project areas is shown in Table 3. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $1.50 per acre (from $10.00 per acre to $11.50 per acre) due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	425.00	Pound	.85	361.25
Cows	111.1	Pound	.40	0
Bulls	250.0	Pound	.50	0
			Total	361.25

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	400.0	Pound	0.10	40.00
Salt & Minerals	50.0	Pound	0.20	10.00
Marketing	1.0	Head	6.25	6.25
Veterinary Medicine	1.0	Head	12.00	12.00
Miscellaneous	1.0	Head	5.00	5.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	114.62

Note: This budget is for presentation of the information used in the investment analysis only. Values herein are representative of a typical ranch in the Lower Frio and Nueces Watersheds. The budget is based on 1 cow-calf pair per animal unit. Variable costs listed here include only items which change as a result of implementing a brush control program and adjusting livestock numbers to meet changes in grazing capacity. Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included, nor have fixed costs been considered.

* Nueces River watershed.

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. In the Northern portion of the watershed they range from $19.73 per acre for control of moderate mesquite and mixed brush to $34.49 per acre for the control of heavy mesquite and mixed brush (Table 4a). In the Southern portion of the watershed they range from $17.14 per acre for control of moderate mesquite and mixed brush to $36.53 per acre for the control of heavy mixed brush (Table 4b).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the Northern portion of the project area range from $54.50 for control of heavy mesquite with chemical treatments to $135.93 for control of heavy mesquite and mixed brush by mechanical method. State per acre cost share of brush control in the Southern portion of the project area range from $53.30 for control of heavy mesquite with chemical treatments to $104.73 for control of heavy mesquite brush by mechanical method. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Tables 4a and 4b.

Table 4a. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control Practice	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Mesquite	Chemical	88.99	34.49	0.39	54.5	0.61
	Rootplow	130.42		0.26	95.93	0.74
	Doze & Plow[1]	170.42		0.20	135.93	0.80
Heavy Mixed Brush	Chemical	113.82	34.49	0.30	79.33	0.70
	Chop[2]	92.67		0.37	58.18	0.63
	Rootplow	120.42		0.29	85.93	0.71
	Doze & Plow[1]	170.42		0.20	135.93	0.80
Moderate Mesquite	Treatment Choice	83.99	19.73	0.23	64.26	0.77
Moderate Mixed Brush	Treatment Choice	83.99		0.23	64.26	0.77
Average		117.24	31.21	0.28	86.03	0.72

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise venture of 100% cow-calf cattle. In this region, 20% of typical ranch resources are assigned to wildlife production, but this budget is based on a 100% assignment of carrying capacity to the livestock operation.

[1] The (pre)doze and plow category is for extra heavy brush canopy cover classifications in excess of 40% canopy cover.

[2] The "Chop" category is for roller chopping, heavy disking, or for the use of heavy "aerator"-type treatments. This category is not for use in areas where mesquite or other plants which sprout from the root crown, unless additional means for controlling those plants are used.

*Northern portion of Nueces River Watershed

Table 4b. Landowner / State Cost-Shares of Brush Control*

Brush Type & Density	Control	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher % Percent	State Share ($/Acre)	State % Percent
Heavy Mesquite	Chemical	88.99	35.69	0.40	53.3	0.60
	Doze & Plow[1]	140.42		0.25	104.73	0.75
Heavy Mixed Brush	Chemical (Chop)[2]	108.69	36.53	0.34	72.16	0.66
	Chop[3]	92.67		0.39	56.14	0.61
	Doze & Plow[1]	140.42		0.26	103.89	0.74
Moderate Mesquite	Treatment Choice	76.64	17.14	0.22	59.5	0.78
Moderate Mixed Brush	Treatment Choice	83.99		0.20	66.85	0.80
Average		104.55	30.75	0.30	73.80	0.70

Note: Averages are simple averages, and do not reflect actual project averages based on the relative percent of each brush category. Rancher ability to pay is based on the net present value of a 10 year income stream which is realized by engaging in an production agriculture enterprise venture of 100% cow-calf cattle. In this region, 20% of typical ranch resources are assigned to wildlife production, but this budget is based on a 100% assignment of carrying capacity to the livestock operation.

[1] The (pre)doze and plow category is for extra heavy brush canopy cover classifications in excess of 40% canopy cover. However, only one category of cost was included for all rootplow treatment options.. A cost average between heavy and extra heavy was used.

[2] This chemical treatment can be used in combinations of chemical or mechanical chop methods for retreatments.

[3] The "Chop" category is for roller chopping, heavy disking, or for the use of heavy "aerator"-type treatments. This category is not for use in areas where mesquite or other plants which sprout from the root crown, unless additional means for controlling those plants

*Southern portion of Nueces River Watershed

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water was determined to average $46.62per acre foot for the entire Nueces Watershed (Table 5). Sub-basins range from costs per added acre foot of $17.91 to $210.72.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin	Total State Cost ($)	Avg. Annyual Gallon Increase	Avg. Annual Ac.Ft. Incr.	Added Ac.Ft 10Yr. Disctd	St. Cost per Ac.Ft. Added Water ($)
103-1	1056370.14	1414267725.54	4340.23	33862.46	31.20
103-2	232591.4	266342739.08	817.38	6377.17	36.47
103-3	304834.22	349396300.51	1072.26	8365.76	36.44
103-4	2567728.32	1918521816.63	5887.73	45936.05	55.90
103-5	175906.72	188770359.24	579.31	4519.82	38.92
103-6	2703524.08	3117000052.05	9565.72	74631.76	36.22
103-7	159824.26	102630321.75	314.96	2457.32	65.04
103-8	5487458.5	4773980674.51	14650.81	114305.61	48.01
103-9	1140984.08	574126070.86	1761.93	13746.56	83.00
103-10	169528.08	85931291.87	263.71	2057.49	82.40
103-11	1573902.06	536623175.82	1646.84	12848.61	122.50
103-12	1984420.34	1318786059.44	4047.21	31576.30	62.85
103-13	2057829.56	2054423492.56	6304.79	49190.00	41.83
103-14	681075.02	346226693.95	1062.53	8289.86	82.16
103-15	1166706.14	519492019.20	1594.26	12438.44	93.80
103-16	2400807.46	1358462299.40	4168.97	32526.29	73.81
103-17	9283966.92	5337149321.29	16379.11	127789.81	72.65
103-18	2151308.64	1090743834.07	3347.37	26116.18	82.37
103-19	103136.32	80808610.53	247.99	1934.84	53.30
103-20	2772088.6	1364605446.00	4187.82	32673.37	84.84
103-21	2176805.26	939273365.13	2882.52	22489.45	96.79
103-22	6341224.36	4290798954.93	13167.98	102736.57	61.72
103-23	2525872.78	764873355.71	2347.31	18313.71	137.92
103-24	1755823.8	349593029.84	1072.86	8370.47	209.76
103-25	1291357.36	274419236.21	842.16	6570.55	196.54
103-26	3288577.6	651803261.83	2000.31	15606.42	210.72
103-27	345333.24	805495461.58	2471.97	19286.35	17.91
104-1	995370.46	1024497673.64	3144.07	24530.02	40.58
104-2	2036292.72	1916984351.55	5883.01	45899.24	44.36

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) (Continued)

Subbasin	Total State Cost ($)	Avg. Annyual Gallon Increase	Avg. Annual Ac.Ft. Incr.	Added Ac.Ft 10Yr. Disctd	St. Cost per Ac.Ft. Added Water ($)
104-3	80132	90032374.72	276.30	2155.69	37.17
104-4	10322.22	11241431.87	34.50	269.16	38.35
104-5	24505.08	26046089.33	79.93	623.63	39.29
104-6	1316272.96	1136227555.62	3486.95	27205.22	48.38
104-7	8073651.28	8102852553.30	24866.74	194010.32	41.61
104-8	1686386.64	1211845962.67	3719.02	29015.78	58.12
104-9	628099.24	528173810.22	1620.91	12646.31	49.67
104-10	4161225.54	3298248908.54	10121.95	78971.49	52.69
104-11	8663361.04	5107811496.10	15675.30	122298.67	70.84
104-12	836396.66	677691567.87	2079.76	16226.28	51.55
104-13	621123.34	510597398.72	1566.97	12225.47	50.81
104-14	2147678.32	1639591211.81	5031.72	39257.48	54.71
104-15	1758168.8	1233410499.62	3785.20	29532.11	59.53
104-16	4454628.94	3888068842.33	11932.05	93093.82	47.85
104-17	1418228.74	1110972841.62	3409.45	26600.53	53.32
104-18	1792497.88	1682614640.70	5163.75	40287.61	44.49
104-19	2748009.96	2102369548.66	6451.94	50338.00	54.59
104-20	1941567.4	1574101831.77	4830.74	37689.44	51.51
104-21	3961764.32	2862891542.71	8785.89	68547.53	57.80
104-22	9257742.48	4931171271.75	15133.21	118069.30	78.41
104-23	1913725.1	2409293865.36	7393.85	57686.83	33.17
105-1	6403998.6	7202561754.64	22103.85	172454.24	37.13
105-2	2648937.6	3046064694.75	9348.03	72933.32	36.32
105-3	6718939.2	7303544422.78	22413.75	174872.12	38.42
105-4	2691507.6	2599148716.16	7976.49	62232.61	43.25
105-5	126316.8	139344631.70	427.63	3336.39	37.86
105-6	639014.4	841876886.09	2583.63	20157.44	31.70
105-7	4495546.8	6086590296.67	18679.06	145734.02	30.85
105-8	418966.2	624237731.85	1915.72	14946.41	28.03
105-9	178767.18	150287922.74	461.22	3598.41	49.68
105-10	417904.02	393925347.04	1208.91	9431.94	44.31
105-11	3939772.14	3382120967.48	10379.35	80979.67	48.65
105-12	956788.56	682201621.53	2093.60	16334.27	58.58
105-13	6646415.4	6148279054.56	18868.38	147211.07	45.15
105-14	4886169.3	5453648088.24	16736.63	130579.20	37.42
105-15	3198251.16	1896687372.85	5820.72	45413.26	70.43
105-16	2641917.55	2269624483.79	6965.22	54342.66	48.62
105-17	3732538.68	3151790312.35	9672.49	75464.76	49.46
105-18	352402.2	261284864.47	801.85	6256.06	56.33
105-19	2917719	2668235018.71	8188.51	63886.78	45.67
105-20	171190.3	162019146.73	497.22	3879.30	44.13
105-21	6995387.55	9256666847.58	28407.67	221636.62	31.56
105-22	7430127.3	9524908246.03	29230.87	228059.25	32.58
105-23	1783837.8	1834787912.96	5630.76	43931.17	40.61
105-24	6778096.7	9021023218	27684.50	215994.50	31.38
105-25	2951419.14	2312767883	7097.62	55375.66	53.30
105-26	4838710.32	3490629992	10712.35	83577.76	57.89
105-27	2052765.72	1134325721	3481.12	27159.68	75.58
105-28	2919049.92	2200841945	6754.14	52695.77	55.39
105-29	3034931.4	3443341892	10567.23	82445.51	36.81

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) (Continued)

Subbasin	Total State Cost ($)	Avg. Annyual Gallon Increase	Avg. Annual Ac.Ft. Incr.	Added Ac.Ft 10Yr. Disctd	St. Cost per Ac.Ft. Added Water ($)
105-30	3367436.22	3941034554	12094.59	94362.00	35.69
105-31	584524.8	1140239767	3499.27	27301.28	21.41
105-32	1062005.4	1780757498	5464.94	42637.49	24.91
105-33	1450863	2029101374	6227.08	48583.71	29.86
105-34	5574193.2	7862632769	24129.53	188258.62	29.61
105-35	2180435.4	2555591663	7842.82	61189.70	35.63
105-36	1318586.4	1662131655	5100.89	39797.18	33.13
105-37	2165265	2811565745	8628.38	67318.61	32.16
105-38	1122919.2	1793966993	5505.48	42953.77	26.14
105-39	2853428.4	2955517041	9070.15	70765.30	40.32
105-40	2344059	2540594339	7796.80	60830.62	38.53
105-41	1942972.2	2572420628	7894.47	61592.65	31.55
105-42	5519703.6	4014900999	12321.28	96130.62	57.42
105-43	3439578.6	2142356683	6574.65	51295.43	67.05
105-44	3159235.8	2416289720	7415.32	57854.33	54.61
105-45	2832143.4	3413799468	10476.57	81738.17	34.65
Total	250310874.5			5369726.49	
Average					$46.62

*Nueces River watershed

CHAPTER 13

PEDERNALES RIVER WATERSHED – HYDROLOGIC SIMULATION

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METHODS

Climate

For the simulations actual weather data from 1960-1998 were used. The model used daily maximum and minimum air temperatures, precipitation and solar radiation. Solar radiation was generated using the WGEN model based on parameters for the specific climate station. Climate stations are shown in Figure P-1. For each subbasin, precipitation and temperature data are retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin.

Topography

The outlet or "catchment" for the portion of the Pedernales River simulated in this study is Lake Travis, which is located in subbasin number 1. The subbasin delineation and numbers are shown in Figure P-2. Roads (obtained from the Census Bureau) are overlaid in Figure P-3.

Soils

The dominant soil series in the Pedernales River watershed are Tarrant, Brackett, Doss, Hensley, and Purves. These six soil series represent about 56 percent of the watershed area. A short description of each follows:

Tarrant. The Tarrant series consists of a very shallow and shallow, well drained, moderately slow permeable soils formed in residum from limestone, and includes interbedded marls, shalks, and marly materials. These upland soils have slopes ranging from 1 to 50 percent.

Brackett. The Brackett series consists of deep, well drained moderately permeable soils that formed in marly loamy earth interbedded with chalky limestone. These soils are on uplands with slopes ranging from 1 to 30 percent.

Doss. The Doss series consists of shallow, well drained moderately slow permeable soils that formed in marls and limestone. The soils are on gently sloping to slopint uplands. Slopes range from 1 to 8 percent.

Hensley. The Hensley series consists of shallow, well draijned, slowly permeable soils fromed in residuum of weathered limestone. These upland soils hav slopes ranging from 0 to 5 percent.

Purves. The Purves series consists of shallow, well drained moderately slowly permeable soils that formed in interbedded limestone and marl. These upland soils have slopes mainly of 1 to 5 percent, but the range is 1 to 40 percent.

Land Use/Land Cover
Figure P-4 shows the areas of heavy and moderate brush (oak not included) in the Pedernales River Watershed. This is the area of brush removed or treated in the no-brush simulation. Oak that was included in any mixed brush was split out so any cedar or mesquite was removed. This corresponds to 25% of the total watershed area

Model Input Variables
Significant input variables for the SWAT model for the Pedernales River Watershed are shown in Table P-1. Input variables for all subbasins in the watershed were the same, with three exceptions:

It was necessary to increase the curve number by 5 in order to calibrate flow at stream gauge feeding into Lake Travis.

1. The base flow factor was calculated to be 0.013. Also the amount of heat units for the crops to mature were for cedar 4769 degree days, oak 4149 degree days and brushy range 3195 degree days.
2. We assumed the re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units is 0.4, and for non-brush units is 0.1. Also, for the non-brush condition curve number increased by 5 units to account for the change from fair to good hydrologic conditions and from brush to range conditions.

PEDERNALES RIVER WATERSHED RESULTS

Calibration
SWAT was calibrated for the flow at stream gauges near Johnson City. The results of calibration are shown on Figures P-5. Measured and predicted average monthly flows compare reasonably well with a 4% difference between measured and simulated cumulative flow. At Johnson City the measured monthly mean is 12,830 acre-feet, and predicted monthly mean is 12,284 acre-feet. The coefficient of determination (r^2) was 0.99 between measured and simulated. Average base flow for the entire watershed is 16% of total flow.

Brush Removal Simulation
The average annual rainfall for the Pedernales River Watershed is 23.24 inches. Average annual evapo-transpiration (ET) is 19.61 inches for the brush condition (calibration) and 18.14 inches for the no-brush condition. This represents 84% and 78% of precipitation for the brush and no-brush conditions, respectively.

The increases in water yield by subbasin for the Pedernales River Watershed are shown in Figures P-6, 7 and 8 and Table P-2. The amount of annual increase varies among the subbasins and ranges from 739 gallons per acre of brush removed per year in subbasin number 26, to 611,720 gallons per acre in subbasin number 32. Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. Table P-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the entire simulated watershed, the average annual water yield increases by 36 % or approximately 89,348 acre-feet. The average annual flow to Lake Travis increases by 57,050 acre-feet. The increase in volume of flow to Lake Travis is slightly less than the water yield because of stream channel transmission losses that occur after water leaves each subbasin and the shallow soils that allow for percolation.

TABLE P-1

SWAT INPUT VARIABLES FOR PEDERNALES RIVER WATERSHED		
VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	+5	+10
Soil Available Water Capacity Adjustment (%)	0	0
Soil Evaporation Compensation Factor ($in^3 in^{-3}$)	0.99	0.99
Min. Shallow Aqu. Storage for GW flow (inches)	0	0
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0.3	0.3
Potential Heat Units (degree-days)		
Heavy Cedar	4769	N/A
Heavy Mesquite	N/A	N/A
Heavy Mixed Brush	N/A	N/A
Moderate Cedar	4149	N/A
Moderate Mesquite	N/A	N/A
Moderate Mixed Brush	N/A	N/A
Heavy Oak	4149	4149
Moderate Oak	3911	3911
Light Brush & Open Range/Pasture	3195	3195
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.02	0.02
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.16	0.16

Table P-2. Pedernales areas and water yield

Subbasin	Subbasin Total Area (acres)	Brush Removal Area (acres)	Fraction of Subbasin Containing Brush	Avg. Annual Water Yield (gallons)	Water Yield Per acre (gal/ac)
1	26,951	11,294	0.42	3509934604	310766
2	48,747	12,456	0.26	3830330157	307505
3	23,362	11,487	0.49	1173085471	102122
4	18,206	7,322	0.40	1203434375	164352
5	37,687	12,304	0.33	2613606806	212420
6	21,437	3,836	0.18	2078427110	541837
7	72,037	16,982	0.24	2142472557	126164
8	12,075	2,620	0.22	143029849	54591
9	9,397	1,983	0.21	969947825	489030
10	43,245	6,735	0.16	3499761808	519659
11	8,532	1,021	0.12	82369342	80663
12	32,645	10,810	0.33	3339561545	308919
13	12,319	2,284	0.19	45832580	20066
14	20,595	6,368	0.31	1120243861	175919
15	19,478	6,074	0.31	482484548	79440
16	29,202	6,743	0.23	224459965	33290
17	7,359	0	0.00	0	
18	5,272	1,432	0.27	552188395	385687
19	3,665	412	0.11	54225936	131751
20	24,943	3,774	0.15	2606809374	690679
21	4,661	0	0.00	0	
22	27,850	6,144	0.22	3290299232	535568
23	27,156	7,292	0.27	686889242	94197
24	26,025	5,497	0.21	1530495204	278402
25	17,631	4,026	0.23	803690121	199616
26	24,708	2,861	0.12	2113161	739
27	23,364	3,142	0.13	1352300667	430366
28	3,780	507	0.13	1858684	3669
29	23,396	5,569	0.24	1073272439	192729
30	12,893	3,171	0.25	476201733	150173
31	19,389	2,808	0.14	324609923	115592
32	18,093	2,478	0.14	1515842097	611720
33	13,794	1,866	0.14	300394705	160941
34	56,624	21,884	0.39	2445623566	111752
35	23,757	10,570	0.44	24635822	2331

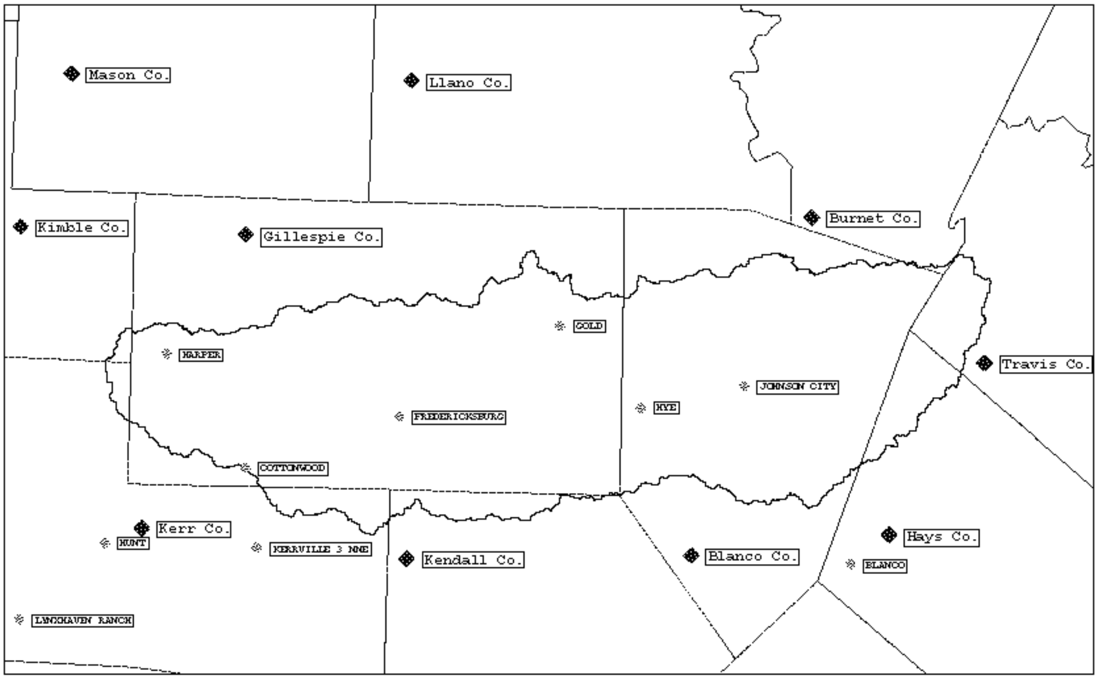

Figure P-1 Climate Stations in the Pedernales Watershed.

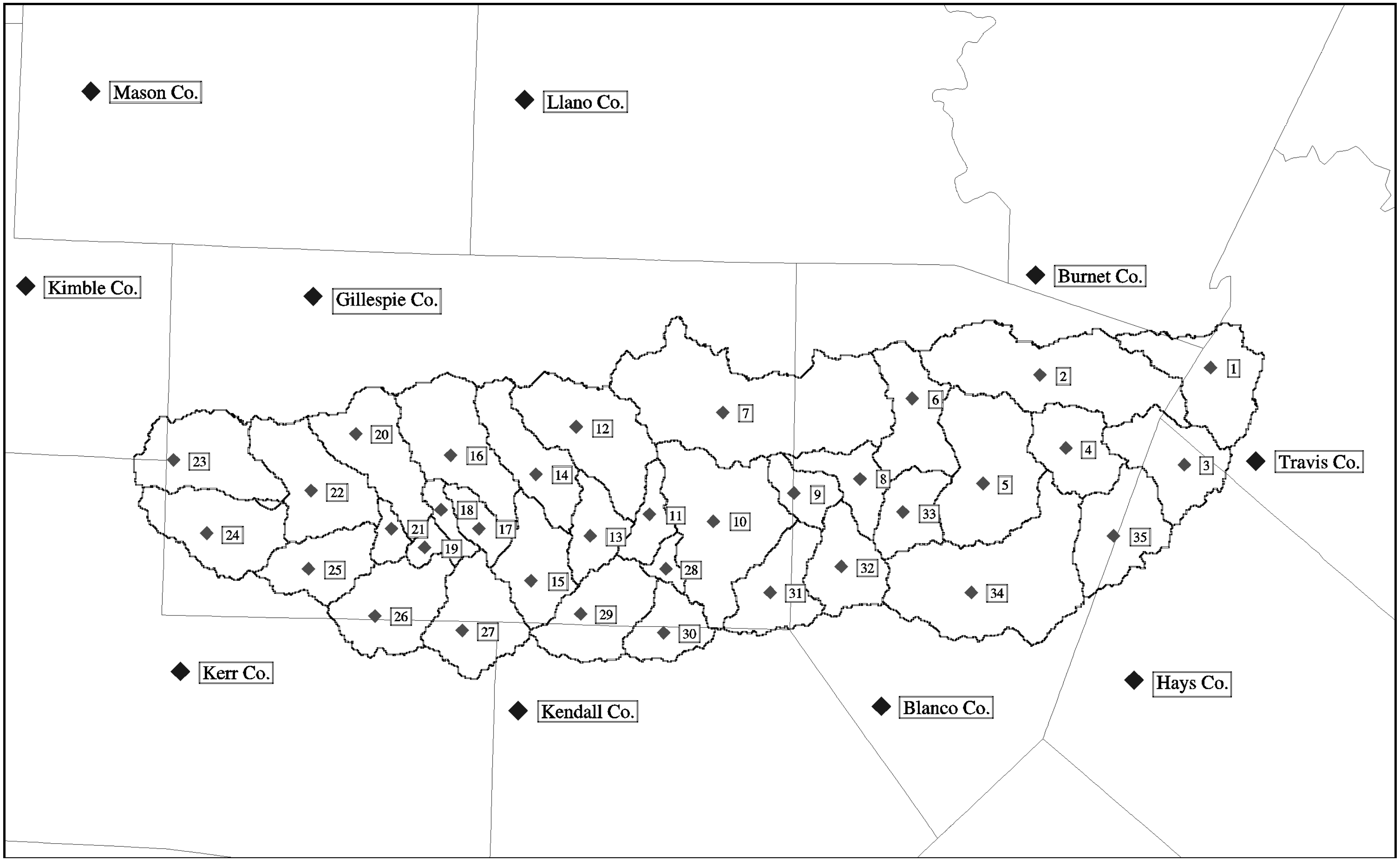

Figure P-2. Pedernales River Watershed subbasin map.

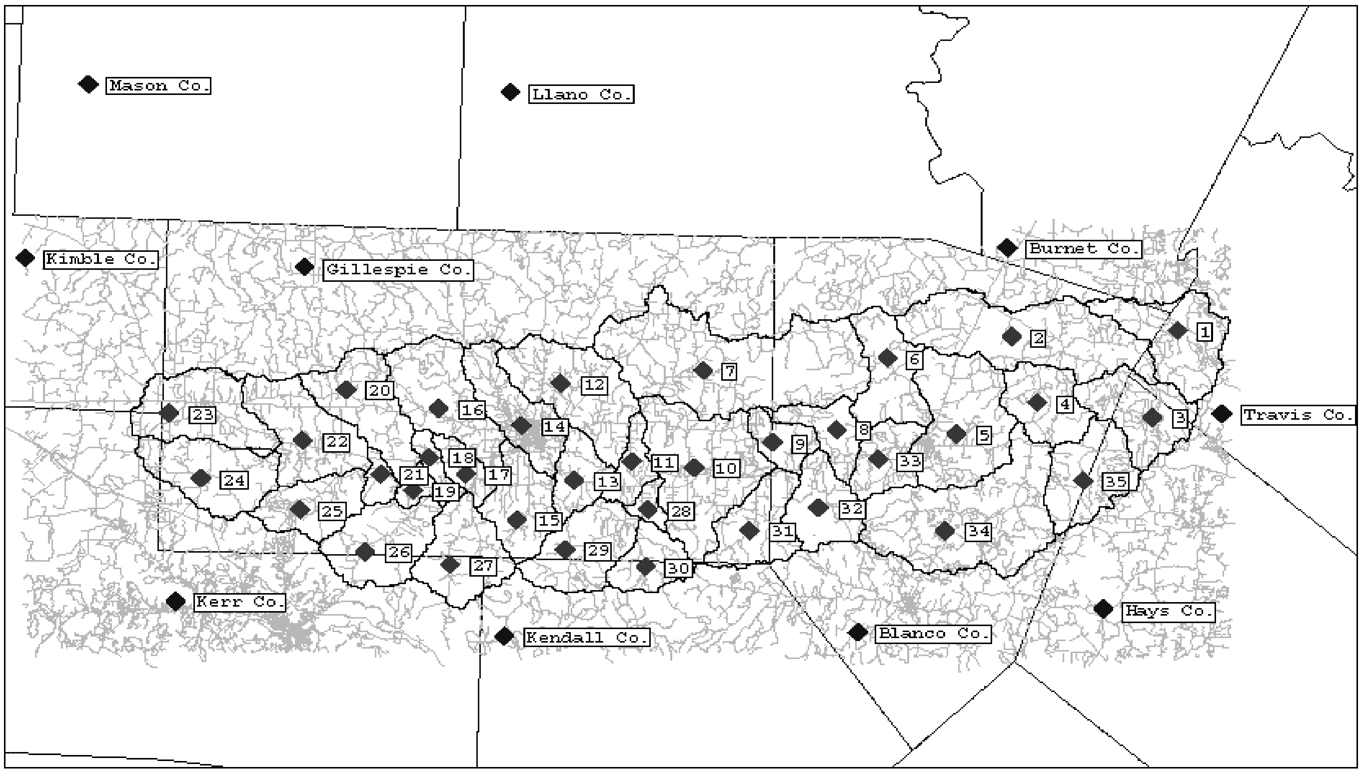

Figure P-3. Pedernales River Watershed roads map.

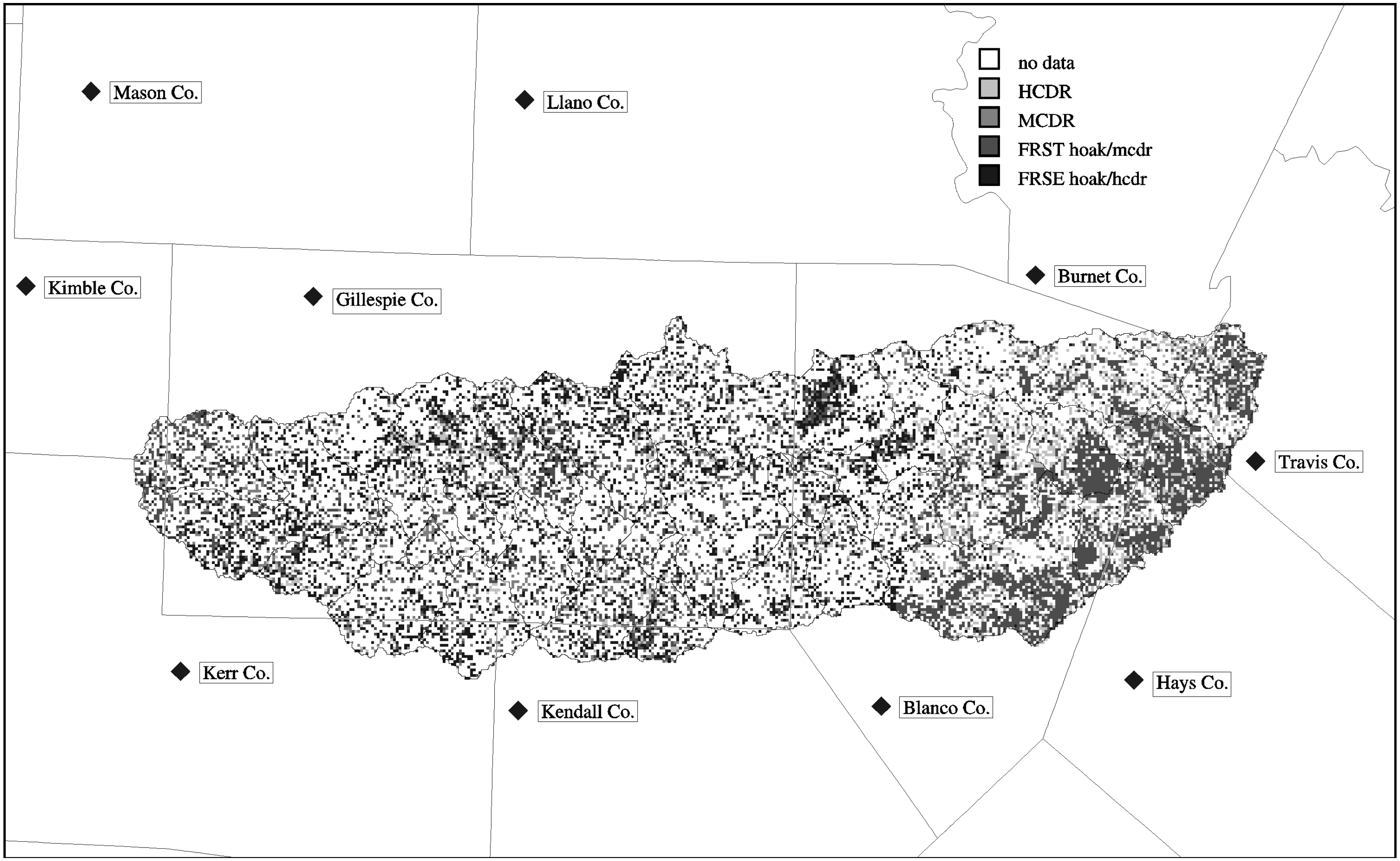

Figure P-4. Areas of heavy and moderate brush (oak not included) in the Pedernales River Watershed.

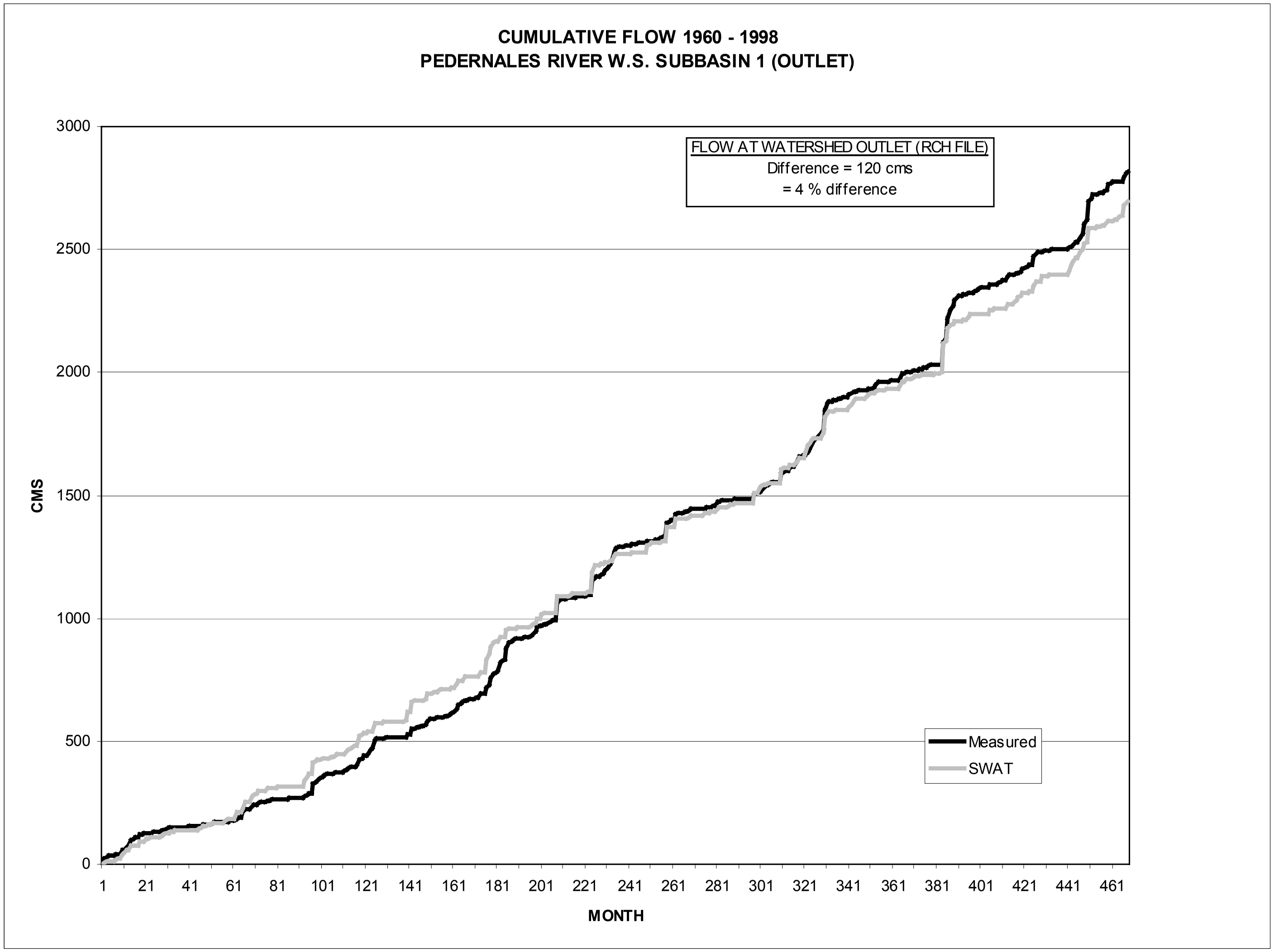

Figure P-5. Measured and simulated cumulative stream flow at the Johnson City gauging station.

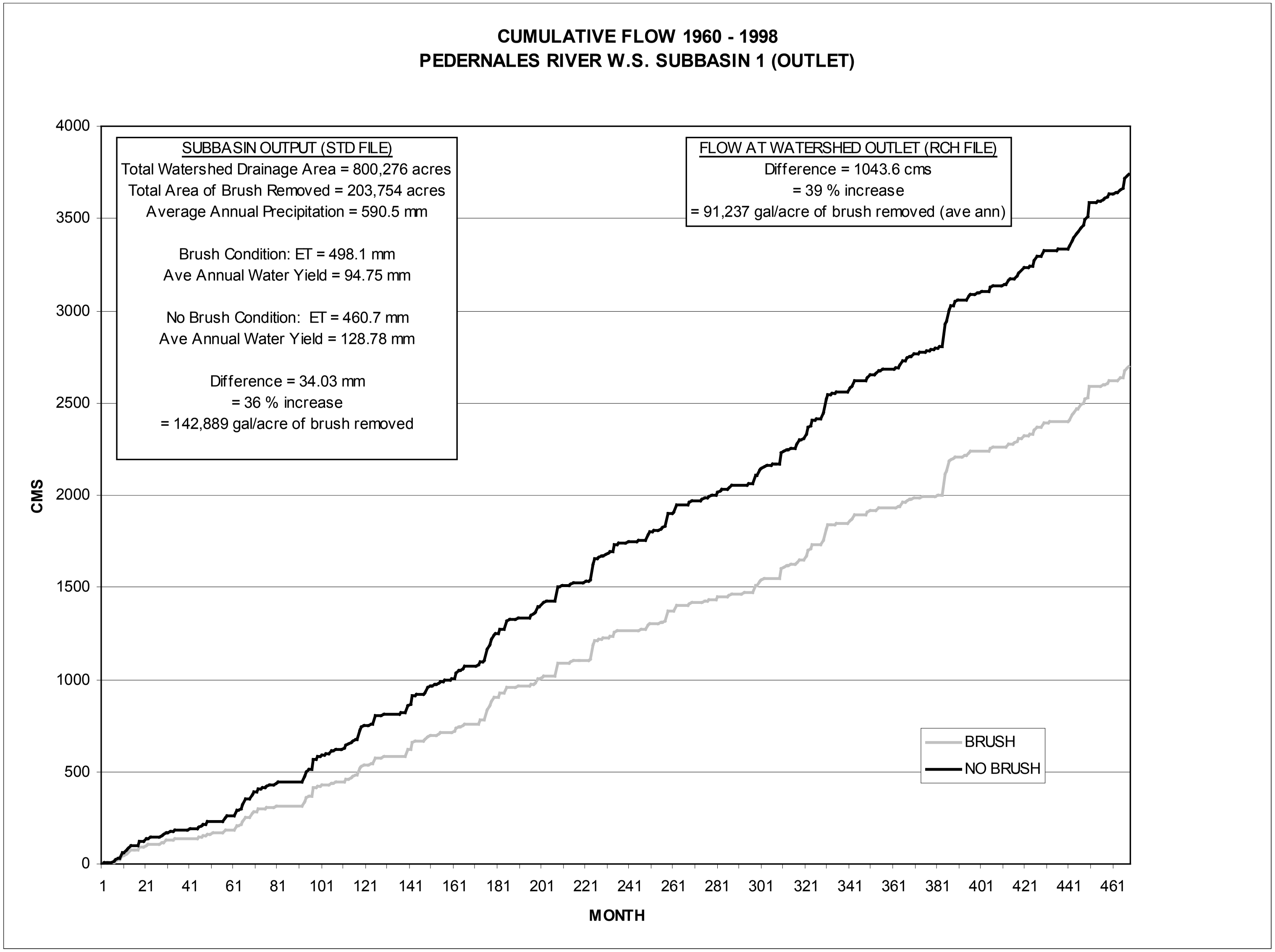

Figure P-6. Simulated cumulative flow at the outlet for brush and no brush conditions.

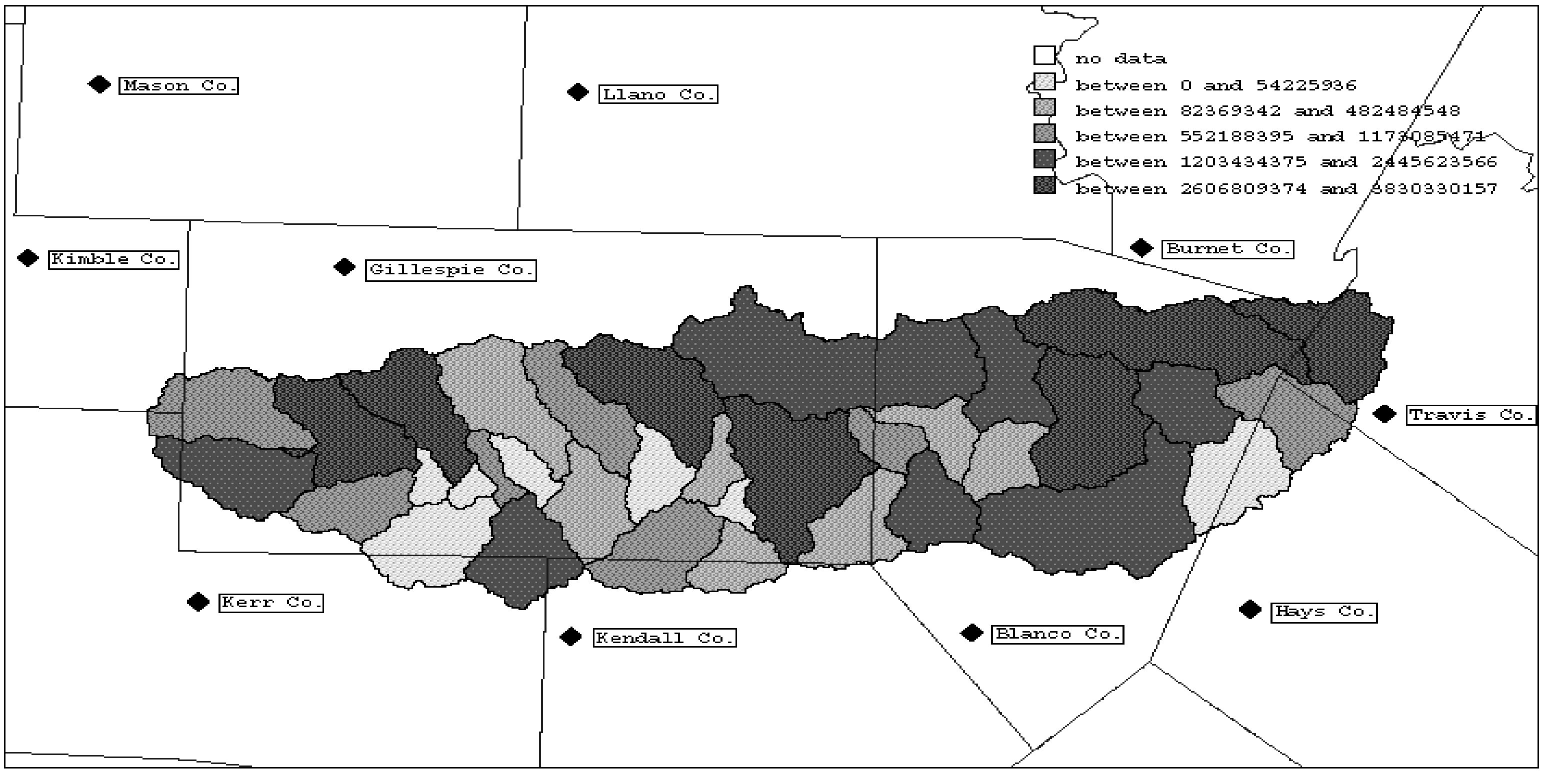

Figure P-7. Increased water yield (gallons) by subbasin.

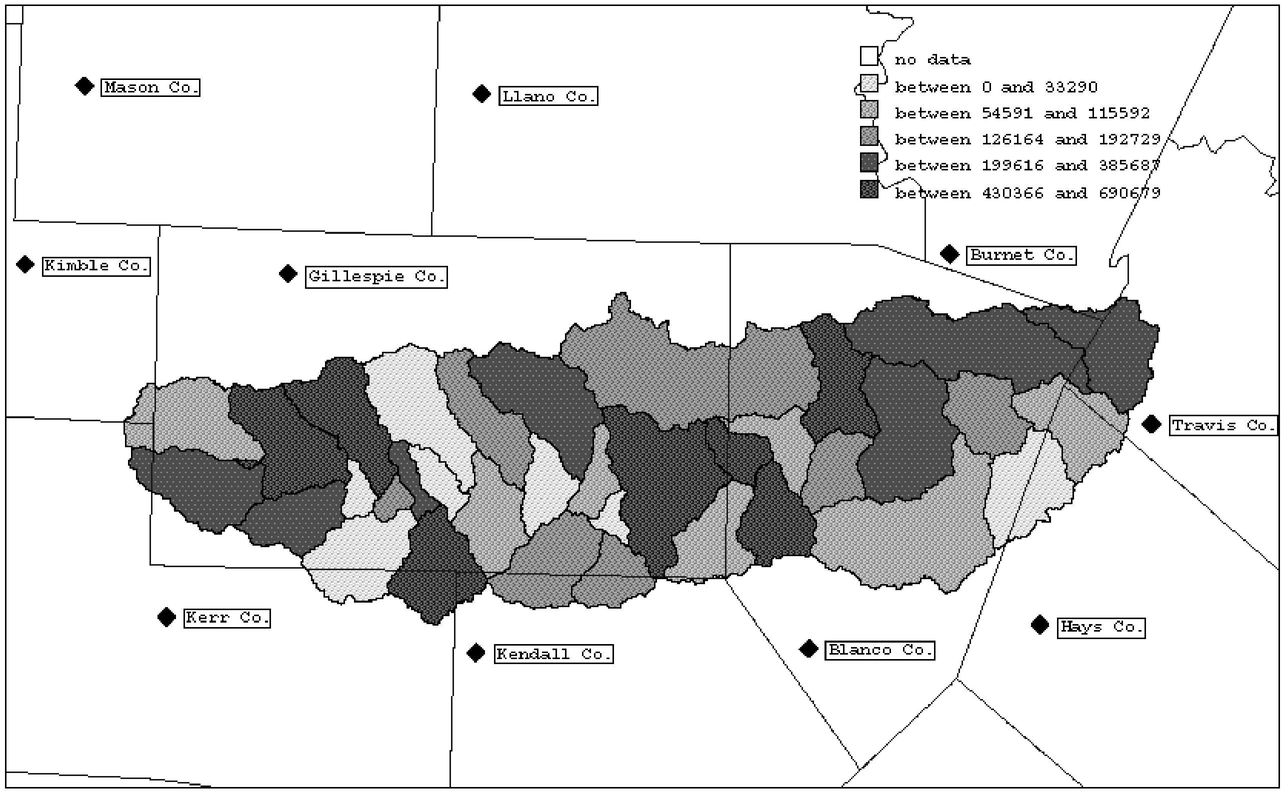

Figure P-8. Increase in water yield per treated acre due to brush removal from 1960 through 1998.

CHAPTER 14

PEDERNALES RIVER WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Pedernales River watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs in the project area (per acre) range from $70.42 for moderate mesquite that can be initially controlled with herbicide treatments to $160.42 for mechanical control of heavy cedar, mesquite and mixed brush. The costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Table 1.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar - Mechanical[1]

Year	Treatment	Acre Cost	Present Value
0	Tree Doze or Shear	100.00	100.00
5	IPT or Burn	30.00	20.42
		Total:	120.42

[1] Doze or tree shear, stack, and burn.

Extra Heavy Cedar – Mechanica1[1]

Year	Treatment	Acre Cost	Present Value
0	Pre-doze & Tree Doze	140.00	140.00
5	IPT or Burn	30.00	20.42
		Total:	160.42

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy pre-doze, rake, stack and burn.

Heavy Mesquite - Herbicide[1]

Year	Treatment	Acre Cost	Present Value
0	Chemical Herbicide	60.00	60.00
4	Chemical Herbicide	35.00	25.73
7	Choice IPT or Burn	25.00	14.59
		Total:	100.32

[1] Either aerial or individual chemical application may may be used.

Heavy Mesquite – Rootplow[1]

Year	Treatment	Acre Cost	Present Value
0	Rootplow	110.00	110.00
6	IPT or Burn	30.00	18.91
		Total:	128.91

[1] Rootplow, rake, stack, and burn.

Extra Heavy Mesquite – Rootplow with Pre-Doze[1]

Year	Treatment	Acre Cost	Present Value
0	Pre-doze and Rootplow	140.00	140.00
6	IPT or Burn	30.00	18.91
		Total:	158.91

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Heavy Mixed Brush - Chemical Herbicide[1]

Year	Treatment	Acre Cost	Present Value
0	Chemical Herbicide	60.00	60.00
4	Chemical Herbicide	35.00	25.73
7	Choice IPT or Burn	25.00	14.59
		Total:	100.32

[1] Individual chemical application may also be used.

Heavy Mixed Brush – Rootplow[1]

Year	Treatment	Acre Cost	Present Value
0	Rootplow	110.00	110.00
6	IPT or Burn	30.00	18.91
		Total:	128.91

[1] Rootplow, rake, stack, and burn.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Extra Heavy Mixed Brush – Rootplow with Pre-Doze[1]

Year	Treatment	Acre Cost	Present Value
0	Pre-doze and Rootplow	140.00	140.00
6	IPT or Burn	30.00	18.91
		Total:	158.91

Note: Canopy Cover for this practice is 40% or greater

[1] Heavy tree-doze, rootplow, rake, stack, and burn.

Moderate Cedar – Mechanical[1]

Year	Treatment	Acre Cost	Present Value
0	Tree Doze or Shear	60.00	60.00
5	IPT or Burn	30.00	20.42
		Total:	80.42

[1] Doze or shear, stack, and burn.

Moderate Mesquite – Chemical Herbicide[1]

Year	Treatment	Acre Cost	Present Value
0	Aerial or IPT Herbicide	50.00	50.00
5	IPT or Burn	30.00	20.42
		Total:	70.42

[1] Either aerial or individual chemical application may be used.

Moderate Mixed Brush – Chemical Herbicide[1]

Year	Treatment	Acre Cost	Present Value
0	Aerial or IPT Herbicide	50.00	50.00
5	IPT or Burn	30.00	20.42
		Total:	70.42

[1] Either aerial or individual chemical application may be used.

* Pedernales River Watershed

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the watershed are shown in Table 2. Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type-Density Classification	Brush Control (Or) No Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Brush Control	45.0	39.3	33.7	28.0	28.0	28.0	28.0	28.0	28.0	28.0
	No Control	45.0	45.1	45.1	45.2	45.2	45.3	45.3	45.4	45.4	45.5
Heavy Mesquite	Brush Control	28.0	23.7	19.3	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	No Control	28.0	28.0	28.1	28.1	28.1	28.2	28.2	28.2	28.2	28.3
Heavy Mixed Brush	Brush Control	40.0	34.0	28.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
	No Control	40.0	40.0	40.1	40.1	40.2	40.2	40.3	40.3	40.4	40.4
Moderate Cedar	Brush Control	38.0	34.7	31.3	28.0	28.0	28.0	28.0	28.0	28.0	28.0
	No Control	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	38.0	39.9
Moderate Mesquite	Brush Control	24.0	21.0	18.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
	No Control	24.0	24.1	24.3	24.4	24.5	24.7	24.8	24.9	25.1	25.2
Moderate Mixed brush	Brush Control	34.0	30.0	26.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
	No Control	34.0	34.2	34.4	34.6	34.8	34.9	35.1	35.3	35.5	35.7

* Pedernales River Watershed

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. Livestock grazing capacities range from about 15 acres per AUY for land on which mesquite is controlled to 45 acres per animal unit year (AUY) for land infested with heavy cedar.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle, sheep, and goats) in the project areas is shown in Tables 3a, 3b, and 3c. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $0.50 per acre (from $8.00 per acre to $8.50 per acre) due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3a. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	403.75	Pound	.91	367.41
Cows	111.1	Pound	.40	0.00
Bulls	250.0	Pound	.50	0.00
			Total	367.41

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	740.00	Pound	0.10	74.00
Salt & Minerals	100.0	Pound	0.20	20.00
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	14.00	14.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows	1.0	Head	35.28	35.28
Net Replacement Bulls	1.0	Head	3.09	6.09
			Total	167.69

* Pedernales River Watershed

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3b. Investment Analysis Budget, Sheep Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Lambs	290.0	Pound	0.85	246.50
Cull Ewes	0.83	Head	20.00	0.00
Cull Rams	0.038	Head	40.00	0.00
Wool	40.00	Pounds	0.60	24.00
			Total	270.50

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	400.0	Pound	0.10	40.00
Salt & Minerals	72.00	Pound	0.25	18.00
Marketing	1.0	Head	2.00	10.00
Veterinary Medicine	1.0	Head	3.20	16.00
Miscellaneous	1.0	Head	1.20	6.00
Shearing	1.0	Head	1.80	9.00
Net Replacement Ewes	1.0	Head	6.96	34.80
Net Replacement Rams	1.0	Head	0.05	7.80
			Total	141.60

* Pedernales Concho River Watershed
This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

Table 3c. Investment Analysis Budget, Meat Goat Production*

Partial Revenues

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Kid Goats	252.00	Pound	0.90	226.80
Cull Nannies	1.0	Head	20.00	0.00
Cull Bucks	0.045	Head	40.00	0.00
			Total	226.80

Partial Variable Costs

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	200.0	Pound	0.10	20.00
Salt & Minerals	75.0	Pound	0.20	15.00
Marketing	1.0	Head	2.55	12.00
Veterinary Medicine	1.0	Head	2.29	16.00
Miscellaneous	1.0	Head	1.03	7.20
Net Replacement Nannies	1.0	Head	5.21	36.48
Net Replacement Bucks	1.0	Head	0.02	4.74
			Total	111.42

*Pedernales River Watershed

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $21.22 per acre for control of moderate mesquite and mixed brush to $40.61 per acre for the control of heavy mesquite (Table 4).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the project area range from $49.20 for control of moderate mesquite and mixed brush with chemical treatments to $128.56 for control of heavy cedar. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Table 4.

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush Category Type & Density	Control Practice	PV Total Cost ($/Acre)	Landowner Share ($/Acre)	Landowner Percent	State Share ($/Acre)	State Percent
Heavy Cedar	Doze or Shear	120.42	31.86	0.26	88.56	0.74
	Doze - Heavy	160.42		0.20	128.56	0.80
Heavy Mesquite	Chemical	100.32	40.61	0.40	59.71	0.60
	Rootplow	128.91		0.32	88.30	0.68
	Doze & Plow[1]	158.91		0.26	118.30	0.74
Heavy Mixed Brush	Chemical	100.32	33.31	0.33	67.01	0.67
	Rootplow	128.91		0.26	95.60	0.74
	Doze & Plow[1]	158.91		0.21	125.60	0.79
Moderate Cedar	Doze or Shear	80.42	25.74	0.32	54.68	0.68
Moderate Mesquite	Chemical	70.42	21.22	0.30	49.20	0.70
Moderate Mixed Brush	Chemical	70.42	21.22	0.30	49.20	0.70
	Averages:	16.22	32.15	0.29	84.07	0.71

* Pedernales River Watershed

[1]Average is calculated as simple average, not relative average. The averages are based on the Heavy Mesquite Chemical comprising 50% of the cost for Heavy Mesquite control and Heavy Mesquite Mechanical comprising the other 50% of the cost for Heavy Mesquite. Also, it is assumed that Mechanical and Chemical comprise 50% each of cost for Moderate Mesquite control. Actual averages may change depending on relative amounts of each Type- Density Category of brush in each control category.

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water was determined to average $16.41 per acre foot for the entire basin and ranges from $5.92 per acre foot for Subbasin 18 to over $6,139.23 per acre foot for Subbasin 26. Details of the costs of added water for each Subbasin of the Pedernales are shown in Table 5.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	938,379.39	10,771.59	84,039.97	11.17
2	1,076,826.70	11,754.85	91,711.35	11.74
3	862,557.20	3,600.07	28,087.72	30.71
4	579,534.36	3,693.20	28,814.38	20.11
5	1,063,687.50	8,020.86	62,578.79	17.00
6	416,425.30	6,378.46	49,764.73	8.37
7	1,503,135.60	6,575.01	51,298.20	29.30
8	231,102.24	438.94	3,424.63	67.48
9	172,041.49	2,976.66	23,223.91	7.41
10	731,119.03	10,740.37	83,796.40	8.72
11	55,839.22	252.78	1,972.21	28.31
12	923,234.38	10,248.74	79,960.65	11.55
13	124,894.59	140.66	1,097.39	113.81
14	495,537.10	3,437.90	26,822.51	18.47
15	450,494.89	1,480.69	11,552.35	39.00
16	595,143.09	688.84	5,374.35	110.74
17	0.00	0.00	0.00	0.00
18	78,285.36	1,694.60	13,221.30	5.92
19	22,506.29	166.41	1,298.36	17.33
20	409,738.01	8,000.00	62,416.03	6.56
21	0.00	0.00	0.00	0.00
22	534,242.78	10,097.56	78,781.14	6.78
23	398,726.56	2,107.99	16,446.50	24.24
24	451,531.88	4,696.92	36,645.35	12.32
25	353,602.60	2,466.43	19,243.12	18.38
26	310,622.73	6.49	50.60	6,139.23
27	341,117.23	4,150.06	32,378.76	10.54
28	27,700.89	5.70	44.50	622.45
29	488,733.87	3,293.75	25,697.85	19.02
30	274,075.84	1,461.41	11,401.92	24.04
31	304,869.05	996.19	7,772.28	39.23
32	269,065.96	4,651.95	36,294.50	7.41
33	102,060.22	921.88	7,192.49	14.19
34	1,689,484.70	7,505.34	58,556.69	28.85
35	820,034.68	75.60	589.87	1,390.20
Totals:	$17,096,351.00	----------	$1,041,550.82	Average: $16.41

* Pedernales River Watershed

CHAPTER 15

TWIN BUTTES/NASWORTHY WATERSHED – HYDROLOGIC SIMULATION

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Blackland Research Center

WATERSHED DATA

Location

The Twin Buttes/Nasworthy watershed was divided into four different drainages for ease of modeling. These sub-watersheds are the Middle Concho River, Spring & Dove Creeks, South Concho River and Pecan Creek. These delineations are shown in Figure TBN–1.

Topography

The outlet or "catchment" for the Middle Concho River simulated in this study is the north pool of Twin Buttes Reservoir, which is located in subbasin number 28. This modeling subdivision is shown in Figure TBN-2. The outlet for Spring and Dove Creeks (Figure TBN-3) is also the north pool of Twin Buttes Reservoir located in subbasin number 23. The catchment for the South Concho River (Figure TBN-4) is the south pool of Twin Buttes Reservoir, which is located in subbasin number 18. The outlet or "catchment" for Pecan Creek (Figure TBN-5) in this study is Lake Nasworthy located in subbasin number 13.

Figures TBN-2 through TBN-5 show the subbasin delineation, numbers, and roads (obtained from the Census Bureau) for each modeling subdivision.

Weather Stations

Climate stations for each modeling subdivision (Middle Concho, Spring & Dove Creeks, South Concho, and Pecan Creek) are shown in Figures TBN-6 through TBN-9. For each subbasin, precipitation and temperature data were retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin. USGS stream gauge stations are also shown in these figures.

Soils

The soils in the Twin Buttes/Nasworthy Watershed are represented largely by STATSGO soil associations. The dominant soil series of these associations are Ector, Reagan, Angelo, Tarrant, Rioconcho, and Tobosa. These six soil series represent about 93 percent of the soils polygons in the watershed area. A short description of each follows:

> Ector. The Ector series consists of very shallow or shallow, well drained soils that are moderately permeable above a very slowly permeable limestone bedrock. They formed in loamy residuum. These gently sloping to very steep upland soils have slopes ranging from 1 to 60 percent.

Reagan. The Reagan series consists of very deep, well drained, moderately permeable calcareous soils that formed in calcareous loamy materials. These nearly level to gently sloping upland soils are on broad flats, filled valleys and fans. Slopes range from 0 to 3 percent.

Angelo. The Angelo series consists of deep or very deep, well drained, moderately slowly permeable soils formed in calcareous loamy and clayey alluvium. The deep phase is underlain by limestone. These nearly level to gently sloping upland soils have slopes ranging from 0 to 3 percent.

Tarrant. The Tarrant series consists of very shallow and shallow, well drained, moderately slowly permeable soils on uplands. They formed in residuum from limestone, and includes interbedded marls, chalks, and marly materials.

Rioconcho. The Rioconcho series consists of very deep, moderately well drained, slowly permeable soils that formed in clayey or silty alluvium. These nearly level soils are on flood plains and in narrow valleys. Slopes range from 0 to 2 percent.

Tobosa. The Tobosa series consists of very deep, well drained, very slowly permeable soils formed in calcareous clayey materials. These nearly level to gently sloping soils are on uplands. Slopes range from 0 to 3 percent.

Land Use/Land Cover

Figures TBN-10 through TBN-13 show the areas of heavy and moderate brush (oak not included) in the Twin Buttes/Nasworthy Watershed by modeling subdivision. This is the area of brush removed or treated in the no-brush simulation.

Ponds and Reservoirs

Surface area, storage, and drainage area were obtained from the Texas Natural Resource Conservation Commission (TNRCC) for existing inventory-sized ponds and reservoirs in the watershed (Figures TBN-14 through TBN-17), and input to the SWAT model. The stream networks are also shown in these figures.

Model Input Variables

Significant input variables for the SWAT model for the Twin Buttes/Nasworthy Watershed are shown in Table TBN-1. Input variables were adjusted as needed by subbasin in order to calibrate flow at the applicable USGS stream gauge. Channel transmission losses were assumed to be 0.98 inches per hour in the Middle Concho River with no return base flow. The channel transmission losses were assumed to be 0.94 inches per hour in Spring Creek above gauge 08129300 (Tankersley) and 0.06 inches per hour in Dove Creek above gauge 08130500 (Knickerbocker). Losses in channel transmission were assumed to be 0.79 inches per hour in the South Concho River with 75% of this amount returning as base flow. Channel transmission losses were assumed to be 0.59 inches per hour in Pecan Creek with 60% of this amount returning as base flow. The calibration simulation represents the current "with brush" condition.

The input variables for the no-brush condition, with one exception, were the same as the calibration variables, with the change in landuse being the only difference between the two simulations. The exception is that we assumed the shallow aquifer re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and the opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units (HRU – combinations of soil and land use/cover) is 0.4, and for non-brush HRU's is 0.1.

RESULTS

Calibration

SWAT was calibrated for flow at stream gauges 08128400 (Middle Concho River above Tankersley) (Figure TBN-6), 08129300 (Spring Creek at Tankersley) & 08130500 (Dove Creek at Knickerbocker) (Figure TBN-7), 08128000 (South Concho River at Christoval) (Figure TBN-8) and 08131400 (Pecan Creek near San Angelo) (Figure TBN-9). The results of calibrations are shown for these gauges on Figures TBN-18 through TBN-22.

Measured and predicted total monthly flows for the Middle Concho compare well with a R^2 value of 0.82 for gauge 08128400 (Figure TBN-18). The measured monthly mean is 1,023 acre-feet, and the predicted monthly mean is 917 acre-feet. The predicted total flow was just slightly less than measured. Most of this deviation occurred at the end of the simulation (in 1992) and may have resulted from the spatial distribution of one large rainfall event.

Figures TBN-19 and TBN-20 show measured and predicted total monthly flows of Spring and Dove Creeks comparing reasonably well with R^2 values of 0.85 for gauge 08129300 and 0.46 for gauge 08130500. At gauge 08129300 the measured monthly mean is 810 acre-feet, and predicted monthly mean is 789 acre-feet. Gauge 08130500 has a measured mean of 981 acre-feet, and a predicted mean of 1,002 acre-feet. At gauge 08129300 total predicted flow for the simulation period is slightly lower than measured (Figure TBN-19). The lines of cumulative measured and predicted flow diverge somewhat near the beginning of the simulation, but converge toward the end. This may have been due to climate variability that is not reflected in measured data. At gauge 08130500 predicted total flow was more than measured (Figure TBN-20). In 1977, SWAT under-estimated flow by a large amount, causing the cumulative lines of measured and predicted flow to diverge significantly. It is possible that large amounts of rainfall occurred during this time that was not measured accurately at any of the climate stations. The measured and predicted lines for the remainder of the simulated period are generally parallel, with the predicted line approaching and nearly catching up to the measured line near the end of the simulation.

Gauge 08128000 on the South Concho measured and predicted total monthly flows do not compare as well as the other modeling subdivisions in the Twin Buttes/Nasworthy watershed with a R^2 value of 0.26 (Figure TBN-21). Average base flow for this modeling subdivision is 63 % of total flow, which is reasonably close to measured base flow of approximately 70 %. The measured monthly mean is 1,578 acre-feet, and the predicted monthly mean is 1,727 acre-feet. The predicted total flow was more than measured. Most of this deviation is probably attributed to not accurately predicting the large amount of base flow in the channel.

The results of calibration with gauge 08131400 (Pecan Creek) are shown on Figure TBN-22. Measured and predicted total monthly flows do not compare as well as some of the other modeling subdivisions in the Twin Buttes/Nasworthy watershed with a R^2 value of 0.30 for this gauge. The measured monthly mean is 128 acre-feet, and the predicted monthly mean is 171 acre-feet. The predicted total flow was more than measured. Most of this deviation is probably attributed to the fact that only one climatic station was used for rainfall and this station did not accurately represent conditions in the watershed because it is located near the outlet.

Brush Removal Simulation

The average annual rainfall for the Middle Concho River varies from 14.7 inches in the western portion of the watershed to 20.0 inches in the eastern portion. The composite average for the entire subdivision is 18.3 inches. Average annual evapo-transpiration (ET) is 17.45 inches for the brush condition (calibration) and 17.09 inches for the no-brush condition. This represents 95% and 93% of precipitation for the brush and no-brush conditions, respectively.

The average annual rainfall for Spring and Dove Creeks varies from 18.5 inches in the western portion of the watershed to 21.6 inches in the eastern portion. The composite average for the entire subdivision is 20.4 inches. Average annual evapo-transpiration (ET) is 17.78 inches for the brush condition (calibration) and 16.67 inches for the no-brush condition. This represents 87% and 82% of precipitation for the brush and no-brush conditions, respectively.

The average annual rainfall for the South Concho River varies from 20.3 inches in the western portion of the watershed to 21.6 inches in the eastern portion. The composite average for the entire subdivision is 21.2 inches. Average annual evapo-transpiration (ET) is 19.75 inches for the brush condition (calibration) and 18.62 inches for the no-brush condition. This represents 93% and 88% of precipitation for the brush and no-brush conditions, respectively.

The average annual rainfall for Pecan Creek is 20.3 inches. Average annual evapo-transpiration (ET) is 18.44 inches for the brush condition (calibration) and 17.11 inches for the no-brush condition. This represents 91% and 85% of precipitation for the brush and no-brush conditions, respectively.

Figure TBN-23 shows the predicted cumulative monthly total flow to Twin Buttes Reservoir for the brush and no-brush conditions from 1960 through 1998. Figure TBN-24 shows the predicted cumulative monthly total flow to Lake Nasworthy for the brush and no-brush conditions from 1960 through 1998. The increase in water yield by subbasin for the Twin Buttes/Nasworthy Watershed is shown in Figure TBN-25. The amount of annual increase varies among the subbasins and ranges from 5,467 gallons per acre of brush removed per year in subbasin number 7 (Middle Concho), to 61,184 gallons per acre in subbasin number 4 (Spring & Dove Creeks). Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. Table TBN-2 gives the total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin.

For the entire simulated watershed, the average annual water yield at the subbasin level increased by 74 % or approximately 77,990 acre-feet. The average annual flow to Twin Buttes Reservoir and Lake Nasworthy increased by 41,325 acre-feet and 2,264 acre-feet respectively, for a total watershed increase of 43,589 acre-feet. The increase in volume of flow to Twin Buttes Reservoir and Lake Nasworthy is less than the water yield because of the capture of runoff by upstream reservoirs, as well as stream channel transmission losses that occur after water leaves each subbasin.

TABLE TBN-1

SWAT INPUT VARIABLES FOR TWIN BUTTES/NASWORTHY WATERSHED								
VARIABLE	**BRUSH CONDITION (CALIBRATION)**				**NO BRUSH CONDITION**			
	Middle Concho	Spring & Dove	South Concho	Pecan Creek	Middle Concho	Spring & Dove	South Concho	Pecan Creek
Runoff Curve Number Adjustment	-8	-8	-8	-8	-8	-8	-8	-8
Soil Avail. Water Capacity Adjust. (in. H^2O/in. soil)	+0.05	N/A	+0.05	N/A	+0.05	N/A	+0.05	N/A
Soil Evaporation Compensation Factor	0.1	0.1	0.1	0.10	0.10	0.10	0.10	0.10
Min. Shallow Aqu. Storage for GW flow (inches)	0	0	0	0.00	0.00	0.00	0.00	0.00
Ground Water Delay (days)	265	35	35	35	265	35	35	35
Shallow Aqu. Re-Evaporation (Revap) Coefficient	0.4	0.4	0.4	0.40	0.10	0.10	0.10	0.10
Min. Shallow Aqu. Storage for Revap (inches)	0	0	0.04	0.00	0.00	0.00	0.04	0.00
Potential Heat Units (^oC)								
Heavy Juniper	4150	4150	4150	4150	N/A	N/A	N/A	N/A
Heavy Mesquite	3610	3610	3610	3611	N/A	N/A	N/A	N/A
Heavy Mixed Brush	3860	3860	3860	3860	N/A	N/A	N/A	N/A
Moderate Juniper	3610	3610	3610	3611	N/A	N/A	N/A	N/A
Moderate Mesquite	3195	3195	3195	3196	N/A	N/A	N/A	N/A
Moderate Mixed Brush	3405	3405	3405	N/A	N/A	N/A	N/A	N/A
Heavy Oak	3610	3610	3610	3611	3610	3610	3610	3611
Moderate Oak	3195	3195	3195	N/A	3195	3195	3195	N/A
Light Brush & Open Range/Pasture	2820	2820	2820	2781	2820	2820	2820	2781
Precipitation Interception (Inches)								
Heavy Juniper	0.79	0.79	0.79	0.79	N/A	N/A	N/A	N/A
Heavy Mesquite	0.00	0.00	0.00	0.00	N/A	N/A	N/A	N/A
Heavy Mixed Brush	0.59	0.59	0.59	0.59	N/A	N/A	N/A	N/A
Moderate Juniper	0.59	0.59	0.59	0.59	N/A	N/A	N/A	N/A
Moderate Mesquite	0.00	0.00	0.00	0.00	N/A	N/A	N/A	N/A
Moderate Mixed Brush	0.39	0.39	0.39	0.39	N/A	N/A	N/A	N/A
Heavy Oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moderate Oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light Brush & Open Range/Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant Rooting Depth (feet)								
Heavy and Moderate Brush	6.5	6.5	6.5	6.5	N/A	N/A	N/A	N/A
Light Brush & Open Range/Pasture	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Maximum Leaf Area Index								
Heavy Juniper	6	6	6	6	N/A	N/A	N/A	N/A
Heavy Mesquite	4	4	4	4	N/A	N/A	N/A	N/A
Heavy Mixed Brush	4	4	4	4	N/A	N/A	N/A	N/A
Moderate Juniper	5	5	5	5	N/A	N/A	N/A	N/A
Moderate Mesquite	2	2	2	2	N/A	N/A	N/A	N/A
Moderate Mixed Brush	3	3	3	3	N/A	N/A	N/A	N/A
Heavy Oak	4	4	4	4	4	4	4	4
Moderate Oak	3	3	3	3	3	3	3	3
Light Brush	2	2	2	2	2	2	2	2
Open Range/Pasture	1	1	1	1	1	1	1	1
Channel Transmission Loss (inches/hour)	0.98	0.94 & 0.06	0.79	0.59	0.98	0.94 & 0.06	0.79	0.59
Subbasin Transmission Loss (inches/hour)	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.00	0	0.75	0.60	0.00	0.00	0.75	0.60

TABLE TBN-2

SUBBASIN DATA - TWIN BUTTES/NASWORTHY WATERSHED					
Subbasin	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
**# MC1	211,304	0	0.00	0	0
MC2	7,332	4,379	0.60	5,473	23,967,709
**#MC3	176,942	0	0.00	0	0
**#MC4	73,600	0	0.00	0	0
MC5	14,159	3,533	0.25	8,198	28,961,239
** MC6	68,281	0	0.00	0	0
MC7	52,662	14,673	0.28	5,467	80,219,580
MC8	6,857	1,061	0.15	8,860	9,403,568
MC9	74,712	9,248	0.12	10,310	95,354,657
MC10	3,996	437	0.11	6,690	2,921,367
**#MC11	125,727	0	0.00	0	0
MC12	39,428	20,798	0.53	8,303	172,689,922
MC13	26,630	19,504	0.73	10,918	212,938,097
MC14	13,950	9,230	0.66	11,229	103,650,307
MC15	16,415	5,479	0.33	9,474	51,912,762
MC16	108,522	40,498	0.37	9,234	373,960,351
MC17	36,146	24,760	0.69	13,029	322,602,068
MC18	56,713	34,833	0.61	10,503	365,844,550
MC19	15,512	9,539	0.61	9,810	93,584,365
MC20	1,752	1,115	0.64	9,045	10,085,112
MC21	53,743	30,200	0.56	9,160	276,620,604
MC22	31,175	19,523	0.63	10,994	214,634,970
MC23	85,184	62,653	0.74	14,777	925,853,301
MC24	43,765	34,045	0.78	15,082	513,448,349
MC25	54,769	40,059	0.73	13,997	560,713,394
MC26	73,256	51,616	0.70	10,618	548,050,093
MC27	78,179	57,271	0.73	10,047	575,423,771
MC28	50,151	27,310	0.54	7,966	217,552,581
SD1	57,402	31,897	0.56	30,137	961,288,661
SD2	42,467	19,547	0.46	48,346	945,015,702
SD3	63,664	26,024	0.41	54,400	1,415,720,275
SD4	11,201	9,336	0.83	61,184	571,234,993
SD5	326	164	0.50	26,780	4,402,416
SD6	13,329	10,857	0.81	41,189	447,206,055
SD7	17,567	13,422	0.76	39,540	530,712,082
SD8	8,300	4,957	0.60	30,599	151,684,470
SD9	18,570	9,849	0.53	34,186	336,687,178
SD10	14,253	10,320	0.72	34,221	353,162,102
SD11	24,063	17,983	0.75	40,785	733,442,938
SD12	24,908	19,009	0.76	42,505	807,955,606
SD13	12,340	9,644	0.78	47,654	459,589,309

TABLE TBN-2 (continued)

Subbasin	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
SD14	20,589	15,527	0.75	40,981	636,308,516
SD15	20,285	14,816	0.73	34,593	512,534,487
SD16	15,538	12,671	0.82	36,271	459,572,044
SD17	13,072	10,158	0.78	33,994	345,312,501
SD18	11,656	8,834	0.76	26,465	233,800,919
SD19	2,367	1,576	0.67	8,775	13,832,035
SD20	25,674	15,031	0.59	21,164	318,128,906
SD21	17,473	12,300	0.70	34,199	420,650,953
SD22	3,949	1,243	0.31	9,196	11,427,179
SD23	10,658	5,649	0.53	27,772	156,871,387
SC1	42,406	0	0.00	0	0
SC2	12,852	2,543	0.20	59,410	151,090,053
SC3	24,476	12,192	0.00	50,043	610,107,105
SC4	15,563	8,351	0.00	43,884	366,458,887
SC5	13,052	7,977	0.61	47,893	382,050,413
SC6	1,900	1,401	0.00	33,718	47,242,081
SC7	15,486	5,904	0.38	49,485	292,180,472
SC8	11,434	5,287	0.46	49,545	261,958,329
SC9	8,718	6,755	0.77	37,161	251,003,374
SC10	10,660	8,392	0.79	35,020	293,876,898
SC11	37,330	26,004	0.00	51,328	1,334,706,343
SC12	12,802	9,034	0.71	43,521	393,175,577
SC13	36,712	27,184	0.74	36,569	994,076,780
SC14	1,109	666	0.60	39,826	26,535,836
SC15	21,100	14,255	0.68	46,832	667,605,094
SC16	21,889	17,340	0.79	41,654	722,288,072
SC17	18,194	13,108	0.72	39,749	521,019,605
SC18	7,260	3,346	0.46	5,945	19,890,993
PE1	7,257	3,853	0.53	53,424	205,850,701
PE2	3,388	2,442	0.72	46,275	113,017,068
PE3	4,463	3,633	0.81	31,541	114,599,104
PE4	4,478	3,142	0.70	33,351	104,780,481
PE5	13,853	11,243	0.81	37,947	426,626,535
PE6	2,664	2,094	0.79	49,633	103,924,649
PE7	6,595	4,757	0.72	35,325	168,040,884
PE8	3,141	2,486	0.79	46,278	115,044,144
PE9	3,462	2,555	0.74	22,266	56,891,695
PE10	1,473	813	0.55	16,525	13,430,196
PE11	1,255	969	0.77	15,335	14,863,737
PE12	3,104	1,957	0.63	8,027	15,705,989
PE13	5,268	3,143	0.60	5,809	18,258,260

TABLE TBN-2 (continued)

TWIN BUTTES/NASWORTHY WATERSHED					
	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
	2,423,854 *(1,768,001 ac. treated subs)*	1,015,407	0.57 *(based on treated subs)*	25,028	25,413,232,785 (77,990 Ac-Ft/yr.)

Notes:

1 - Numbers prefaced by MC denote subbasins in the Middle Concho River

2 - Numbers prefaced by SD denote subbasins in Spring and Dove Creeks

3 - Numbers prefaced by SC denote subbasins in the South Concho River

4 - Numbers prefaced by PE denote subbasins in Pecan Creek

*5 - ** No brush control modeled in these subbasins*

6 - # Subbasins 1, 3, 4, & 11 in Middle Concho modeled as <u>NOT</u> contributing to stream gage.

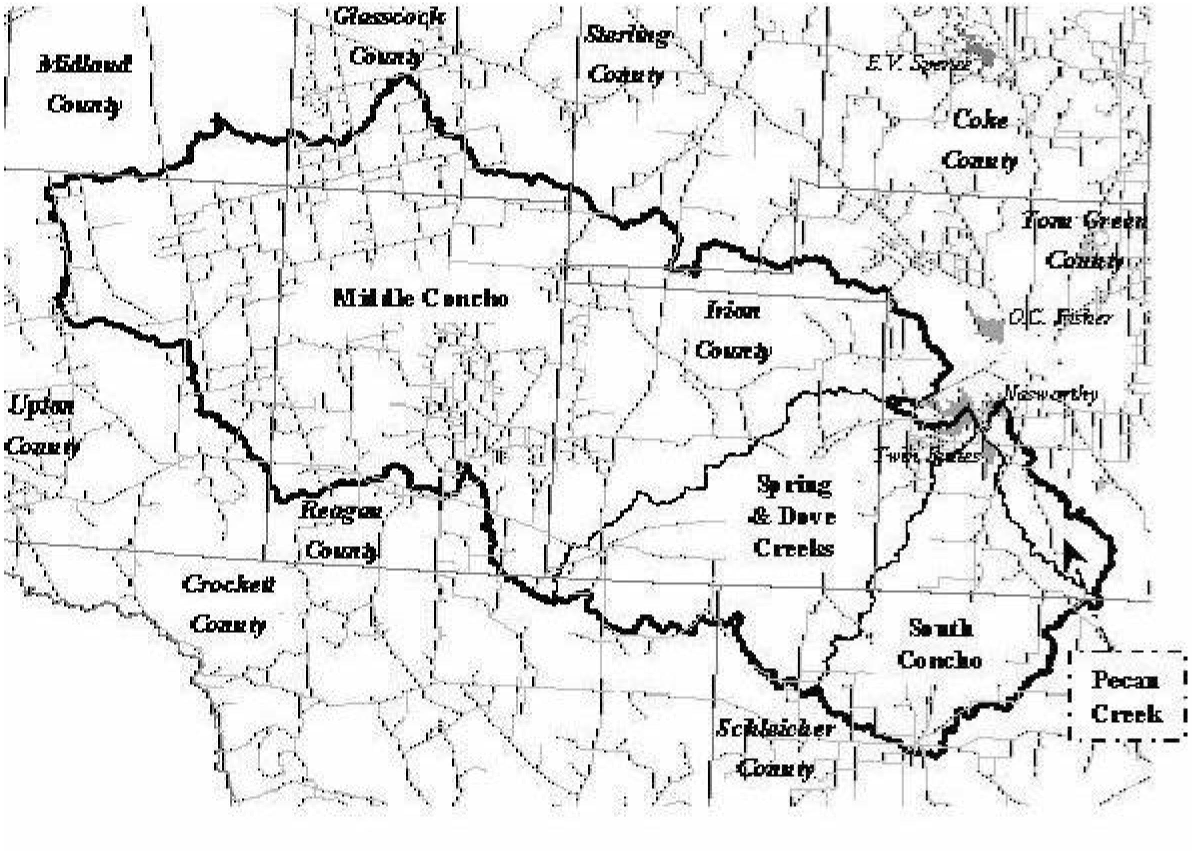

Figure TBN-1 Location Map - Major subdivisions of the Twin Buttes/Nasworthy watershed

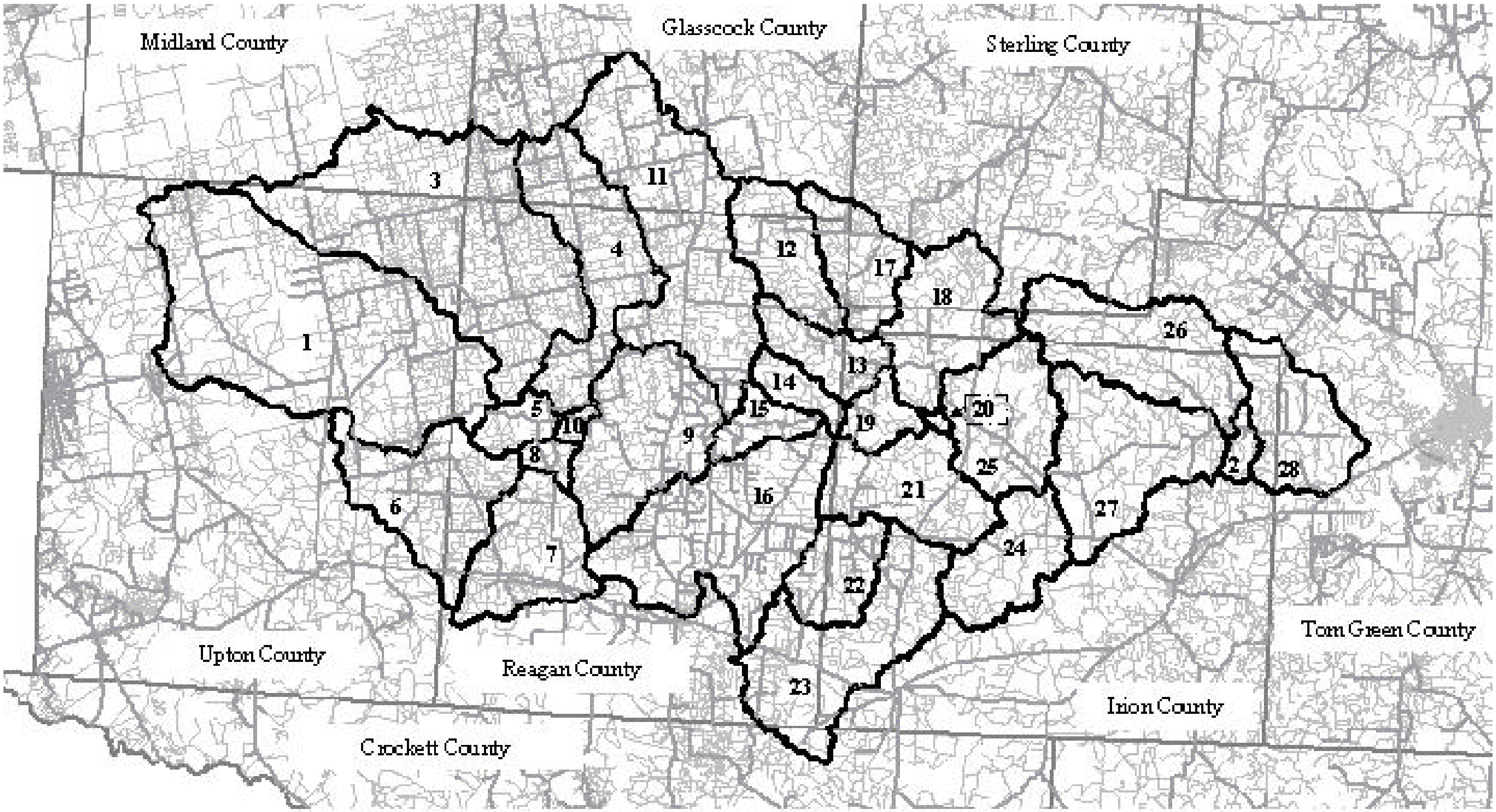

Figure TBN-2. Middle Concho River subbasin map.

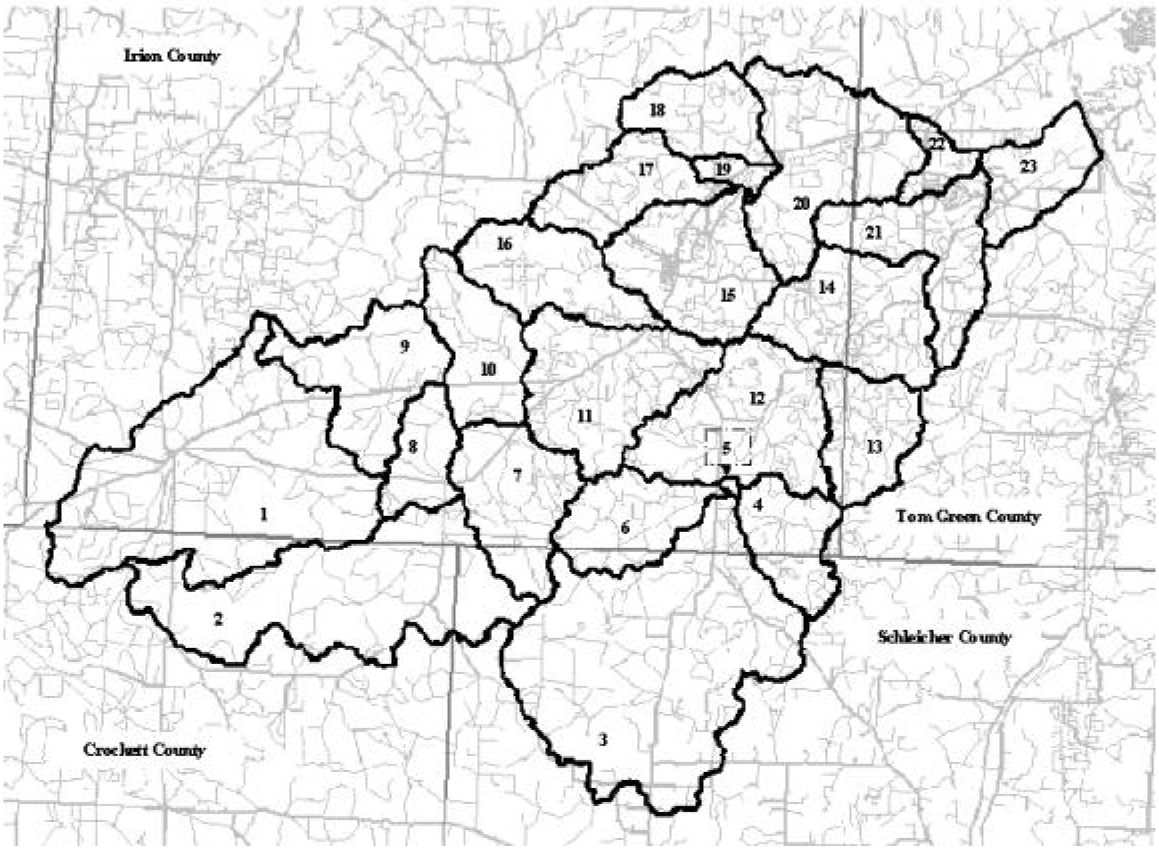

Figure TBN-3. Spring and Dove Creeks subbasin map.

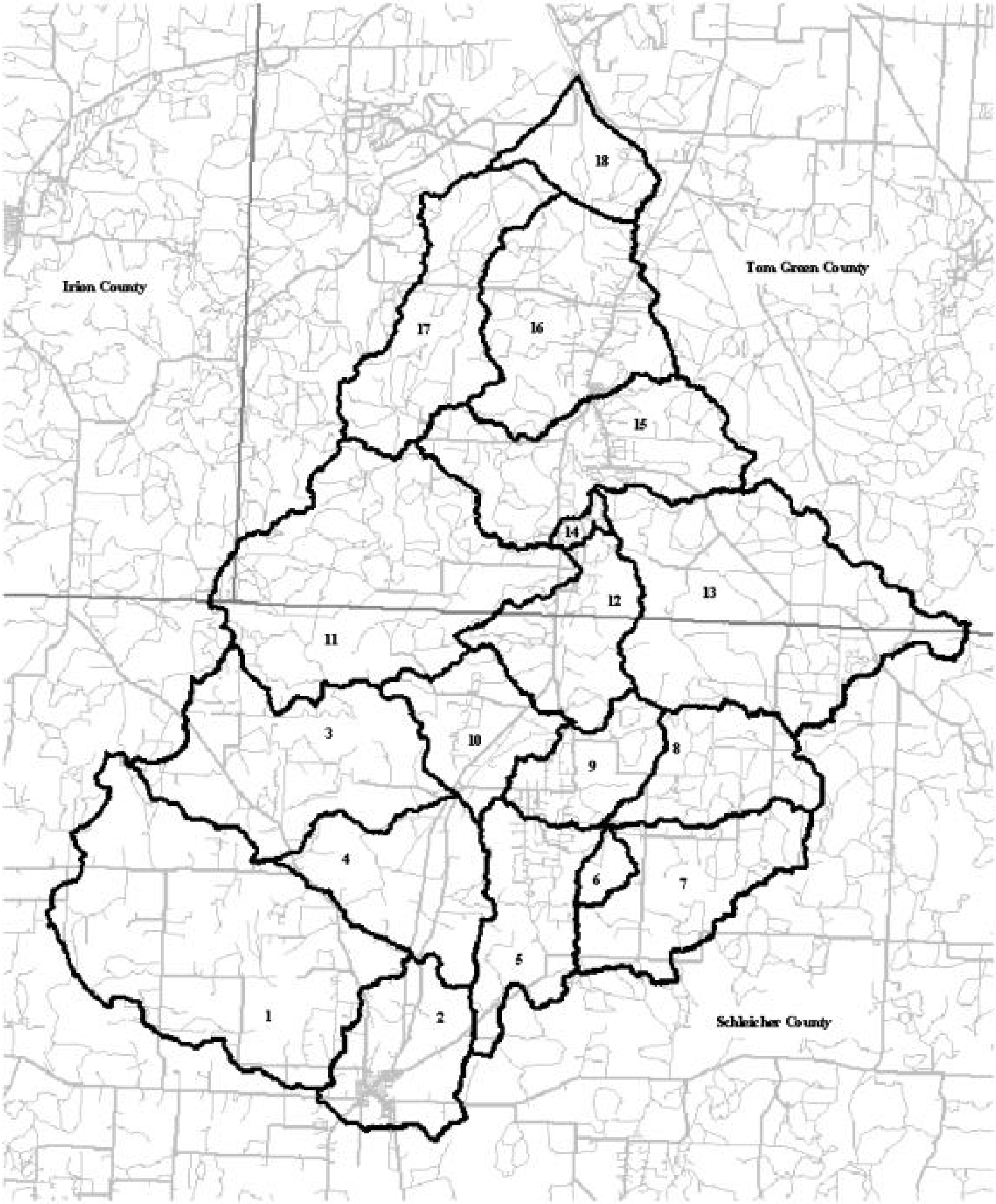

Figure TBN-4. South Concho River subbasin map.

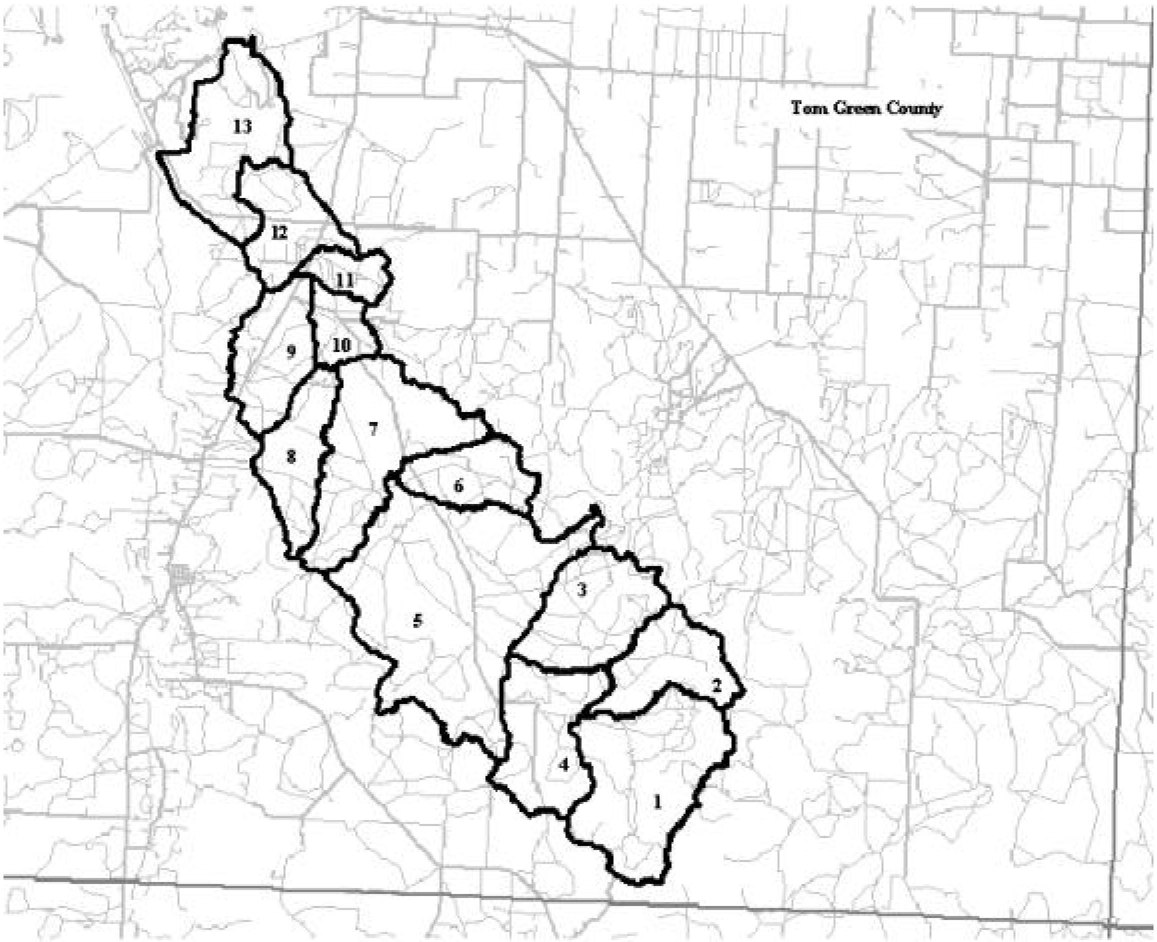

Figure TBN-5. Pecan Creek subbasin map.

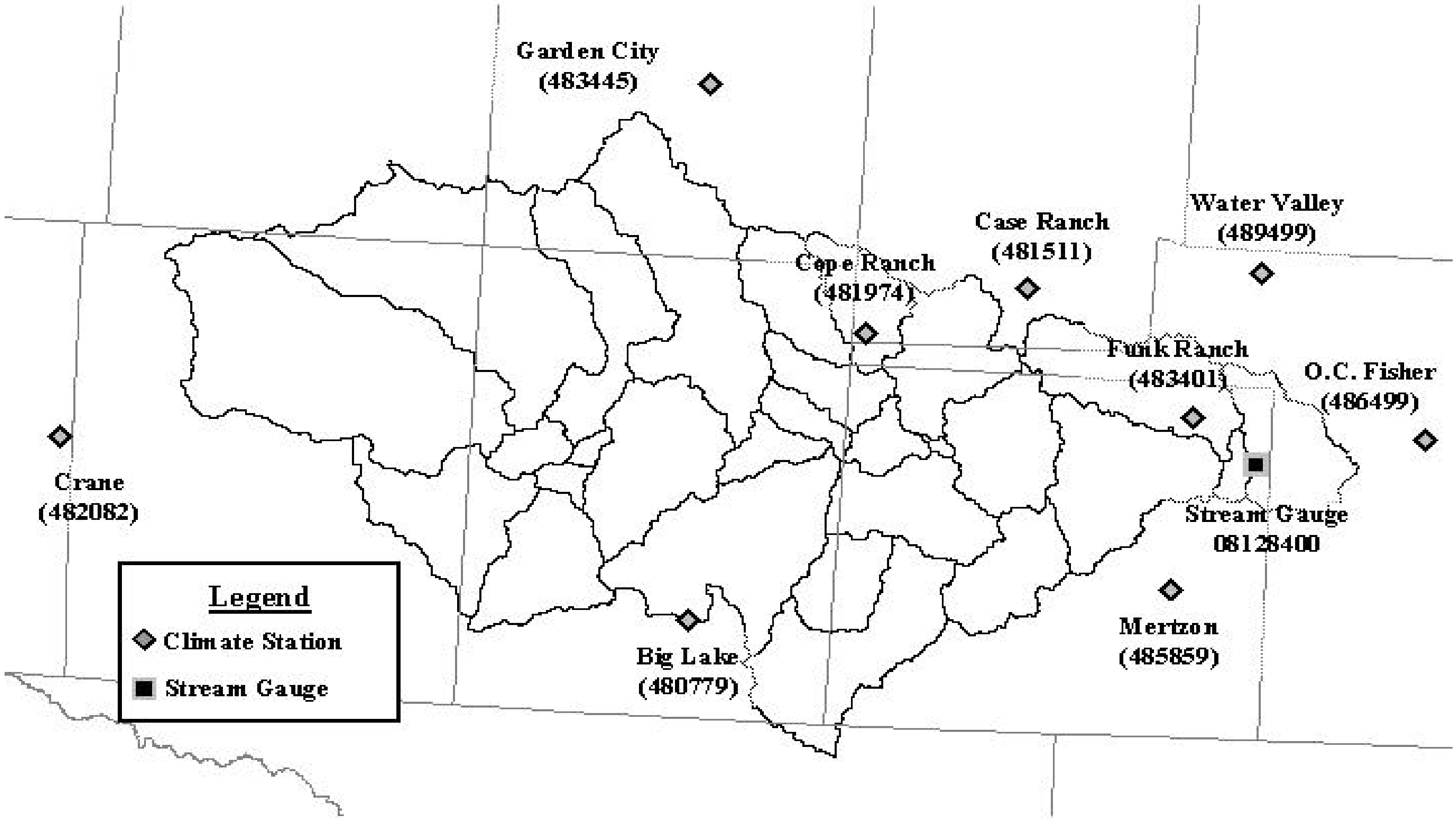

Figure TBN-6. Climate and Stream Gauge stations in the Middle Concho River.

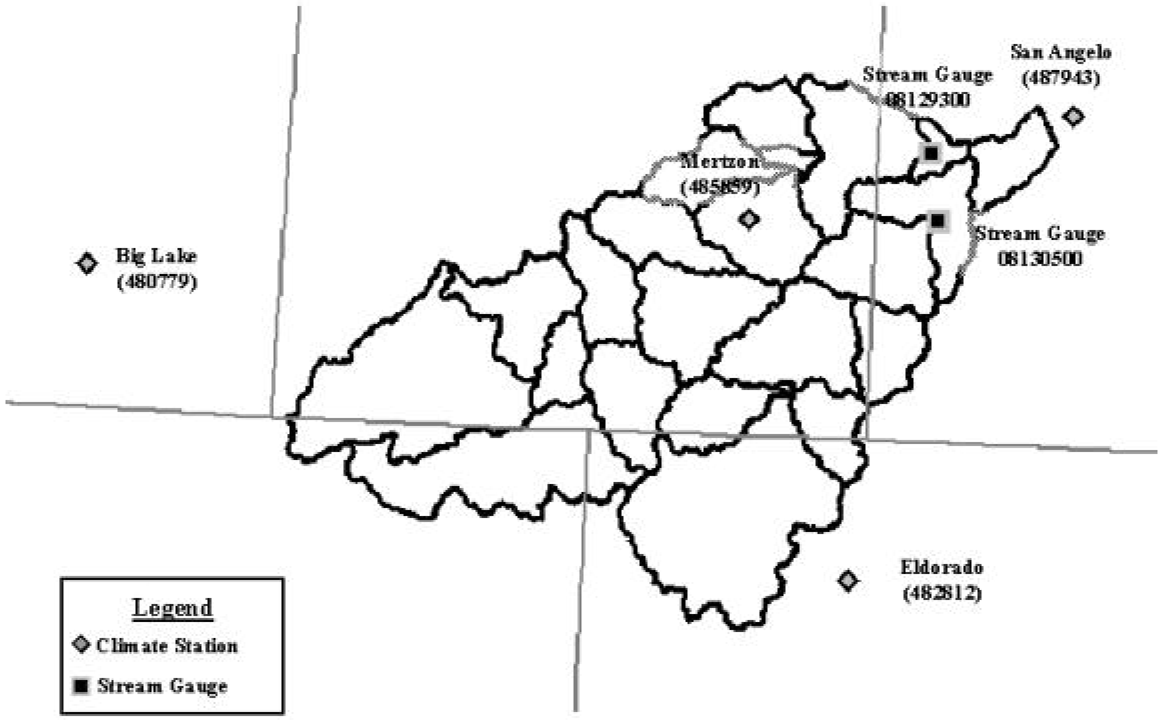

Figure TBN-7. Climate and Stream Gauge stations in Spring and Dove Creeks.

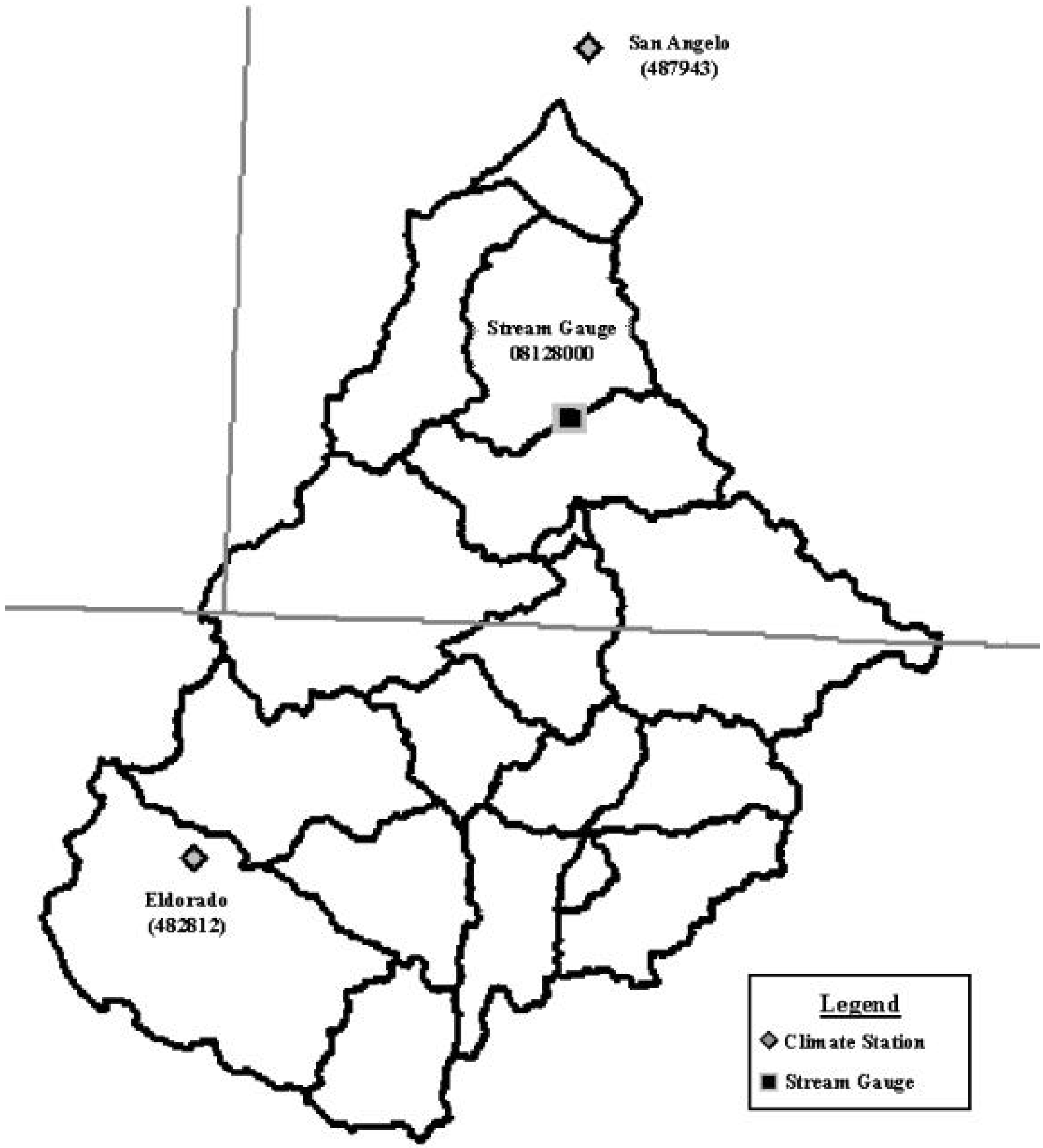

Figure TBN-8. Climate and Stream Gauge stations in the South Concho River.

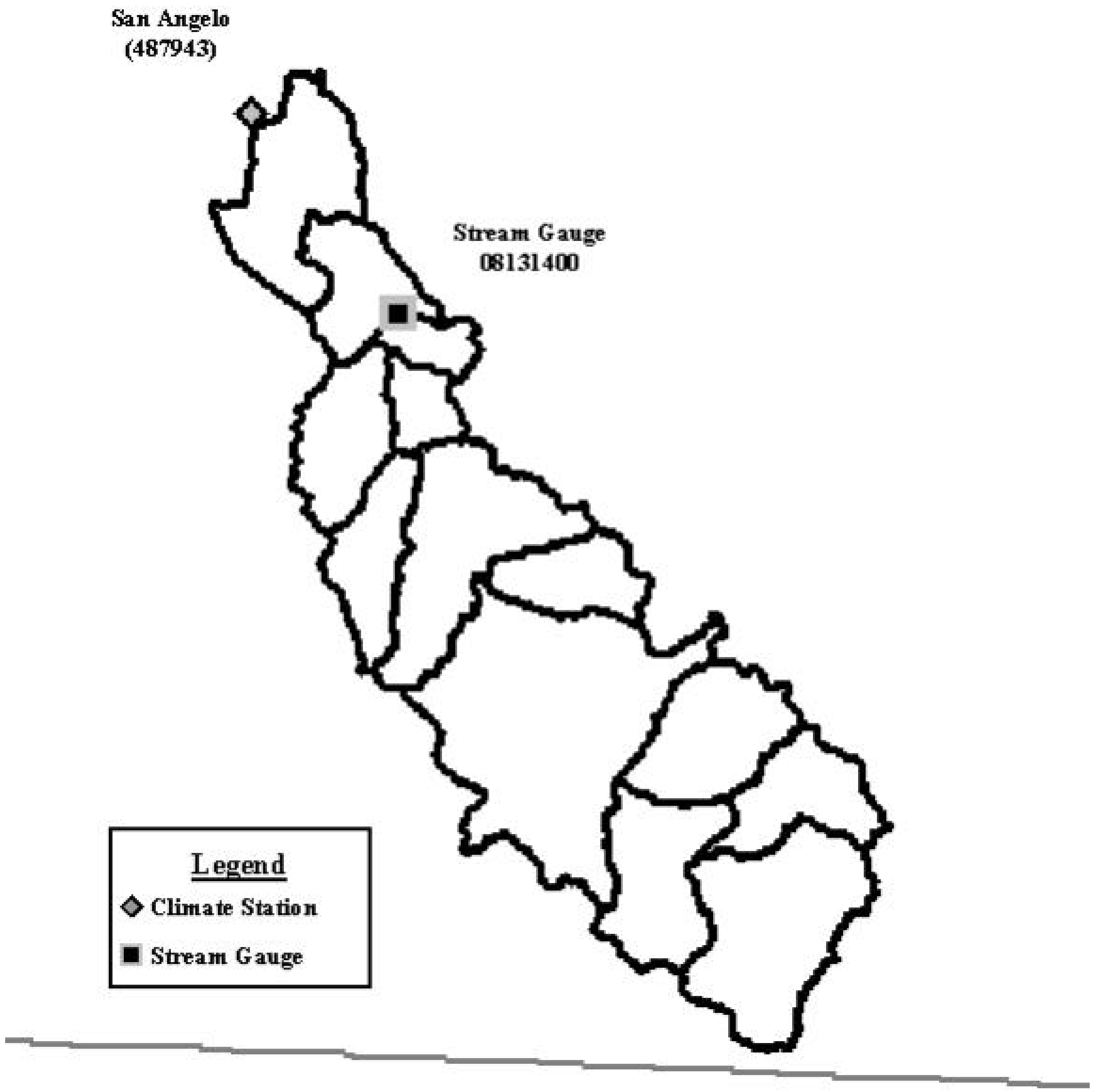

Figure TBN-9. Climate and Stream Gauge stations in Pecan Creek.

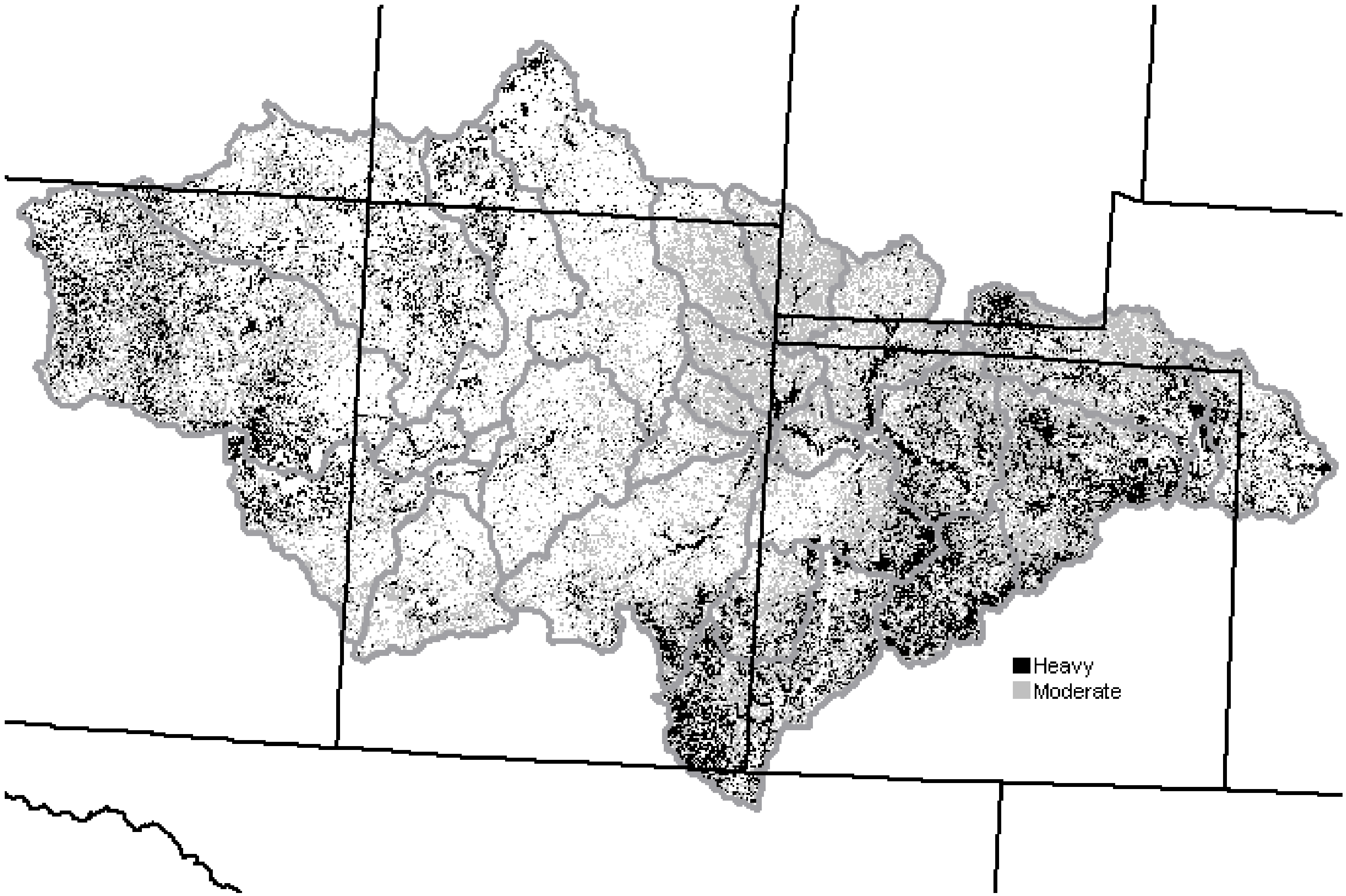

Figure TBN-10. Areas of heavy and moderate brush (oak not included) in the Middle Concho River.

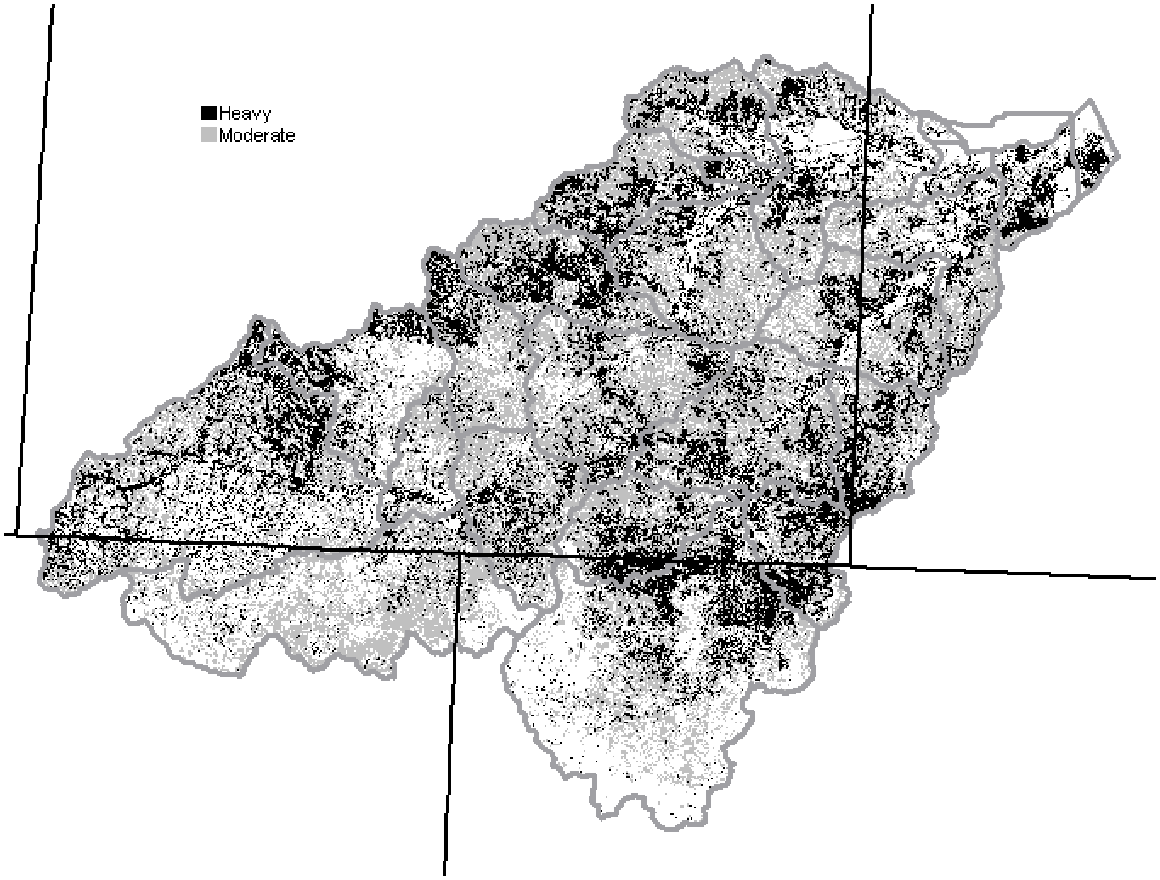

Figure TBN-11. Areas of heavy and moderate brush (oak not included) in Spring and Dove Creeks.

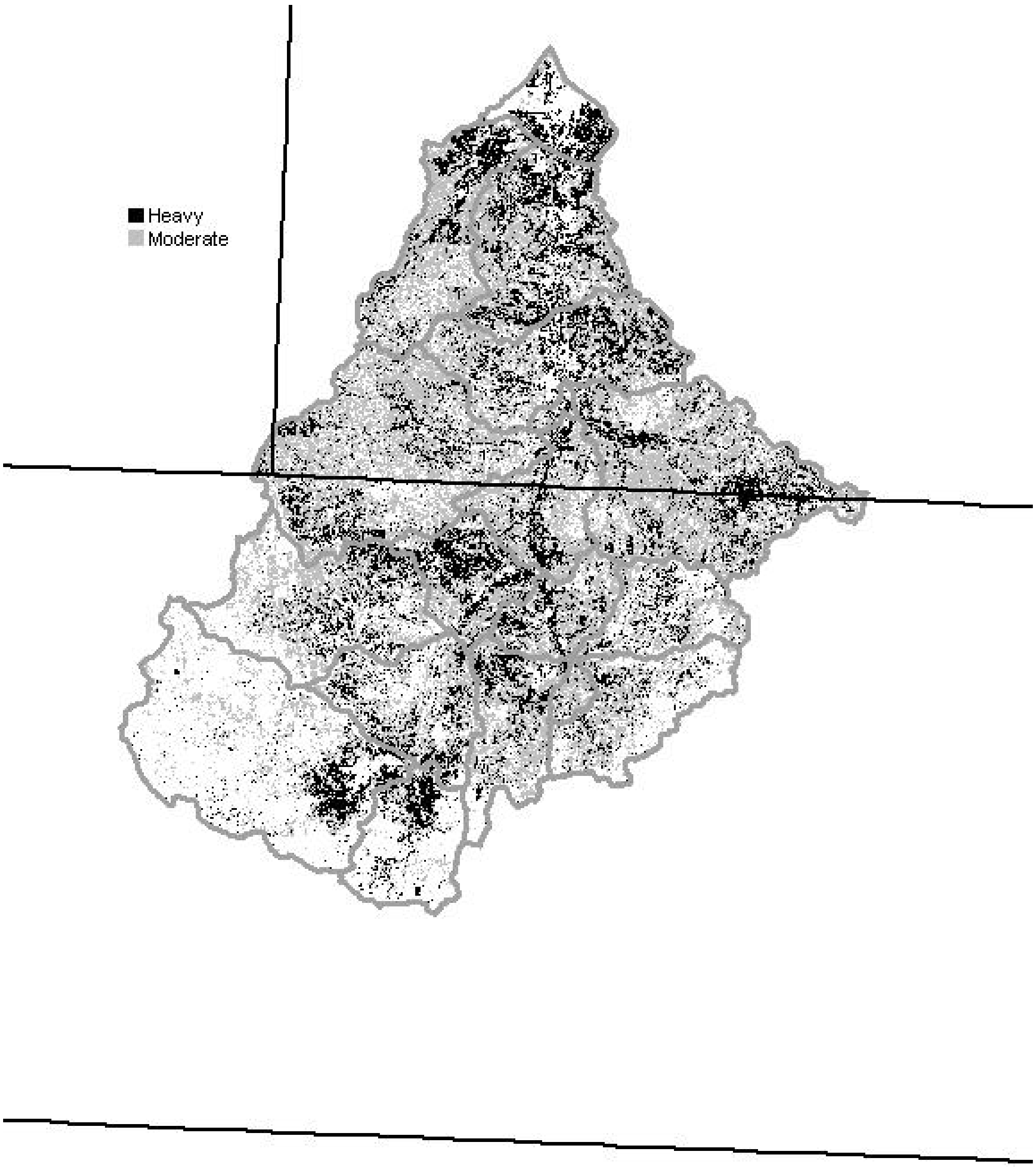

Figure TBN-12. Areas of heavy and moderate brush (oak not included) in the South Concho River.

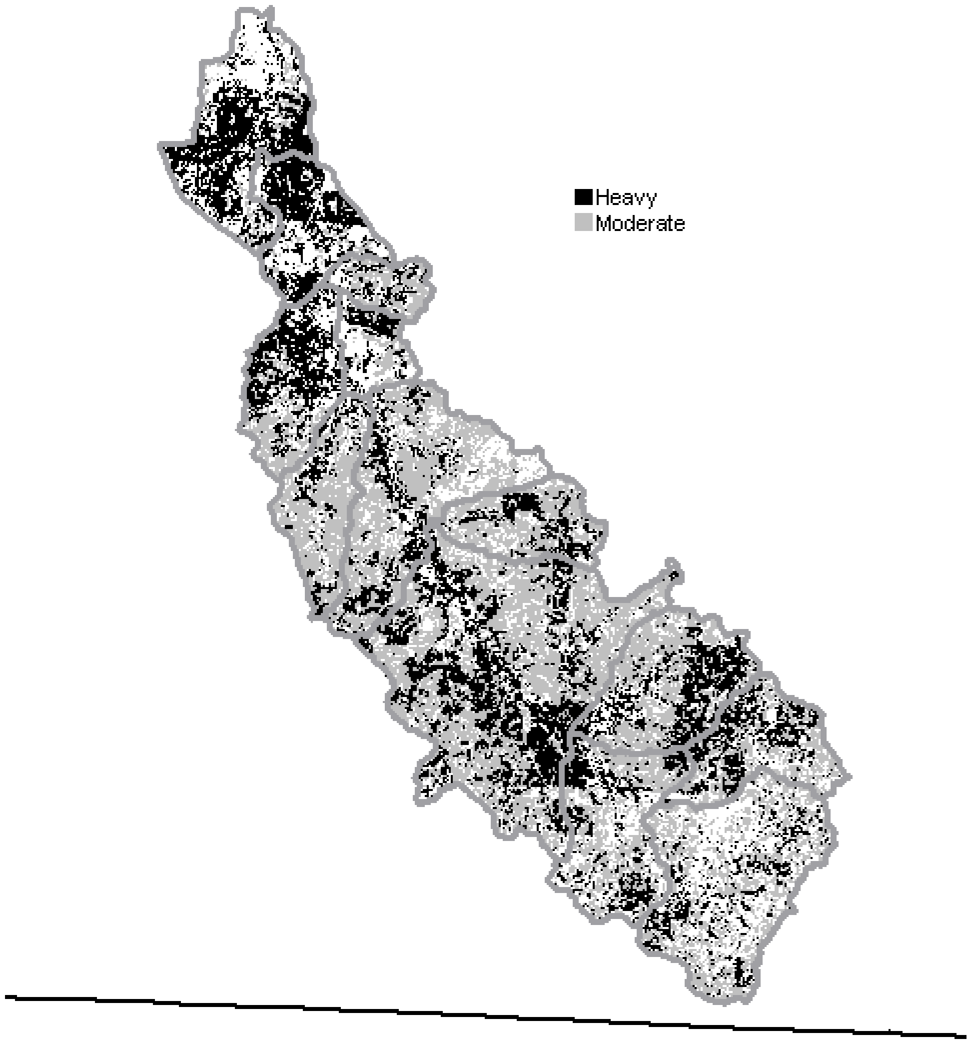

Figure TBN-13. Areas of heavy and moderate brush (oak not included) in Pecan Creek.

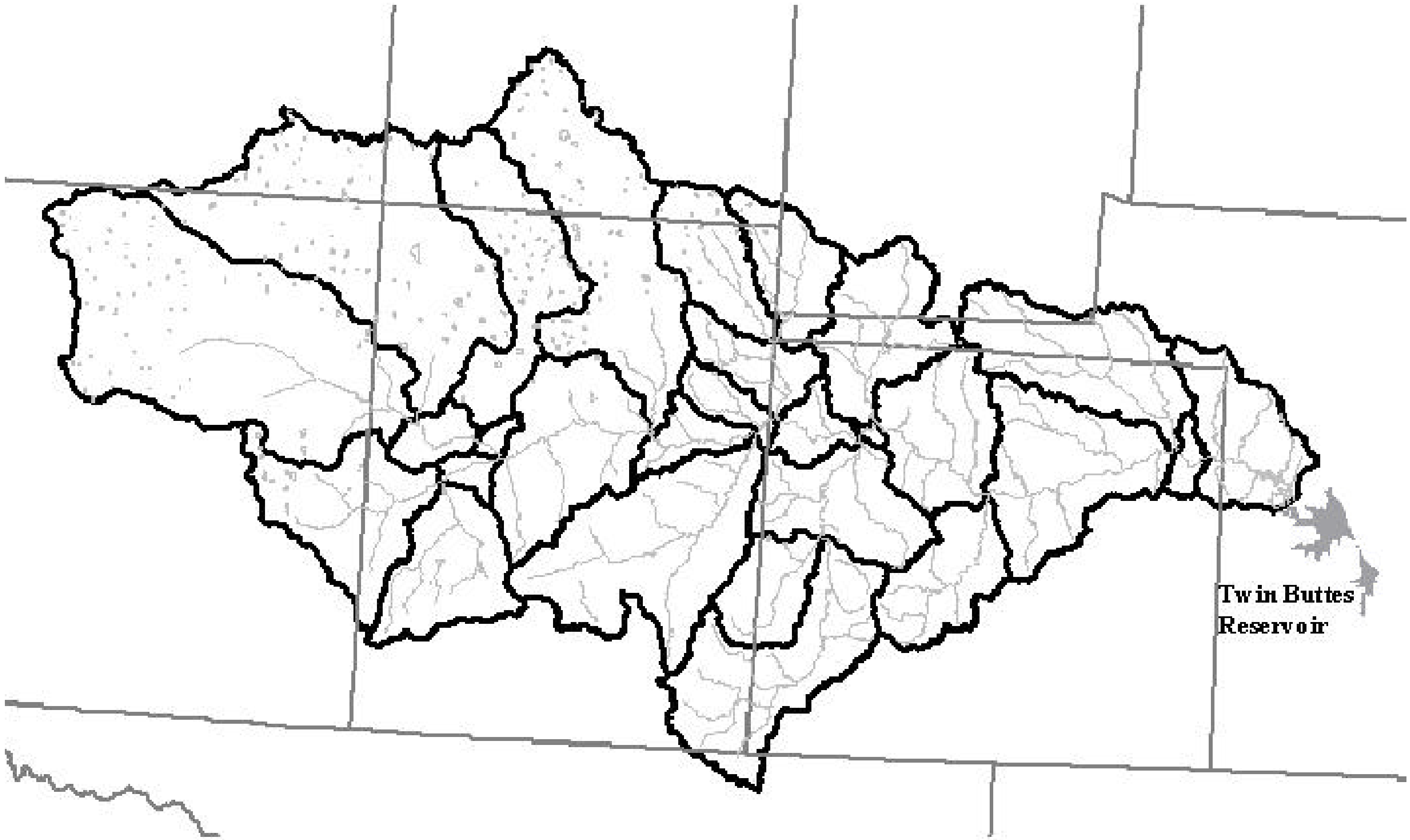

Figure TBN-14. Stream network and Twin Buttes Reservoir in the Middle Concho River.

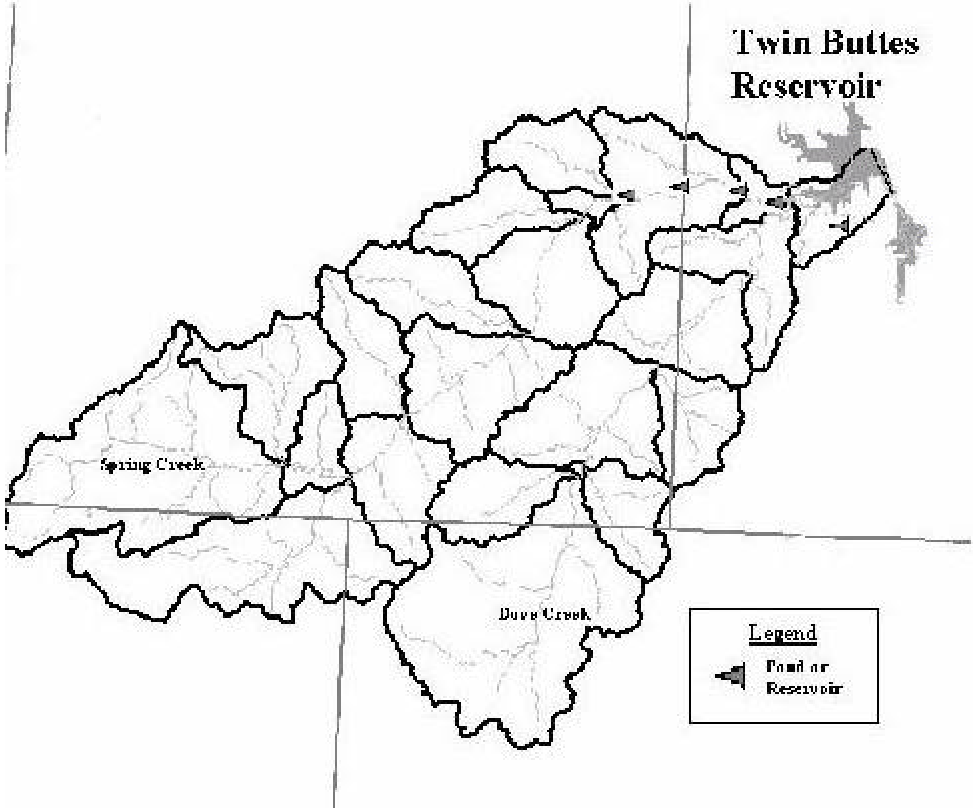

Figure TBN-15. Stream network and significant ponds and reservoirs in Spring and Dove Creeks (from Texas Natural Resource Conservation Commission inventory of dams).

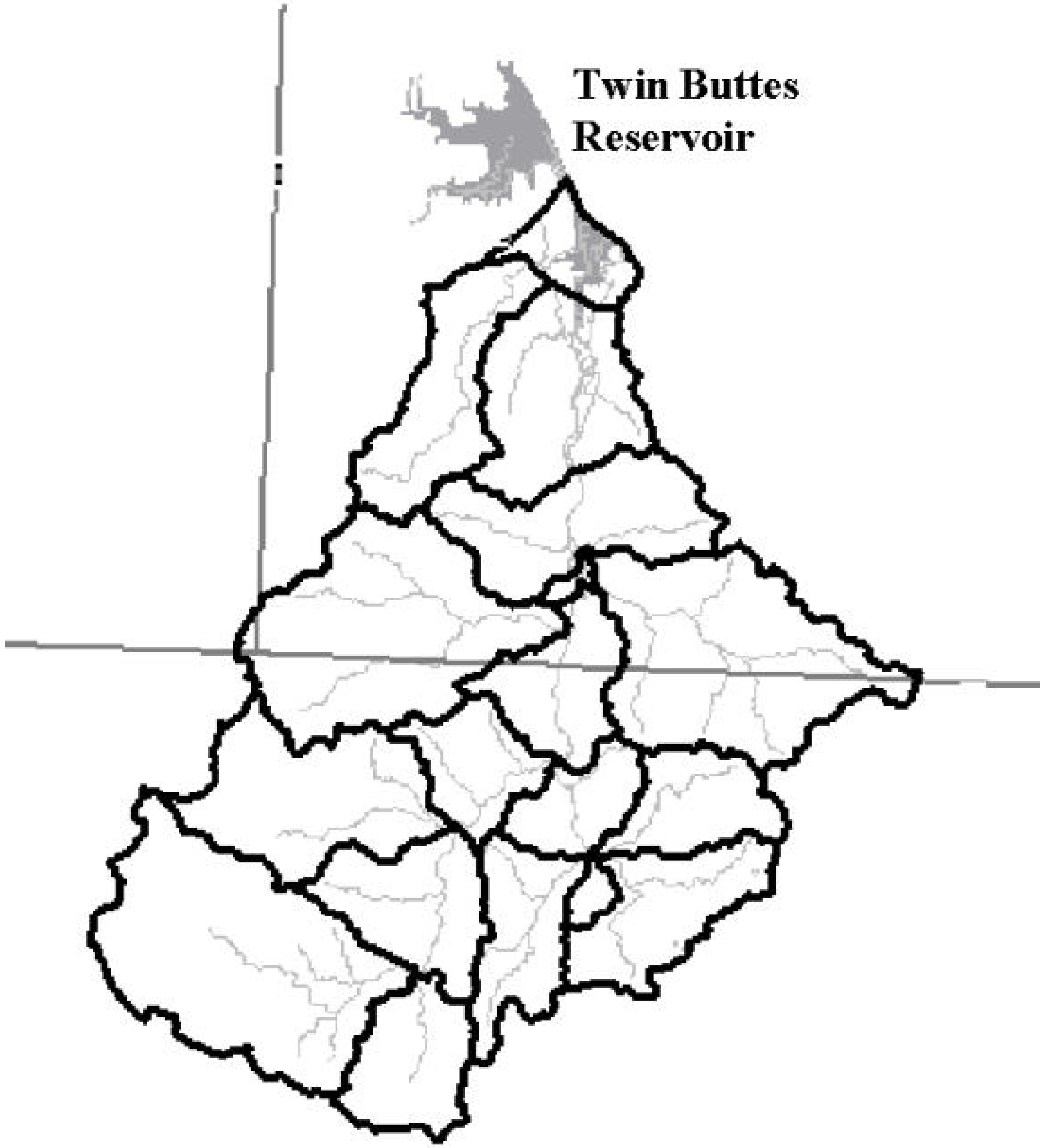

Figure TBN-16. Stream network and Twin Buttes Reservoir in the South Concho River.

Figure TBN-17. Stream network and Lake Nasworthy in Pecan Creek.

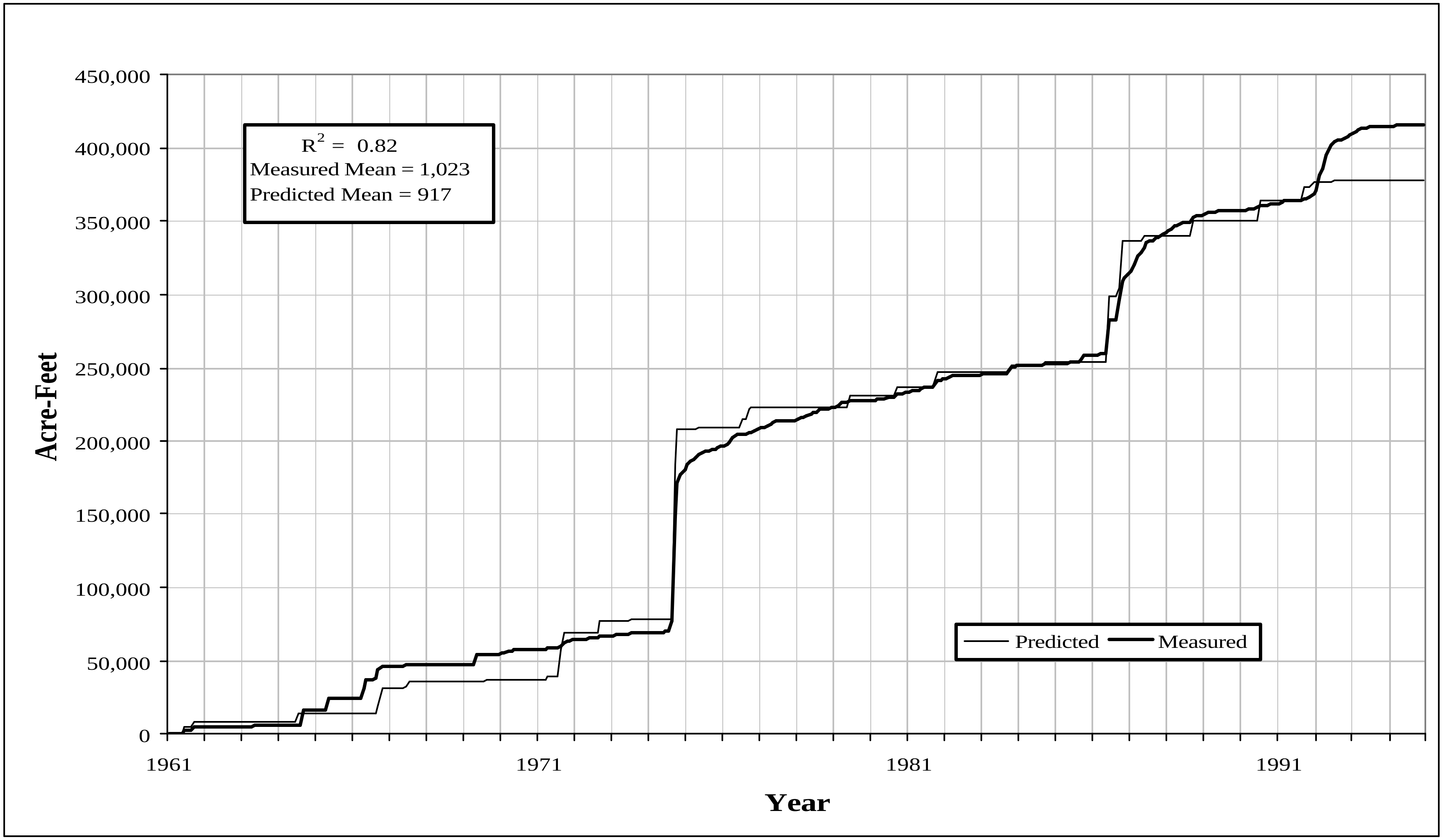

Figure TBN-18. Cumulative monthly total measured and predicted stream flow at gauge 08128400 (near Tankersley), Middle Concho River, 1961 through 1994. Monthly statistics are shown in box.

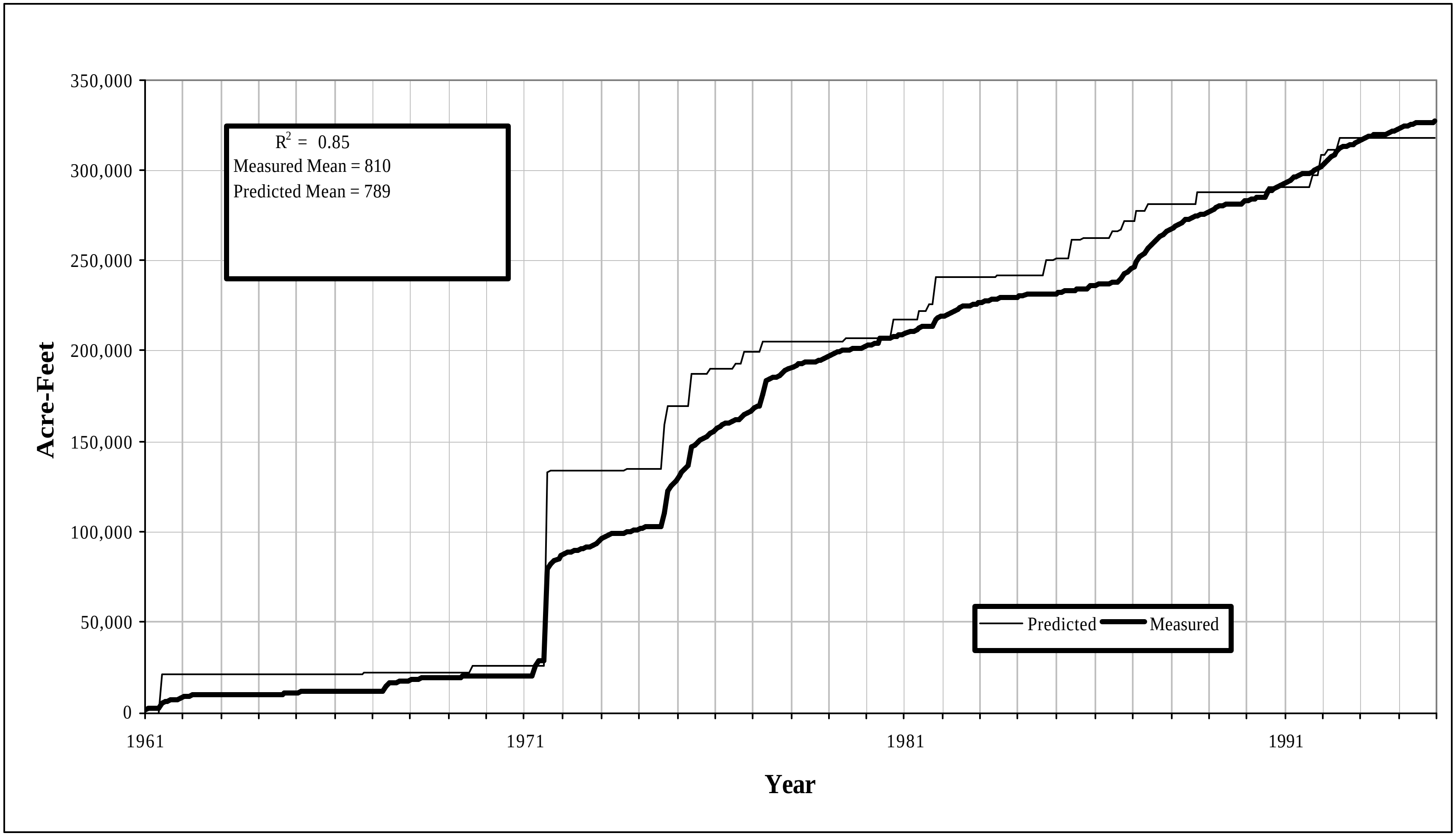

Figure TBN-19. Cumulative monthly total measured and predicted stream flow at gauge 08129300 (above Tankersley), Spring Creek, 1961 through 1994. Monthly statistics are shown in box.

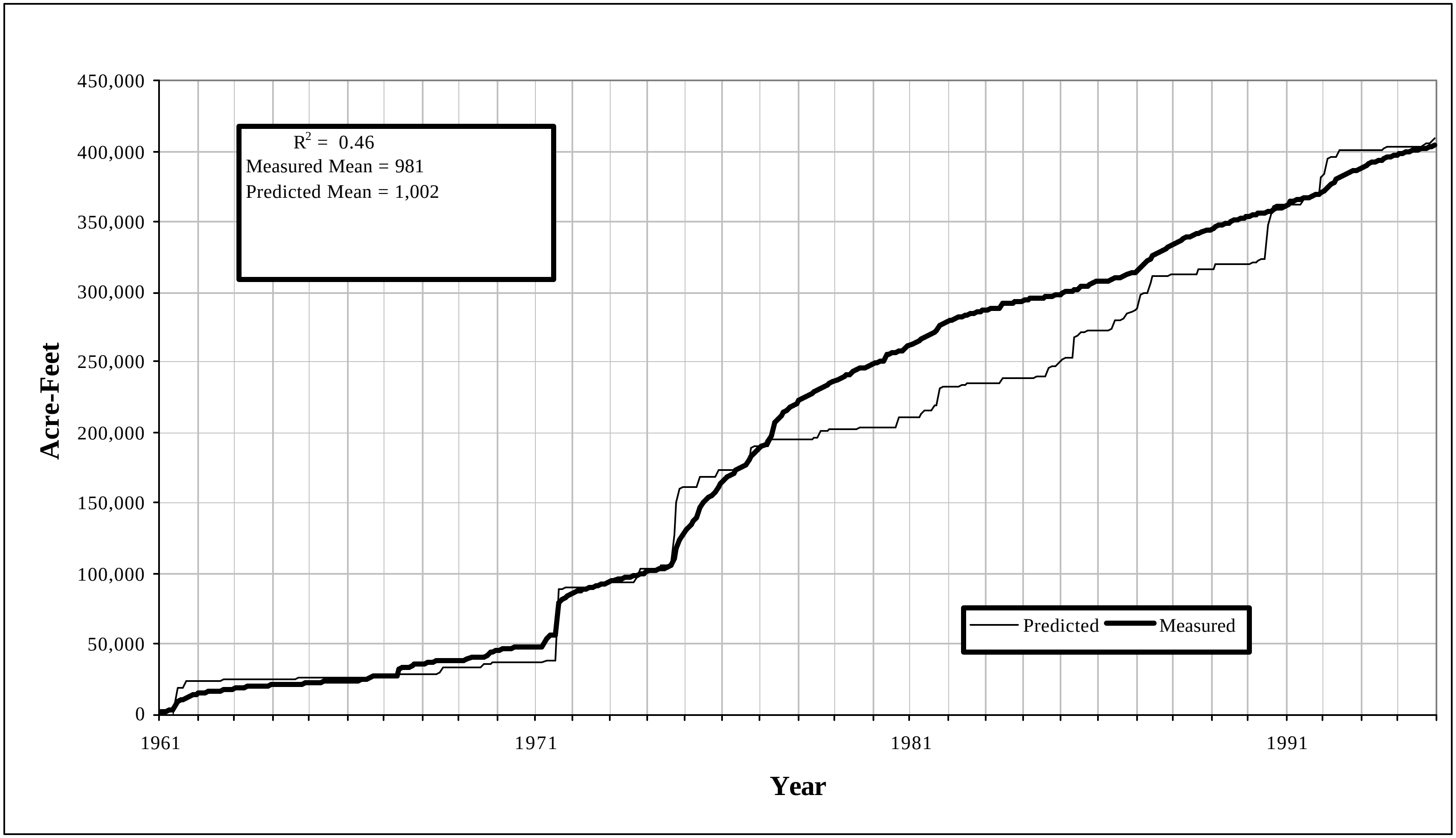

Figure TBN-20. Cumulative monthly total measured and predicted stream flow at gauge 08130500 (at Knickerbocker), Dove Creek, 1961 through 1994. Monthly statistics are shown in box.

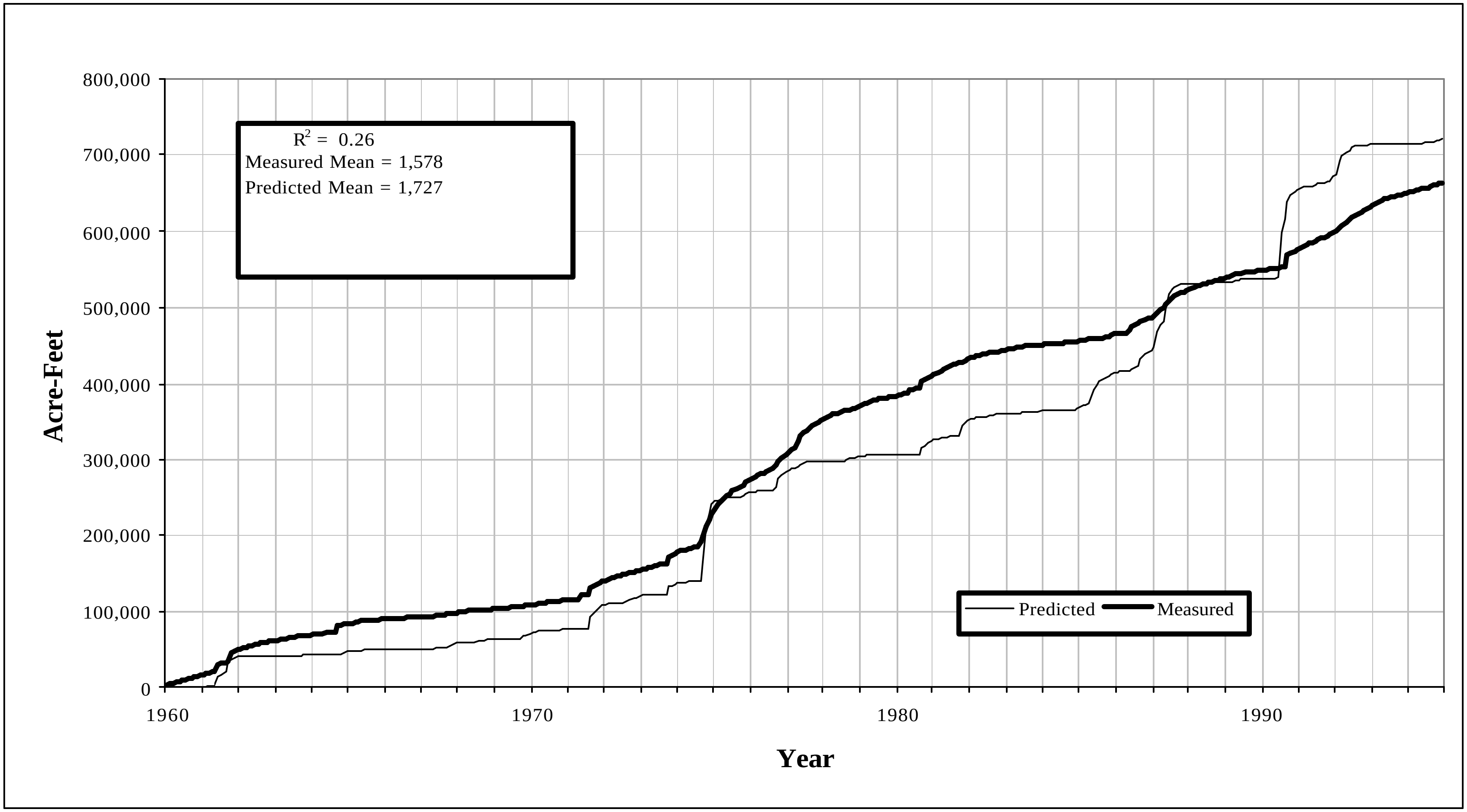

Figure TBN-21. Cumulative monthly total measured and predicted stream flow at gauge 08128000 (at Christoval), South Concho River, 1960 through 1994. Monthly statistics are shown in box.

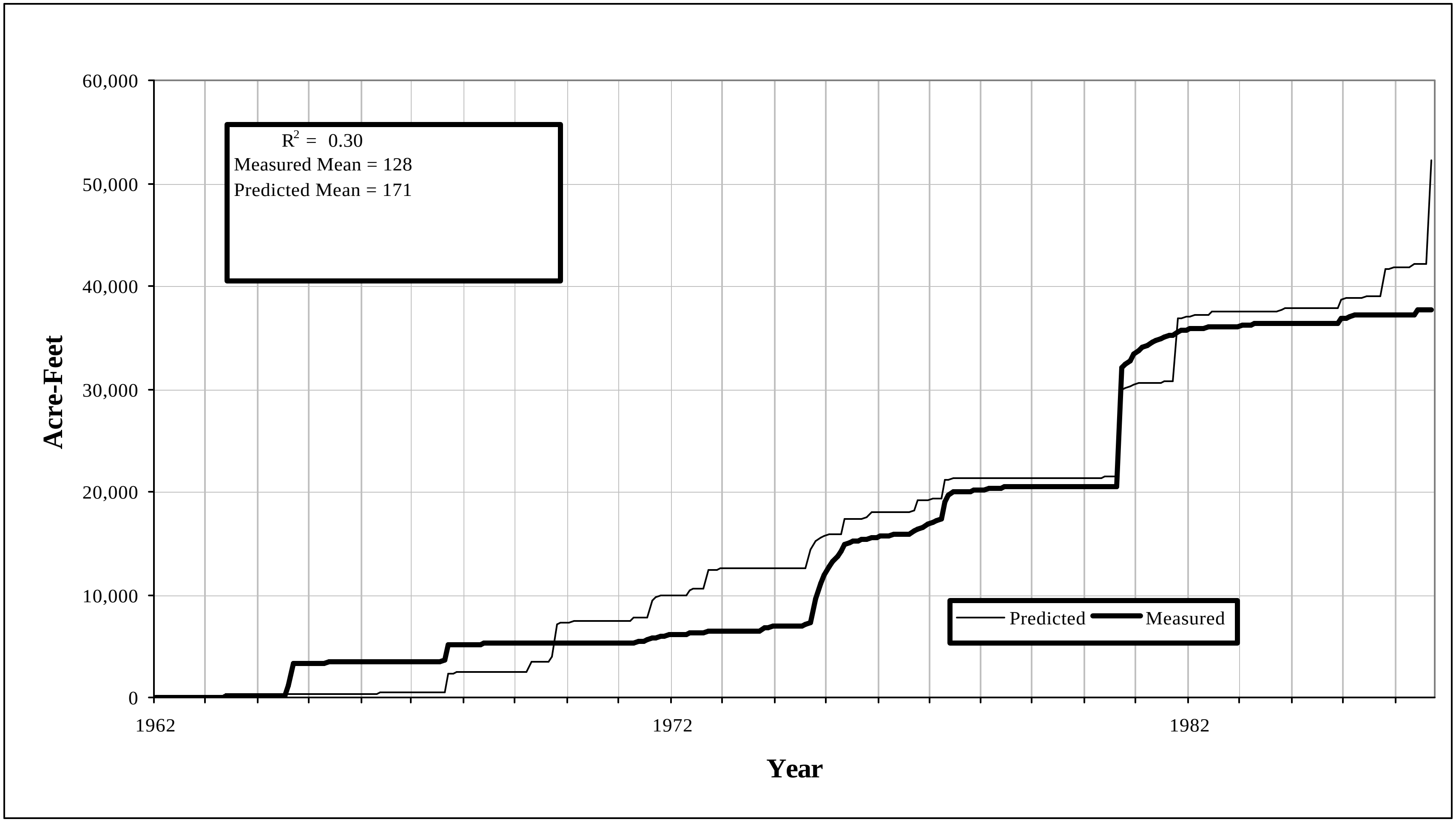

Figure TBN-22. Cumulative monthly total measured and predicted stream flow at gauge 08131400 (near San Angelo), Pecan Creek, 1962 through 1986. Monthly statistics are shown in box.

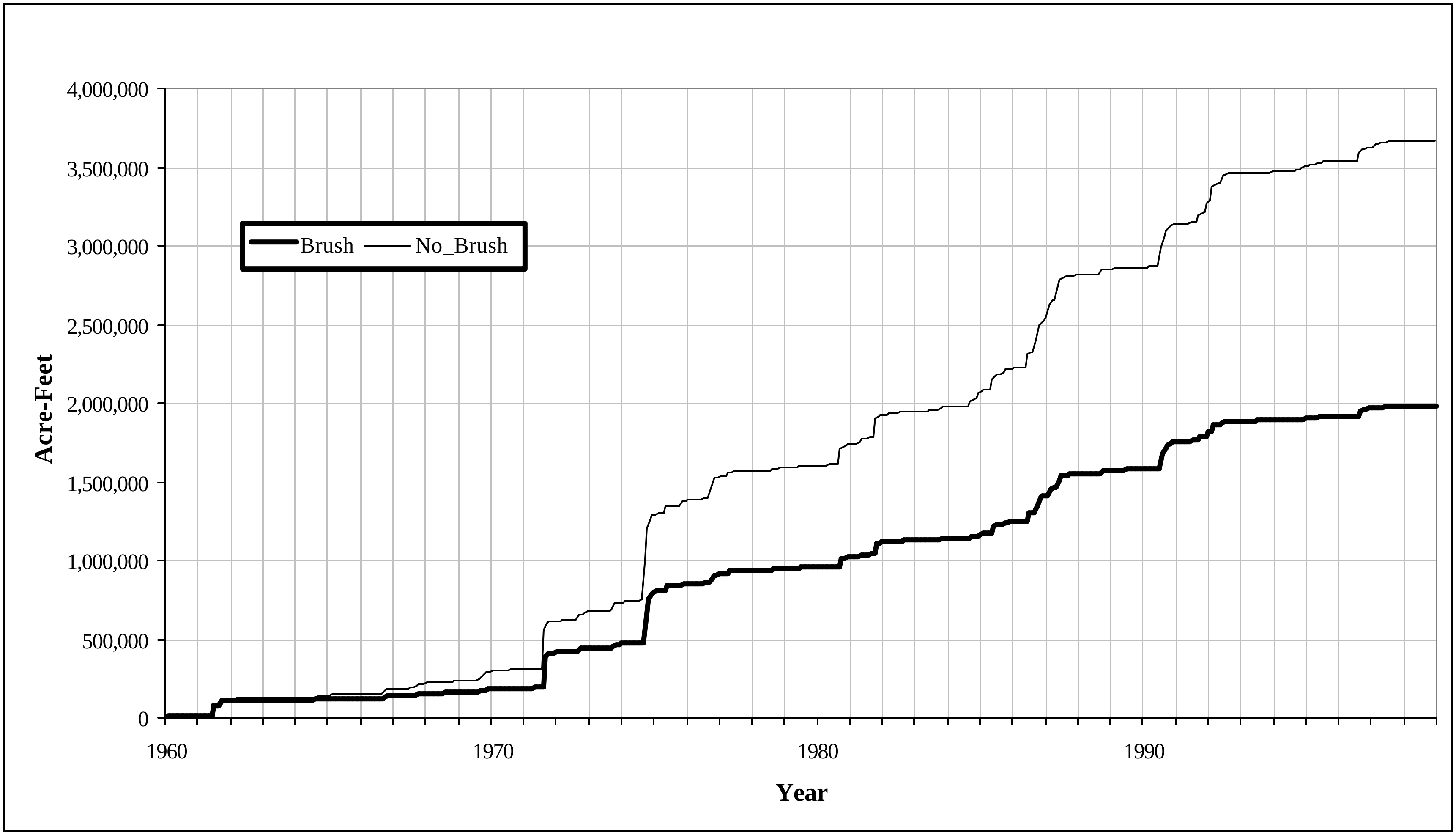

Figure TBN-23. Cumulative monthly total predicted flow to Twin Buttes Reservoir with and without brush, 1960 through 1998.

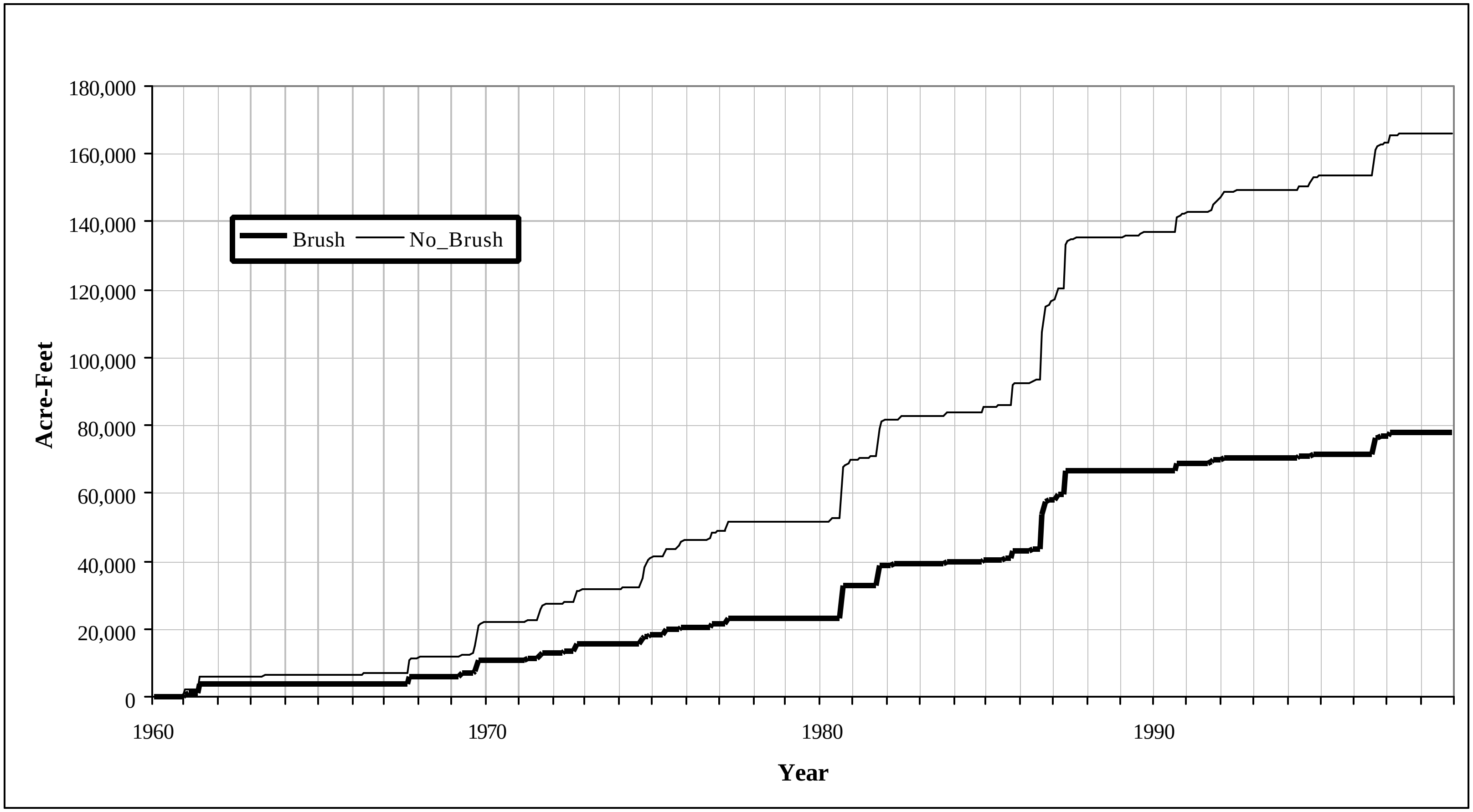

Figure TBN-24. Cumulative monthly total predicted flow to Lake Nasworthy with and without brush, 1960 through 1998.

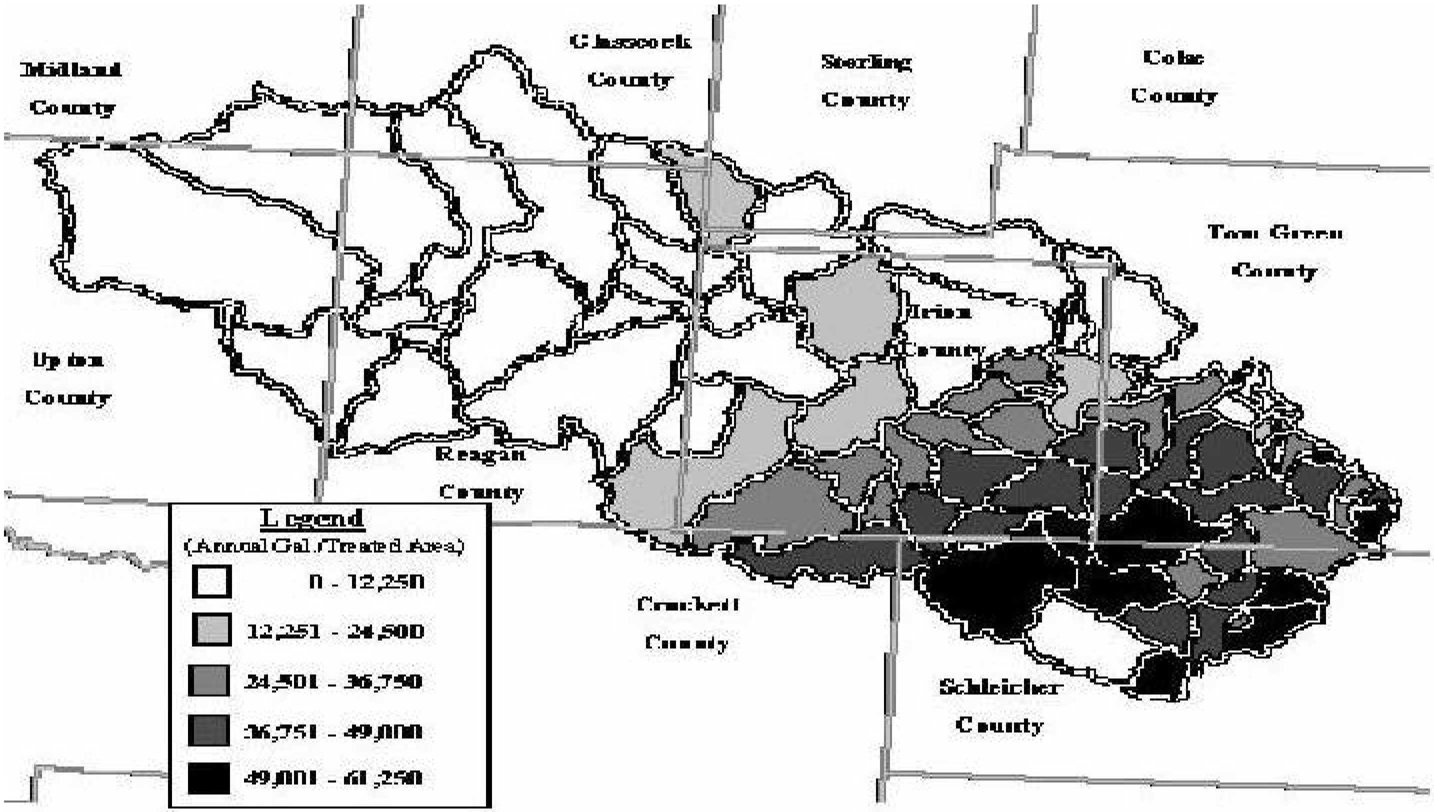

Figure TBN-25. Annual increase in water yield per treated acre due to brush removal, Twin Buttes/Nasworthy Watershed, 1960 through 1998..

CHAPTER 16

TWIN BUTTES/NASWORTHY WATERSHED ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Twin Buttes/Nasworthy watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs in the project area (per acre) range from $39.61 for moderate mesquite that can be initially controlled with herbicide treatments to $94.89 for mechanical control of heavy cedar, mesquite and mixed brush. The costs of treatments, year those treatments are needed and treatment life for each brush type density category are detailed in Table 1.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	85.00	85.00
5	IPT or Burn	15.00	9.89
		Total	94.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Heavy Mesquite – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	85.00	85.00
5	IPT or Burn	15.00	9.89
		Total	94.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Heavy Mesquite – Chemical

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	26.00	26.00
5	Aerial Herbicide	26.00	17.70
8	IPT or Burn	15.00	7.65
		Total	51.35

Heavy Mixed – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	85.00	85.00
5	IPT or Burn	15.00	9.89
		Total	94.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Moderate Cedar – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	55.00	55.00
5	IPT or Burn	15.00	9.89
		Total	64.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Moderate Mesquite – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	55.00	55.00
5	IPT or Burn	15.00	9.89
		Total	64.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

Moderate Mesquite - Chemical

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	26.00	26.00
5	IPT or Burn	20.00	13.61
		Total	39.61

Table 1. Middle Concho Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Moderate Mixed – Mechanical Choice[1]

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	55.00	55.00
5	IPT or Burn	15.00	9.89
		Total	64.89

[1]Choice of tree dozing with rake, stack and burn, tree shearing with stump spray and later burn, or excavation and later burn.

* Middle and South Concho River Watersheds

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the watersheds draining to the Twin Buttes Reservoir and Lake Nasworthy are shown in Table 2. Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type-Density Classification	Brush Control (Or) No Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Cedar	Brush Control	70.0	55.0	45.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
	No Control	70.0	70.0	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8
Heavy Mesquite	Brush Control	38.0	33.0	28.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	38.0	38.0	38.1	38.1	38.2	38.2	38.3	38.3	38.4	38.4
Heavy Mix	Brush Control	50.0	43.0	36.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	50.0	50.0	50.1	50.2	50.3	50.4	50.5	50.5	50.6	50.6
Moderate Cedar	Brush Control	52.0	43.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0	35.0
	No Control	52.0	52.3	52.7	53.0	53.4	53.8	54.1	54.4	54.7	54.9
Moderate Mesquite	Brush Control	32.0	28.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	32.0	32.2	32.4	32.6	32.8	33.0	33.2	33.4	33.6	33.7
Moderate Mix	Brush Control	40.0	35.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
	No Control	40.0	40.2	40.5	40.8	41.0	41.3	41.6	41.8	42.0	42.2

* Middle and South Concho River Watersheds

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with landowners, Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area. Livestock grazing capacities range from about 25 acres per AUY for land on which mesquite is controlled to 70 acres per animal unit year (AUY) for land infested with heavy cedar.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle, sheep, and goats) in the project areas is shown in Tables 3a, 3b, and 3c. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $0.50 per acre (from $8.00 per acre to $8.50 per acre) due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3a. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	472.50	Pound	0.77	363.83
Cows	111.1	Pound	.40	0
Bulls	10.0	Pound	.50	0
			Total	363.83

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	500.0	Pound	0.10	50.00
Salt & Minerals	27.0	Pound	0.20	5.40
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	15.00	15.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	6.09	6.09
			Total	130.09

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
* Middle and South Concho River Watersheds

Table 3b. Investment Analysis Budget, Sheep Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Lambs	315.0	Pound	0.85	267.75
Ewes	0.83	Head	30.00	0
Rams	0.037	Head	50.00	0
Wool	8.0	Pound	1.00	8.00
			Total	275.75

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	400.0	Pound	0.10	40.00
Salt & Minerals	90.0	Pound	0.20	18.00
Marketing	1.0	Head	1.00	5.00
Veterinary Medicine	1.0	Head	3.00	15.00
Shearing	1.2	Head	2.00	12.00
Miscellaneous	1.2	Head	1.00	6.00
Net Replacement Ewes[3]	1.0	Head	34.80	34.80
Net Replacement Rams[4]	1.0	Head	7.80	7.80
			Total	138.60

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
* Middle and South Concho River Watersheds

Table 3c. Investment Analysis Budget, Meat Goat Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Kids	0.80	Head	50.00	240.00
Nannies	0.167	Head	25.00	0
Bucks	0.0076	Head	50.00	0
			Total	$240.00

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	400.0	Pound	0.10	40.00
Salt & Minerals	73.5	Pound	0.20	14.70
Marketing	1.0	Head	1.00	6.00
Veterinary Medicine	1.0	Head	2.50	15.00
Miscellaneous	1.0	Head	1.17	7.00
Net Replacement Nannies[3]	1.0	Head	36.48	36.48
Net Replacement Bucks[4]	1.0	Head	9.36	9.36
			Total	$128.54

WARNING – This Information Does Not Contain All Revenues Nor All Costs Associated With The Described Production Enterprise.
* Middle and South Concho River Watersheds

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $9.91 per acre for control of moderate mixed brush to $16.59 per acre for the control of heavy cedar (Table 4).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the project area range from $29.12 for control of moderate mesquite with chemical treatments to $79.23 for control of heavy mesquite by mechanical method. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Table 4.

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush Category by Type & Density	PV Total Cost ($/Acre)	Landowner Share ($/Acre)	Landowner (Percent)	State Share ($/Acre)	State (Percent)
Heavy Cedar	94.89	16.59	17.5	78.30	82.5
Heavy Mesquite (Mechanical One)	94.89	15.66	16.5	79.23	83.5
Heavy Mesquite (Chemical)	51.35	15.66	30.5	35.69	69.5
Heavy Mixed Brush	94.89	16.35	17.2	78.54	82.8
Moderate Cedar	64.89	11.79	18.2	53.10	81.8
Moderate Mesquite (Mechanical)	64.89	10.49	16.2	54.40	83.8
Moderate Mesquite (Chemical)	39.61	10.49	26.5	29.12	73.5
Moderate Mixed Brush	64.89	9.91	15.3	54.98	84.7
Average[1]	71.29	13.37	19.74	57.92	80.26

* Twin Buttes and Nasworthy Watersheds

[1] Average is calculated as simple average, not relative average. The averages are based on the Heavy Mesquite Chemical comprising 50% of the cost for Heavy Mesquite control and Heavy Mesquite Mechanical comprising the other 50% of the cost for Heavy Mesquite. Also, it is assumed that Mechanical and Chemical comprise 50% each of cost for Moderate Mesquite control. Actual averages may change depending on relative amounts of each Type- Density Category of brush in each control category.

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The Twin Buttes/Nasworthy watershed is a complex of individual watersheds including the Middle Concho River, Spring and Dove Creeks, the South Concho River, and Pecan Creek, all of which drain into the Twin Buttes Reservoir and Lake (Nasworthy before becoming the Main Concho River. Costs of added water resulting from the removal of brush was determined for each component of the complex.

The cost of added water was determined to average $204.05 per acre-foot for the Middle Concho Watershed (Table 5a). For the Dove and Spring Creek Watersheds, the cost of added water from brush control averages $60.14 per acre-foot (Table 5b). Average cost per acre-foot for added water in the South Concho watershed is $50.92 (Table 5c). For the Pecan Creek watershed, the cost of added water from brush control averages $70.80 per acre-foot (Table 5d). The average cost of water gained from brush control is $90.79 per acre-foot for the entire Twin Buttes/Nasworthy watershed.

Table 5a. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	0.00	0.00	0.00	0.00
2	263,044.78	73.55	573.87	458.37
3	0.00	-------	-------	0.00
4	0.00	-------	-------	0.00
5	196,104.30	88.88	693.43	282.80
6	0.00			0.00
7	738,932.40	246.18	1,920.73	384.71
8	58,794.56	28.86	225.15	261.13
9	491,068.80	292.63	2,283.12	215.09
10	23,204.70	8.97	69.95	331.74
11	0.00	-------	-------	0.00
12	991,240.84	529.97	4,134.79	239.73
13	951,419.52	653.48	5,098.47	186.61
14	448,585.92	318.09	2,481.75	180.75
15	266,848.74	159.31	1,242.97	214.69
16	2100,789.60	1,147.64	8,953.90	234.62
17	1137,920.00	990.03	7,724.21	147.32
18	1743,997.00	1,122.74	8,759.58	199.10
19	490,770.52	287.20	2,240.73	219.02
20	57,670.86	30.95	241.47	238.83
21	1668,651.50	848.92	6,623.25	251.94
22	1097,959.40	658.69	5,139.10	213.65
23	3511,937.00	2,841.34	22,168.13	158.42
24	2119,024.20	1,575.72	12,293.73	172.37
25	2338,374.70	1,720.77	13,425.42	174.18
26	2725,217.00	1,681.90	13,122.21	207.68
27	3382,707.30	1,765.91	13,777.64	245.52
28	1436,962.30	667.64	5,208.96	275.86
Totals:	28,241,226.00	----------	138,402.60	Average: $204.05

* Middle Concho River Watershed

Table 5b. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	1,696,697.98	2,950.09	23,016.58	73.72
2	935,717.30	2,900.15	22,626.94	41.35
3	1,329,157.42	4,344.69	33,897.24	39.21
4	532,079.44	1,753.06	13,677.34	38.9
5	9,210.58	13.51	105.41	87.38
6	604,906.52	1,372.42	10,707.66	56.49
7	728,537.52	1,628.70	12,707.08	57.33
8	259,313.22	465.5	3,631.85	71.4
9	584,263.92	1,033.26	8,061.46	72.48
10	596,360.72	1,083.81	8,455.92	70.53
11	994,549.26	2,250.85	17,561.16	56.63
12	1,073,602.04	2,479.52	19,345.25	55.5
13	566,362.68	1,410.43	11,004.16	51.47
14	873,983.02	1,952.76	15,235.43	57.37
15	846,784.56	1,572.91	12,271.85	69
16	783,846.14	1,410.37	11,003.74	71.23
17	606,748.36	1,059.73	8,267.98	73.39
18	516,411.00	717.51	5,598.00	92.25
19	94,034.04	42.45	331.19	283.93
20	872,345.14	976.3	7,617.11	114.52
21	682,862.88	1,290.93	10,071.84	67.8
22	68,301.02	35.07	273.61	249.63
23	333,447.24	481.42	3,756.04	88.78
Totals:	15,589,522.00	----------	259,224.83	Average: $60.14

* Spring and Dove Creek Watersheds

Table 5c. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	0.00	0.00	0.00	0.00
2	141,602.83	463.68	3,617.62	39.14
3	611,666.89	1,872.35	14,608.07	41.87
4	420,561.43	1,124.62	8,774.29	47.93
5	419,905.69	1,172.47	9,147.61	45.90
6	71,133.39	144.98	1,131.14	62.89
7	292,600.67	896.67	6,995.81	41.83
8	257,138.27	803.92	6,272.19	41.00
9	361,328.87	770.30	6,009.89	60.12
10	461,294.92	901.88	7,036.43	65.56
11	1,302,785.48	4,096.06	31,957.49	40.77
12	463,386.63	1,206.61	9,413.98	49.22
13	1,448,543.59	3,050.71	23,801.64	60.86
14	34,600.85	81.44	635.36	54.46
15	793,152.09	2,048.80	15,984.78	49.62
16	959,060.47	2,216.62	17,294.07	55.46
17	676,635.19	1,598.95	12,475.01	54.24
18	209,888.66	61.04	476.26	440.70
Totals:	8,925,285.94	-----------	175,631.64	Average: $50.82

* South Concho River Watershed

Table 5d. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	203,244.20	631.73	4,928.78	41.24
2	144,765.20	346.84	2,706.02	53.50
3	216,383.10	351.69	2,743.90	78.86
4	181,265.50	321.56	2,508.81	72.25
5	664,743.10	1,309.27	10,214.91	65.08
6	122,015.10	318.93	2,488.32	49.04
7	261,917.40	515.70	4,023.48	65.10
8	132,148.50	353.06	2,754.56	47.97
9	147,649.20	174.59	1,362.18	108.39
10	48,561.62	41.22	321.57	151.02
11	56,165.89	45.62	355.89	157.82
12	118,131.50	48.20	376.06	314.13
13	196,544.80	56.03	437.17	449.59
Totals:	$2,493,535.00	----------	35,221.63	Average: $70.80

*Pecan Creek Watershed

CHAPTER 17

UPPER COLORADO RIVER WATERSHED – HYDROLOGIC SIMULATION

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WATERSHED DATA

Location
The Upper Colorado River Watershed is located in west and central Texas (Figures 1 and UC-1). The upper portion of the watershed is in the High Plains Major Land Resource Area (MLRA), and the lower portion is in the Edwards and Rolling Plains MLRA'0s.

Topography
The outlet or "catchment" for the portion of the Upper Colorado River simulated in this study is Lake O.H. Ivie, which is located in subbasin number 70. The subbasin delineation and numbers are shown in Figure UC-2. Roads (obtained from the Census Bureau) are shown in Figure UC-3.

Weather Data
The average annual rainfall for the Upper Colorado River Watershed varied from 14.3 inches in the western portion of the watershed to 24.7 inches in the eastern portion. The composite average for the entire watershed was 18.4 inches. Weather stations used for modeling are shown in Figure UC-4. For each subbasin, precipitation and temperature data were retrieved by the SWAT input interface for the climate station nearest the centroid of the subbasin.

Soils
The dominant soil series in the portion of the Upper Colorado River watershed where brush treatment was simulated were Amarillo, Brownfield, Ector, Miles, Nuvalde, Olton, Portales, Potter, Rowena, and Vernon. These ten soil series represented about 53 percent of the area. A short description of each follows:

Amarillo. The Amarillo series consists of very deep, well drained, moderately permeable soils. These soils formed in calcareous, loamy eolian sediments in the Blackwater Draw Formation of Pleistocene age. These soils are on nearly level to gently sloping plains. Slope ranges from 0 to 5 percent. Mean annual precipitation is 19 inches and the mean annual temperature is 60 degrees F.

Brownfield. The Brownfield series consists of very deep, well drained, moderately permeable soils that formed in moderately sandy, eolian sediments in the Blackwater Draw Formation of Pleistocene age. Brownfield soils are on nearly level to gently sloping plains. Slope ranges from 0 to 5 percent. The mean annual precipitation is 19 inches and the mean annual temperature is 61 degrees F.

Ector. The Ector series consists of very shallow or shallow, well drained soils that are moderately permeable above a very slowly permeable limestone bedrock. They formed in loamy residuum. These gently sloping to very steep upland soils have slopes ranging from 1 to 60 percent.

Miles. The Miles series consists of very deep, well drained, moderately permeable soils that formed in loamy alluvial materials. These soils are on nearly level to moderately sloping terrace pediments on uplands in the Central Rolling Red Plains (MLRA 78B, 78C). Slopes range from 0 to 8 percent.

Nuvalde. The Nuvalde series consists of very deep, well drained, moderately permeable soils that formed in limey alluvium. These soils are on nearly level to gently sloping stream terraces and alluvial fans. Slopes range from 0 to 5 percent.

Olton. The Olton series consists of very deep, well drained, moderately slowly permeable soils that formed in loamy, calcareous eolian sediments in the Blackwater Draw Formation of Pleistocene age. These soils are on nearly level to gently sloping plains and upper side slopes of playas and draws. Slope ranges from 0 to 5 percent. Mean annual precipitation is 20 inches, and mean annual temperature is 62 degrees F.

Portales. The Portales series consists of very deep, well drained, moderately permeable soils. These soils formed in medium to moderately fine textured, calcareous, lacustrine sediments of Pleistocene age. These soils are on nearly level to very gently sloping concave plains associated with playa lake basins. Slope ranges from 0 to 1 percent. The mean annual precipitation is about 18 inches and the mean annual temperature is about 61 degrees F.

Potter. The Potter series consists of soils that are shallow to a fractured and weathered caliche layer. They are well drained, moderately permeable soils that formed in moderately to strongly cemented caliche of Miocene-Pliocene age. These soils are on very gently sloping to steep sloping convex hills, ridges, and upper side slopes, around the margin of larger playa lakes, ancient drainageways, and along the Caprock Escarpment. Slopes range from 1 to 30 percent. The mean annual precipitation is 19 inches and the mean annual temperature is 61 degrees F.

Rowena. The Rowena series consists of very deep, well drained, moderately slowly permeable soils on upland plains. They formed in calcareous loamy and clayey sediments. Slopes range from 0 to 3 percent.

Vernon. The Vernon series consists of moderately deep, well drained, very slowly permeable soils that formed in residuum weathered from claystone. These soils are on gently sloping to steep uplands of the Central Rolling Red Plains (MLRA-78B, 78C), Central Limestone Prairies (MLRA 78D) and North Central Prairie (MLRA 80B). Slopes range from 1 to 45 percent.

Land Use/Land Cover

Figure UC-5 shows the areas of heavy and moderate brush (oak not included) in the Upper Colorado River Watershed. This was the area of brush removed or treated in the no-brush simulation. Brush treatment was not simulated in subbasins west of the 18 inch isohyet.

Ponds, Reservoirs, Withdrawals

Surface area, storage, and drainage area were obtained from the Texas Natural Resource Conservation Commission (TNRCC) for existing inventory-sized ponds and reservoirs in the watershed (Figure UC-6), and input to the SWAT model. Withdrawals from reservoirs for municipal and other uses were estimated from data obtained from Texas Water Development Board (TWDB). Since data for low flow withdrawals (brine control) from the Colorado River was not available, an estimated withdrawal of 7 cubic feet per second (14 acre-feet per day) was used for subbasin 53.

Model Input Variables

Significant input variables for the SWAT model for the Upper Colorado River Watershed are shown in Table UC-1. The input variables for the no-brush condition, with one exception, were the same as the calibration variables, with the change in landuse being the only difference between the two simulations. The exception is that we assumed the shallow aquifer re-evaporation coefficient would be higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units (HRU – combinations of soil and land use/cover) is 0.4, and for non-brush HRU's is 0.1.

UPPER COLORADO RIVER WATERSHED RESULTS

Calibration

SWAT was calibrated for flow at 13 USGS stream gauges shown in Figure UC-7. The results of calibration are shown for gauges 08117995, 08123800, 08121000 and 08126380 in Figures UC-8 through UC-11. The simulation period for gauge 08117995 was 1988 through 1998. The simulation period for the other 3 gauges was 1960 through 1998. Measured and predicted total monthly flows compare reasonably well with R^2 values of 0.49 for gauge 08123800, 0.50 for gauge 08121000, 0.44 for gauge 08126380, and 0.24 for gauge 08117995. The low value of R^2 at gauge 08117995 was probably due to the spatial variability of rainfall which was not reflected in measured weather data.

The measured and predicted monthly means were reasonably close for all four gauges. However, SWAT over-predicted flow at gauge 08123800 and under-predicted by a small amount at the other three gauges. At all four stream gauge stations, SWAT under-predicted flows in some portions of the simulation period and over-predicted in others. Again, this was most likely due to spatial variability of rainfall which was not reflected in measured weather data.

Brush Removal Simulation

Average annual evapo-transpiration (ET) was 17.59 inches for the brush condition (calibration) and 17.34 inches for the no-brush condition, or 96% and 94% of precipitation for the brush and no-brush conditions, respectively.

The total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin are shown in Table UC-2. The amount of annual increase varied among the subbasins and ranged from 0 gallons per acre of brush removed per year in subbasin number 46, to 55,354 gallons per acre in subbasin number 67. Variations in the amount of increased water yield were expected and were influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields were most likely due to greater rainfall volumes as well as increased density and canopy of brush.

A gray-scale graph of the subbasins in the Upper Colorado River watershed, with water yield increases represented by varying color intensities is shown in Figure UC-12. Darker shading represents higher water yield increases. Subbasin lines are not shown for the area west of the 18-inch isohyet, because brush treatment was not modeled in this area.

Figure UC-13 shows the average annual flow to Lakes Thomas, Colorado City, Champion Creek, Oak Creek, Spence, Ballinger, Elm Creek, and Ivie for the brush and no-brush conditions from 1960 through 1998. The average annual increase in flow to these lakes is shown in Table UC-3. The increase in volume of flow to the reservoirs was less than the water yield in some cases because of the capture of runoff by upstream reservoirs, as well as stream channel transmission losses that occurred between each subbasin and the watershed outlet.

For the entire simulated watershed, the average annual water yield increased by about 49% or 142,667 acre-feet, and flow at the watershed outlet (Lake O.H. Ivie) increased by 41,995 acre-feet.

Table UC-1. SWAT Input Variables

VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	- 6 to + 4	- 6 to + 4
Soil Available Water Cap. Adj.(inches H^2O/in.soil)	0 & -0.03	0 & -0.03
Soil Evaporation Compensation Factor	0.1	0.1
Min. Shallow Aqu. Storage for GW flow (inches)	0.04 to 3.94	0.04 to 3.94
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0	0
Potential Heat Units (^{o}C)		
Heavy Cedar	3900	N/A
Heavy Mesquite	3393	N/A
Heavy Mixed Brush	3627	N/A
Moderate Cedar	3393	N/A
Moderate Mesquite	3003	N/A
Moderate Mixed Brush	3198	N/A
Heavy Oak	3393	3393
Moderate Oak	3003	3003
Light Brush & Open Range/Pasture	2613	2613
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.04 to 3.94	0.04 to 3.94
Subbasin Transmission Loss (inches/hour)	0.015 to 3.94	0.015 to 3.94
Fraction Trans. Loss Returned as Base Flow	0.5	0.5

Table UC-2. Subbasin Data and Water Yield
(Subbasins west of 18 inch isohyet not shown)

Subbasin No.	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
12	219,688	67,370	0.31	8,304	559,439,440
13	114,447	38,974	0.34	8,752	341,114,277
16	41,400	2,905	0.07	7,740	22,483,504
17	332,809	80,307	0.24	3,221	258,662,343
18	115,928	8,008	0.07	7,940	63,578,516
45	192,855	70,409	0.37	13,303	936,651,614
48	86,673	33,792	0.39	19,737	666,957,730
LakeThomas Sub-Total	1,103,799	301,765	---	---	2,848,887,423
14	410,310	85,244	0.21	283	24,125,643
34	214,246	111,558	0.52	9,958	1,110,858,823
35	12,402	6,358	0.51	7,453	47,384,781
39	55,689	27,724	0.50	1,752	48,580,691
40	251,022	65,750	0.26	1,384	90,973,764
41	115,948	48,184	0.42	4,160	200,435,985
42	35,165	17,519	0.50	7,421	130,000,262
43	312,065	193,394	0.62	26,671	5,158,068,825
44	166,797	71,372	0.43	12,340	880,704,493
46	101,104	0	0.00	0	0
47	286,802	153,260	0.53	13,650	2,091,998,799
49	112,026	34,266	0.31	23,106	791,750,571
50	129,158	51,670	0.40	26,237	1,355,656,892
51	37,252	14,785	0.40	15,451	228,437,699
52	6,044	1,900	0.31	21,404	40,658,577
53	34,026	8,453	0.25	19,775	167,150,103
54	46,604	19,347	0.42	10,368	200,585,259
55	12,614	5,700	0.45	18,376	104,738,881
56	69,810	32,679	0.47	10,501	343,156,838
57	42,491	14,283	0.34	17,874	255,292,573
58	46,588	10,170	0.22	25,548	259,833,678
59	50,020	14,575	0.29	11,143	162,403,864
60	115,737	40,347	0.35	31,535	1,272,324,292
61	209,281	118,333	0.57	26,205	3,100,969,477
63	207,677	145,343	0.70	46,389	6,742,303,822
71	49,384	32,119	0.65	37,078	1,190,934,522
Lake Spence Sub-Total	3,130,263	1,324,333	---	---	25,999,329,115
23	275	68	0.25	30,304	2,056,702
62	151,532	96,616	0.64	47,225	4,562,662,619
64	191,842	103,836	0.54	30,568	3,174,002,519
65	113,345	44,505	0.39	25,291	1,125,582,148
66	64,080	18,768	0.29	43,104	808,987,807
67	148,849	54,485	0.37	55,354	3,015,979,797
68	297,452	76,466	0.26	37,586	2,874,039,243
69	34,341	7,319	0.21	20,590	150,706,327
70	146,571	47,122	0.32	40,874	1,926,086,710
Lake Ivie Sub-Total	1,148,288	449,185	---	---	17,640,103,873
GRAND TOTAL	**5,382,350**	**2,075,282**	**---**	**---**	**46,488,320,411**
Watershed Average	**---**	**---**	**0.39**	**22,401**	**---**

Table UC-3. Inflow to Reservoirs

RESERVOIR	INFLOW TO RESERVOIRS (AC-FT/YR) BRUSH	NO BRUSH	INCREASE
J.B. THOMAS	12,188	16,734	4,546
COLORADO CITY	5,807	8,369	2,562
CHAMPION CREEK	9,101	11,880	2,779
OAK CREEK	18,307	30,974	12,666
E.V. SPENCE	72,293	124,162	51,870
LAKE BALLINGER	18,339	27,595	9,256
ELM CREEK	22,885	31,706	8,821
O.H. IVIE	97,598	139,593	41,995

Note: The flow to Lake O.H. Ivie shown in Table UC-3 does not include flow from the Main Concho. Main Concho flow to Ivie is given in the “Main Concho” chapter of this report.

Figure UC-1. Location of the Upper Colorado River Watershed.

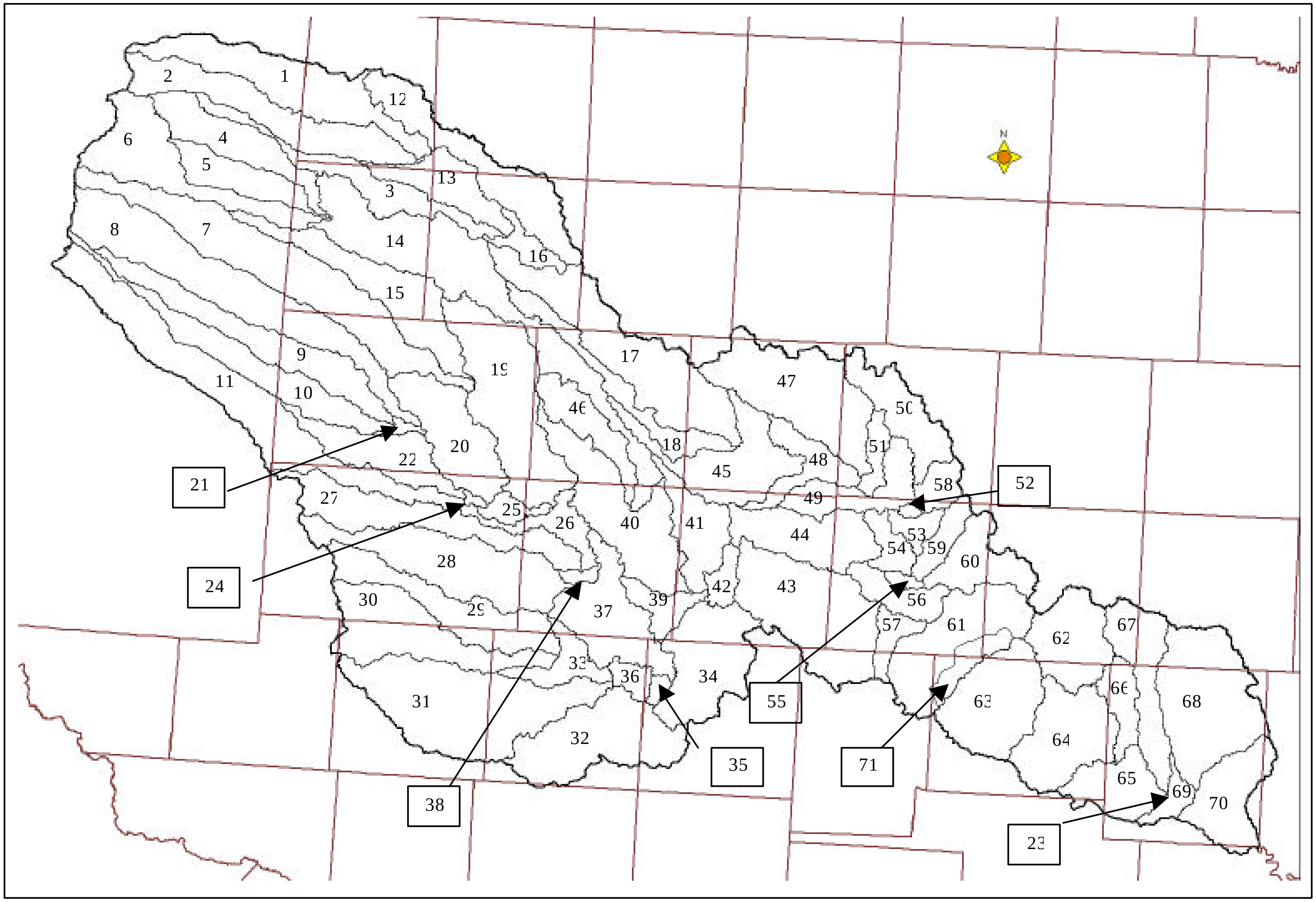

Figure UC-2. Upper Colorado River Watershed subbasin map.

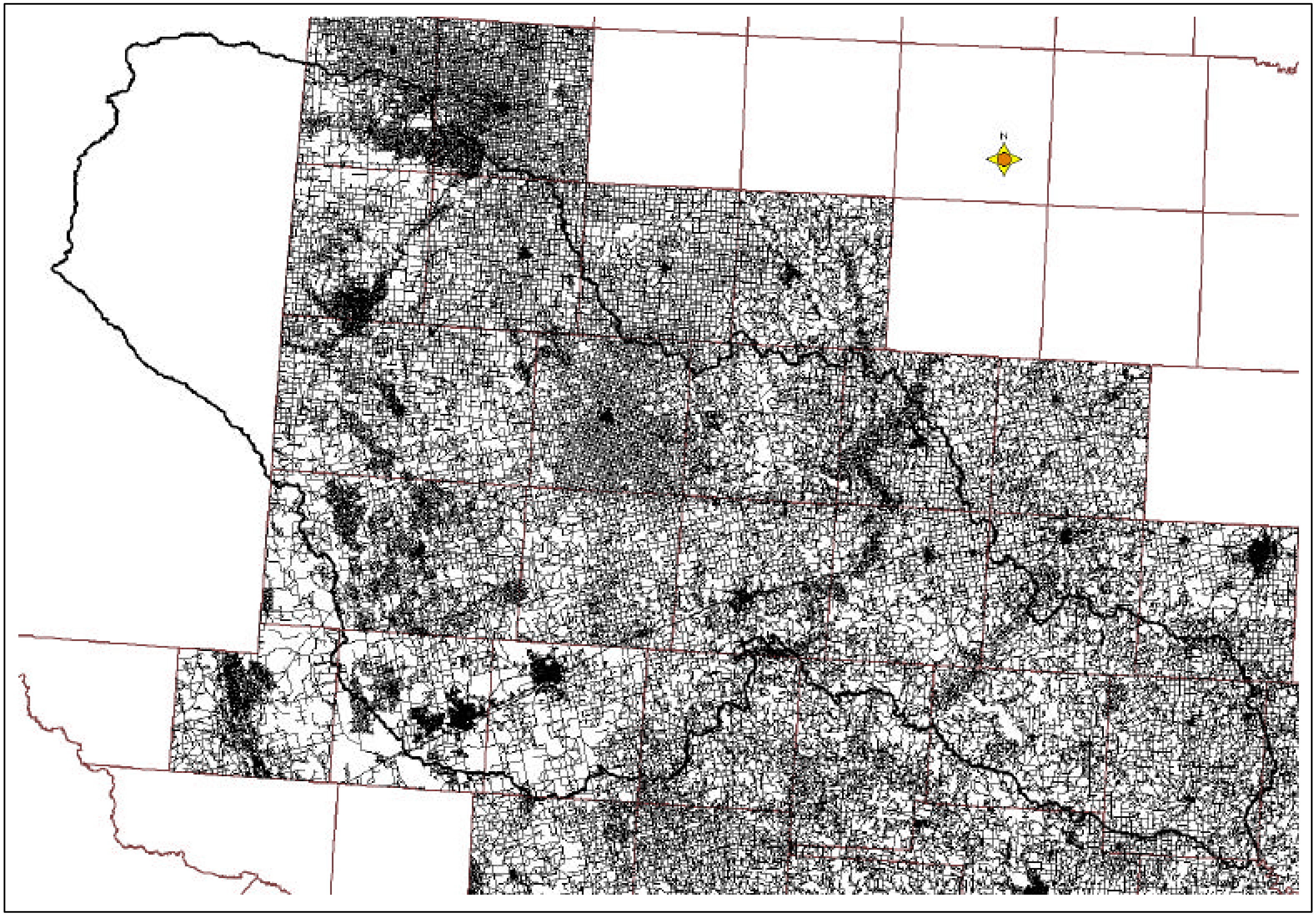

Figure UC-3. Upper Colorado River Watershed roads map.

Figure UC-4. Weather stations in the Upper Colorado River Watershed.

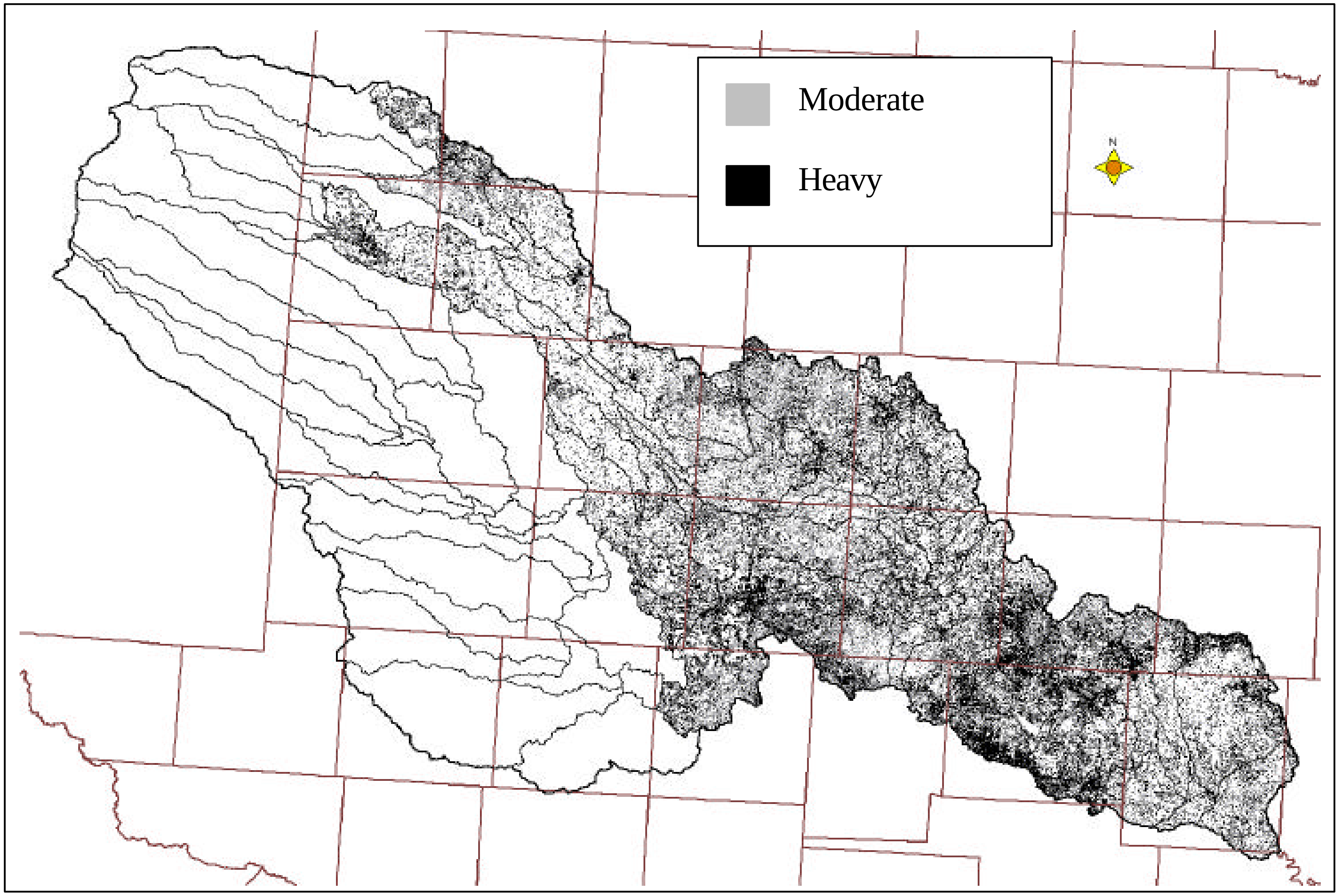

Figure UC-5. Areas of heavy and moderate brush planned for treatment (oak not included) in the Upper Colorado River Watershed (brush treatment not planned in subbasins west of 18 inch isohyet).

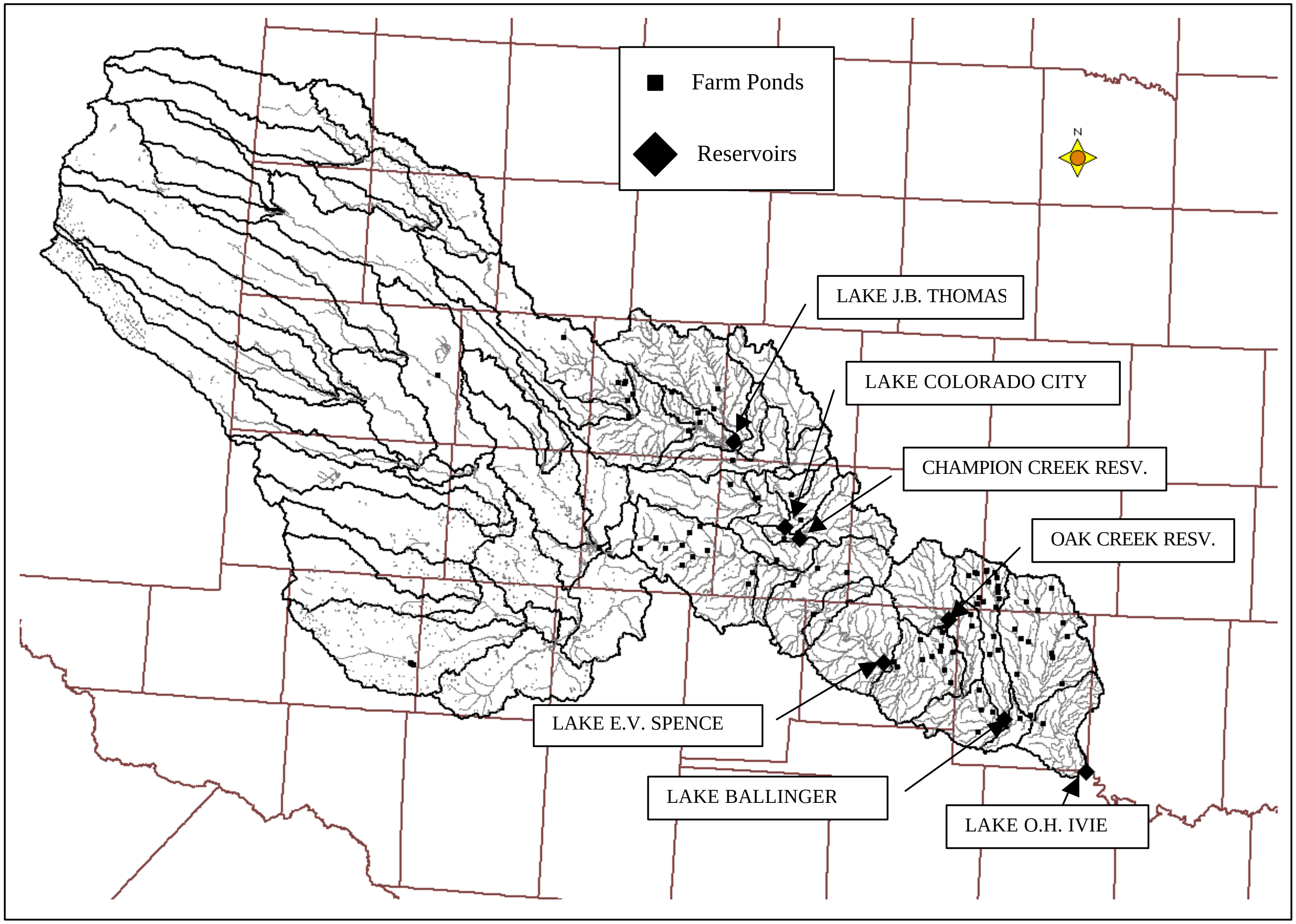

Figure UC-6. Significant ponds and reservoirs in the Upper Colorado River Watershed (from Texas Natural Resource Conservation Commission inventory of dams).

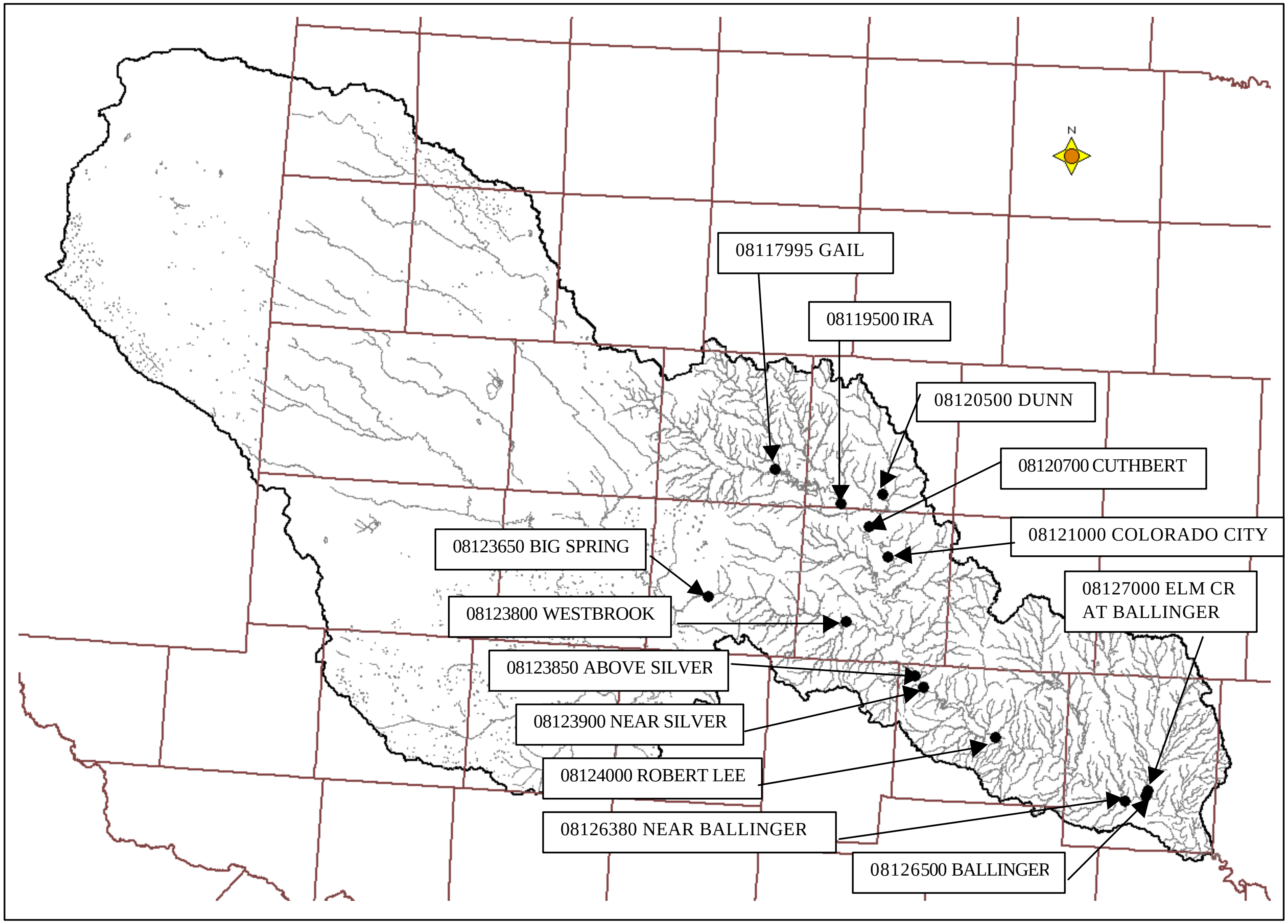

Figure UC-7. Stream gauges used for calibration of the Upper Colorado River Watershed.

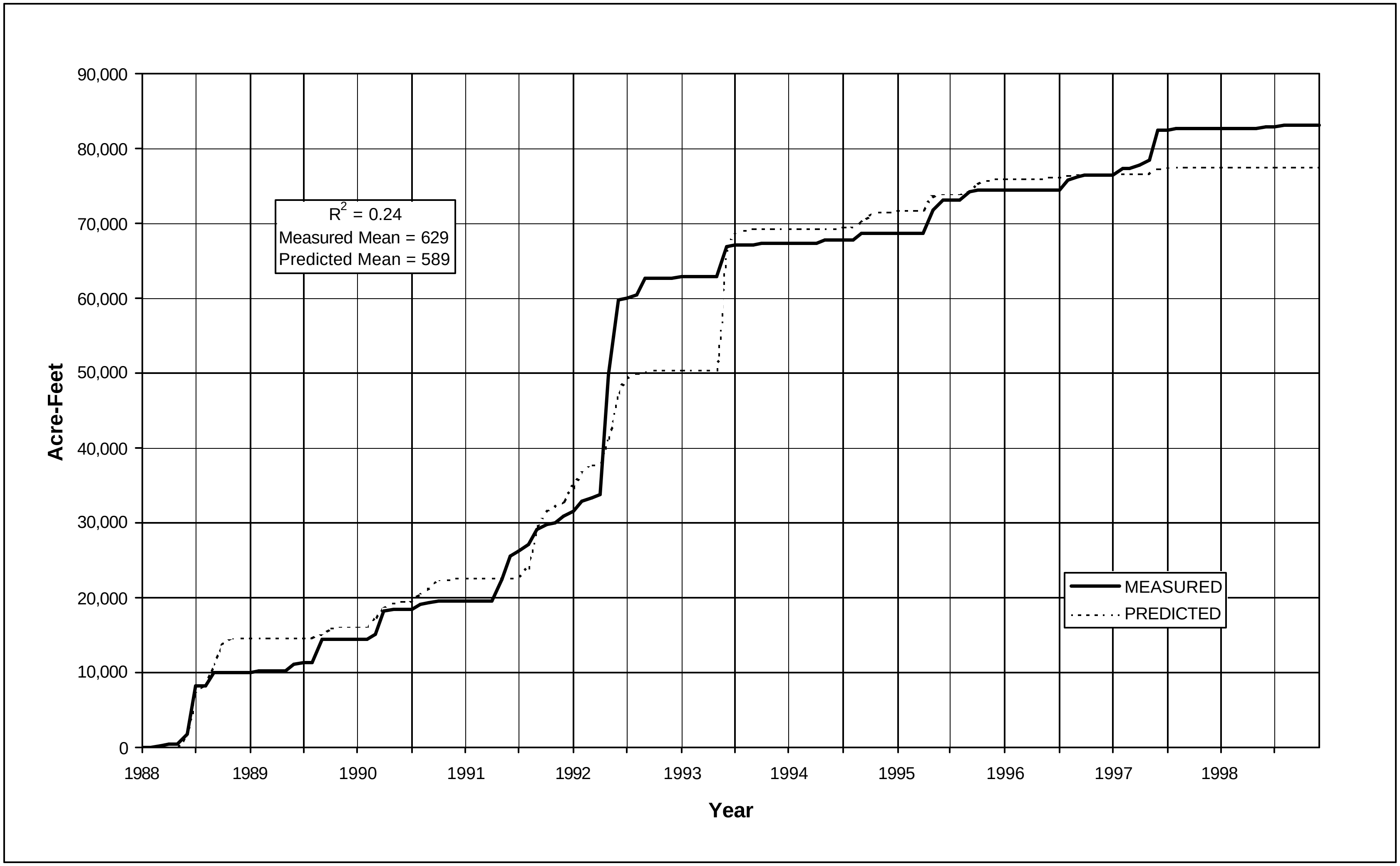

Figure UC-8. Cumulative monthly measured and predicted stream flow at gauge 08117995 (Gail), Upper Colorado River Watershed, 1988 through 1998. Monthly statistics are shown in box.

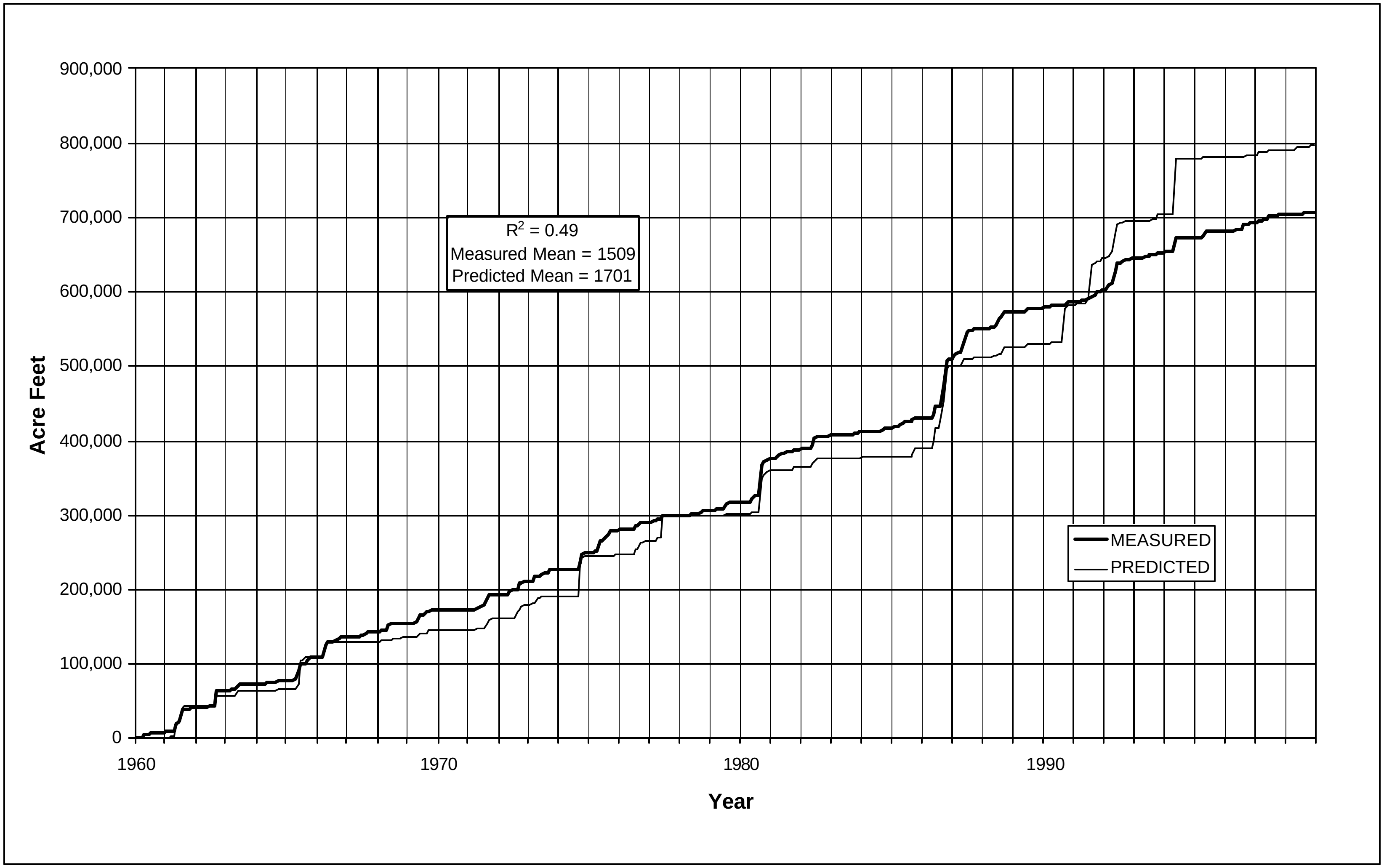

Figure UC-9. Cumulative monthly measured and predicted stream flow at gauge 08123800 (Westbrook), Upper Colorado River Watershed, 1960 through 1998. Monthly statistics are shown in box.

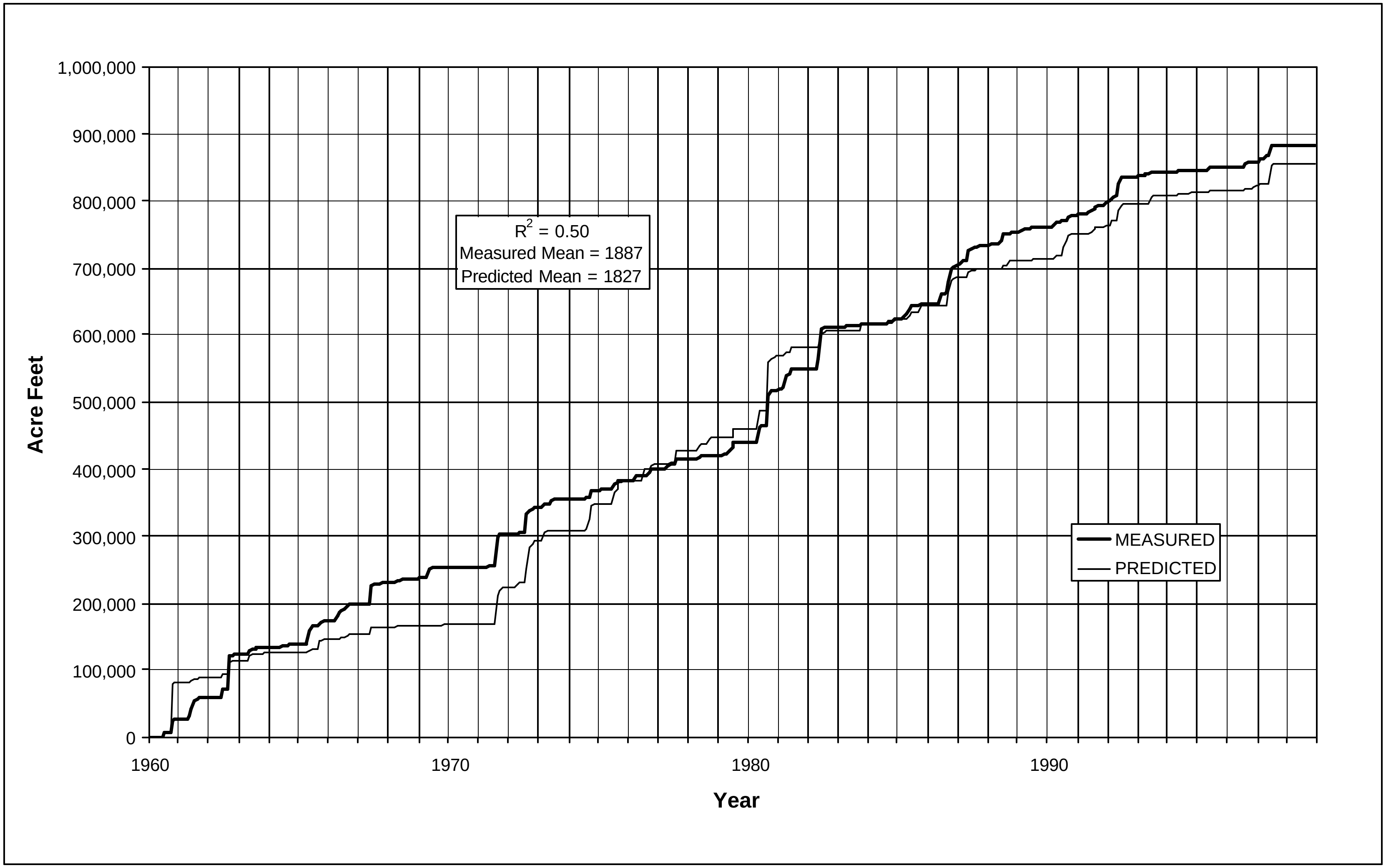

Figure UC-10. Cumulative monthly measured and predicted stream flow at gauge 08121000 (Colorado City), Upper Colorado River Watershed, 1960 through 1998. Monthly statistics are shown in box.

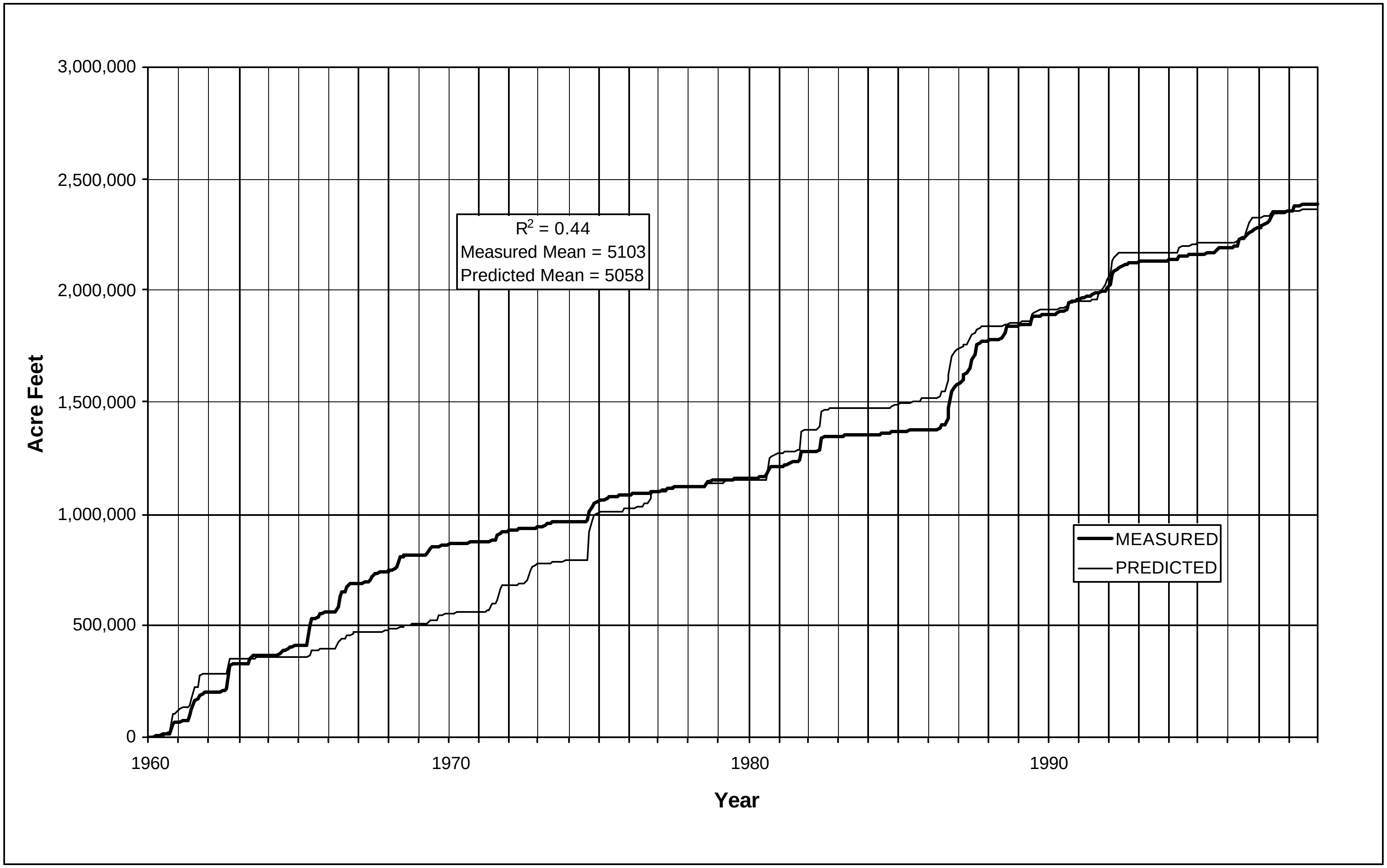

Figure UC-11. Cumulative monthly measured and predicted stream flow at gauge 08126380 (Near Ballinger), Upper Colorado River Watershed, 1960 through 1998. Monthly statistics are shown in box.

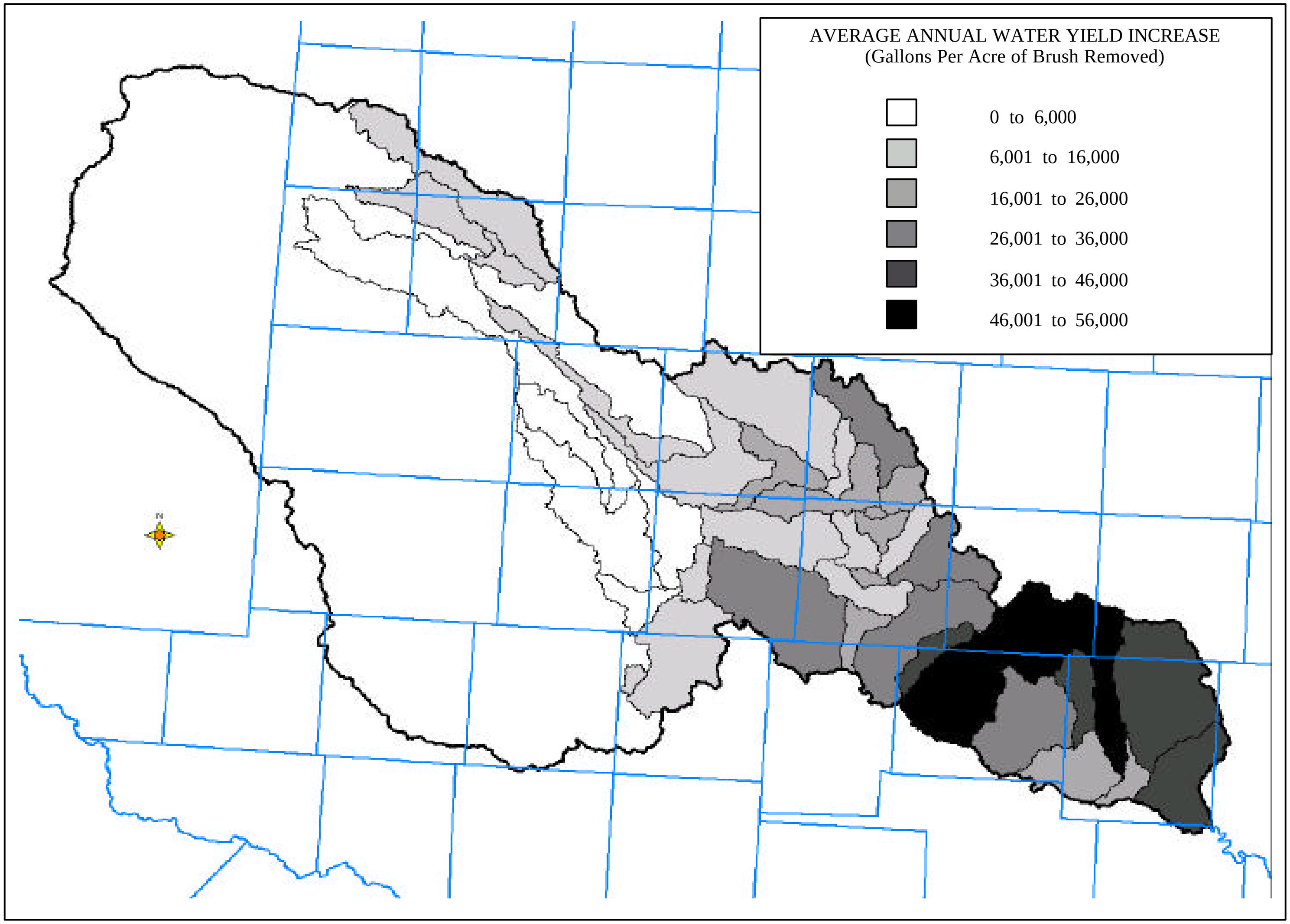

Figure UC-12. Increase in water yield per unit area of brush treated, Upper Colorado River Watershed, 1960 through 1998. Subbasin boundaries and water yields are shown only for areas where brush treatment was planned and simulated.

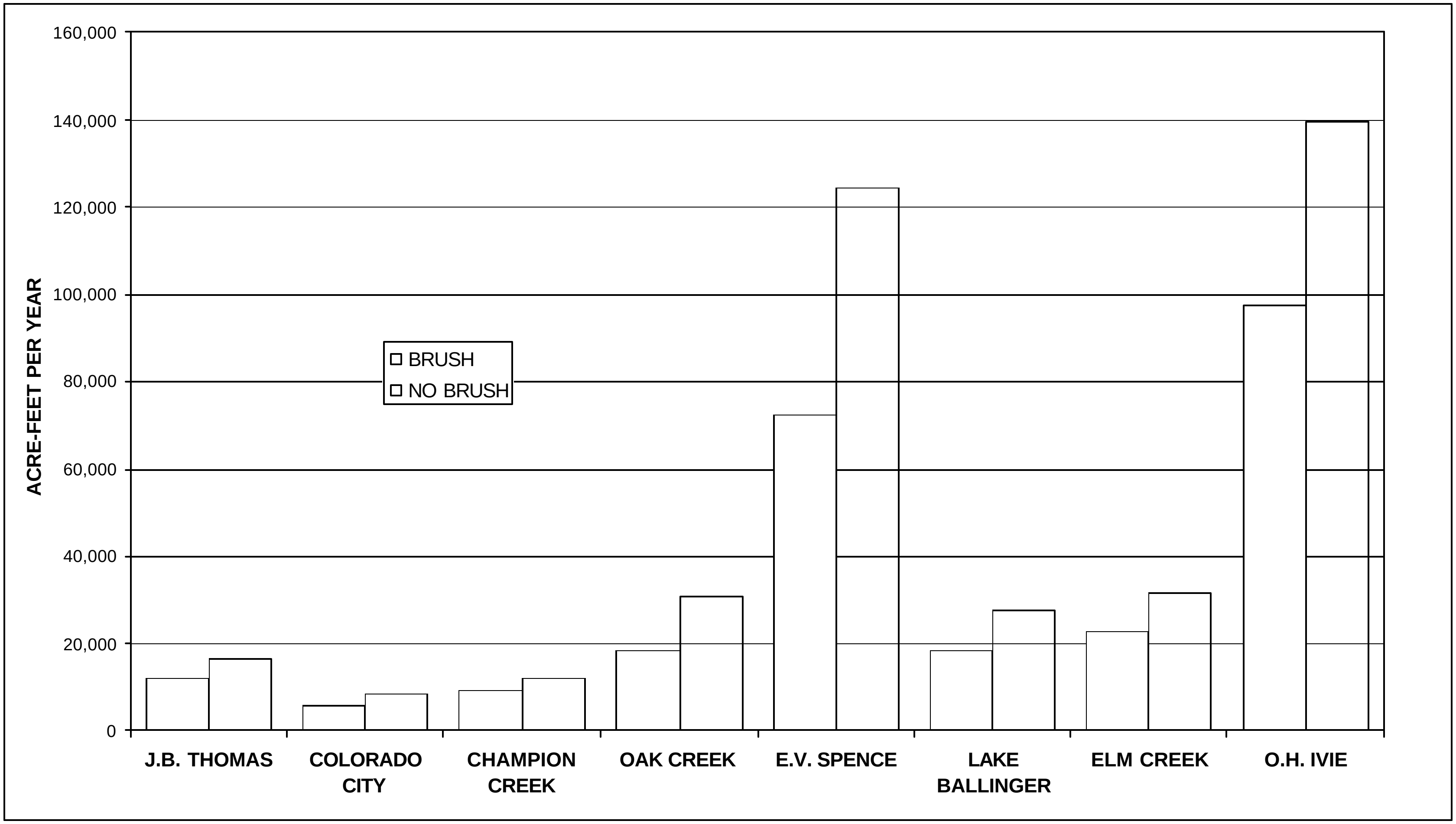

Figure UC-13. Average annual inflow to reservoirs for brush and no-brush conditions, Upper Colorado River Watershed, 1960 through 1998. Flow to O.H. Ivie does not include flow from the Main Concho. Flow to Ivie from the Main Concho is given in the "Main Concho" chapter of this report.

CHAPTER 18

UPPER COLORADO WATERSHED - ECONOMIC ANALYSIS

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CONTROL COSTS

Control costs include initial and follow-up treatments required to reduce brush canopy to 5% or less and maintain it at the reduced level for at least 10 years. Obviously, the costs will vary with brush type-density categories. Present values of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs per acre range from $94.89 for mechanical control of heavy mesquite to $35.89 for moderate mesquite that can be initially controlled with herbicide treatments. Costs of treatments, year those treatments are needed for each brush type density category are detailed in Table 1. Although labeled as Upper Colorado, these practices and costs apply to only the sub-basins which drain to reservoirs up stream of Lake Ivey. Brush control practices and costs discussed in the Main Concho watershed report (Chapter 10) apply to Upper Colorado sub-basins # 23, 62, 64, 65, 66, 67, 68, 69, and 70.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Cedar Mech. (tree doze, rake & burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Tree doze, rake, burn	70.00	70.00
5	IPT or Burn	15.00	9.89
		Total	79.89

Heavy Cedar Mech. (two way chain & burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Two way chain , burn	28.00	28.00
5	IPT or Burn	15.00	9.89
		Total	37.89

Heavy Mesquite (Mech. Choice - tree doze, rake & burn - shears, spray, burn - extricate, burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	85.00	85.00
5	IPT or Burn	15.00	9.89
		Total	94.89

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Heavy Mesquite (Herbicide)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	26.00	26.00
5	Aerial Herbicide	26.00	17.70
8	IPT or Burn	15.00	7.65
		Total	51.35

Heavy Mixed (Mech. Or Herbicide/ Mech. Choice - spray/ tree doze, rake & burn - shears, spray, burn - extricate, burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech./Herb. Choice	70.00	70.00
5	IPT or Burn	15.00	9.89
		Total	79.89

Moderate Cedar (Mech. Choice - tree doze, rake & burn - shears, spray, burn - extricate, burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	35.00	35.00
5	IPT or Burn	15.00	9.89
		Total	44.89

Moderate Mesquite (Herbicide)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Aerial Herbicide	26.00	26.00
5	IPT or Burn	15.00	9.89
		Total	35.89

Moderate Mesquite (Mech. Choice - tree doze, rake & burn - shears, spray, burn - extricate, burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	35.00	35.00
5	IPT or Burn	15.00	9.89
		Total	44.89

Moderate Mixed (Mech. Choice - tree doze, rake & burn - shears, spray, burn - extricate, burn)

Year	Treatment	Treatment Cost($)/Acre	Present Value($)/Acre
0	Mech. Choice	35.00	35.00
5	IPT or Burn	15.00	9.89
		Total	44.89

*Upper Colorado River watershed

RANCHER BENEFITS AND STATE'S COST SHARE

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. In order for the rancher to have no net benefit from the state's portion of the control cost, he is expected to invest or incur costs for an amount equal to his total net benefits. Therefore, his total benefits are equal to the maximum amount that a profit maximizing rancher could be expected to spend on a brush control program (for a specific brush density category). These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program.

For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories are shown in Table 2.

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

YEAR	0	1	2	3	4	5	6	7	8	9
Heavy Cedar										
Controlled	70	55	45	35	35	35	35	35	35	35
No Control	70	70	70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8
Heavy Mesquite										
Controlled	38	33	28	25	25	25	25	25	25	25
No Control	38	38	38.1	38.1	38.2	38.2	38.3	38.3	38.4	38.4
Heavy Mixed										
Controlled	50	43	36	30	30	30	30	30	30	30
No Control	50	50	50.1	50.2	50.3	50.4	50.5	50.5	50.6	50.6
Moderate Cedar										
Controlled	52	43	35	35	35	35	35	35	35	35
No Control	52	52.3	52.7	53	53.4	53.8	54.1	54.4	54.7	54.9
Moderate Mesquite										
Controlled	32	28	25	25	25	25	25	25	25	25
No Control	32	32.2	32.4	32.6	32.8	33	33.2	33.4	33.6	33.7
Moderate Mixed										
Controlled	40	35	30	30	30	30	30	30	30	30
No Control	40	40.2	40.5	40.8	41	41.3	41.6	41.8	42	42.2

*Upper Colorado River Watershed

As with the brush control practices, the grazing capacity estimates represent a consensus of expert opinion obtained through discussions with Texas Agricultural Experiment Station and Extension Service Scientists and USDA-NRCS Range Specialists with brush control experience in the area.

Livestock grazing capacities range from about 70 acres per animal unit year (AUY) for land infested with heavy cedar to about 25 acres per AUY for land on which mesquite is controlled.

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into production investment analysis budgets. This information for the livestock enterprise (cattle) in the area is in Table 3. The data are reported per animal unit for the livestock enterprises. From these budgets, data was entered into the investment analysis model (see Chapter 2).

Table 3. Investment Analysis Budget, Cow-Calf Production*

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	382.5	Pound	.80	306.00
Cows	111.1	Pound	.40	0
Bulls	250.0	Pound	.50	0
			Total	306.00

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	480.0	Pound	0.10	48.00
Salt & Minerals	27.0	Pound	0.20	5.40
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	15.00	15.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	128.09

Note: This budget is for presentation of the information used in the investment analysis only. Values herein are representative of a typical ranch in the Main Concho and Upper Colorado River Basins, Lake Ivey Watershed. The budget is based on 1 cow-calf pair per animal unit. Variable costs listed here include only items which change as a result of implementing a brush control program and adjusting livestock numbers to meet changes in grazing capacity. Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included, nor have fixed costs been considered.

*Upper Colorado River Watershed

Rancher benefits were also calculated for changes in existing wildlife operations. Most of these operations were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy mesquite, mixed brush and cedar, wildlife revenues are expected to increase by about $0.50 per acre due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

With this information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $16.76 per acre for the control of heavy cedar to $10.25 per acre for control of moderate mixed brush (Table 4).

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush type/density	PV of Total Cost ($/Acre)	Rancher Share ($/Acre)	Rancher %	State Share ($/Acre)	State %
Hv. Cedar - TD	79.89	16.76	21.0	63.13	79.0
Hv. Cedar Chn	37.89	16.76	44.2	21.13	55.8
Hv. Mes. Mec.	94.89	15.89	16.7	79.00	83.3
Hv. Mes. Hrb.	51.35	15.89	37.8	35.46	69.1
Hv. Mx.	79.89	15.07	18.9	64.82	81.1
Mod. Cedar	44.89	11.90	26.5	32.99	73.5
Mod. Mes. Mec	44.89	10.55	23.5	34.34	76.5
Mod. Mes. Hrb.	35.89	10.55	29.4	25.34	70.6
Mod. Mx.	44.89	10.25	22.8	34.64	77.2
	Average		26.8**		73.2

***Upper Colorado River Watershed

**Based on Heavy Cedar being controlled with 50% chaining-50% tree dozing and all Mesquite controlled with 50% mechanical-50% herbicide.

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state cost share per acre of brush control range from $79.001 for control of heavy mesquite to $21.13 for control of heavy cedar with chaining. Present values for total treatment cost, rancher benefits and state cost share for all brush type - density categories are shown in Table 4.

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate). The cost of added water thus determined averages $96.76per acre foot for the entire Upper Colorado watershed (Table 5). Sub-basins range from costs per added acre foot of $44.11 to $7,672.72.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Subbasin	Total State Cost ($)	Avg. Annual Gallon Increase	Avg. Annual Ac.Ft. Increase	Added Ac.Ft 10Yr. Disctd	St. Cost per Ac.Ft. Added Water ($)
1	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00
12	2962397.01	559439439.82	1716.86	13394.92	221.16
13	1469706.17	341114276.75	1046.84	8167.46	179.95
14	4432154.69	24125643.20	74.04	577.65	7672.72
15	0.00	0.00	0.00	0.00	0.00
16	166245.14	22483503.71	69.00	538.33	308.81
17	3438849.36	258662342.75	793.81	6193.27	555.26
18	264176.01	63578516.39	195.12	1522.29	173.54
19	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00
23	3969.12	2056701.64	6.31	49.24	80.60
24	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00
34	4804346.83	1110858822.57	3409.10	26597.80	180.63
35	305199.37	47384781.14	145.42	1134.56	269.00
36	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00
39	5109546.20	48580690.87	149.09	1163.19	4392.70
40	5414745.57	90973763.56	279.19	2178.23	2485.85
41	2029570.94	200435984.87	615.12	4799.13	422.90
42	902016.22	130000262.03	398.96	3112.66	289.79
43	8594379.96	5158068825.25	15829.53	123502.01	69.59
44	2812453.79	880704492.53	2702.78	21087.11	133.37
45	2865851.29	936651613.87	2874.48	22426.68	127.79
46	0.00	1405132.30	4.31	33.64	0.00

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot) (Continued)

Subbasin	Total State Cost ($)	Average Annual Gal. Increase	Avg. Annual Ac.Ft. Incr.	Added Ac.Ft 10Yr. Disctd	St. Cost per Ac.Ft. Added Water ($)
47	6534598.50	2091998798.91	6420.11	50089.69	130.46
48	1443277.16	666957730.15	2046.82	15969.27	90.38
49	1475584.03	791750571.44	2429.79	18957.25	77.84
50	2542729.81	1355656892.25	4160.36	32459.11	78.34
51	623534.41	228437699.33	701.05	5469.59	114.00
52	97885.70	40658577.40	124.78	973.51	100.55
53	470543.15	167150103.04	512.96	4002.15	117.57
54	909316.20	200585258.76	615.57	4802.70	189.33
55	298472.83	104738881.26	321.43	2507.81	119.02
56	1570582.10	343156837.85	1053.11	8216.36	191.15
57	541136.21	255292573.20	783.46	6112.59	88.53
58	615236.09	259833678.17	797.40	6221.32	98.89
59	784132.84	162403863.53	498.40	3888.51	201.65
60	2076647.32	1272324291.72	3904.62	30463.84	68.17
61	5660618.85	3100969477.45	9516.53	74247.93	76.24
62	6008825.07	4562662618.69	14002.30	109245.92	55.00
63	7273478.12	6742303822.35	20691.37	161434.07	45.06
64	6711608.80	3174002519.43	9740.66	75996.60	88.31
65	2669410.19	1125582148.22	3454.28	26950.33	99.05
66	1107822.48	808987807.10	2482.69	19369.97	57.19
67	3185660.82	3015979797.49	9255.70	72212.99	44.11
68	4847857.35	2874039242.71	8820.10	68814.44	70.45
69	469023.51	150706327.03	462.50	3608.43	129.98
70	2542332.41	1926086710.43	5910.94	46117.18	55.13
71	1665068.91	1190934522.12	3654.84	28515.09	58.39
TOTAL	107700990.51			1113124.83	
Average					$96.76

*Upper Colorado River watershed.

CHAPTER 19

WICHITA RIVER WATERSHED – HYDROLOGIC SIMULATION

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WATERSHED DATA

Location
The Wichita River watershed is located in north-central Texas in the Rolling Plains Major Land Resource Area (MLRA) (Figure 1).

Topography
The outlet or "catchment" for the portion of the Wichita River simulated in this study is Lake Kemp, which is located in subbasin number 48. The subbasin delineation and numbers are shown in Figure W-1. Roads (obtained from the Census Bureau) are shown in Figure W-2.

Weather Data
The average annual rainfall for the Wichita River Watershed (1960 – 1998) varied from 22.1 inches in the western portion of the watershed to 25.9 inches in the eastern portion. The composite average for the entire watershed was 24.6 inches. Weather stations used for modeling are shown in Figure W-3. For each subbasin, precipitation and temperature data were retrieved by the SWAT input interface for the weather station nearest the centroid of the subbasin.

Soils
The dominant soil series in the Wichita River watershed are Carey, Knoco, Miles, Owens, Tillman, and Vernon. These six soil series represent about 55 percent of the watershed area. A short description of each follows:

Carey. The Carey series consists of very deep, well drained, moderately permeable soils that formed in weakly consolidated silty or sandy sediments of Permian age. These soils are on nearly level to moderately sloping shoulders and summits of dissected terraces on uplands of the Central Rolling Red Plains (MLRA 78B, 78C). Surfaces are generally smooth to gently convex and slopes range from 0 to 8 percent.

Knoco. The Knoco series consists of very shallow and shallow, well drained, very slowly permeable soils that formed in residuum over dense non-cemented claystone bedrock of Permian age. These soils are on very gently sloping to very steep ridges, sideslopes and erosional footslopes on uplands of the Central Rolling Red Plains (MLRA-78B, 78C), Rolling Limestone Prairie (MLRA-78D), and North Central Prairie (MLRA-80B). Slopes range from 1 to 60 percent.

Miles. The Miles series consists of very deep, well drained, moderately permeable soils that formed in loamy alluvial materials. These soils are on nearly level to moderately sloping terrace pediments on uplands in the Central Rolling Red Plains (MLRA 78B, 78C). Slopes range from 0 to 8 percent.

Owens. The Owens series consists of soils that are moderately deep to dense, weathered shale. They are well drained, very slowly permeable soils. They formed in residuum weathered from shale. These soils are on gently sloping to steep uplands. Slopes range from 1 to 40 percent.

Tillman. The Tillman series consists of very deep, well drained, slowly permeable soils. These soils formed in loamy and clayey alluvium derived from redbed clays and claystone sediments of Permian age. These soils are on nearly level to gently sloping uplands of the Central Rolling Red Plains (MLRA-78C) and the Rolling Limestone Prairie (MLRA-78D). Slope ranges from 0 to 5 percent.

Vernon. The Vernon series consists of moderately deep, well drained, very slowly permeable soils that formed in residuum weathered from claystone. These soils are on gently sloping to steep uplands of the Central Rolling Red Plains (MLRA-78B, 78C), Central Limestone Prairies (MLRA 78D) and North Central Prairie (MLRA 80B). Slopes range from 1 to 45 percent.

Land Use/Land Cover

Figure W-4 shows the areas of heavy and moderate brush (oak not included) in the Wichita River Watershed. This is the area of brush removed or treated in the no-brush simulation.

Ponds and Reservoirs

Surface area, storage, and drainage area were obtained from the Texas Natural Resource Conservation Commission (TNRCC) for existing inventory-sized ponds and reservoirs in the watershed (Figure W-5), and input to the SWAT model. Diversions of stream flow from the low-flow dam in the South Wichita at gauge 07311782 (Guthrie) were also input. This diversion was pumped to an evaporation reservoir (Truscott Brine Lake) in subbasin 32.

Model Input Variables

Significant input variables for the SWAT model for the Wichita River Watershed are shown in Table W-1. Input variables for all subbasins in the watershed were the same, with three exceptions:

1. It was necessary to reduce soil available water capacity fraction by 0.03 (inches H_2O/inch soil) in the area below stream gauges 07311700 and 07311800 (Figure W-5) in order to calibrate flow at stream gauge 07311900.

2. Comparisons of measured and predicted flow from preliminary SWAT runs indicated that channel transmission losses may have been higher in the North Wichita River. Therefore, 0.16 inches per hour was assumed in the North Wichita River above gauge 07311700 (Truscott) and 0.04 inches per hour in the remainder of the watershed.

3. The re-evaporation coefficient was assumed higher for brush than for other types of cover because brush is deeper rooted, and opportunity for re-evaporation from the shallow aquifer is higher. The re-evaporation coefficient for all brush hydrologic response units (HRU – combinations of soil and land use/cover) is 0.4, and for non-brush HRU's is 0.1.

WICHITA RIVER WATERSHED RESULTS

Calibration

SWAT was calibrated for flow at stream gauges 07311600 (Paducah), 07311700 (Truscott), 07311800 (Benjamin), and 07311900 (Seymour) (Figure W-6). The results of calibration are shown for gauges 07311700 and 07311800 on Figures W-7 and W-8. Measured and predicted total monthly flows compared reasonably well with R^2 values of 0.56 for gauge 07311700 and 0.54 for gauge 07311800. At gauge 07311700 the measured monthly mean was 4,027 acre-feet, and predicted monthly mean was 3,900 acre-feet. At gauge 07311800 the measured mean was 2,493 acre-feet, and predicted mean was 2,535 acre-feet. Average base flow for the entire watershed was 47 % of total flow, which is very close to measured base flow of about 45 %.

At gauge 07311700 predicted flow was less than measured (Figure W-7). In July and August 1966, SWAT under-estimated flow by a large amount, causing the cumulative lines of measured and predicted flow to diverge significantly. It is possible that large amounts of rainfall occurred in those two months that was not measured accurately at any of the weather stations. The measured and predicted lines for the remainder of the simulated period are parallel, with the predicted line approaching and nearly catching up to the measured line near the end of the simulation.

At gauge 07311800 predicted flow for the simulation period was slightly higher than measured (Figure W-8). The lines of cumulative measured and predicted flow diverge somewhat near the beginning of the simulation, but converge toward the end. Again, this may have been due to precipitation variability that was not reflected in measured data.

Brush Removal Simulation

Average annual evapo-transpiration (ET) was 23.82 inches for the brush condition (calibration) and 21.87 inches for the no-brush condition, or 97% and 89% of precipitation for the brush and no-brush conditions, respectively.

Figure W-9 shows the cumulative monthly flow to Lake Kemp for the brush and no-brush conditions from 1960 through 1998.

Total subbasin area, area of brush treated, fraction of subbasin treated, water yield increase per acre of brush treated, and total water yield increase for each subbasin is given in Table W-2. The amount of annual increase varied among the subbasins and ranged from 25,733 gallons per acre of brush removed per year in subbasin number 1, to 112,803 gallons per acre in subbasin number 26. Variations in the amount of increased water yield were expected and were influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields were most likely due to greater rainfall volumes as well as increased density and canopy of brush.

A gray-scale graph of the subbasins in the Wichita River watershed, with water yield increases represented by varying color intensities is shown in Figure W-10. Darker shading represents higher water yield increases.

For the entire simulated watershed, the average annual water yield increased by 95 % or approximately 152,004 acre-feet. The average annual flow at the outlet (Lake Kemp) increased by 145,426 acre-feet. The increase in volume of flow to Lake Kemp was slightly less because of stream channel transmission losses that occurred between each subbasin and the watershed outlet.

Table W-1. SWAT Input Variables

VARIABLE	BRUSH CONDITION (CALIBRATION)	NO BRUSH CONDITION
Runoff Curve Number Adjustment	-2	-2
Soil Available Water Cap. Adj. (inches H^2O/in.soil)	0 & -0.03	0 & -0.03
Soil Evaporation Compensation Factor	0.9	0.9
Min. Shallow Aqu. Storage for GW flow (inches)	0	0
Shallow Aqu.Re-Evaporation (Revap) Coefficient	0.4	0.1
Min. Shallow Aqu. Storage for Revap (inches)	0.04	0.04
Potential Heat Units (^oC)		
Heavy Cedar	4036	N/A
Heavy Mesquite	3511	N/A
Heavy Mixed Brush	3753	N/A
Moderate Cedar	3511	N/A
Moderate Mesquite	3108	N/A
Moderate Mixed Brush	3310	N/A
Heavy Oak	3511	3511
Moderate Oak	3108	3108
Light Brush & Open Range/Pasture	2704	2704
Precipitation Interception (inches)		
Heavy Cedar	0.79	N/A
Heavy Mesquite	0	N/A
Heavy Mixed Brush	0.59	N/A
Moderate Cedar	0.59	N/A
Moderate Mesquite	0	N/A
Moderate Mixed Brush	0.39	N/A
Heavy Oak	0	0
Moderate Oak	0	0
Light Brush & Open Range/Pasture	0	0
Plant Rooting Depth (feet)		
Heavy and Moderate Brush	6.5	N/A
Light Brush & Open Range/Pasture	3.3	3.3
Maximum Leaf Area Index		
Heavy Cedar	6	N/A
Heavy Mesquite	4	N/A
Heavy Mixed Brush	4	N/A
Moderate Cedar	5	N/A
Moderate Mesquite	2	N/A
Moderate Mixed Brush	3	N/A
Heavy Oak	4	4
Moderate Oak	3	3
Light Brush	2	2
Open Range & Pasture	1	1
Channel Transmission Loss (inches/hour)	0.04 & 0.16	0.04 & 0.16
Subbasin Transmission Loss (inches/hour)	0.015	0.015
Fraction Trans. Loss Returned as Base Flow	0.8	0.8

Table W-2. Subbasin Data and Water Yield

Subbasin	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
1	13,284	8,397	0.63	25,733	216,078,477
2	46,661	30,680	0.66	26,291	806,618,075
3	16,465	6,444	0.39	54,483	351,071,993
4	12,540	5,379	0.43	57,122	307,249,997
5	13,218	8,466	0.64	28,865	244,374,486
6	16,045	10,190	0.64	31,556	321,550,392
7	52,577	36,449	0.69	48,479	1,767,011,514
8	63,469	36,484	0.57	53,421	1,949,006,716
9	75,950	27,853	0.37	49,033	1,365,711,107
10	38,072	10,354	0.27	42,432	439,342,078
11	16,875	6,077	0.36	28,882	175,513,199
12	25,793	8,635	0.33	39,043	337,141,059
13	14,297	5,214	0.36	33,746	175,936,804
14	15,746	6,561	0.42	49,251	323,150,848
15	10,065	6,504	0.65	56,787	369,339,822
16	9,556	4,362	0.46	52,946	230,953,724
17	3,487	1,498	0.43	59,154	88,598,722
18	27,369	9,758	0.36	67,891	662,499,876
19	6,946	2,875	0.41	48,545	139,554,585
20	20,393	5,109	0.25	56,850	290,468,358
21	48,065	45,344	0.94	36,223	1,642,475,517
22	1,740	1,740	1.00	38,843	67,570,378
23	23,426	23,426	1.00	39,538	926,201,635
24	39,149	30,253	0.77	46,765	1,414,809,041
25	30,972	17,655	0.57	56,219	992,525,495
26	26,178	16,266	0.62	112,803	1,834,812,503
27	37,728	29,769	0.79	76,963	2,291,117,650
28	38,736	32,625	0.84	51,446	1,678,437,006
29	36,312	33,632	0.93	53,234	1,790,377,239
30	78,253	73,592	0.94	49,096	3,613,105,492
31	12,973	7,682	0.59	76,732	589,436,878
32	17,945	11,119	0.62	78,029	867,629,691
33	7,416	5,133	0.69	62,115	318,809,773
34	25,855	14,691	0.57	71,967	1,057,275,748
35	23,341	15,678	0.67	102,176	1,601,924,107
36	15,506	9,301	0.60	57,447	534,305,149
37	14,308	10,405	0.73	75,260	783,103,216
38	13,845	6,367	0.46	64,976	413,706,250
39	86,420	61,795	0.72	70,117	4,332,850,136
40	68,762	40,987	0.60	74,741	3,063,455,505

TABLE W-2 (continued)

Subbasin	Total Area (acres)	Brush Area (Treated) (acres)	Brush Fraction (Treated)	Increase in Water Yield (gal/acre/year)	Increase in Water Yield (gallons/year)
41	13,173	5,769	0.44	60,820	350,870,423
42	10,277	7,041	0.69	104,070	732,734,977
43	14,712	10,786	0.73	59,100	637,434,654
44	9,971	8,017	0.80	98,940	793,220,592
45	5,829	5,040	0.86	99,532	501,654,934
46	4,715	3,896	0.83	90,861	353,972,889
47	13,104	1,129	0.09	35,353	39,919,370
48	93,786	66,988	0.71	85,776	5,745,911,288
TOTALS	**1,311,305**	**833,413**	**---**	**---**	**49,530,819,369**
Watershed Average	**---**	**---**	**0.64**	**59,431**	**---**

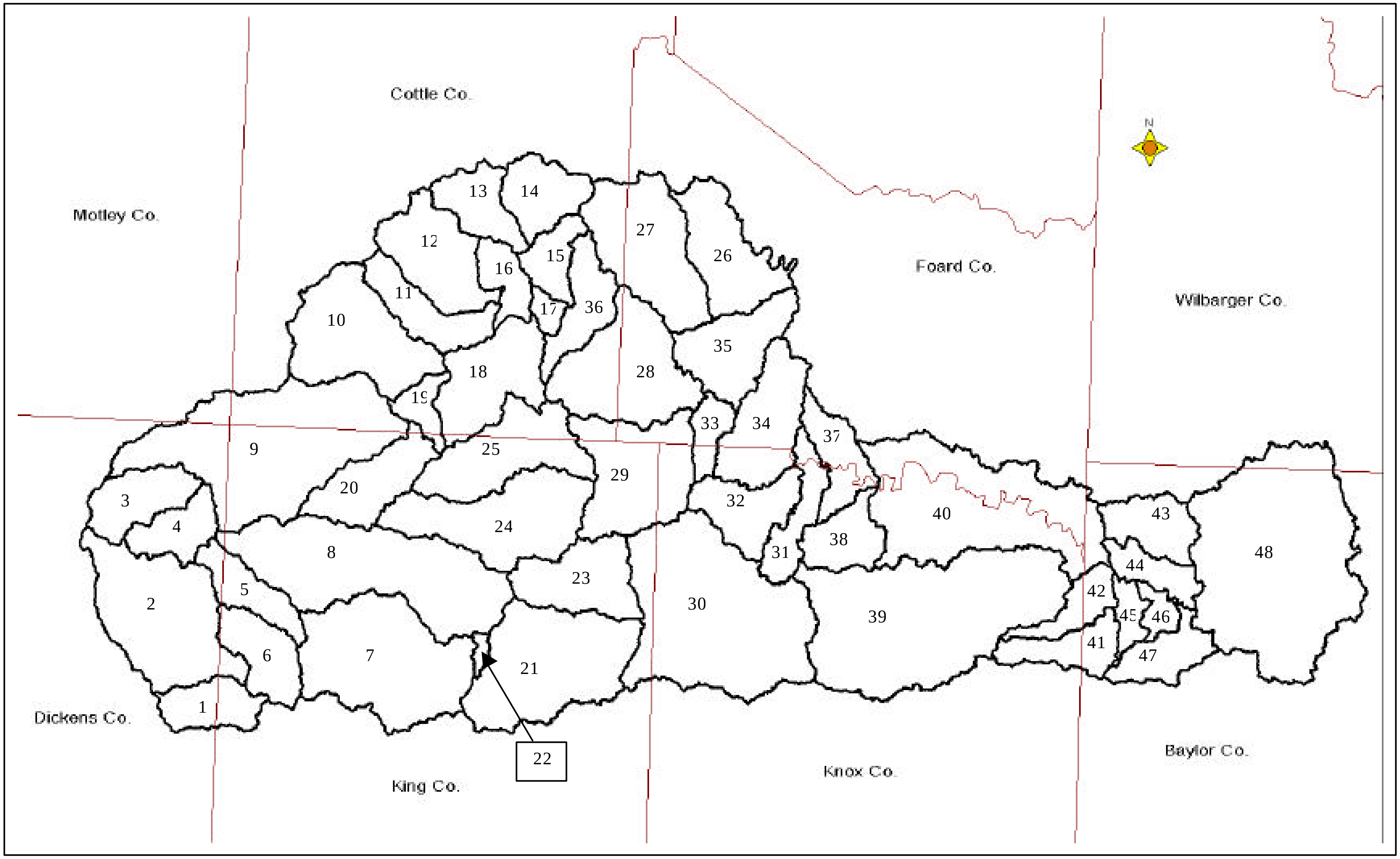

Figure W-1. Wichita River Watershed subbasin map.

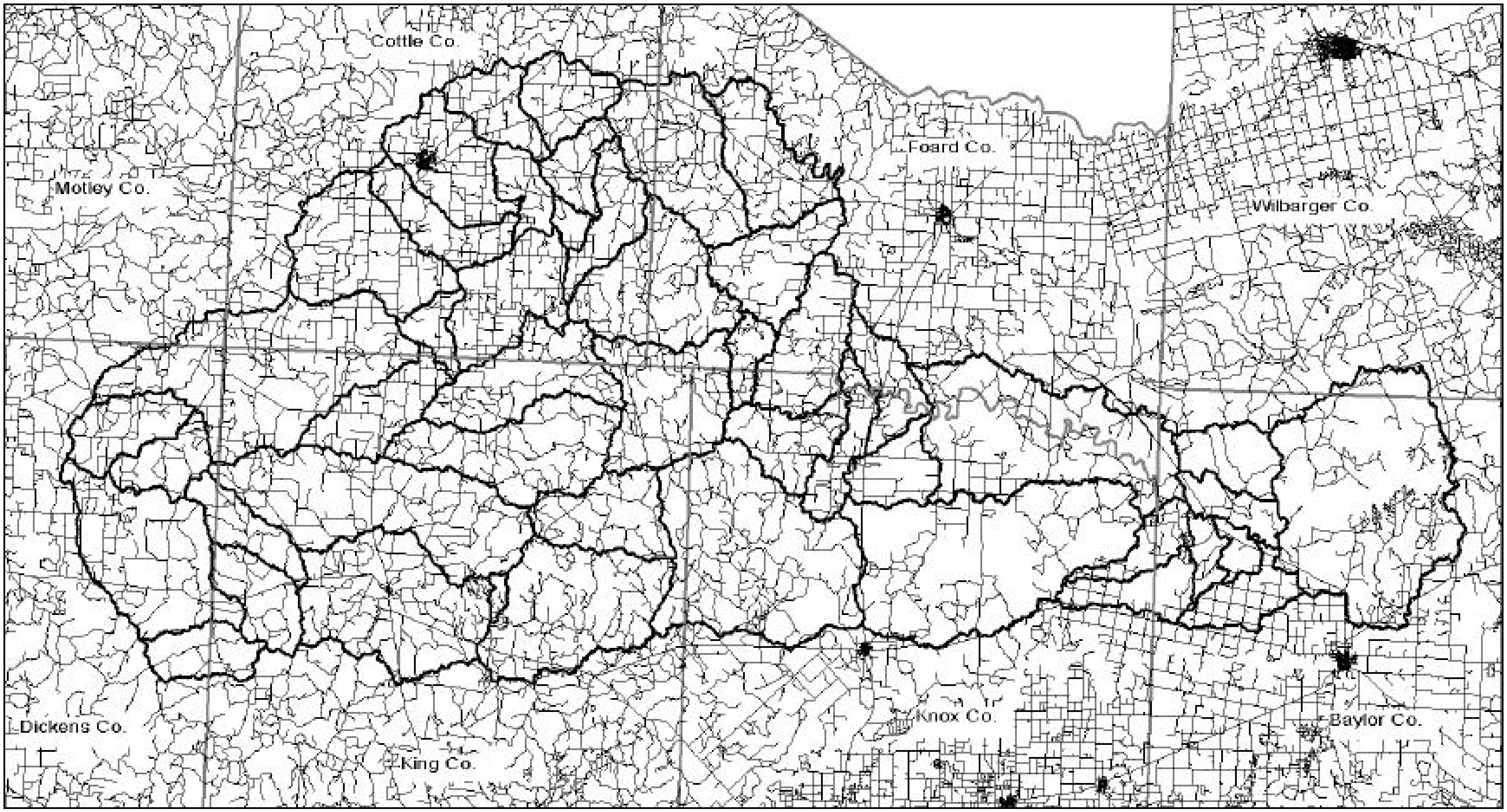

Figure W-2. Wichita River Watershed roads map.

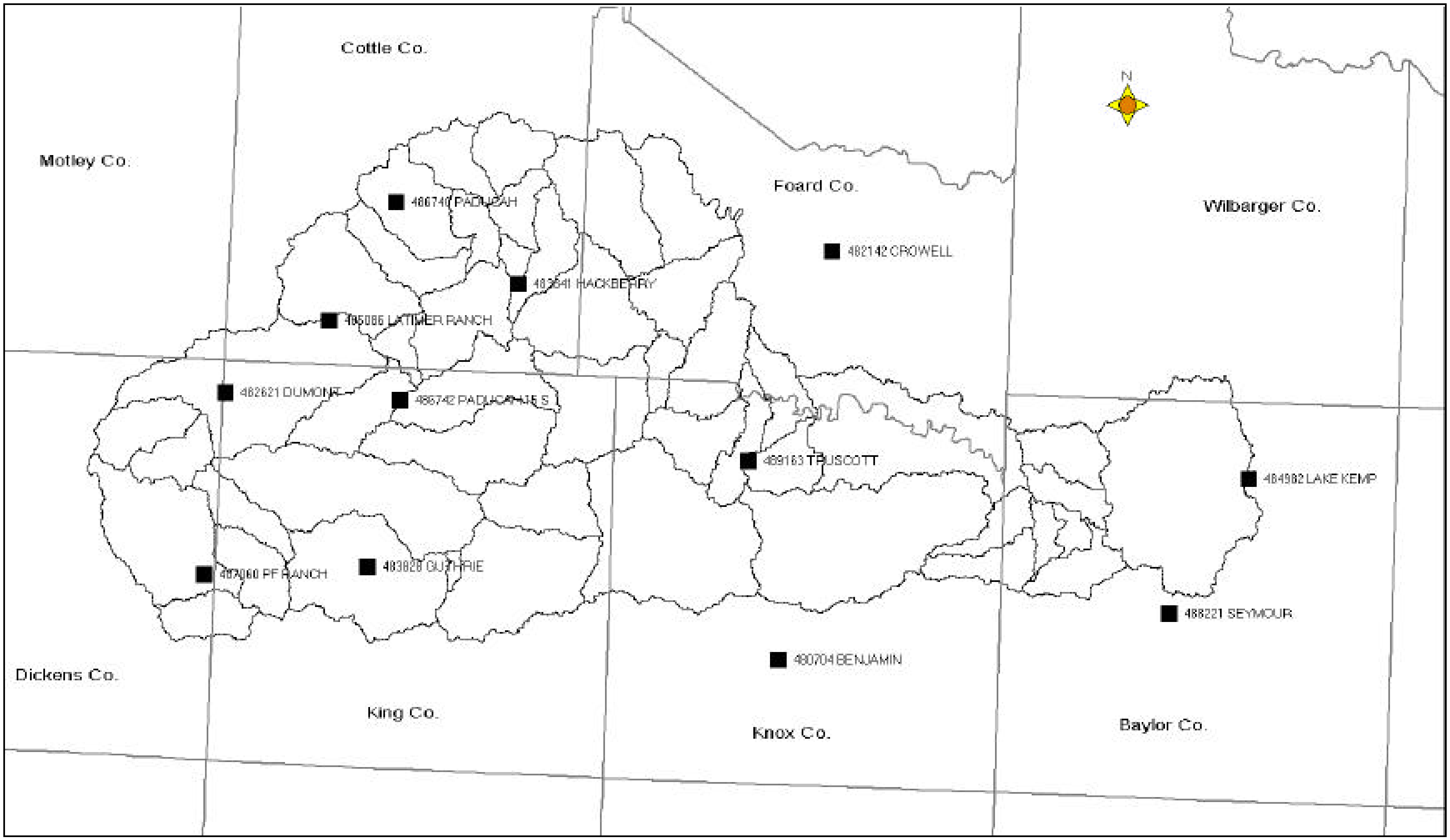

Figure W-3. Weather stations in the Wichita River Watershed.

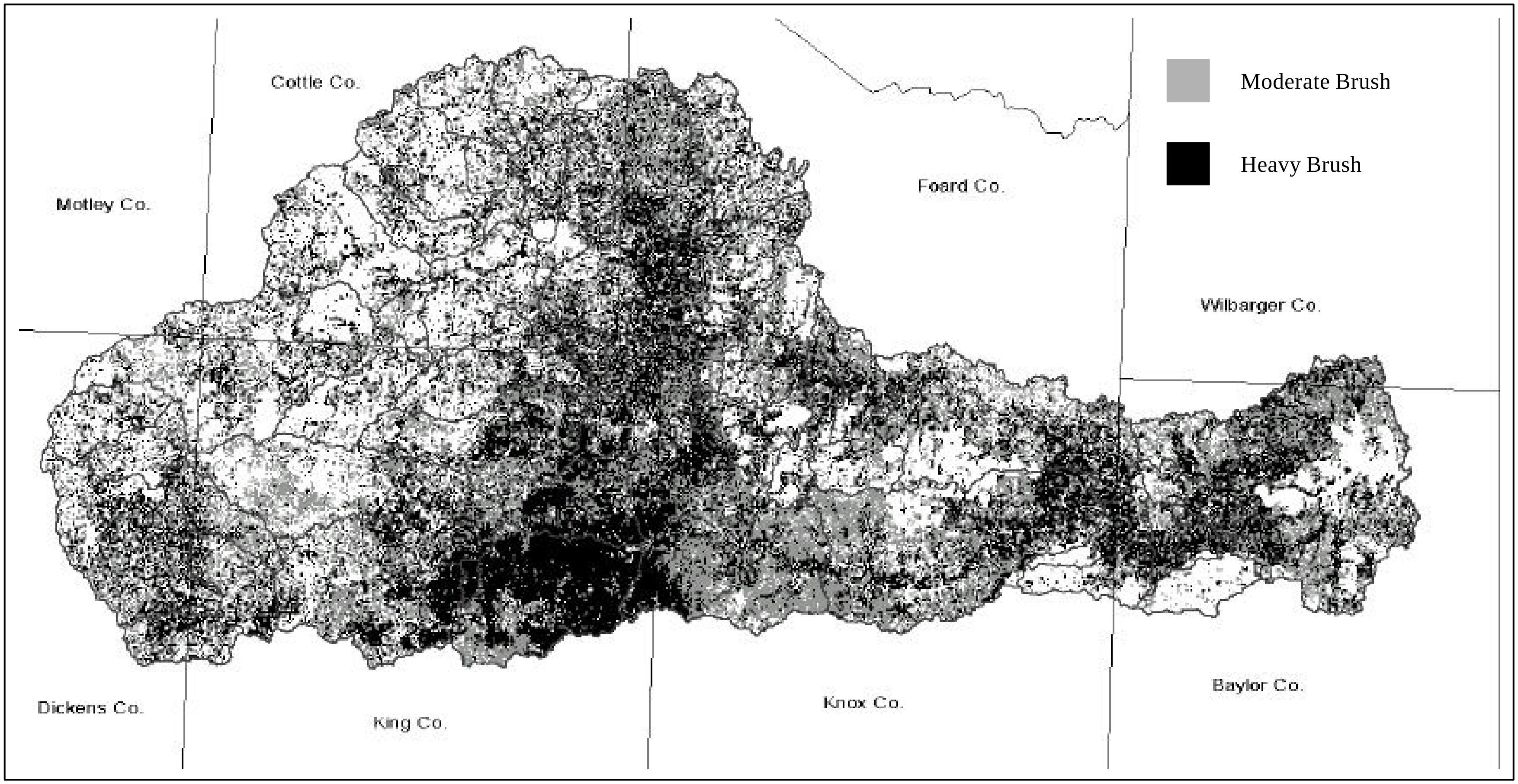

Figure W-4. Areas of heavy and moderate brush (oak not included) in the Wichita River Watershed.

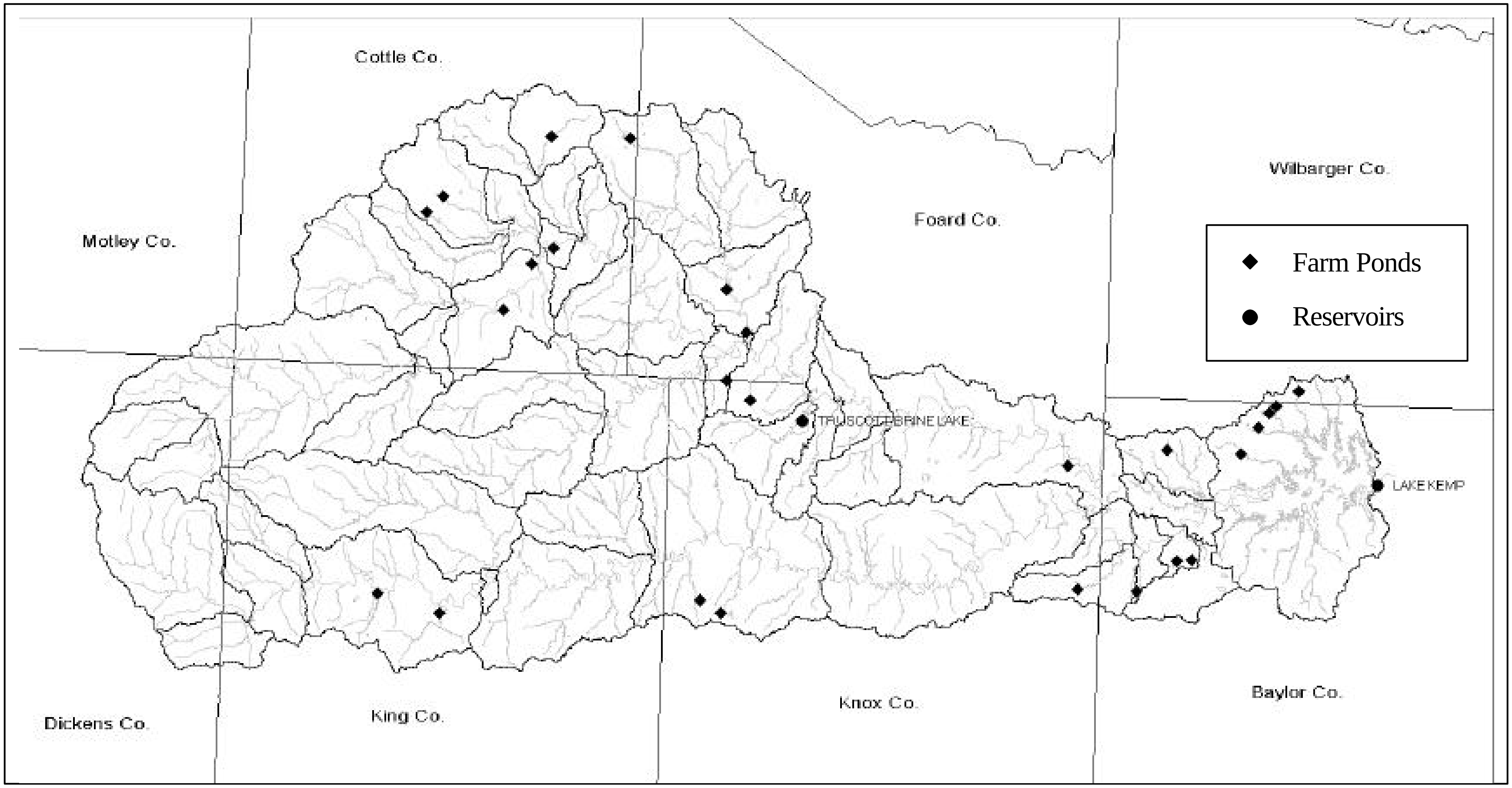

Figure W-5. Significant ponds and reservoirs in the Wichita River Watershed (from Texas Natural Resource Conservation Commission inventory of dams).

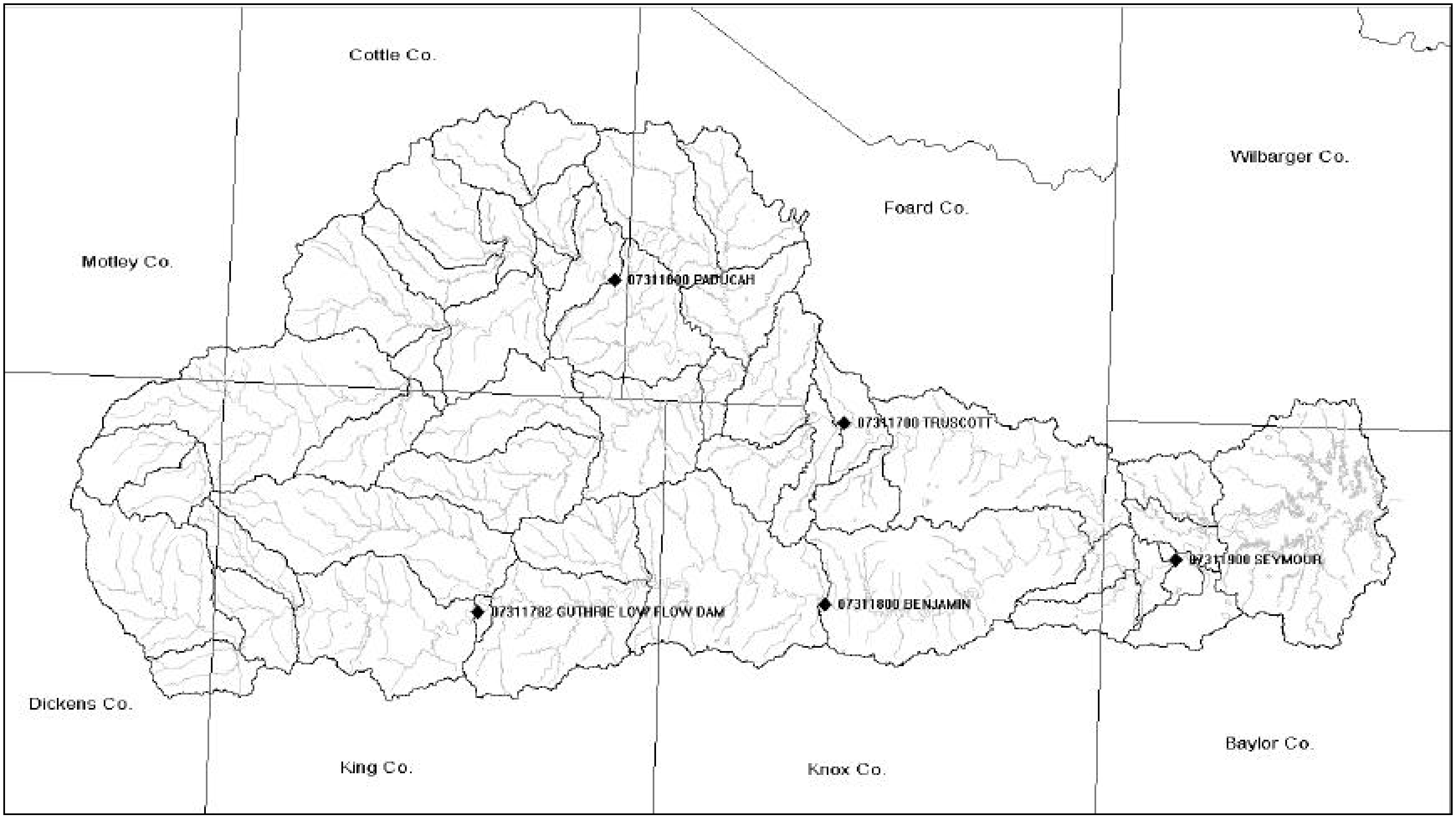

Figure W-6. Stream gauges used for calibration of flow in the Wichita River Watershed.

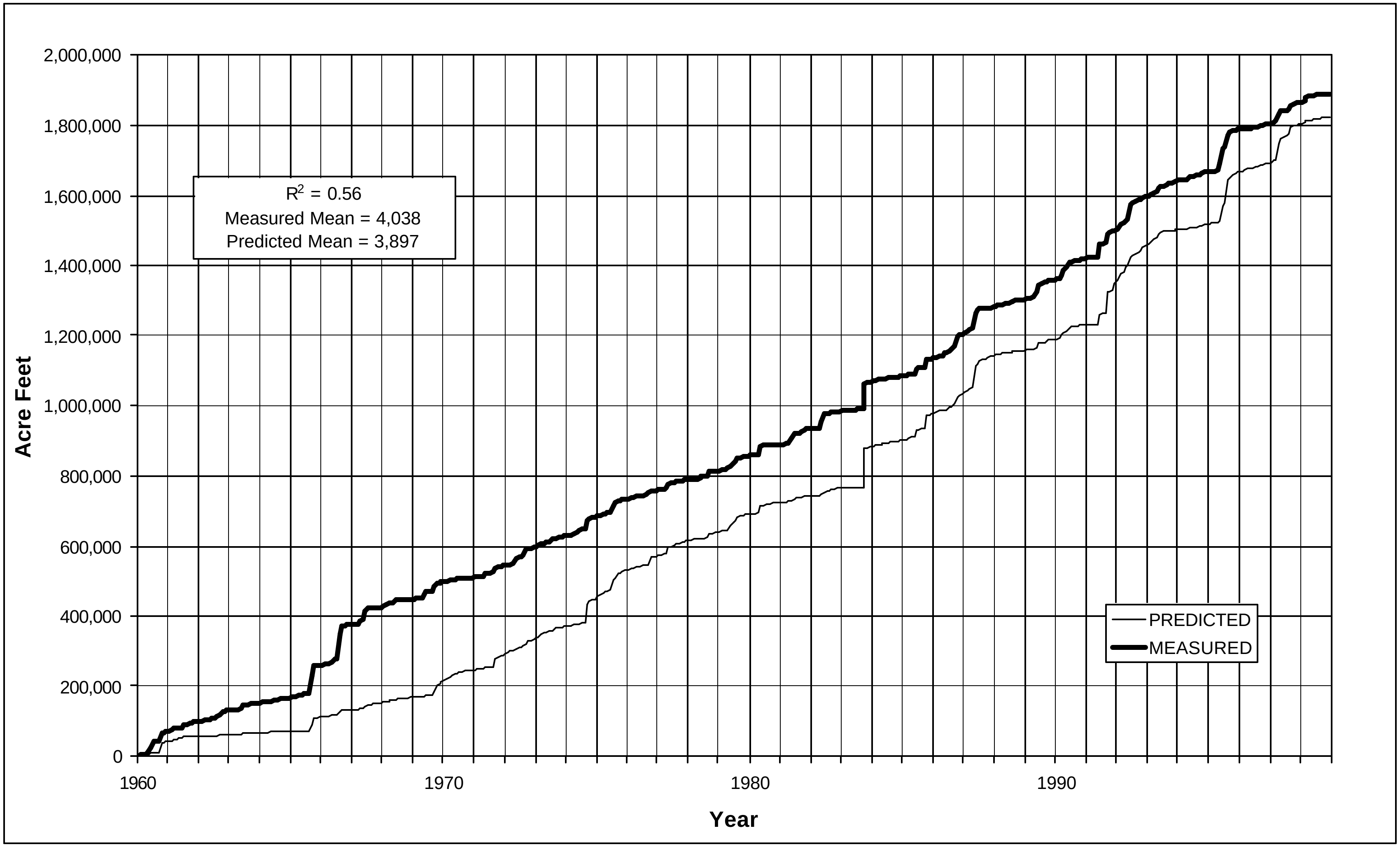

Figure W-7. Cumulative monthly measured and predicted stream flow at gauge 07311700 (Truscott), Wichita River Watershed, 1960 through 1998. Monthly statistics are shown in box.

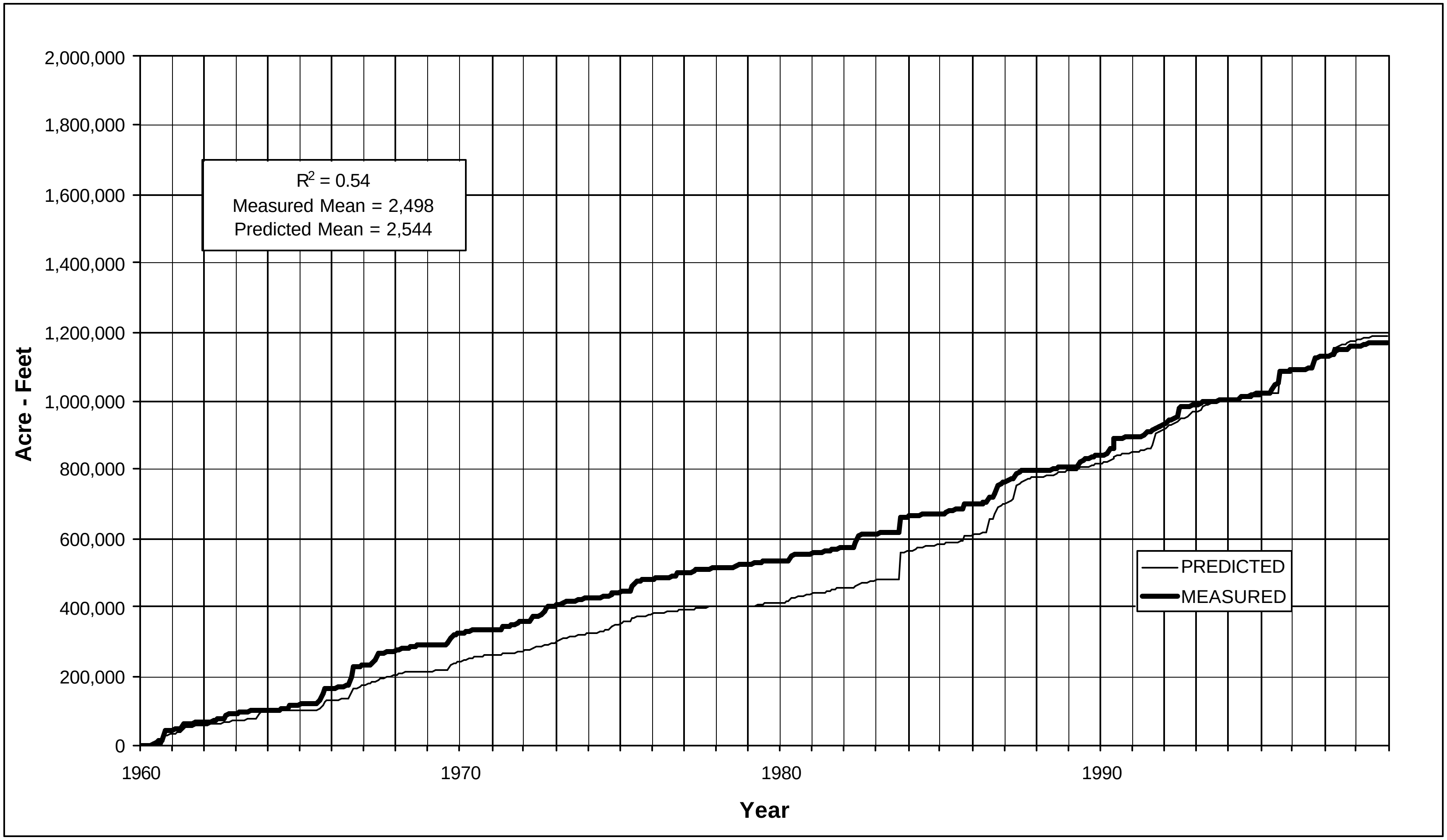

Figure W-8. Cumulative monthly measured and predicted stream flow at gauge 07311800 (Benjamin), Wichita River Watershed, 1960 through 1998. Monthly statistics are shown in box.

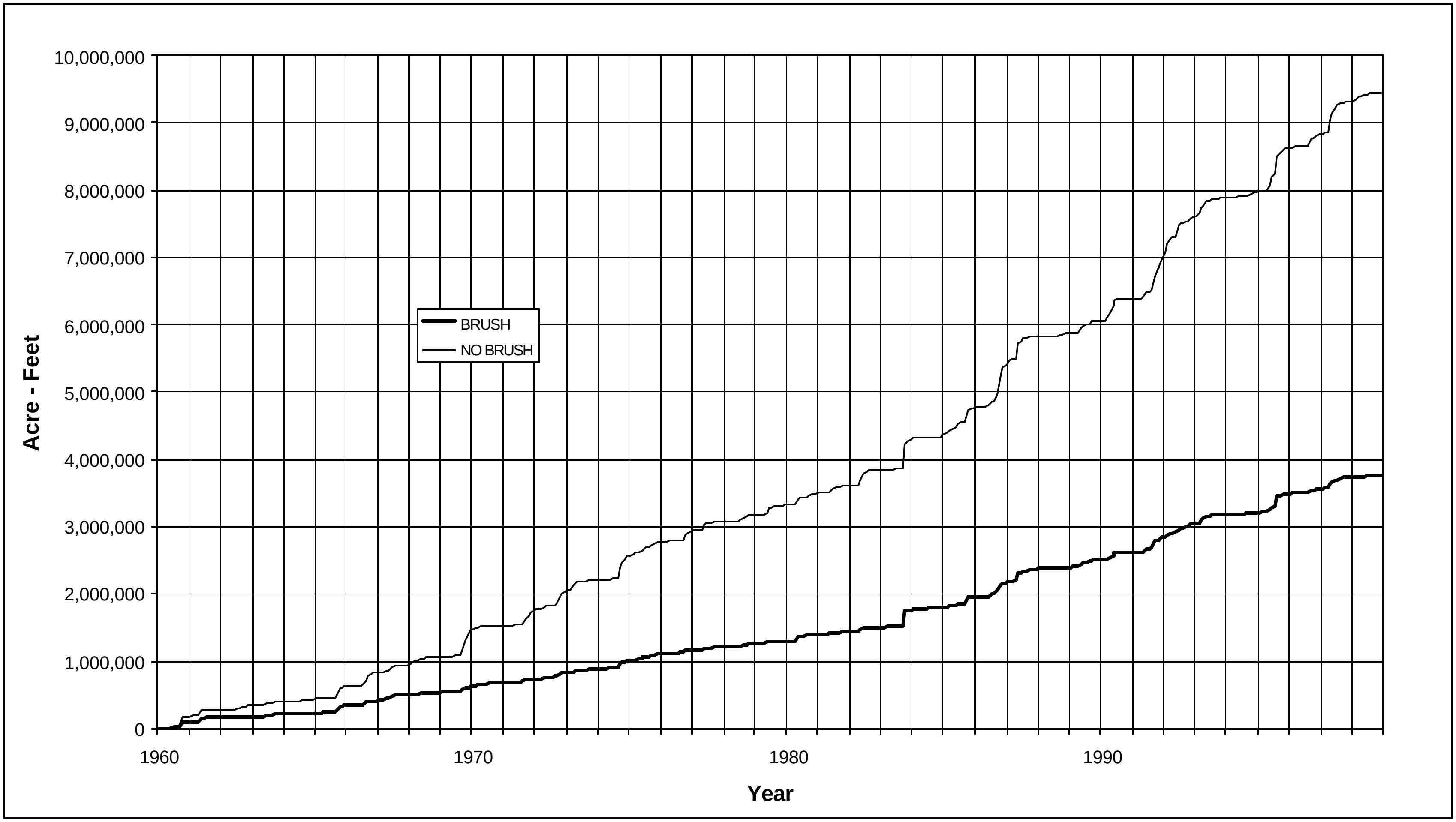

Figure W-9. Cumulative monthly predicted flow to Lake Kemp for brush and no-brush conditions, Wichita River Watershed, 1960 through 1998.

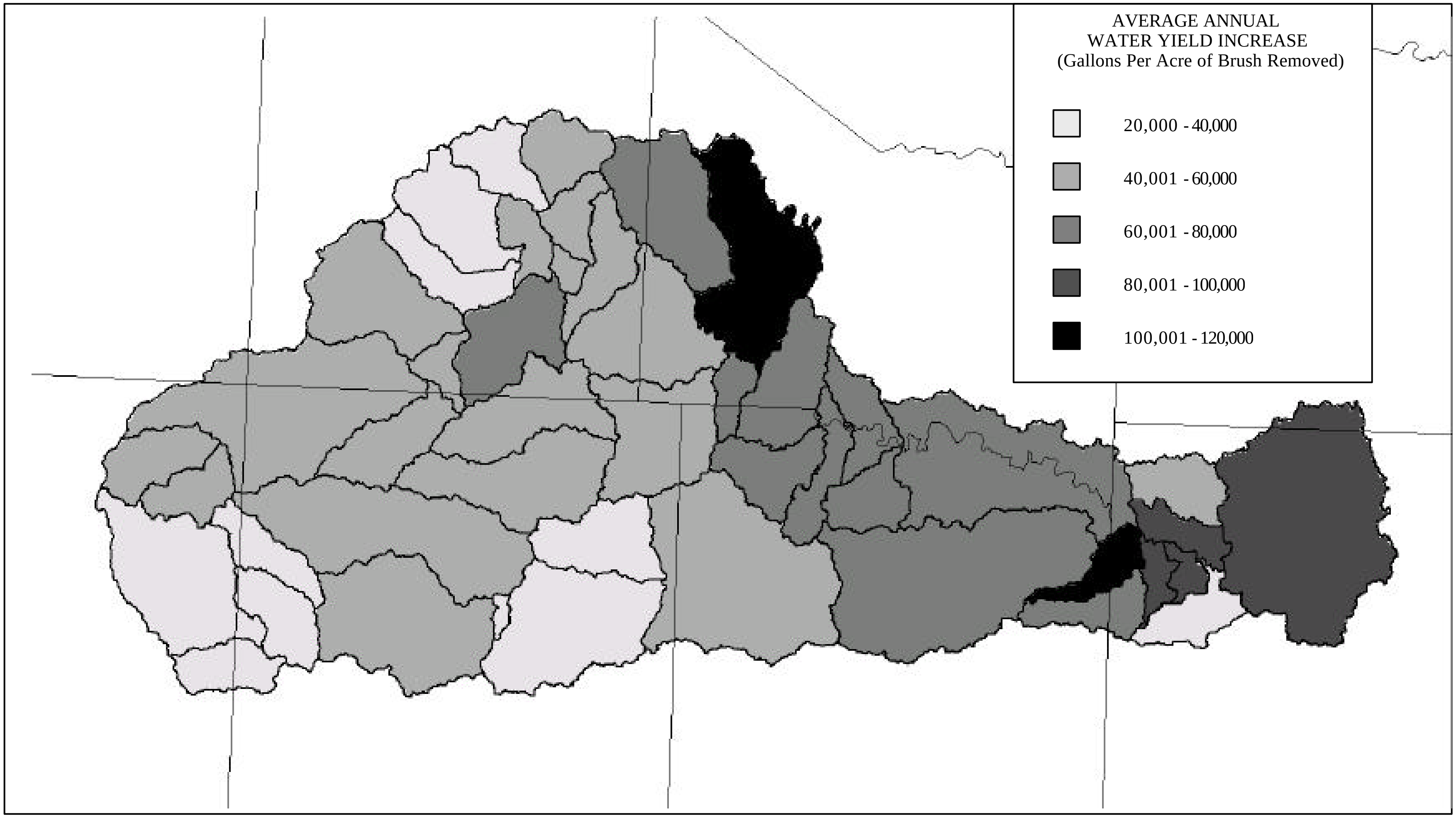

Figure W-10. Increase in water yield per unit area of brush removed, Wichita River Watershed, 1960 through 1998.

CHAPTER 20

WICHITA RIVER WATERSHED - ECONOMIC ANALYSIS

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INTRODUCTION

Amounts of the various types and densities of brush cover in the watershed were detailed in the previous chapter. Changes in water yield (runoff and percolation) resulting from control of specified brush type-density categories were estimated using the SWAT hydrologic model. This economic analysis utilizes brush control processes and their costs, production economics for livestock and wildlife enterprises in the watershed and the previously described, hydrological-based, water yield data to determine the per acre-foot costs of a brush control program for water yield for the Lake Kemp watershed.

BRUSH CONTROL COSTS

Brush control costs include both initial and follow-up treatments required to reduce current brush canopies to 5% or less and maintain it at the reduced level for at least 10 years. Both the types of treatments and their costs were obtained from meetings with landowners and Range Specialists of the Texas Agriculture Experiment Station and Extension Service, and USDA-NRCS with brush control experience in the project areas. All current information available (such as costs from recently contracted control work) was used to formulate an average cost for the various treatments for each brush type-density category.

Obviously, the costs of control will vary among brush type-density categories. Present values (using an 8% discount rate) of control programs are used for comparison since some of the treatments will be required in the first and second years of the program while others will not be needed until year 6 or 7. Present values of total control costs in the project area (per acre) range from $33.75 for moderate mesquite that can be initially controlled with herbicide treatments to $159.45 for mechanical control of heavy mesquite. Costs of treatments and year those treatments are needed for each brush type - density category are detailed in Table 1.

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category*

Heavy Mesquite - Chemical

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
4	Aerial Spray Herbicide	25.00	18.38
7	Choice Type IPT or Burn	15.00	8.75
		Total:	$ 52.13

Heavy Mesquite – Mechanical Choice[1]

Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze or Root Plow, Rake and Burn	150.00	150.00
6	Choice Type IPT or Burn	15.00	9.45
		Total:	$159.45

[1]Tree Doze, Root-Plow, Rake, and Burn

Heavy Cedar – Mechanical Choice[1]

Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
		Total:	$ 128.86

[1]Tree-Doze or Excavate, Stack and Burn

Heavy Cedar – Two-Way Chaining

Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
		Total:	$ 46.36

Two-Way Chain and Burn

Table 1. Cost of Water Yield Brush Control Programs by Type-Density Category (Continued)

Heavy Mixed Brush – Mechanical Choice

Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
		Total:	$ 128.86

Heavy Mixed Brush – Two-Way Chaining

Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
		Total:	$ 46.36

Two-Way Chain and Burn

Moderate Mesquite – Treatment Choice[1]

Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
7	Choice Type IPT or Burn	15.00	8.75
		Total:	$ 33.75

[1] Treatment choice between mechanical, fire or chemical methods.

Moderate Cedar –Treatment Choice[1]

Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
		Total:	$ 53.75

[1] Treatment choice between mechanical, fire, or chemical methods.

Moderate Mixed Brush - Treatment Choice[1]

Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
		Total:	$ 53.75

[1] Treatment choice between mechanical, fire, or chemical methods.

*Wichita River Watershed

LANDOWNER AND STATE COST SHARES

Rancher benefits are the total benefits that will accrue to the rancher as a result of the brush control program. These total benefits are based on the present value of the improved net returns to the ranching operation through typical cattle, sheep, goat and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program. For the livestock enterprises, an improvement in net returns would result from increased amounts of usable forage produced by controlling the brush and thus eliminating much of the competition for water and nutrients within the plant communities on which the enterprise is based. The differences in grazing capacity with and without brush control for each of the brush type-density categories in the watersheds draining to Lake Kemp are shown in Table 2. Data relating to grazing capacity was entered into the investment analysis model (see Chapter 2).

Table 2. Grazing Capacity With and Without Brush Control (Acres/AUY)*

Brush Type-Density Classification	Brush Control (Or) No Control	Program Year									
		0	1	2	3	4	5	6	7	8	9
Heavy Mesquite	Brush Control	32.5	28.1	23.8	23.8	21.9	20.0	20.0	20.0	20.0	20.0
	No Control	32.5	32.5	32.6	32.6	32.6	32.7	32.7	32.7	32.8	32.8
Heavy Cedar	Brush Control	50.0	40.0	35.0	30.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	50.0	50.0	50.1	50.1	50.2	50.2	50.3	50.3	50.4	50.5
Heavy Mix	Brush Control	38.5	33.0	28.0	24.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	38.5	38.5	38.5	38.6	38.6	38.7	38.7	38.8	38.8	38.9
Moderate Mesquite	Brush Control	25.0	22.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	25.0	25.1	25.3	25.4	25.6	25.7	25.8	25.9	26.1	26.3
Moderate Cedar	Brush Control	40.0	30.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	No Control	40.0	40.2	40.5	40.8	41.1	41.4	41.6	41.8	42.0	42.2
Moderate Mix	Brush Control	32.5	29.0	26.0	22.5	20.0	20.0	20.0	20.0	20.0	20.0
	No Control	32.5	32.7	32.9	33.1	33.2	33.4	33.6	33.8	34.1	34.3

* Wichita River Watershed

Livestock production practices, revenues, and costs representative of the watershed were obtained from personal interviews with a focus group of local ranchers. Estimates of the variable costs and returns associated with the livestock and wildlife enterprises typical of each area were then developed from this information into livestock production investment analysis budgets. This information for the livestock enterprises (cattle) in the project areas is shown in Table 3. It is important to note once again (refer to Chapter 2) that the investment analysis budgets are for analytical purposes only, as they do not include all revenues nor all costs associated with a production enterprise. The data are reported per animal unit for each of the livestock enterprises. From these budgets, data was entered into the investment analysis model, which was also described in Chapter 2.

Rancher benefits were also calculated for the financial changes in existing wildlife operations. Most of these operations in this region were determined to be simple hunting leases with deer, turkeys, and quail being the most commonly hunted species. Therefore, wildlife costs and revenues were entered into the model as simple entries in the project period. For control of heavy brush categories, wildlife revenues are expected to increase by about $0.50 per acre due principally to the resulting improvement in quail habitat. Wildlife revenues would not be expected to change with implementation of brush control for the moderate brush type-density categories.

Table 3. Investment Analysis Budget, Cow-Calf Production*

Revenues

Production Item	Marketed Percentage	Quantity	Unit	$ Per Unit	$ Return
Beef Cull Bull	0.01 (Head)	19.50	Cwt	50.00	0.00
Beef Cull Cow	0.105 (Head)	11.00	Cwt	40.00	0.00
Calves	0.84 (Head)	5.55	Cwt	75.00	416.25
				Total:	$416.25

Partial Variable Costs[4]

Variable Cost Description	Quantity	Unit	$ per Unit	$ Cost
Supplemental Feed	-------	-----	-------	50.00
Cattle Marketing - All Cattle	-----	Head of Cow	-----	18.16
Vitamin / Salt / Mineral	60.0	Pound	0.183	11.00
Veterinary and Medicine	1.0	Head	14.50	14.50
Net Cost for Purchased Cows	-----	Head	700.00	37.80
Net Cost for Purchased Bulls	-----	Head	1500.00	3.50
			Total:	$134.96

*Wichita River Watershed

This budget is for presentation of the information used in the investment analysis only.
Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included.

With the above information, present values of the benefits to landowners were estimated for each of the brush type-density categories using the procedure described in Chapter 2. They range from $12.05 per acre for control of moderate mixed brush to $21.80 per acre for the control of heavy mixed brush (Table 4).

The state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher benefits. Present values of the state per acre cost share of brush control in the project area range from $21.70 for control of moderate mesquite with chemical treatments to $140.75 for control of heavy mesquite by mechanical methods. Total treatment costs and landowner and state cost shares for all brush type-density categories are shown by both cost-share percentage and actual costs in Table 4.

Table 4. Landowner / State Cost-Shares of Brush Control*

Brush Category by Type & Density	PV Total Cost ($/Acre)	Landowner Share ($/Acre)	Landowner (Percent)	State Share ($/Acre)	State (Percent)
Heavy Mesquite	52.13 – 159.45	18.70	35.87 - 11.60	33.43 – 140.75	64.13 – 88.40
Heavy Cedar	46.36 – 128.86	18.79	40.53 – 14.58	27.57 – 110.07	59.47 - 85.42
Heavy Mixed Brush	46.36 – 128.86	21.80	47.02 - 16.92	24.56 – 107.06	52.98 - 83.08
Moderate Mesquite	33.75	12.05	35.70	21.70	64.30
Moderate Cedar	53.75	15.13	28.15	38.62	71.85
Moderate Mixed Brush	53.75	19.09	35.53	34.65	64.47
Average[1]	$70.38	$17.59	30.44%	$52.79	69.56%

* Wichita River Watershed

[1] Average is calculated as simple average, not relative average. The averages are based on the Heavy Mesquite Chemical comprising 50% of the cost for Heavy Mesquite control and Heavy Mesquite Mechanical comprising the other 50% of the cost for Heavy Mesquite. Also, it is assumed that Mechanical and Chemical comprise 50% each of cost for Moderate Mesquite control. Actual averages may change depending on relative amounts of each Type- Density Category of brush in each control category.

COST OF ADDITIONAL WATER

The total cost of additional water is determined by dividing the total state cost share if all eligible acreage were enrolled in the program by the total added water estimated to result from the brush control program over the assumed ten-year life of the program. The brush control program water yields and the estimated acreage by brush type-density category by sub-basin were supplied by the Blacklands Research Center, Texas Agricultural Experiment Station in Temple, Texas (see previous Chapter). The total state cost share for each sub-basin is estimated by multiplying the per acre state cost share for each brush type-density category by the eligible acreage in each category for the sub-basin. The cost of added water resulting from the control of the eligible brush in each sub-basin is then determined by dividing the total state cost share by the added water yield (adjusted for the delay in time of availability over the 10-year period using a 6% discount rate).

The cost of added water was determined to average $36.59 per acre foot for the entire Wichita Watershed (Table 53). Subbasins range from costs per added acre foot of $17.56 to $91.76.

Table 5. Cost of Added Water From Brush Control By Sub-Basin (Acre-Foot)*

Sub-basin No.	Total State Cost (Dollars)	Avg. Annual Water Increase (Acre-Feet)	10 Year Added Water (Acre-Feet)	State Cost for Added Water (Dollars Per Acre Foot)
1	457,182.65	663.12	5,173.66	88.37
2	1,772,111.33	2,475.42	19,313.20	91.76
3	344,487.78	1,077.40	8,405.87	40.98
4	270,611.17	942.91	7,356.62	36.78
5	405,303.90	749.96	5,851.16	69.27
6	551,815.58	986.80	7,699.02	71.67
7	1,829,171.16	5,422.75	42,308.32	43.23
8	1,620,183.78	5,981.27	46,665.90	34.72
9	1,338,434.24	4,191.21	32,699.81	40.93
10	590,024.30	1,348.29	10,519.36	56.09
11	343,140.75	538.63	4,202.39	81.65
12	440,716.10	1,034.65	8,072.31	54.60
13	262,233.00	539.93	4,212.53	62.25
14	299,909.61	991.71	7,737.34	38.76
15	354,443.07	1,133.46	8,843.26	40.08
16	187,848.00	708.77	5,529.82	33.97
17	84,634.43	271.90	2,121.36	39.90
18	522,247.77	2,033.13	15,862.52	32.92
19	124,871.50	428.28	3,341.42	37.37
20	246,020.32	891.41	6,954.81	35.37
21	2,730,475.37	5,040.57	39,326.50	69.43
22	110,738.33	207.37	1,617.87	68.45
23	1,369,643.80	2,842.40	22,176.44	61.76
24	1,563,106.99	4,341.88	33,875.38	46.14
25	971,017.42	3,045.95	23,764.46	40.86
26	771,619.10	5,630.83	43,931.70	17.56
27	1,478,568.35	7,031.17	54,857.21	26.95
28	1,801,533.32	5,150.93	40,187.54	44.83
29	1,948,506.76	5,494.46	42,867.77	45.45
30	3,769,655.99	11,088.20	86,510.14	43.57
31	439,757.96	1,808.91	14,113.14	31.16
32	613,063.06	2,662.65	20,774.03	29.51
33	260,808.40	978.39	7,633.40	34.17
34	722,243.11	3,244.66	25,314.81	28.53
35	801,913.88	4,916.12	38,355.56	20.91
36	472,961.33	1,639.72	12,793.10	36.97
37	522,081.31	2,403.25	18,750.18	27.84
38	293,231.45	1,269.62	9,905.55	29.60
39	3,111,539.76	13,297.01	103,743.29	29.99
40	2,006,939.15	9,401.39	73,349.63	27.36
41	307,258.55	1,076.78	8,401.04	36.57
42	424,456.46	2,248.68	17,544.19	24.19

43	493,711.42	1,956.21	15,262.37	32.35
44	452,996.05	2,434.30	18,992.42	23.85
45	272,492.79	1,539.52	12011.34	22.69
46	243,926.57	1,086.30	8475.32	28.78
47	24,499.30	122.51	955.81	25.63
48	3,371,088.17	17,633.53	137576.82	24.50
Total	$43,395,224.59	--------	1185937.68	Average: $36.59

* Wichita River Basin