TEXAS WATER DEVELOPMENT BOARD

REPORT 168

WOODY PHREATOPHYTES ALONG THE BRAZOS RIVER AND SELECTED TRIBUTARIES ABOVE POSSUM KINGDOM LAKE

By

Frank E. Busby, Jr.
Research Associate

and

Joseph L. Schuster
Professor and Chairman

Department of Range and Wildlife Management
Texas Tech University

Prepared by Texas Tech University
under interagency contract with the
Texas Water Development Board

April 1973

FOREWORD

In the arid western part of Texas, phreatophytes along streams remove large quantities of water from a very limited supply. The increase in area and density of these plants over the years, and the resultant increase in their water consumption, are of concern to the Texas Water Development Board.

The Board has contracted with Texas Tech University for two studies on phreatophytes to obtain needed information on the significance of these plants to the hydrologic regime and availability of water supplies. The resulting reports are being published in the Board's continuing effort to provide the public with information on important aspects of water resources.

The two original reports are here combined and published in a single volume for convenience of the readers. Together, these reports provide an inventory of phreatophytes along a major part of the Brazos River drainage system, and an estimate of their water consumption.

The Board thanks the authors for providing valuable data and analyses important to water resource planning and management.

TEXAS WATER DEVELOPMENT BOARD

Harry P. Burleigh

Harry P. Burleigh
Executive Director

Woody Phreatophytes Along the Brazos River and Selected Tributaries Above Possum Kingdom Lake

Texas Water Development Board Report 168

ERRATA

The description accompanying Figure 3 on page 5 should read

Figure 3.--Aerial Photographs Indicating Saltcedar Increase and River Channel Position Changes, 1940 to 1969. The 1940 Photograph (Upper Left) Indicates a Large Amount of Open Ground (Light Tones). By 1950 (Above) Most of This Area Had Been Invaded by Small Clumps of Saltcedar, and Some of the Area Had Extensive Clumps of Dense Saltcedar. By 1969 (Left), Most of the Flood Plain Had Been Invaded by Dense Stands of Saltcedar. Point 1 on All Three Photographs Indicates a Typical Area of Saltcedar Invasion. The Arrows Show the Direction of River Channel Change. This Position Change is Partly Caused by the Reduction in Floodwater Carrying Capacity Caused by the Vegetation Increase. Site is in Southeast Knox County.

instead of as shown.

TABLE OF CONTENTS

PART I

BRAZOS RIVER FROM POSSUM KINGDOM LAKE TO THE CONFLUENCE OF THE SALT AND DOUBLE MOUNTAIN FORKS

	Page
ABSTRACT	1
INTRODUCTION	2
LOCATION AND DESCRIPTION OF THE STUDY AREA	2
METHODS AND PROCEDURES	3
RESULTS AND DISCUSSION	6
Description and Distribution of Plant Communities	6
Acreage Changes in Species and Land Use, 1940 to 1969	10
Trends of Saltcedar and Mesquite Spread	11
Comparisons of Soil Series and Plant Community Occurrence	12
SUMMARY AND CONCLUSIONS	15
LITERATURE CITED	17

APPENDICES

A.	Common and Scientific Names of Plants Referred to in the Report	18
B.	List of Aerial Photographs Used in the Survey	18
C.	Location and Description of Transect Lines	18
D.	Crown Cover Intercepted by Each Transect	22
E.	Average Composition of Saltcedar Community	23
F.	Average Composition of Mesquite Community	23

TABLES

1.	Moisture Variation Within the Study Area	3
2.	Land Use and Species Composition on the Brazos River Flood Plain Above Possum Kingdom Lake, 1969	7

TABLE OF CONTENTS (Cont'd.)

Page

3. Average Crown Cover Intercepted by the Transects in Each County 8

4. Saltcedar Acreage Equivalent for 100 Percent Volume Density, 1969 12

5. Acreage Comparisons in Species and Land Use, 1940, 1950, and 1969 13

6. Trend of Saltcedar and Mesquite Spread 14

FIGURES

1. Map Showing Location of the Study Area 3

2. Aerial Photograph With Plant Communities Delineated 4

3. Aerial Photographs Indicating Saltcedar Increase and River Channel Position Change, 1940 to 1969 5

4. Graph Showing Distribution of Woody Plant Communities on the Flood Plain, by County, 1969 6

5. Graph Showing Ratios of the Flood-Plain Area Having No Woody Plant Cover to the Area With Woody Plant Cover, by County, 1969 7

6. Photograph of Dense Saltcedar Adjacent to the River Channel 9

7. Photograph of Dense Saltcedar 600 Feet From the River Channel 9

8. Photograph of Saltcedar-Baccharis Community in an Open Stand 10

9. Photograph of Saltcedar and Mesquite Growing in Adjacent Areas and Forming an Ecotone Between the Two Communities 11

10. Photograph of Mesquite Community 12

11. Photograph of Cottonwood Community Near the River Channel With a Saltcedar Understory 13

12. Photograph of Mixed Community 14

TABLE OF CONTENTS (Cont'd.)

PART II

SALT AND DOUBLE MOUNTAIN FORKS FROM THEIR CONFLUENCE TO THE HEADWATERS

	Page
ABSTRACT	25
INTRODUCTION	26
LOCATION AND DESCRIPTION OF THE STUDY AREA	26
METHODS AND PROCEDURES	28
RESULTS AND DISCUSSION	31
SUMMARY AND CONCLUSIONS	35
LITERATURE CITED	38

APPENDICES

A.	Common and Scientific Names of Plants Referred to in the Report	39
B.	List of Aerial Photographs Used in the Survey	39
C.	Acreages of the Total Area, River Bed, Flood Plain, Cleared Areas, and Area of Phreatophyte Occurrence Along Major Streams	40
D.	Acreages of Phreatophytes Along the Salt Fork Brazos River and Major Tributaries	41
E.	Acreages of Phreatophytes Along the Double Mountain Fork Brazos River and Major Tributaries	41

TABLES

1.	Climatic Variation in the Study Area	29
2.	Number of Line Transects and Community Samples	30
3.	Acreages of Phreatophyte Communities	32
4.	Major Species and Average Vegetative Cover Determined From Transects	32
5.	Average Species Composition of the Saltcedar Communities	33
6.	Equivalent Acreage of Saltcedar at 100 Percent Volume Density	34
7.	Average Species Composition of the Mesquite Communities	35
8.	Equivalent Acreage of Mesquite at 100 Percent Volume Density	35

FIGURES

1.	Map Showing Location of the Study Area	27

TABLE OF CONTENTS (Cont'd.)

		Page
2.	Photograph of Vegetation on a Wide Flood Plain Along the Salt Fork Brazos River	28
3.	Photograph of Vegetation on a Narrow Flood Plain Along the Salt Fork Brazos River	29
4.	Graph Showing Monthly Precipitation, Evaporation, and Temperature at Lubbock and Spur	30
5.	Photograph of Extensive Saltcedar on a Wide Flood Plain With a Shallow Water Table	33
6.	Photograph of Mesquite on the Outer Flood Plain	34
7.	Photograph of Cottonwood on an Area Protected From Flooding	36
8.	Photograph of Sand Sagebrush in a Sandy, Dry Area on an Upper Tributary	37

PART I

BRAZOS RIVER FROM POSSUM KINGDOM LAKE TO THE CONFLUENCE OF THE SALT AND DOUBLE MOUNTAIN FORKS

ABSTRACT

Woody phreatophyte vegetation was inventoried along the Brazos River upstream from Possum Kingdom Lake to the confluence of the Double Mountain and Salt Forks. The kinds, amounts, distribution, history of spread, and volume density of the phreatophytes were determined along with their relation to flood-plain location.

Saltcedar is the most widely distributed phreatophyte in the study area, and usually occurs in a dense stand adjacent to the river channel. It dominated 18 percent of the river flood plain in 1940, increasing to 28 percent in 1950 and 36 percent in 1969. The plant invaded toward the river channel after it became established on the outer portion of the flood plain. Average volume density is 46 percent, and total growth is equivalent to 6,104 acres at 100 percent volume density. Saltcedar along this reach of the Brazos River is estimated to use approximately 44,000 acre-feet of water annually.

Mesquite occurs on the outer portion of the flood plain, and occurs extensively where the flood plain is wide. It has spread slightly toward the river channel, invading 760 additional acres from 1940 to 1969. Average volume density is 27 percent, and total growth is equivalent to 2,181 acres at 100 percent volume density. Mesquite on the flood plain of this river reach is estimated to use as much as 7,200 acre-feet of water annually.

The cottonwood community and a mixed community consisting of varying amounts of hackberry, elm, willow, cottonwood, pecan, baccharis, and saltcedar occur where moisture conditions are favorable. Extensive concentrations of these communities occur in Young County.

Sixty-three percent of the 48,000-acre Brazos River flood plain above Possum Kingdom Lake is occupied by one or more of these plant communities. Because these species diminish the available water resource and are normally considered of low economic benefit, these extensive areas of phreatophyte vegetation deserve further attention to determine proper land use.

PART I

BRAZOS RIVER FROM POSSUM KINGDOM LAKE TO THE CONFLUENCE OF THE SALT AND DOUBLE MOUNTAIN FORKS

INTRODUCTION

Water is a valuable and scarce resource in the western portion of Texas. Researchers work continuously to discover ways of conserving or more efficiently using the limited water supplies. Some progress has been made, but Rechenthin and Smith (1967) estimate that water-wasting plants invading the native grasslands of Texas waste more water every year than is used by all the towns, factories, farms, and people of the State.

Much of this undesirable plant growth is in dense stands of brush that have grown up in the flood plains of our watercourses (Gillette, 1968). These plants are capable of sending their roots into the water table or the capillary fringe overlying the water table and of removing large quantities of water from the underground aquifer. They are able to produce vigorous growth even during periods of severe drought. Plants with this characteristic are called phreatophytes. The term is derived from two Greek words and literally means "well plant" (Meinzer, 1923; Robinson, 1958).

Phreatophytes have been reported by the U.S. Department of Interior (1959) to cover 16 million acres in the western United States and to use 20 to 25 million acre-feet of water per year. The Department reported the following water-use rates for several common phreatophytes: Saltcedar[1/], 4.7 to 9.2 acre-feet per acre per year (depending upon the region of growth); mesquite, 3.3 acre-feet per acre per year; cottonwood, 5.2 to 7.6 acre-feet per acre per year; and baccharis, 4.7 acre-feet per acre per year. These plants are not normally considered to be economically important, although they provide wildlife habitat and esthetic values.

The purpose of this study was to inventory the woody phreatophyte vegetation along the mainstem Brazos River upstream from Possum Kingdom Lake. The kinds, amounts, distribution, history of spread, and volume densities of the woody phreatophytes were studied along with their relation to flood-plain location. Preliminary estimates were made of the water usage of the most extensive plant communities. This study was carried out by Texas Tech University under interagency contract with the Texas Water Development Board [Contract IAC (68-69)-411].

LOCATION AND DESCRIPTION OF THE STUDY AREA

The study area includes all of the flood plain of the Brazos River from the confluence of the Salt and Double Mountain Forks in Stonewall County to upper Possum Kingdom Lake in Young County, a distance of approximately 170 river miles (Figure 1). The total area of flood plain under study is about 48,000 acres.

The uplands surrounding the river are mostly formed by rocks of Permian age. Quaternary alluvial deposits mantle some of the Permian rocks in Knox and Baylor Counties. Rocks exposed in southeastern Young County are of Pennsylvanian age.

Material of recent age found in the Brazos River flood plain consists of alluvial red clay, silt, and sand. Maximum thickness of this stratified alluvium is probably about 40 feet in Knox County (Ogilbee and Osborne, 1962), and thickness may reach 60 feet along the inside of river bends in Young County (Morris, 1964).

Soils developing from the flood-plain alluvium are immature and have a nearly level to gently sloping surface. Some are moderately alkaline (pH less than 8.5). Soils near the river channel are subject to frequent flooding and are not considered suitable for cultivation. Colorado-Mangum and Lincoln-Yahola soil associations predominate.

In general, the hardness and salinity of the ground water beneath the flood plain decrease from Stonewall

1/ See Appendix A for a list of common and scientific names of plants mentioned in this report.

to Young County. Water quality is poor, and, although the water is used by livestock, its mineral content generally exceeds the recommended limits for human consumption set forth by the U.S. Public Health Service (Cronin and others, 1963).

The climate is characterized by high temperatures, high evaporation rates, and low effective rainfall. Moisture variation within the study area is summarized in Table 1. Young County has the most favorable available moisture situation because of the higher average annual precipitation and lower average annual surface evaporation.

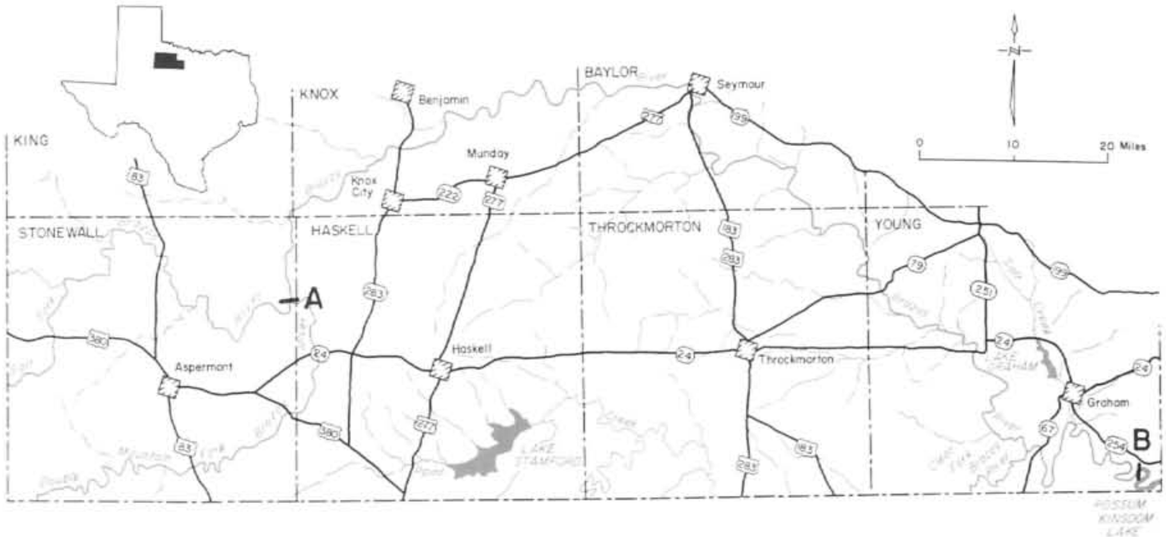


Figure 1.—Location of the Study Area. Survey Extends From Northeast Stonewall County (Point A) to Southeast Young County (Point B) Near Possum Kingdom Lake.

Table 1.—Moisture Variation Within the Study Area

COUNTY	APPROXIMATE AVERAGE ANNUAL RAINFALL, 1940-1965 1/	APPROXIMATE AVERAGE ANNUAL GROSS LAKE-SURFACE EVAPORATION, 1940-1965 2/
Stonewall	22 in.	77 in.
Knox	24 in.	75 in.
Baylor	25 in.	73 in.
Throckmorton	25 in.	75 in.
Young	27 in.	74 in.

1/ Kane, 1967, pl. 4.
2/ Kane, 1967, pl. 6.

METHODS AND PROCEDURES

Aerial photographs taken in 1963, 1967, and 1968 were used as base maps in the survey. These were secured by the Texas Water Development Board from the Aerial Photography Western Laboratory, U.S. Department of Agriculture, Salt Lake City, Utah, (see Appendix B for a list of aerial photograph numbers). The 1969 land use and occurrence of the phreatophyte communities were delineated on these aerial photographs. Aerial photographs taken in 1940 and 1950 were studied at local offices of the U.S. Soil Conservation Service to determine the spread of the various species of vegetation during these time periods. Some photographs were missing from the older sets, and the 1940 photographs of Baylor County were not available. In making comparisons, when data on an area were missing from one photograph set, the area was disregarded in all photograph sets.

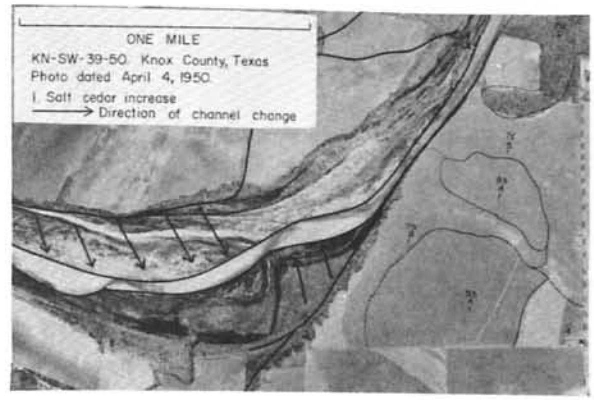
Phreatophyte communities were identified by field surveys during the period January through July 1969. Known areas of each stand were recorded on the current (1963-68) aerial photographs and their occurrence correlated to photograph characteristics such as tone, shape, dimension, texture, and shadow pattern. The remaining areas of phreatophytes were identified by photograph interpretation (Figure 2). The accuracy of aerial photograph interpretation was checked by aerial reconnaissance flights and field surveys.

Figure 2.—Aerial Photograph With Plant Communities Delineated. The Saltcedar Communities (SC) are Identified by the Uniform Dark Tone and Smooth Photograph Texture. The Mesquite Areas (MS) Exhibit a Coarse Texture and Varying Tone Typical of Species Growing in Open Canopy Stands. Cottonwood Communities (CW) Are a Typical Light Tone and Also Exhibit Characteristics of Species Growing in Open Stands. The Mixed Communities (MX) Are More Variable in Tone, and Often Clumps of Different Species Can be Identified. Species Occurring in Mixtures Were Identified by Field Surveys. Arrow Labeled 15 is a Transect Location. Straight Match Lines at Top and Bottom Mark the Limit of Mapping Between This and Adjacent Photographs.

The 1940 and 1950 aerial photographs were interpreted using the same photograph characteristics as those determined from use of the current photographs. However, reliable identification of subdominant species occurring in mixtures was not possible. Therefore, areas were only identified as being occupied by dominant species on the older photographs (Figure 3). Both the dominant species and mixtures were identified on current aerial photographs. Acreage of occurrence of the species on all photographs was determined with a compensating polar planimeter.

Increases in saltcedar crown cover and the direction of spread were determined by measuring on corresponding 1940, 1950, and recent photographs the distance from a point in the river bed to the first occurrence of light and dense saltcedar in the flood plain. Also, the first interception of mesquite was recorded to determine if any change had occurred in its location on the flood plain since 1940. A common point on all photograph sets was located by drawing coordinate lines through landmarks visible on the corresponding photographs. Points at which the river channel had changed position were avoided.

Soil information was obtained from current soil surveys being made for conservation planning in Stonewall and Baylor Counties by the U.S. Soil Conservation Service. Plant species common to each soil series on the flood plain were determined, and plant



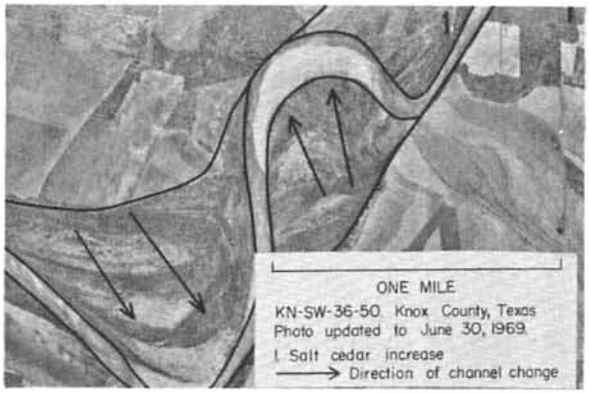


Figure 3.—Aerial Photographs Indicating Saltcedar Increase and River Channel Position Changes, 1940 to 1969. The 1940 Photograph (Upper Left) Indicates a Large Amount of Open Ground (Light Tones). By 1950 (Left) Most of This Area Had Been Invaded by Small Clumps of Saltcedar, and Some of the Area Had Extensive Clumps of Dense Saltcedar. By 1969 (Above), Most of the Flood Plain Had Been Invaded by Dense Stands of Saltcedar. Point 1 on All Three Photographs Indicates a Typical Area of Saltcedar Invasion. The Arrows Show the Direction of River Channel Change. This Position Change is Partly Caused by the Reduction in Floodwater Carrying Capacity Caused by the Vegetation Increase. Site is in Southeast Knox County.

community occurrence was correlated with location of soils, their surface texture and subsurface stratification, and soil-water relationships.

Forty-three transects were studied in the field to gather information necessary to calculate percentage composition and volume density of each phreatophyte community according to procedures outlined by Horton and others (1964). The transect lines crossed the entire flood plain. The kind, locations, amounts of crown cover, maximum heights of plants, and depths of foliage were recorded for each woody species as it was intersected by the transect line. Fourteen transects were taken in Young County, 3 in Throckmorton, 13 in Baylor, 9 in Knox, and 4 in Stonewall (See Appendix C for location and description of each transect).

Each transect location was selected according to its accessibility and to the amount of information it could provide. Areas that had been cleared of woody vegetation were avoided. This selection process insured the maximum amount of desired information from each transect, but limited the use of the data to show species composition and density in uncleared, selected areas. Therefore, it was not used as a check on the overall extent of phreatophytes determined from the aerial photographs.

The flood-plain transects were broken down into community transects where distinct changes occurred in the kinds or amounts of species along the transect line. This division yielded the following community transects: 46 saltcedar, 18 mesquite, 9 saltcedar-baccharis, 14 mixed, 5 saltcedar-mesquite, and 2 cottonwood. The species composition, location, and amount of crown cover were determined for each community. In addition, maximum plant height and depth of foliage were determined for the saltcedar and mesquite-dominated communities. Volume density, expressed as a percentage, was calculated for these two communities by the following formula:

$$\text{Volume density} = \frac{\text{Total feet of crown intercept recorded for dominant species of each association}}{\text{Total feet measured through each association}} \times \frac{\text{Height of Plant (Not to exceed optimum depth of foliage)} \times 100}{\text{Optimum depth of foliage}}$$

RESULTS AND DISCUSSION

Description and Distribution of Plant Communities

Eleven species of woody vegetation cover 30,629 acres of the study area. Only cultivated fields, tame pastures, and the river channel are free of woody vegetation. The eleven species occur in four principal plant communities, saltcedar, mesquite, cottonwood, and mixed. The acreage of each community is listed in Table 2. Some plants were found to occupy small acreages and are not considered important to water consumption. These are included in the table division "Other" to provide a complete record.

The most important factor in regional distribution of species is favorable moisture conditions (Table 1). This fact is exemplified in Table 3 several ways. First, the species commonly associated with moist areas, such as hackberry, elm, willow, and cottonwood, are most abundant in Young County (Figure 4). Their occurrence in relatively drier Stonewall County is low. Second, the amount of vegetation overlap and the number of species present are higher in Young County. Vegetative overlap indicates favorable moisture. Third, the ratio of area with no woody cover to area with woody vegetative cover decreases from Stonewall to Young Counties (Figure 5). As this ratio decreases, moisture conditions must improve to support the increased volume of vegetation.

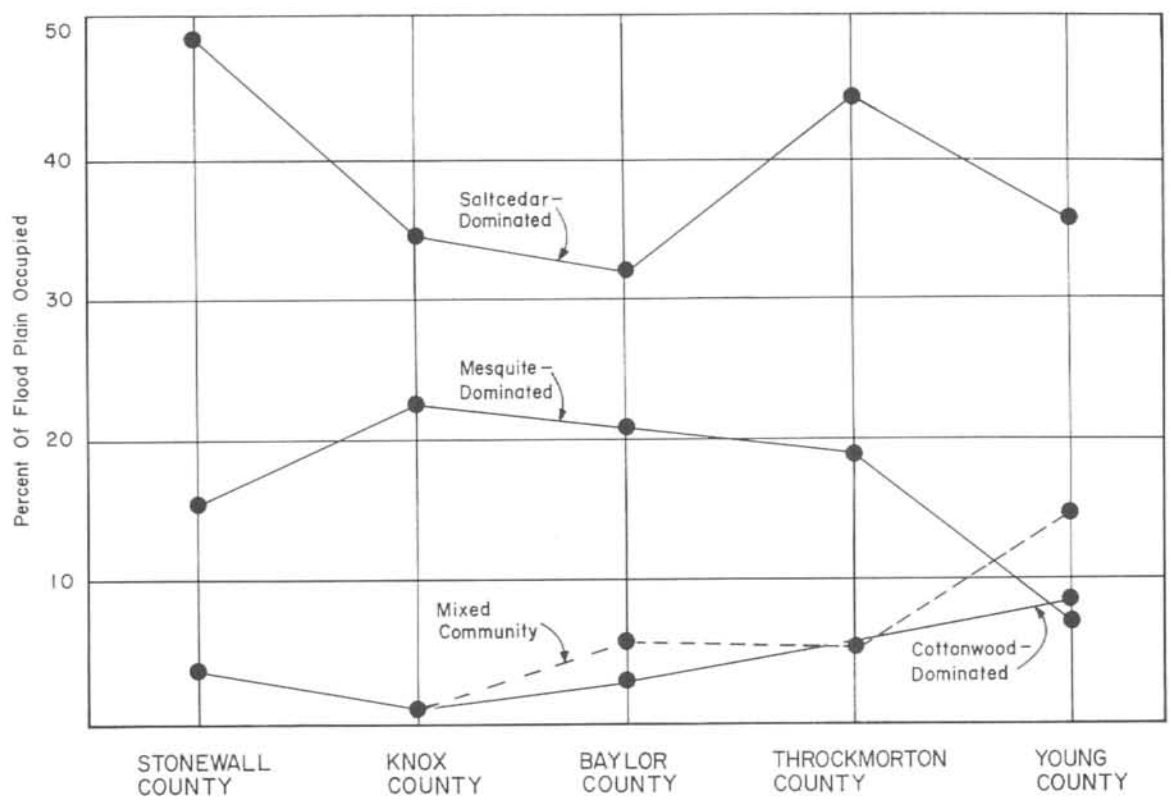


Figure 4.—Distribution of Woody Plant Communities on the Flood Plain, by County, 1969. Data from Table 2.

Saltcedar

Saltcedar is the most widely and evenly distributed phreatophyte (Figure 4), dominating 36 percent of the entire flood-plain area. Saltcedar stands form an almost continuous band of vegetation along both sides of the river channel. Dense stands adjacent to the river and along old flood terraces occupy 28 percent of the flood plain (Figures 6 and 7). A saltcedar-baccharis community covers 5 percent of the area and is generally found only where crown cover of saltcedar is less than 25 percent (Figure 8). A saltcedar-mesquite community occurs on 3 percent of the flood plain as an ecotone between saltcedar and mesquite-dominated areas (Figure 9). The mesquites are small and probably represent pioneer plants invading into an old saltcedar community.

The percentage of saltcedar is highest in areas where the flood plain is narrow and flat and the river channel is straight. These areas provide the most optimum water-table conditions for saltcedar growth. These flood-plain characteristics explain the high percentage of saltcedar occurrence in Stonewall and Throckmorton Counties where the flood plain is flat and the river channel is relatively straight.

Table 2.—Land Use and Species Composition on the Brazos River Flood Plain Above Possum Kingdom Lake, (Figures in Parenthesis are Summations of all Areas Dominated by the Species.)

LAND USE	STONEWALL COUNTY (ACRES)	KNOX COUNTY (ACRES)	BAYLOR COUNTY (ACRES)	THROCKMORTON COUNTY (ACRES)	YOUNG COUNTY (ACRES)	TOTAL (ACRES)
Cultivated fields and tame pastures	232	3,917	2,954	826	2,299	10,288
River bed	551	1,757	1,541	629	2,721	7,199
Saltcedar dominated	(1,179)	(4,915)	(3,790)	(2,482)	(4,833)	(17,199)
Saltcedar alone	1,057	4,008	3,056	1,487	3,608	13,216
Saltcedar-baccharis	26	192	500	691	1,118	2,527
Saltcedar-mesquite	96	715	234	304	107	1,456
Mesquite dominated	373	3,176	2,476	1,065	989	8,079
Cottonwood dominated	(86)	(120)	(324)	(311)	(1,140)	(1,981)
Cottonwood alone	30	55	91	113	349	588
Cottonwood-saltcedar	—	20	—	198	193	411
Cottonwood-mesquite	56	95	233	—	598	982
Mixed: Hackberry, elm, cottonwood, willow, pecan, baccharis, saltcedar	—	195	656	290	2,089	3,230
Other: Live oak, lote-bush, tasajillo	—	18	45	—	77	140
Total	2,421	14,098	11,786	5,603	14,148	48,056

Saltcedar communities were intersected by 24,179 feet of transect line. Of this, 11,183 feet was saltcedar canopy and 1,450 feet was associated species. (See Appendix E for typical saltcedar community composition.) Saltcedar crown cover averaged 46 percent. The average plant height was 12.8 feet, and the average foliage depth was 11.4 feet. The only county that did not have a 100 percent vertical density was Stonewall, where the average plant height was less than the average foliage depth for the survey and a vertical density of 93 percent was computed. The calculations necessary to determine the saltcedar acreage equivalent for 100 percent volume density are given in Table 4.

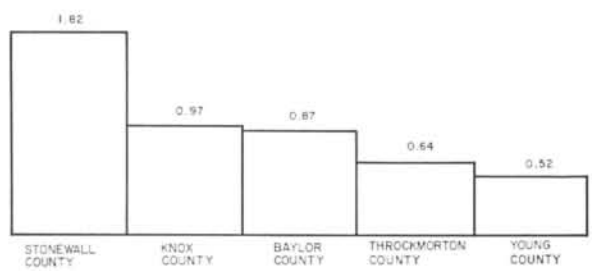


Figure 5.—Ratios of the Flood-Plain Area Having No Woody Plant Cover to the Area With Woody Plant Cover, 1969. The Ratios Are Smaller Eastward, Reflecting More Favorable Moisture Conditions.

As shown in Table 4, the amount of saltcedar in the study area is equivalent to 6,104 acres at full crown cover and at optimum foliage depth. This acreage, times an expected water use per acre, will be used to obtain an estimate of the amount of water used by saltcedar.

Mesquite

Mesquite occurs on the higher portions of the flood plain (Figure 10). Its most extensive occurrences are where the flood plain is wide or where oxbows have been formed. Observation of the old and new photographs indicated that mesquite spread was influenced by changes in the location of the river channel. New plants invade when the channel cuts farther away, and old stands die when the channel moves toward the stand. Mesquite was not found growing in areas with evidence of recent flooding. It was never found on low lands near the river channel, nor did it occur in large proportions where the flood plain narrowed. Poor soil aeration, a high water table, and an increased frequency of flooding probably served as limiting factors in those areas. The narrow, flat flood

Table 3.—Average Crown Cover Intercepted by the Transects in Each County (See Appendix D for the Crown Cover Intercepted by Each Transect)

COUNTY	NUMBER OF TRANSECTS PER COUNTY	INTERCEPT AS AN AVERAGE PERCENTAGE OF TRANSECT LENGTH									
		SALT-CEDAR	BACCHARIS	MESQUITE	COTTON-WOOD	WILLOW	ELM	HACK-BERRY	OTHER	NO WOODY COVER	VEGETATIVE OVERLAP
Young	14	31	6	8	5	6	7	2	3	38	6
Throckmorton	3	44	6	2	3	7	0	5	0	42	9
Baylor	13	39	1	7	Trace	Trace	Trace	2	Trace	47	1
Knox	9	33	4	11	Trace	0	0	2	1	50	1
Stonewall	4	31	4	Trace	1	0	0	0	0	65	1

Figure 6.—Dense Saltcedar Adjacent to the River Channel. Complete Dominance and Closed Cover Are Exhibited by the Pure Stand.

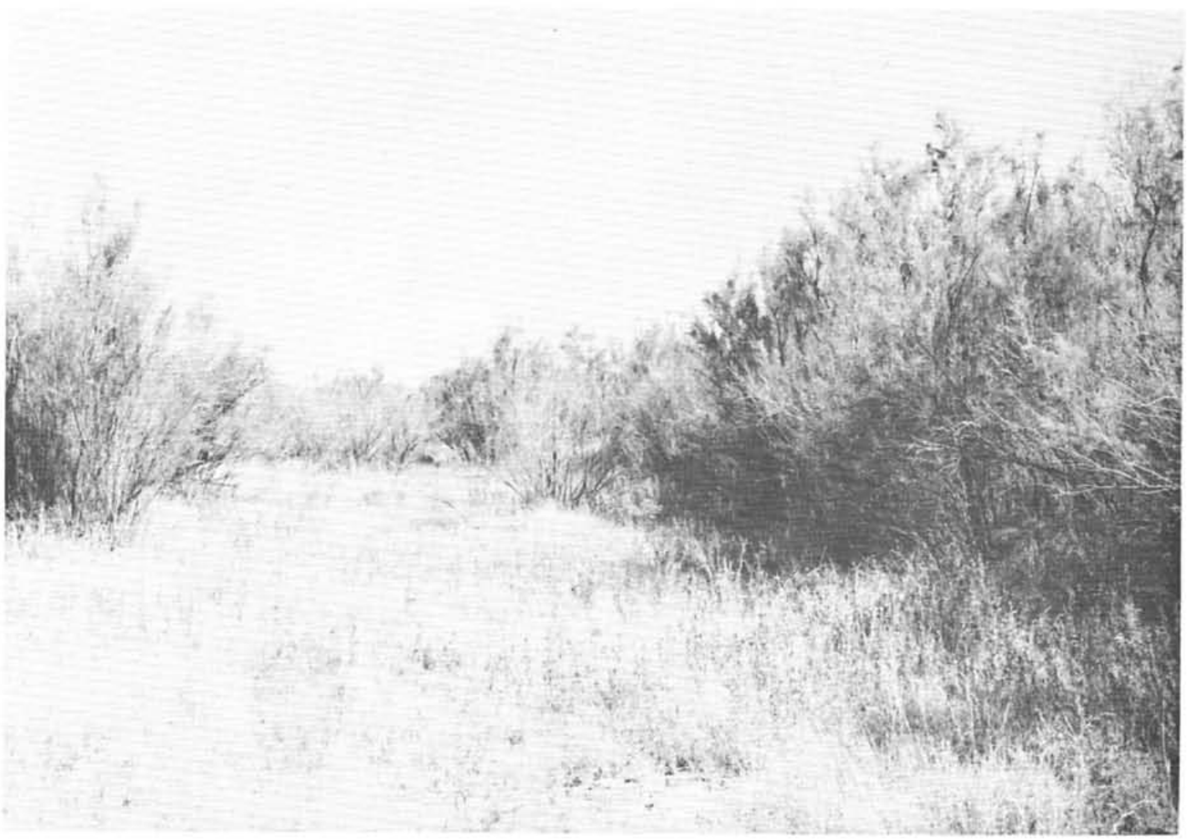


Figure 7.—Dense Saltcedar 600 Feet From the River Channel. Notice the Complete Dominance of Saltcedar.

Figure 8.—Saltcedar-Baccharis Community in an Open Stand. Saltcedar Crown Cover in This Community is Usually Less Than 25 Percent, Which Probably Allows Invasion of Baccharis.

plain in Stonewall County and a narrow flood plain and a high water table in Young County possibly explain the low percentage of mesquite occurrence in these areas (Figure 4). Water backed up by Possum Kingdom Lake and the high water table associated with it prevented mesquite from growing on the flood plain in southeast Young County. Mesquite was not found growing on the flood plain from the lake upstream to the mouth of the Clear Fork Brazos River (See Appendix D).

Mesquite communities were intersected by 7,277 feet of transect line. Of this, 2,000 feet was mesquite canopy and 320 feet was associated species. (See Appendix F for typical mesquite community composition.) The remainder of the transects did not intersect woody plant cover. Mesquite crown cover averaged 27 percent. The average plant height was 16.4 feet, and the average foliage depth was 9.7 feet. All counties had some areas with a vertical density of 100 percent. Therefore, the volume density for the survey was 27 percent, and the acreage equivalent at 100 percent volume density was 2,181 acres.

Cottonwood

Cottonwood communities occur at random locations on the flood plain. Cottonwoods did occur singly, but more commonly were mixed with mesquite on the outer flood plain or with saltcedar on the inner flood plain (Figure 11). The percentage of cottonwood increased from Stonewall to Young County. This increase probably is related to more favorable moisture conditions (Table 1).

Mixed Community

A mixed community (Figure 12), varying in species composition but usually consisting of elm, hackberry, willow, cottonwood, and saltcedar, occurred at many points within the study area (Figure 4). This mixture was usually located at narrow points in the flood plain and was positioned behind (progressing outward from the river channel) a saltcedar stand. Much overlapping of vegetative cover occurred within this association. A high percentage of the flood plain in southeast Young County was dominated by this mixture.

Acreage Changes in Species and Land Use, 1940 to 1969

Inspection of the aerial photographs used as field sheets indicated that saltcedar and mesquite occurred in

Figure 9.—Saltcedar and Mesquite Growing in Adjacent Areas and Forming an Ecotone Between the Two Communities. Dense Saltcedar Stand is in Left Background, Dense Mesquite Stand in Right Background.

the study area prior to 1940. Saltcedar acreage in 1940 was high (Table 5), but the plants were scattered and crown cover was low. Apparently a flood prior to 1940 deposited saltcedar seed and vegetative material along the edges of the mesquite stands, because in 1940 dense stands of saltcedar occurred in this area of the floodplain. Saltcedar spread from this original location to cover 4,746 acres by 1940. Not including Baylor County, an increase of 2,145 acres occurred between 1940 and 1950. Much of this saltcedar increase was on the sand bars and in the river channel.

A slower acreage increase occurred between 1950 and 1969. Saltcedar increased only 346 acres during this period, but crown cover increased on the areas previously occupied by saltcedar. By 1969, crown cover approached 100 percent in most saltcedar stands.

The rate of mesquite increase was less than the rate of saltcedar increase. There was an increase in mesquite of only 760 acres from 1940 to 1969. This increase was primarily in open grasslands or abandoned fields.

Mesquite was apparently an established and stable community when saltcedar invaded the study area. A small acreage increase since 1940 indicates that mesquite had previously covered most of the area to which it was adapted. Saltcedar was well adapted to the areas that mesquite could not invade, and once it was introduced, it spread rapidly and increased in density.

Trends of Saltcedar and Mesquite Spread

Determination of the distance from a common point in the river channel to the first occurrence of light saltcedar, dense saltcedar, and mesquite revealed that all three groups have spread toward the river channel since 1940. The greatest change occurred in the saltcedar densities (Table 6).

Light saltcedar (small groups of scattered plants) were positioned an average of 306 feet away from the river channel in 1940. Sand bars separated these scattered clumps from the channel. By 1950, the average distance to light saltcedar occurrence had shrunk to 62 feet. Current photographs and field study indicated that light saltcedar stands presently occur directly adjacent to the river channel. The invasion trend was the same for dense saltcedar (extensive clumps with 100 percent crown cover). This group was positioned 364 feet from

Figure 10.—Mesquite Community Adjacent to a Cultivated Field. A Dense and Vigorous Growth is Typical of Mesquite Communities on the Flood Plain.

Table 4.—Saltcedar Acreage Equivalent for 100 Percent Volume Density, 1969

COUNTY	CROWN COVER (PERCENT)	X	VERTICAL DENSITY (PERCENT)	X	ACREAGE	=	ACREAGE EQUIVALENT FOR 100 PERCENT VOLUME DENSITY
Stonewall	35		93		1,057		348
Knox	44		100		4,008		1,764
Baylor	44		100		3,056		1,345
Throckmorton	47		100		1,487		699
Young	54		100		3,608		1,948
Total	46		100		13,216		6,104

the channel in 1940, 178 feet in 1950, and 44 feet in 1969. The original stand became established adjacent to the mesquite community and spread inward toward the river channel.

The position of mesquite on the flood plain remained relatively stable, although it did migrate toward the channel. Mesquite stands averaged 48 feet closer to the river channel in 1969 than in 1940.

Comparisons of Soil Series and Plant Community Occurrence

Current soil survey information was limited to Stonewall and Baylor Counties. The Lincoln and Yahola soils occur most frequently. Saltcedar dominates on areas of Lincoln soil and mesquite dominates on the Yahola soil.

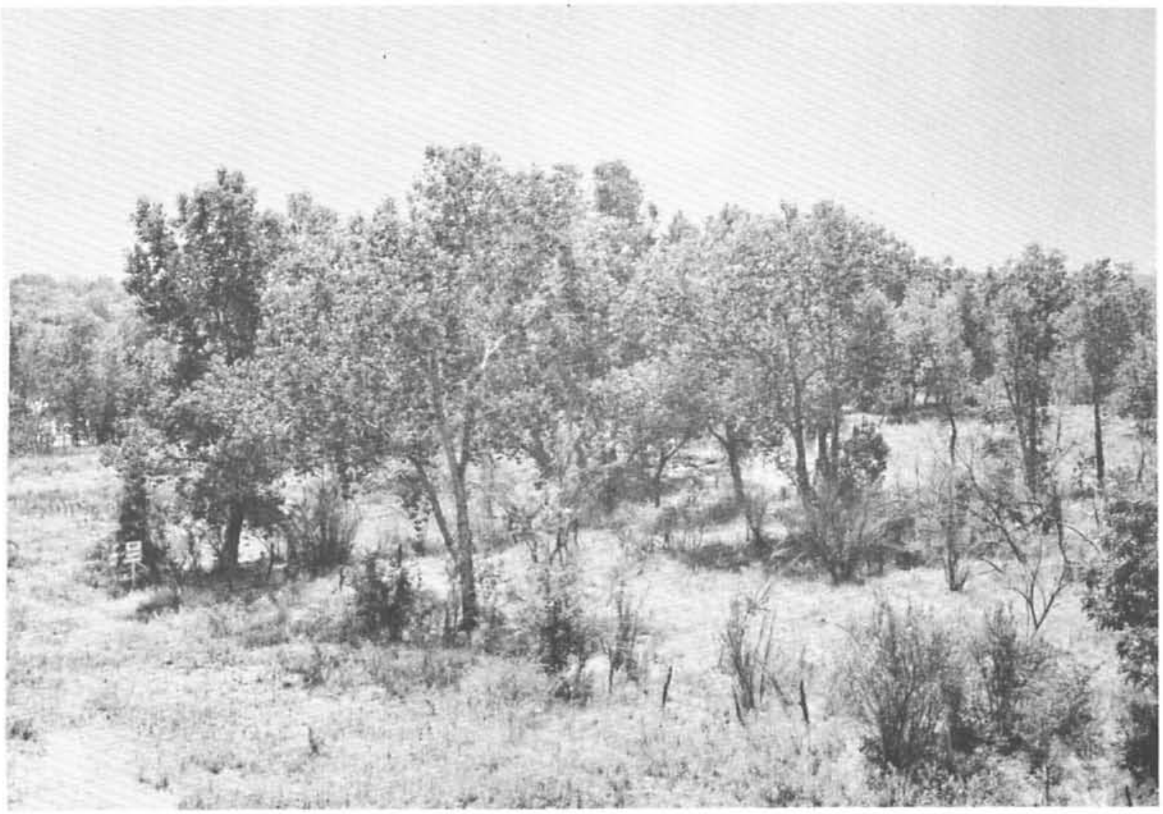


Figure 11.—Cottonwood Community Near the River Channel With a Saltcedar Understory. This Community Often Forms a Dense Stand That is Parallel to the River Channel.

Table 5.—Acreage Comparisons in Species and Land Use, 1940, 1950, and 1969

		AREAS FREE OF WOODY VEGETATION					
COUNTY	YEAR	SAND BAR	GRASSLAND	CULTIVATED	RIVER CHANNEL	SALTCEDAR	MESQUITE
Stonewall	1940	228	41	18	502	641	380
	1950	149	32	18	494	755	388
	1969	0	0	237	519	746	387
Knox	1940	829	156	3,906	2,296	1,886	2,828
	1950	122	90	4,120	1,560	2,933	3,128
	1969	0	0	3,568	1,498	3,165	3,234
Baylor	1940	–	–	–	–	–	–
	1950	0	221	533	1,243	2,328	1,317
	1969	0	0	1,634	1,265	2,325	1,379
Throckmorton	1940	228	492	518	684	1,074	417
	1950	4	212	540	442	1,683	528
	1969	0	0	399	424	1,718	655
Young	1940	868	73	658	1,598	1,145	727
	1950	277	38	716	1,310	1,520	828
	1969	0	0	1,682	1,367	1,608	836
Total (less Baylor County)	1940	2,154	762	5,100	5,080	4,746	4,352
	1950	552	372	5,394	3,806	6,891	4,872
	1969	0	0	5,886	3,808	7,237	5,112

In Stonewall County, Lincoln soils occurred in 21 areas and saltcedar was present on all 21 of these. Mesquite did not occur on Lincoln soil, but did occur on 13 or 14 sites with Yahola soil. Saltcedar dominated the remaining Yahola soil areas. Of the 78 areas of Lincoln soil in Baylor County, saltcedar was present on 72 and

Figure 12.—Mixed Community. Stands of Saltcedar and Willow Are Adjacent to the River Channel, Hackberry and Elm in the Next Layer, and Cottonwood in the Background. The Large Amount of Vegetative Overlap is Common to a Mixed Community.

Table 6.—Trend of Saltcedar and Mesquite Spread (Distances are Feet From a Common Point in the River Channel to the First Occurrence of the Plant Community; Averages are Shown for Each County)

COUNTY AND PLANT TYPE	1940 PHOTOGRAPHS	1950 PHOTOGRAPHS	1969[1]
Stonewall			
Light saltcedar	277	20	0
Dense saltcedar	485	282	11
Mesquite	907	906	899
Knox			
Light saltcedar	464	130	0
Dense saltcedar	344	175	32
Mesquite	778	757	766
Baylor			
Light saltcedar	–	74	0
Dense saltcedar	–	171	25
Mesquite	–	542	533
Throckmorton			
Light saltcedar	281	57	0
Dense saltcedar	381	134	21
Mesquite	661	662	658
Young			
Light saltcedar	204	29	0
Dense saltcedar	247	127	130
Mesquite	612	618	602
Average			
Light saltcedar	306	62	0
Dense saltcedar	364	178	44
Mesquite	739	697	691

1/ Saltcedar and mesquite occurrence as of 1969 was delineated on aerial photographs dated 1963, 1967 and 1968.

mesquite on 6. Yahola occurred in 87 areas, of which 61 were dominated by mesquite, 13 by saltcedar, and 13 were in cultivation.

Lincoln soil occurs adjacent to the river channel and is typically a coarse-textured, recent alluvium. The subsurface material is not differentiated into horizons and is usually a deep deposit of fine sand. The permeability of the Lincoln soil is rapid and the water-holding capacity is low. However, the subsoil is usually wet because of the shallow water table. The Lincoln soil is low in plant nutrients, frequently flooded, and not generally considered suitable for cultivation.

The Yahola soil is much older alluvium than is the Lincoln soil. Yahola soil occurs on the outer portion of the flood plain and is subject to periodic flooding. This soil has a fine sandy loam surface texture. The surface horizon is thin, but is underlain by deep, stratified layers of fine sandy loam, light loam, and silty clay loam. The permeability of the Yahola soil is moderately rapid, and the water-holding capacity is low. The primary differences between the Lincoln and Yahola soils are their flood-plain location and their subsurface horizon stratification.

The difference in where mesquite and saltcedar occur on these two soils can be attributed largely to location on the flood plain with reference to the river channel. This conclusion is supported by the fact that saltcedar always occurred on the inner portion of the flood plain, usually adjacent to and extending various distances from the river channel. Mesquite occurred on the outer portion of the flood plain, never near the river channel. Flood-plain location and associated features of water-table depth and soil aeration appear to be the controlling factors. Apparently mesquite generally is not able to tolerate the moisture and poor aeration conditions immediately adjacent to the river channel while saltcedar can.

SUMMARY AND CONCLUSIONS

The objectives of this study were to determine the kinds, amounts, distribution, and spread of the woody phreatophyte vegetation along the Brazos River upstream from Possum Kingdom Lake to the confluence of the Salt and Double Mountain Forks.

Four major plant communities were identified in the field and delineated on aerial photographs. The most widely distributed community was saltcedar. This plant occurred in pure stands or in combination with baccharis or mesquite. It formed an almost continuous stand adjacent to the river channel. The most extensive occurrences of saltcedar were where the flood plain was flat and the channel was straight. The mesquite community occurred on the outer portion of the flood plain. Extensive areas of mesquite were found where the flood plain was wide and the community would not be subjected to frequent flooding. Mesquite did not occur in southeast Young County where water was backed up by Possum Kingdom Lake. The cottonwood community was distributed throughout the study area, but occurred most extensively in Young County. Cottonwoods grow on the outer portion of the flood plain in combination with mesquite, and near the river channel in association with saltcedar. A mixed community, consisting of varying amounts of hackberry, elm, cottonwood, willow, pecan, baccharis, and saltcedar, occurred extensively in Young County. Lesser amounts of this community occurred in other areas where moisture was favorable.

Aerial photograph interpretations revealed a total of 30,489 acres or 63 percent of the flood-plain area covered by these plant communities. Saltcedar dominated 17,199 acres, mesquite 8,079 acres, cottonwood 1,981 acres, and the mixed community occurred on 3,230 acres.

A comparison of 1940 and 1950 aerial photographs and cover existing in 1969 indicated that the acreage dominated by saltcedar and mesquite has increased. Saltcedar increased 2,491 acres and mesquite 760 acres. The aerial photographs revealed that saltcedar originally occurred in an area adjacent to the mesquite community. Apparently a flood deposited saltcedar seed and vegetative material along the mesquite community prior to 1940 and the plant has since spread toward the river channel. Small scattered clumps quickly spread over a large acreage after the plant was introduced into the area. After establishment, crown cover increased. The small acreage increase of mesquite and its stable position on the flood plain indicate that it had spread to its near-maximum acreage prior to the saltcedar spread.

Line transects extending across the flood plain substantiated the community delineations and flood-plain locations as determined from the aerial photographs. In addition, data to calculate volume density of the saltcedar and mesquite communities were collected. The transects revealed that saltcedar community crown cover averaged 46 percent and that vertical density was 100 percent. The amount of saltcedar in the study area is equivalent to 6,104 acres at 100 percent volume density. For the mesquite community, crown cover averaged 27 percent and vertical density was 100 percent. Mesquite growth is equivalent to 2,181 acres at 100 percent volume density.

No research has been conducted on the water use of phreatophytes in Texas, but Gatewood and others (1950), working in Arizona, reported that saltcedar and mesquite (growing at 100 percent volume density) respectively used 7.2 and 3.3 acre-feet of water per acre annually. Class A pan and lake evaporation in the Safford area of Arizona and the Brazos River study area above Possum Kingdom Lake are similar (Kohler and others, 1959). Assuming that the climatic conditions affecting evaporation also affect transpiration (Penman, 1963), water use by plants in the study area should be comparable with that in Arizona. Therefore, saltcedar in the flood plain of the Brazos River covered by this study should use about 44,000 acre-feet of water annually. Similarly, mesquite in this area should use about 7,200 acre-feet of water annually.

Besides consuming large quantities of water that would otherwise be available for other uses, these plants on the flood plain compete with valuable grazing plants, for water, nutrients, space, and sunlight, and are generally successful in this competition. Further study is needed on the impact these plants have on the area's economy and water supply and the feasibility of control. Any control program, however, must consider the effects that a change in vegetation would have on the wildlife and the esthetic values in the area as well as the effects on the water regime.

LITERATURE CITED

Cronin, J. R., Follett, C. R., Shafer, G. H., and Rettman, P. L., 1963, Reconnaissance investigation of the ground-water resources of the Brazos River basin, Texas: Texas Water Comm. Bull. 6310, 152 p.

Dallas Morning News, 1969, Texas almanac and state industrial guide, 1970-1971: A. H. Belo Corp., Dallas, Texas, 704 p.

Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, J. D., and Halpenny, L. C., 1950, Use of water by bottom-land vegetation in lower Safford Valley, Arizona: U.S. Geol. Survey Water-Supply Paper 1103, 210 p.

Gillette, Jean, 1968, Brush—the water thief: San Angelo Standard-Times, San Angelo, Texas, p. 10.

Horton, J. S., Robinson, T. W., and McDonald, H. R., 1964, Guide for surveying phreatophyte vegetation: U.S. Dept. Agr. Handbook 266, 37 p.

Kane, J. W., 1967, Monthly reservoir evaporation rates for Texas, 1940 through 1965: Texas Water Devel. Board Rept. 64, 111 p.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps for the United States: U.S. Weather Bureau Tech. Paper 37, 18 p.

Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Morris, D. E., 1964, Occurrence and quality of ground water in Young County, Texas: Texas Water Commission Bull. 6415, 83 p.

Ogilbee, William, and Osborne, F. L., Jr., 1962, Ground-water resources of Haskell and Knox Counties, Texas: Texas Water Commission Bull. 6209, 182 p.

Penman, H. L., 1963, Vegetation and hydrology: Commonwealth Bureau of Soils, Tech. Commun. 53, Farnham Royal, Bucks, England, 124 p.

Rechenthin, C. A., and Smith, H. N., 1967, Grassland restoration, Part V, Effects on water yield and supply: U.S. Soil Conservation Service, Temple, Texas, 46 p.

Robinson, T. W., 1958, Phreatophytes: U.S. Geol. Survey Water-Supply Paper 1423, 84 p.

Texas Agricultural Extension Service, 1968, Rolling Plains economic program report: Texas A&M Univ., 196 p.

U.S. Department of Interior, 1959, Report on phreatophytes, for Senate Select Committee on Natural Water Resources: Washington, U.S. Govt. Printing Office, 5 p.

APPENDICES

Appendix A
Common and Scientific Names of Plants Referred to in the Report

Saltcedar	*Tamarix gallica* L.
Mesquite	*Prosopis glandulosa* var. *glandulosa* Torr.
Baccharis	*Baccharis salicina* T. & G.
Cottonwood	*Populus deltoides* Marsh.
Hackberry	*Celtis reticulata* Torr.
Elm	*Ulmus americana* L.
Willow	*Salix nigra* Marsh.
Pecan	*Carya illinoensis* (Wang) K. Kock
Live Oak	*Quercus virginiana* Mill.
Lotebush	*Condalia obtusifolia* (Hook.) Weberb.
Tasajillo	*Opuntia leptocaulis* DC.

Appendix B
List of Aerial Photographs Used in the Survey

The key to the survey position designation follows:

S—Stonewall County	NE—Northeast Quarter
K—Knox County	NW—Northwest Quarter
B—Baylor County	SE—Southeast Quarter
T—Throckmorton County	SW—Southwest Quarter
Y—Young County	

The list below is in downstream order. In each survey position designation, the first number refers to the location of the photograph within the county, and the second locates the photograph within the survey area. Thus, S-NE-1-1 is the first photograph in the county, the first in the survey, and is located in northeast Stonewall County.

PHOTOGRAPH SURVEY POSITION NUMBER	DATE OF FLIGHT	PHOTOGRAPH FLIGHT NUMBER
S-NE-1-1	December 3, 1963	CON-3EE-191
S-NE-2-2	do.	CON-3EE-190
S-NE-4-4	do.	CON-3EE-188
S-NE-6-6	do.	CON-3EE-244
S-NE-8-8	do.	CON-3EE-242
S-NE-10-10	do.	CON-3EE-183
K-SW-3-16	November 15, 1967	CGV-1JJ-13
K-SW-4-17	do.	CGV-1JJ-75
K-SW-8-21	November 17, 1967	CGV-2JJ-62
K-SW-11-24	do.	CGV-2JJ-7
K-SW-12-25	do.	CGV-2JJ-8
K-SW-14-28	do.	CGV-2JJ-107
K-SW-16-30	January 25, 1968	CGV-1JJ-277
K-SW-17-31	November 17, 1967	CGV-2JJ-172
K-SE-19-33	November 18, 1967	CGV-2JJ-191
K-SE-24-38	do.	CGV-2JJ-237
K-SE-26-40	do.	CGV-2JJ-261
K-SE-27-40	do.	CGV-1JJ-107
K-SE-31-45	do.	CGV-1JJ-133
K-SE-36-50	do.	CGV-1JJ-166
K-SE-37-51	do.	CGV-1JJ-193
K-SE-41-55	do.	CGV-1JJ-226
B-SW-1-56	October 15, 1963	CUM-1DD-15
B-SW-3-58	do.	CUM-1DD-52
B-SW-5-60	do.	CUM-1DD-54
B-SW-7-62	do.	CUM-1DD-81
B-SW-8-63	do.	CUM-1DD-119
B-SW-10-65	do.	CUM-1DD-147
B-SW-12-67	do.	CUM-1DD-185
B-SW-13-68	do.	CUM-2DD-13
B-SW-18-73	do.	CUM-2DD-11
B-SW-20-75	do.	CUM-2DD-9
B-SW-22-77	do.	CUM-2DD-7
B-SE-24-79	do.	CUM-2DD-60
B-SE-27-82	do.	CUM-2DD-72
B-SE-28-83	do.	CUM-3DD-125
B-SE-30-85	do.	CUM-2DD-136
B-SE-31-86	October 16, 1963	CUM-3DD-104
B-SE-36-91	do.	CUM-3DD-102
T-NE-1-94	February 24, 1963	CUV-1DD-151
T-NE-6-99	do.	CUV-1DD-157
T-NE-9-102	do.	CUV-1DD-215
T-NE-10-103	do.	CUV-1DD-225
T-NE-14-107	do.	DUV-1DD-228
Y-NW-1-117	November 30, 1967	CUW-1JJ-24
Y-NW-4-120	do.	CUW-1JJ-46
Y-NW-6-122	do.	CUW-1JJ-80
Y-NW-11-127	do.	CUW-1JJ-121
Y-NW-12-128	do.	CUW-1JJ-161
Y-NW-15-131	do.	CUW-1JJ-192
Y-NW-17-133	do.	CUW-1JJ-226
Y-SW-19-135	do.	CUW-1JJ-195
Y-SW-21-137	do.	CUW-1JJ-223
Y-SW-22-138	do.	CUW-1JJ-265
Y-SW-27-143	do.	CUW-1JJ-220
Y-SW-29-145	do.	CUW-1JJ-218
Y-SW-33-149	do.	CUW-1JJ-271
Y-SE-35-151	January 25, 1968	CUW-2JJ-194
Y-SE-38-154	February 7, 1968	CUW-3JJ-33
Y-SE-40-156	do.	CUW-3JJ-31
Y-SE-41-157	do.	CUW-3JJ-30
Y-SE-43-159	January 25, 1968	CUW-2JJ-29
Y-SE-45-161	do.	CUW-2JJ-27
Y-SE-46-162	do.	CUW-2JJ-26
Y-SE-47-163	do.	CUW-2JJ-41
Y-SE-49-165	do.	CUW-2JJ-39
Y-SE-53-169	do.	CUW-2JJ-96
Y-SE-54-170	February 29, 1968	CUW-3JJ-112

Appendix C
Location and Description of Transect Lines

Transects across the Brazos River flood plain listed below are generally in upstream order. For the exact location of each transect, refer to the field maps (Supplement 1) on file at the Texas Water Development Board's office, Austin, Texas.

Transect 1. Photograph Y-SE-54-170. Approximately 200 yds west of downstream limit of study. Backup water from Possum Kingdom Lake fills river channel. Saltcedar plants small; evidence of flooding. *Starting point*: Base of telephone pole below cliff. *Direction*: S. 5° W. *Ending point*: No permanent marker.

Transect 2. Photograph Y-SE-47-163. Near bridge on farm road 1287; 125 yds southeast of bridge. *Starting point*: No permanent marker. *Direction*: S. 30° W. (approximately parallel to bridge). *Ending point*: Directly below barn on edge of cliff.

Transect 3. Photograph Y-SE-47-163. Near bridge on farm road 1287; 200 yds northwest of bridge. *Starting point*: 100 ft west and north along fence line; begin at fence. *Direction*: S. 20° W. *Ending point*: No permanent marker.

Transect 4. Photograph Y-SE-38-154. Flood plain only on one side of the channel. Transect taken from river edge into flood plain. Backup water from Possum Kingdom Lake fills channel. *Starting point*: No permanent marker. *Direction*: Due east. *Ending point*: Base of oil-well pump in cultivated field.

Transect 5. Photograph Y-SE-38-154. Near bridge on Texas Highway 67; 250 yds southeast of bridge. *Starting point*: Juncture of oil pipeline and edge of cultivated field. *Direction*: E. 35° N. *Ending point*: West edge of river bank directly across from an old concrete bridge support.

Transect 6. Photograph Y-SE-35-151. Approximately one mile northeast of the mouth of the Clear Fork Brazos River. *Starting point*: Intersection of oil pipeline and cultivated field. *Direction*: S. 20° W. *Ending point*: No permanent marker.

Transect 7. Photograph Y-SW-27-143. Near bridge on farm road 209. *Starting point*: Edge of field 125 yds north of bridge. *Direction*: W. 30° S. *Ending point*: No permanent marker.

Transect 8. Photograph Y-SW-22-138. *Starting point*: Intersection of cultivated field and telephone line; start from base of telephone pole. *Direction*: S. 30° W. *Ending point*: No permanent marker.

Transect 9. Photograph Y-SW-19-135. *Starting point*: 100 yds north of corner post; start from fence. *Direction*: Due west. *Ending point*: No permanent marker.

Transect 10. Photograph Y-NW-17-133. Near bridge on Texas Highway 24. *Starting point*: Large boulder at base of cliff. *Direction*: W. 10° N. *Ending point*: No permanent marker.

Transect 11. Photograph Y-NW-12-128. Extensive and wide flood plain. *Starting point*: Base of most southerly extension of cliff. *Direction*: S. 5° W. *Ending point*: No permanent marker.

Transect 12. Photograph Y-NW-1-117. Near bridge on Texas Highway 79. *Starting point*: River bed, no permanent marker. *Direction*: Due east. *Ending point*: Corner post of fence.

Transect 13. Photograph Y-NW-1-117. *Starting point*: Bend of dirt road. *Direction*: E. 30° N. *Ending point*: Base of high peak.

Transect 14. Photograph Y-NW-11-127. One mile south of farm road 926. *Starting point*: 30 yds east of fence line dividing fields; start at fence. *Direction*: S. 5° W. *Ending point*: No permanent marker.

Transect 15. Photograph T-NE-14-107. *Starting point*: Base of cliff outcrop. *Direction*: W. 15° N. *Ending point*: No permanent marker.

Transect 16. Photograph T-NE-10-103. *Starting point*: Edge of river bank, no permanent marker. *Direction*: W. 5° N. *Ending point*: 40 yds north of corner of field.

Transect 17. Photograph T-NE-10-103. *Starting point*: Corner of cultivated field. *Direction*: Due east. *Ending point*: Edge of river channel, no permanent marker.

Transect 18. Photograph B-SE-31-86. Near Springtown, Texas. *Starting point*: Edge of river bed, no permanent marker. *Direction*: Due east. *Ending point*: 40 yds north of corner of cultivated field.

Transect 19. Photograph B-SE-24-79. *Starting point*: Triangular corner of cultivated field. *Direction*: S. 15° E. *Ending point*: No permanent marker.

Transect 20. Photograph B-SW-20-75. *Starting point*: Edge of river channel, no permanent marker. *Direction*: Due south. *Ending point*: Corner post on west end of field.

Transect 21. Photograph B-SW-20-75. One-half mile east of U.S. Highway 283. *Starting point*: River bed, no permanent marker. *Direction*: Due west. *Ending point*: Corner post of fence on boundary of flood plain.

Transect 22. Photograph B-SW-18-73. One-quarter mile east of U.S. Highway 283. *Starting point*: 75 yds south of corner post of fence; start at fence. *Direction*: N. 40° E. *Ending point*: Barn at old farmstead.

Transect 23. Photograph B-SW-12-67. 80 yds north of bridge at Seymour, Texas. *Starting point*: Boulders below cliff. *Direction*: Due west. *Ending point*: 200 ft north of edge of field.

Transect 24. Photograph B-SW-12-67. One-quarter mile north of bridge on U.S. Highway 277. *Starting point*: Corner post of fence adjacent to dirt road. *Direction*: Due east. *Ending point*: No permanent marker.

Transect 25. Photograph B-SW-12-67. *Starting point*: Corner post in fence at base of cliff. *Direction*: Due north. *Ending point*: No permanent marker.

Transect 26. Photograph B-SW-10-65. River uncrossable. *Starting point*: Edge of river channel, no permanent marker. *Direction*: Due south. *Ending point*: Corner post of fence at edge of flood plain.

Transect 27. Photograph B-SW-8-63. *Starting point*: Corner post of fence around cultivated field. *Direction*: S. 5° E. *Ending point*: Cattle holding pens.

Transect 28. Photograph B-SW-7-62. *Starting point*: No permanent marker. *Direction*: N. 10° E. *Ending point*: At base of road ending at river channel.

Transect 29. Photograph B-SW-5-60. Vegetation only on one side of the channel. *Starting point*: North side of channel directly across from high peak. *Direction*: N. 20° W. *Ending point*: Corner post in cultivated field.

Transect 30. Photograph B-SW-3-58. *Starting point*: River channel, no permanent marker. *Direction*: W. 40° S. *Ending point*: Corner post of fence.

Transect 31. Photograph K-SE-37-51. Near bridge on farm road 266. *Starting point*: River channel, no permanent marker. *Direction*: N. 10° E. *Ending point*: Triangular corner of cultivated field.

Transect 32. Photograph K-SE-36-50. *Starting point*: 50 yds east of corner post of fence; start from fence. *Direction*: N. 10° E. *Ending point*: River channel, no permanent marker.

Transect 33. Photograph K-SE-26-40. Near bridge along Texas Highway 267. *Starting point*: Fence at boundary of flood plain; start at corner post. *Direction*: N. 20° W. *Ending point*: Edge of mesquite stand; mesquite have been sprayed.

Transect 34. Photograph K-SE-26-40. Near bridge along Texas Highway 267. *Starting point*: Base of large cottonwood tree; tree is at edge of cultivated field. *Direction*: S. 15° E. *Ending point*: Triangular corner of fence.

Transect 35. Photograph K-SW-16-30. Near bridge along Texas Highway 283. *Starting point*: Large mound of dirt, 50 ft west of railroad tracks. *Direction*: S. 10° W. *Ending point*: Corner post of fence around cultivated field.

Transect 36. Photograph K-SW-16-30. Near bridge along Texas Highway 283. *Starting point*: Junk pile on edge of flood plain. *Direction*: N. 10° E. *Ending point*: No permanent marker.

Transect 37. Photograph K-SW-8-21. Near bridge along farm road 143. *Starting point*: River channel, no permanent marker. *Direction*: W. 35° N. *Ending point*: Telephone post at edge of cultivated field.

Transect 38. Photograph K-SW-8-21. Near bridge along farm road 143. *Starting point*: Corner of field, at edge of vegetation. *Direction*: E. 35° S. *Ending point*: River bed, no permanent marker.

Transect 39. Photograph K-SW-3-16. *Starting point*: River channel, directly across from extension of bluff. *Direction*: N. 40° W. *Ending point*: Base of large cottonwood tree.

Transect 40. Photograph S-NE-10-10. *Starting point*: River channel, directly across from road entering channel. *Direction*: W. 5° S. *Ending point*: Oil-field road.

Transect 41. Photograph S-NE-6-6. *Starting point*: At entrance of creek into flood plain. *Direction*: Due west. *Ending point*: Oil-well pump.

Transect 42. Photograph S-NE-6-6. *Starting point*: River edge, directly across river from creek entrance into flood plain. *Direction*: E. 20° S. *Ending point*: 50 yds south of corner post of fence.

Transect 43. Photograph S-NE-2-2. *Starting point*: 35 yds north of fence corner of field; begin from fence. *Direction*: E. 5° S. *Ending point*: North corner post of fence at end of lane.

Appendix D
Crown Cover Intercepted by Each Transect

COUNTY	TRANSECT NUMBER	INTERCEPT AS A PERCENTAGE OF TRANSECT LENGTH									
		SALT-CEDAR	BACCHARIS	MESQUITE	COTTON-WOOD	WILLOW	ELM	HACK-BERRY	OTHER	NO WOODY COVER	VEGETATIVE OVERLAP
Young	1	38	22	–	–	13	5	–	–	27	5
	2	13	–	–	11	29	14	1	6	32	6
	3	28	5	–	2	13	18	2	7	28	3
	4	15	4	–	21	3	44	2	6	18	13
	5	22	1	25	4	1	–	7	–	41	1
	6	27	–	16	3	1	1	3	25	24	–
	7	36	13	31	–	–	4	1	–	29	14
	8	69	2	11	–	–	–	–	–	18	–
	9	16	1	2	7	9	–	–	–	68	3
	10	63	19	–	4	16	–	12	–	9	13
	11	11	17	16	1	–	1	3	3	50	2
	12	50	1	13	–	–	–	–	–	36	–
	13	17	2	3	1	2	–	1	1	74	26
	14	32	3	1	9	–	–	–	–	57	2
Throckmorton	15	52	16	–	–	–	–	2	–	36	6
	16	53	–	3	7	15	–	10	–	30	18
	17	27	3	3	3	4	–	2	–	61	3
Baylor	18	9	2	14	–	–	–	3	–	75	3
	19	34	–	19	–	–	1	11	–	33	2
	20	85	–	–	–	–	–	–	–	15	–
	21	22	–	9	–	–	–	3	–	67	1
	22	21	–	10	–	–	1	8	6	54	–
	23	29	4	30	4	–	–	12	–	24	3
	24	39	–	–	–	–	–	–	–	61	–
	25	94	–	–	–	–	–	–	–	6	–
	26	24	2	1	–	–	–	–	–	73	–
	27	25	2	4	–	3	–	–	–	66	–
	28	36	1	6	–	–	–	3	–	54	–
	29	22	1	22	–	–	–	1	–	55	1
	30	68	–	–	–	–	–	–	–	32	–
Knox	31	9	–	24	–	–	–	10	6	53	2
	32	35	17	–	–	–	–	–	–	47	2
	33	31	–	16	–	–	–	–	–	53	–
	34	10	4	13	2	–	–	–	–	71	–
	35	33	5	13	–	–	–	5	–	44	–
	36	45	–	31	–	–	–	–	–	24	–
	37	54	1	–	–	–	–	–	–	46	1
	38	64	4	–	–	–	–	–	–	33	1
	39	17	6	–	2	–	–	–	–	75	–
Stonewall	40	37	1	–	–	–	–	–	–	62	–
	41	30	13	–	3	–	–	–	–	55	1
	42	34	–	1	–	–	–	–	–	65	–
	43	24	–	–	–	–	–	–	–	76	–

Appendix E
Average Composition of Saltcedar Community

These data summarize 46 saltcedar community transects.

	FEET OF INTERCEPT	PERCENT COMPOSITION
Total length of saltcedar community transects	24,179	–
No woody plant cover	12,156	50
Woody plant cover	12,396	52*
Saltcedar	10,981	46
Baccharis	798	3
Cottonwood	171	1
Hackberry	146	1
Mesquite	125	1
Willow	108	Trace
Elm	67	Trace

* 2 percent vegetative overlap involving saltcedar and baccharis.

Appendix F
Average Composition of Mesquite Community

These data summarize 18 mesquite community transects.

	FEET OF INTERCEPT	PERCENT COMPOSITION
Total length of mesquite community transects	7,277	–
No woody plant cover	5,024	69
Woody plant cover	2,320	32†
Mesquite	2,000	27
Hackberry	97	1
Cottonwood	72	1
Baccharis	69	1
Pecan	62	1
Saltcedar	19	Trace

† 1 percent vegetative overlap involving mesquite and cottonwood.

PART II

SALT AND DOUBLE MOUNTAIN FORKS FROM THEIR CONFLUENCE TO THE HEADWATERS

ABSTRACT

The purpose of this study was to inventory the woody phreatophyte vegetation along the Salt and Double Mountain Forks Brazos River from their confluence to their headwaters. The kinds, amounts, distribution, and volume densities of the phreatophytes were determined along with their relation to flood-plain location.

Saltcedar is the most widely distributed phreatophyte in the study area. It dominates 36 percent of the flood-plain area. Most stands of saltcedar on the upper tributaries are relatively young, with scattered clumps of old trees. Along the main streams, saltcedar forms dense stands adjacent to the river channel. Total saltcedar growth is equivalent to approximately 4,368 acres at 100 percent volume density. Water use by saltcedar in the study area is approximately 31,450 acre-feet annually.

Mesquite dominates 22 percent of the flood-plain area. It usually occurs on the outer portions of the flood plain. Mesquite was observed growing near the river channel along the upper tributaries where flooding rarely occurred. The most extensive stands of mesquite occur on wide portions of the flood plain. Mesquite growth is equivalent to 3,034 acres at 100 percent volume density. Water use by mesquite is approximately 10,000 acre-feet annually.

Cottonwood and sand sagebush dominate only small portions of the study area. Cottonwood occurs throughout the study area where it is protected from flooding. Sand sagebrush dominates sandy, dry areas along the upper tributaries. It is not considered to be a phreatophyte.

Sixty-four percent of the flood-plain area studied is occupied by woody phreatophyte vegetation. Because these species diminish the available water resource and are not normally considered economically beneficial, these extensive areas of phreatophyte vegetation deserve further attention to determine proper land use.

PART II

SALT AND DOUBLE MOUNTAIN FORKS FROM THEIR CONFLUENCE TO THE HEADWATERS

INTRODUCTION

Water is a valuable and scarce resource in western Texas. The Texas Water Development Board (1968) predicted that by the year 2020, much of Texas will not be able to maintain the productivity or growth already achieved if additional water sources are not developed. However, new water sources might also be inadequate unless proper care is taken to prevent waste of our present supplies. Babcock (1968) estimated that 25 million acre-feet of water was lost annually to brush species growing on the flood plains of rivers in the southwest. These brush species are the phreatophytes (Meinzer, 1923). They have the ability to remove water directly from the water table and transpire at a high rate when other plants are forced into dormancy (Fletcher and Elmendorf, 1955). Robinson (1958) considered the largest source of reclaimable water in the southwest to be the moisture used by phreatophytes.

Gatewood and others (1950) reported the following annual rates of water use by phreatophytes growing in Arizona at 100 percent volume density: saltcedar1/, 7.2 acre-feet per acre; baccharis, 4.7 acre-feet per acre; cottonwood, 6.0 acre-feet per acre; and mesquite, 3.3 acre-feet per acre. Saltcedar, baccharis, and cottonwood exist only as phreatophytes in West Texas. Mesquite grows as a phreatophyte when a shallow water table is present (Bogusch, 1951). Saltcedar is one of the most widespread phreatophytes in Texas. Rechenthin and Smith (1967) estimated that 600,000 acres of saltcedar grow in West Texas.

As indicated in Part I of this report, 63 percent (30,500 acres) of the Brazos River flood plain from the confluence of the Salt and Double Mountain Forks downstream to upper Possum Kingdom Lake was occupied by phreatophytes. Because of the high water use potential of these plants and the need for a complete understanding of the influence of phreatophyte vegetation on the upper Brazos River basin, the present study was conducted to survey the vegetation from the confluence of the Salt and Double Mountain Forks to their headwaters.

The kinds, amounts, distribution, and volume densities of the woody phreatophytes were studied along with their relation to flood-plain location. Preliminary estimates are made of the water usage of these plants. The survey methods developed in this study should be useful in surveying phreatophyte vegetation along other streams. This study was carried out by Texas Tech University, Lubbock, Texas, under interagency contract with the Texas Water Development Board [Contract IAC (70-71)213].

LOCATION AND DESCRIPTION OF THE STUDY AREA

The study area includes all of the flood plain upstream from the confluence of the Salt and Double Mountain Forks Brazos River, about 50,000 acres (Figure 1). Varying environmental conditions have allowed the development of different vegetation along each tributary. For this report, the study area was divided into six stream reaches, which are referred to in the report as follows:

White River

upper Salt Fork Brazos River
(above mouth of White River)

lower Salt Fork Brazos River
(below mouth of White River)

North Fork Double Mountain Fork
Brazos River

upper Double Mountain Fork Brazos River
(above mouth of North Fork Double Mountain Fork)

lower Double Mountain Fork Brazos River
(below mouth of North Fork Double Mountain Fork)

These streams are shown on Figure 1.

1/ See Appendix A for a list of common and scientific names of plants mentioned in this report.

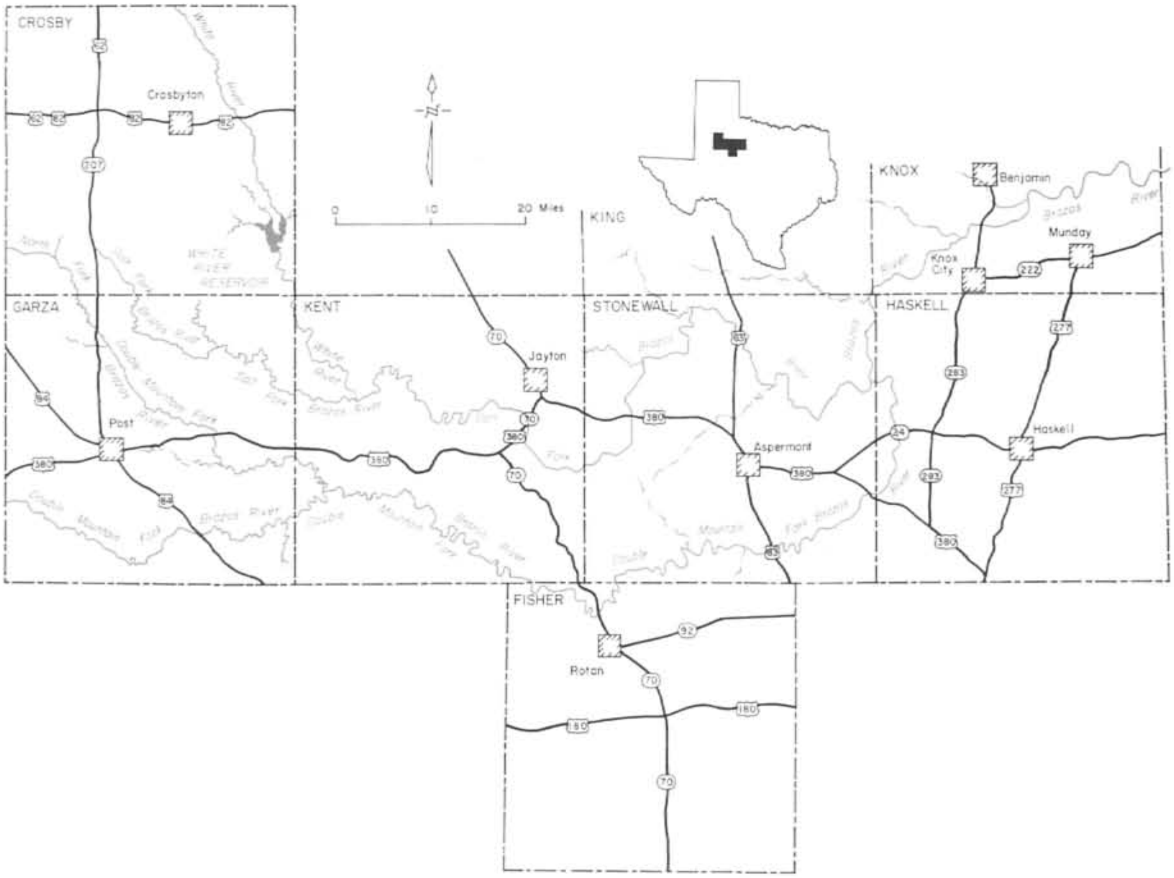


Figure 1.—Location of the Study Area

The uplands of the region were described by Cronin and others (1963) as areas of level to undulating land on the interstream divides with a broken topography along the entrenched streams. The region slopes eastward from an elevation of about 3,000 feet along the escarpment of the Llano Estacado or High Plains to 1,500 feet at the confluence of the Salt and Double Mountain Forks Brazos River.

Rocks exposed within the study area range in age from Permian to Quaternary. Material of Permian age is grouped into the Clear Fork, Pease River, and Whitehorse geological groups. Rocks of the Clear Fork Group are exposed along the Double Mountain Fork Brazos River in Haskell County. Typical geological material included are shale, limestone, marl, and dolomite. In eastern Stonewall County, shale, anhydrite, gypsum, dolomite, and sandstone of the Pease River Group are exposed along the Salt and Double Mountain Forks. The Salt Fork Brazos River cuts through a large area of Quaternary alluvium in northwestern Stonewall and eastern Kent Counties. The alluvium is composed of sand, silt, clay, and gravel. Fine sand, gypsum, anhydrite, shale, and dolomite of the Whitehorse Group are exposed along the Salt and Double Mountain Forks in western Kent and Fisher Counties. Triassic age material of the Dockum Group occurs along the major streams in Garza and Crosby Counties. Rocks included are shale, sandy shale, cross-bedded sandstone, and conglomerate (Cronin and others, 1963).

Material found in the flood plain is of recent origin. Alluvial deposits consists of sand, gravel, silt, and clay. They form the primary aquifer in the study area (Cronin and others, 1963).

Soils derived from the stratified alluvium are immature and have a nearly level to steeply sloping surface. Soils on the outer flood plain are protected from flooding, have more profile development, contain a higher percentage of organic matter, and support a much richer flora than soils near the channel. Sandy soils of the Lincoln-Yahola association occur throughout the study area (Texas Agricultural Extension Service, 1968).

The quality of the ground water and stream water is generally poor. The water is used by livestock, but mineral content usually exceeds the recommended limits for human consumption set forth by the U.S. Public Health Service (Cronin and others, 1963). Water flowing in the Double Mountain Fork carries a high silt load from the clay flat uplands surrounding the river. The

Salt Fork has a high salt content derived from salt flats occurring in Kent and Stonewall Counties (Blank, 1956).

The flood plain varies in width from very wide with a gradual transition into the uplands to narrow with high steep cliffs (Figures 2 and 3). The locations of each type flood plain will be discussed in relation to the distribution of vegetation types.

The climate is characterized by wide variations; however, high temperatures, low precipitation, and high evaporation are typical (Carr, 1967). Table 1 summarizes climatic data from each county. Figure 4 diagrams the monthly precipitation, evaporation, and temperature recorded at Lubbock and Spur. The figure shows that climatic conditions are favorable for high water use by phreatophytes.

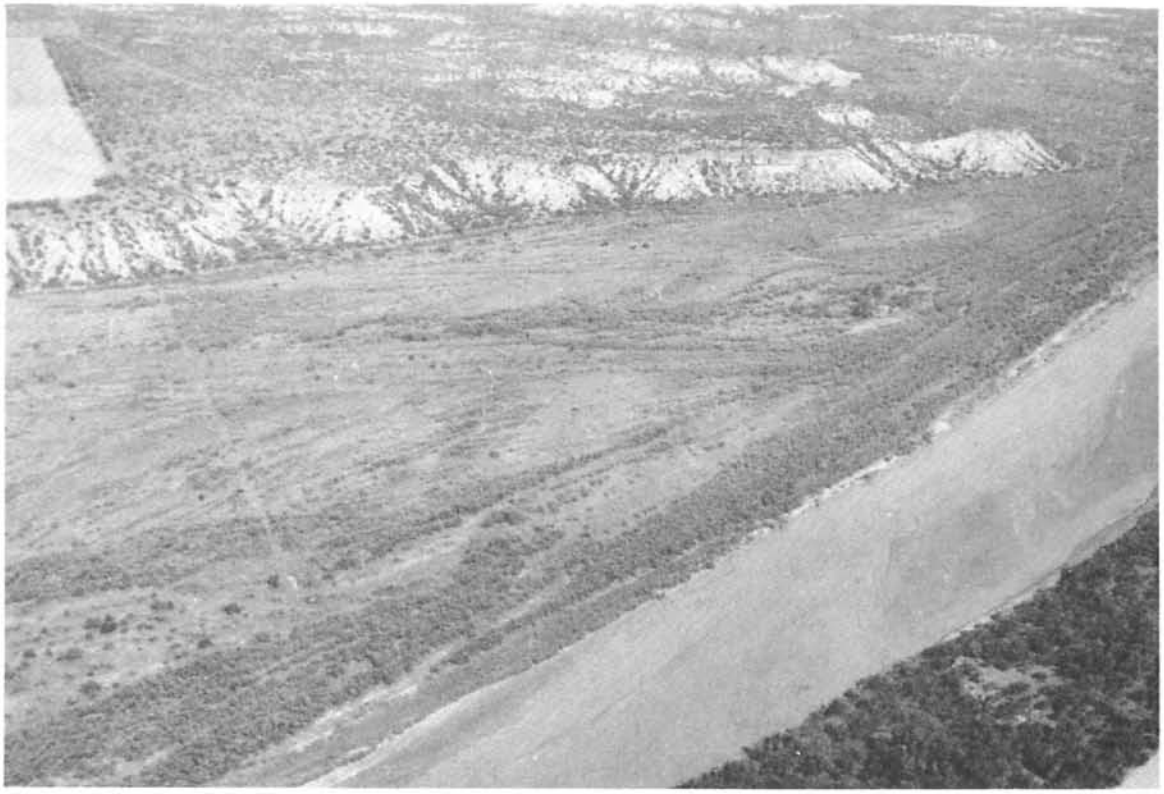


Figure 2.—Vegetation on a Wide Flood Plain Along the Salt Fork Brazos River. In This View, Saltcedar Forms a Mosaic of Light and Dense Stands. The Oldest Plants Usually Occur on the Outer Portion of the Flood Plain While Seedlings Grow in the Moist River Bed.

METHODS AND PROCEDURES

Aerial photographs taken in 1962, 1963, and 1964 were used as base maps in the survey of the woody phreatophytes in the study area. These photos were secured by the Texas Water Development Board from the Aerial Photography Western Laboratory, U.S. Department of Agriculture, Salt Lake City, Utah (see Appendix B for a list of aerial photograph numbers). The 1970 land use and phreatophyte occurrence were delineated on these aerial photographs.

Phreatophyte communities were identified by field surveys. Known occurrences of each stand were recorded on current aerial photographs and their occurrence correlated to photograph characteristics such as tone, shape, dimension, texture, and shadow pattern. The remaining areas of infestation were identified by photograph interpretation. Areas of dominant species and mixtures were delineated on the photographs. The accuracy of interpretation was checked by aerial reconnaissance flights and field surveys. The area occupied by each community was determined with a compensating polar planimeter.

Line transects were used in the field to determine species composition and volume density of the phreatophyte communities according to procedures outlined by Horton, Robinson, and McDonald (1964). The transect lines were positioned perpendicular to the river channel and extended through the woody vegetation on both sides of the river. The kind, location,

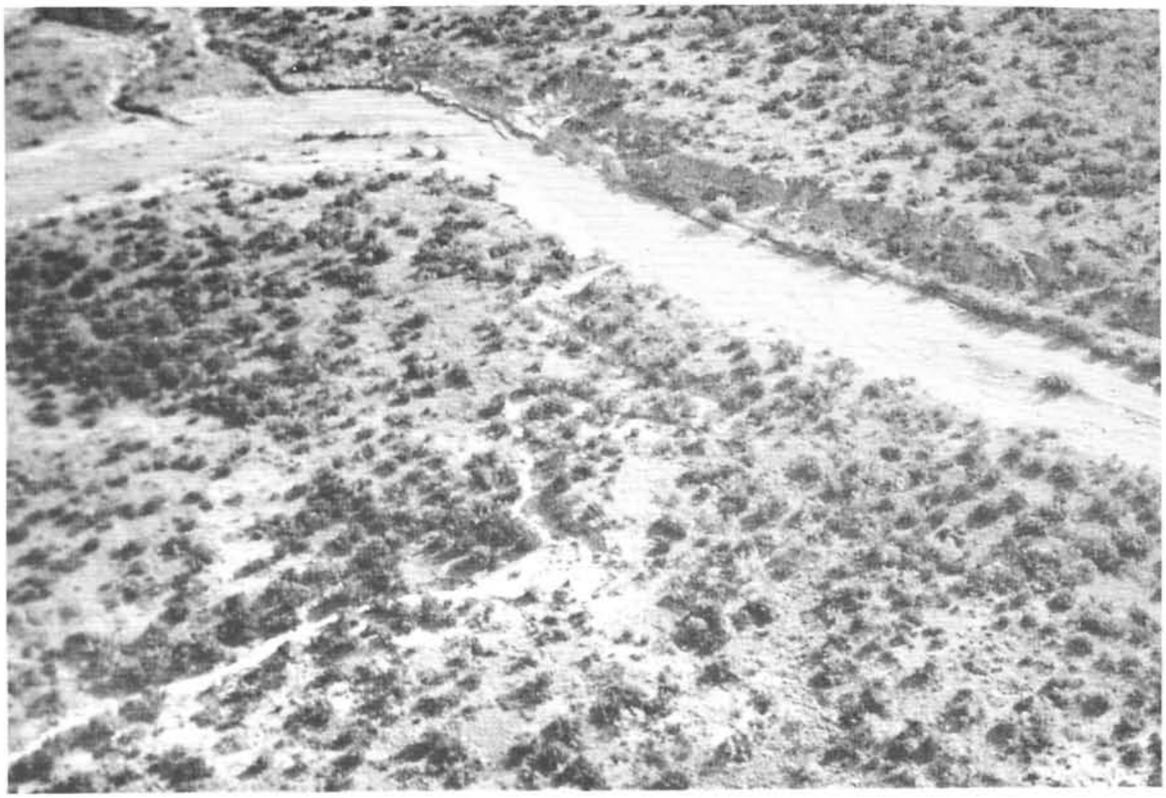


Figure 3.—Vegetation on a Narrow Flood Plain Along the Salt Fork Brazos River. Along the Upper Salt Fork, as Shown Here, Saltcedar Often Grows in the Channel. These Stands Are Washed Away During Periods of High Floodflow. Scattered Clumps of Mature Saltcedar Growing Along the Banks Serve as a Seed Source for the Younger Stands.

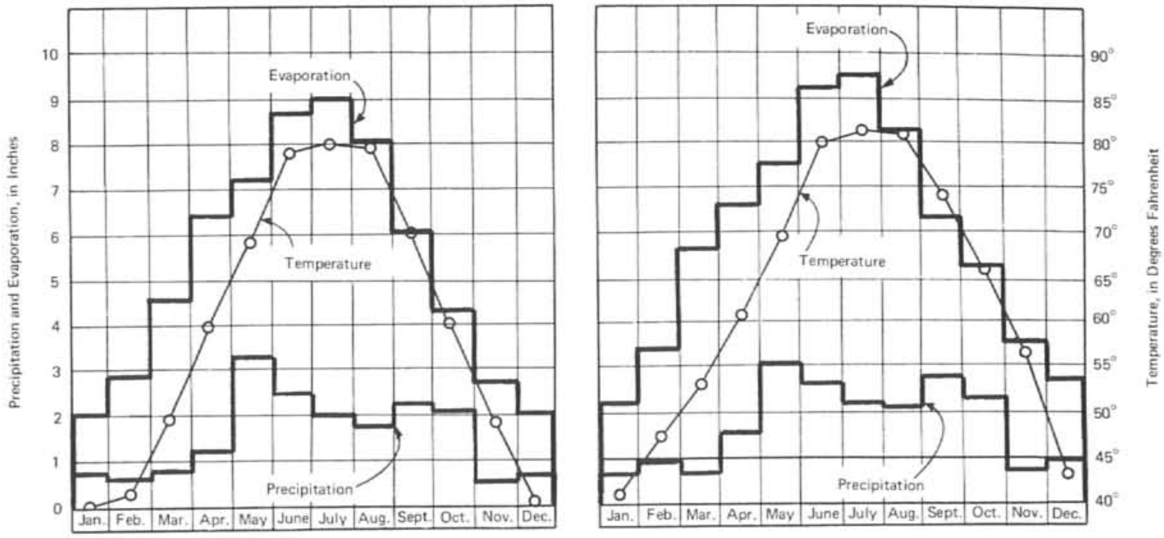
Table 1.—Climatic Variation in the Study Area

	COUNTIES					
	CROSBY	GARZA	KENT	FISHER	STONEWALL	HASKELL
Normal Annual Precipitation[a]	21.3 in.	18.6 in.	20.8 in.	20.4 in.	21.7 in.	23.2 in.
Average Annual Gross Lake Surface Evaporation[b]	76 in.	77 in.	77 in.	79 in.	77 in.	76 in.
Average July Maximum Temperature[a]	94 °F	95 °F	97 °F	96 °F	97 °F	97 °F
Average January Minimum Temperature[a]	26 °F	27 °F	28 °F	28 °F	28 °F	30 °F

[a] Dallas Morning News (1969).
[b] Kane (1967, plate 6).

crown cover, plant height, and foliage depth were recorded for each woody species intersected by the transect line. Plant height and foliage depth were estimated every 20 feet. Herbaceous plants were not studied because their presence is influenced by management as well as natural environmental factors. Seventy-one transect locations were selected according to their accessibility and the amount of information they could provide. Areas that had been cleared of woody vegetation were avoided. This selective process was helpful in collecting desired vegetative information, but it limited the use of the data to checking only species composition as determined from aerial photographs.

The transects crossing the flood plain were used to delineate phreatophyte communities where distinct changes occurred in the kinds or amounts of woody species intersected by the transect lines. Distinct areas had to be intersected by 50 feet or more of the transect line before they were considered to be communities. Areas of single dominants, mixtures of several



Lubbock:

Average Annual Evaporation, 1917-58 64.36 inches

Normal Annual Temperature, 1931-60 59.7° F

Normal Annual Precipitation, 1931-60 18.08 inches

Spur:

Average Annual Evaporation, 1916-60 71.01 inches

Normal Annual Temperature, 1931-60 62.5° F

Normal Annual Precipitation, 1931-60 20.24 inches

Figure 4.—Monthly Precipitation, Evaporation, and Temperature at Lubbock and Spur (Adapted From Cronin and Others, 1963)

dominants, and ecotones between either of these types were considered as communities. The species composition, location of occurrence, crown cover, maximum plant height, and optimum foliage depth were determined for each phreatophyte community. An adequate number of community samples for volume density computations was collected only for the saltcedar and mesquite communities. The number of transects and samples obtained along each major stream reach are listed in Table 2.

Table 2.—Number of Line Transects and Community Samples Obtained Along Major Streams

STREAM	TRANSECTS	COMMUNITY SAMPLES SALTCEDAR	COMMUNITY SAMPLES MESQUITE
White River	4	5	4
upper Salt Fork	6	6	4
lower Salt Fork	21	29	13
North Fork Double Mountain Fork	13	9	4
upper Double Mountain Fork	14	15	4
lower Double Mountain Fork	13	14	10
TOTAL	71	78	39

Volume density was computed for the saltcedar and mesquite communities using the percent crown cover, maximum plant height, and optimum foliage depth determined by the community samples. Species volume density was calculated using the following formula:

$$\text{Volume Density} = \frac{H}{D} \times C,$$

where H = maximum plant height (not to exceed optimum foliage depth),

D = optimum foliage depth, and

C = percent crown cover of the individual species.

The first variable (H/D) is referred to as vertical density and the second (C) as areal density. Volume density times the acreage occupied by a species equals the equivalent acreage at 100 percent volume density. This equivalent acreage is assumed to use water at a rate equal to the potential of the species.

RESULTS AND DISCUSSION

Nine species of woody vegetation occupy about 32,000 acres or 64 percent of the flood-plain area (see Appendix C for acreage computations). Only saltcedar, mesquite, cottonwood, baccharis, and sand sagebrush occur in extensive amounts. The remaining four species (willow, hackberry, elm, and juniper) occur as small stands or individual plants.

Saltcedar, mesquite, cottonwood, and sand sagebrush dominate the flood-plain plant communities. All occur as pure stands and in mixtures with other species. Saltcedar is the most widely and evenly distributed species, dominating 36 percent of the 50,000 acres of flood plain. It occurs in pure stands on 31 percent of the area and in a mixture with baccharis on 5 percent (Table 3).

Along the upper tributaries, saltcedar is the dominant species on large acreages although its crown cover is low. Downstream, saltcedar increases in acreage and crown cover (Table 4). Most stands of saltcedar on the upper tributaries are relatively young (Figure 3), with scattered clumps of old trees. The extent of the clumps of old trees increases downstream. At the confluences of the upper tributaries, dense and mature saltcedar stands cover large areas.

Saltcedar forms almost continuous stands adjacent to the river channel along the main streams of the Salt and Double Mountain Forks. It is, however, restricted to a narrow band directly adjacent to the channel where the flood plain is scarcely wider than the channel. Plants within these stands are of even age, indicating a common date of establishment. Large numbers of seedlings emerge in the wet river bed in the spring, but few survive high streamflows or extended dry periods.

Along wide, flat flood-plain areas (Figure 2), dense stands of saltcedar cover extensive acreages. The oldest plants are away from the river channel with stratified bands of progressively younger plants occurring closer to the channel (Figure 5). Saltcedar crown cover is greatest in the outer stands and decreases toward the river. This stratification of saltcedar indicates periodic migrations toward the channel during favorable moisture periods.

Line transects extending through saltcedar communities indicate a gradual increase in total plant and saltcedar crown cover in the downstream direction. Plants most frequently associated with saltcedar in the saltcedar community are baccharis and mesquite. Willow, elm, cottonwood, sand sagebrush, and hackberry occur in limited amounts in the saltcedar community. Average composition of the saltcedar community is given in Table 5.

The percentages of saltcedar crown cover and vertical density varied between the six stream reaches. The calculation of equivalent acreage at 100 percent volume density is given in Table 6. The computed 4,368 equivalent acres at full crown cover and optimum foliage depth will theoretically use water at the maximum rate for saltcedar in the study area.

The saltcedar-baccharis mixture occurs in open sandy areas along wide, flat portions of the flood plain. Saltcedar crown cover is less than 25 percent and baccharis crown cover ranges from 12 to 19 percent.

Mesquite dominates 22 percent of the flood-plain. It occurs in pure stands on 20 percent of the area, and in mixtures with saltcedar and sand sagebrush on 0.3 and 1.7 percent, respectively (Table 3). Mesquite dominates areas that are drier than those in which saltcedar thrive. Bogusch (1951) reported that mesquite did not survive frequent flooding, prolonged inundation, or a shallow water table.

On the upper tributaries where the water supply was inadequate to maintain a high water table, mesquite grew near the river channel. The most extensive stands, however, occur between the outer saltcedar stands and the flood-plain boundaries (Figure 6). Mesquites near the river are small and probably establish themselves and thrive during dry periods but perish because of floods and a shallow water table during wet years. Near the confluences of the upper tributaries, mesquite stands usually occur on the outer flood plain. Mesquite stands consist of mature although small plants near the headwaters. These probably do not exist as phreatophytes. Downstream the plants are large and luxuriant, characteristic of phreatophytic mesquite.

On the main streams of the Salt and Double Mountain Forks, mesquite is restricted to areas protected from flooding or where a shallow water table does not occur. The most extensive stands occur on wide portions of the flood plain and in oxbows. Mesquites

Table 3.—Acreages of Phreatophyte Communities Occurring Along the Salt and Double Mountain Forks Brazos River and Major Tributaries

PHREATOPHYTES	SALT FORK[1]	DOUBLE MOUNTAIN FORK[2]	TOTAL
Saltcedar dominated	9,429	8,638	18,067
Saltcedar alone	8,706	7,045	15,751
Saltcedar-baccharis	723	1,593	2,316
Mesquite dominated	5,675	5,448	11,123
Mesquite alone	5,471	4,706	10,177
Mesquite-saltcedar	94	73	167
Mesquite-sand sagebrush	110	669	779
Cottonwood	203	2,293	2,496
Cottonwood alone	177	924	1,101
Cottonwood-saltcedar	21	1,107	1,128
Cottonwood-mesquite	5	262	267
Sand sagebrush	184	61	245
Juniper, willow, hackberry	—	20	20
TOTAL	15,491	16,460	31,951

1/ Includes the White River, as well as the Salt Fork.
2/ Includes the North Fork Double Mountain Fork, as well as the Double Mountain Fork.

Table 4.—Major Species and Average Vegetative Cover Determined From Transects Along Major Streams

STREAM	TOTAL ALL SPECIES[a] PERCENT	VEGETATIVE COVER OF MAJOR SPECIES[b] SALTCEDAR (PERCENT)	MESQUITE (PERCENT)	COTTONWOOD (PERCENT)	SAND SAGEBRUSH (PERCENT)	BACCHARIS (PERCENT)
White River	14	5	5	1	1	2
upper Salt Fork	15	8	5	—	c/	2
lower Salt Fork	33	23	9	c/	c/	c/
North Fork Double Mountain Fork	20	11	2	2	c/	5
upper Double Mountain Fork	18	13	4	—	c/	1
lower Double Mountain Fork	40	16	14	4	—	3

a/ "Total all species" may exceed sum of individual species due to inclusion of some minor species.
b/ Minor species intercepted by the line transects were willow, hackberry, and elm.
c/ Less than 0.5 percent cover.

growing along the main streams are larger and more luxuriant than others on the surrounding uplands, indicating increased available moisture on the flood plain.

Line transects extending through the mesquite communities indicate a gradual increase in total plant and mesquite crown cover in the downstream direction. This trend corresponds to the increasing precipitation eastward. Sand sagebrush, willow, saltcedar, baccharis, and hackberry occur in the mesquite community. Average composition of the mesquite community is given in Table 7.

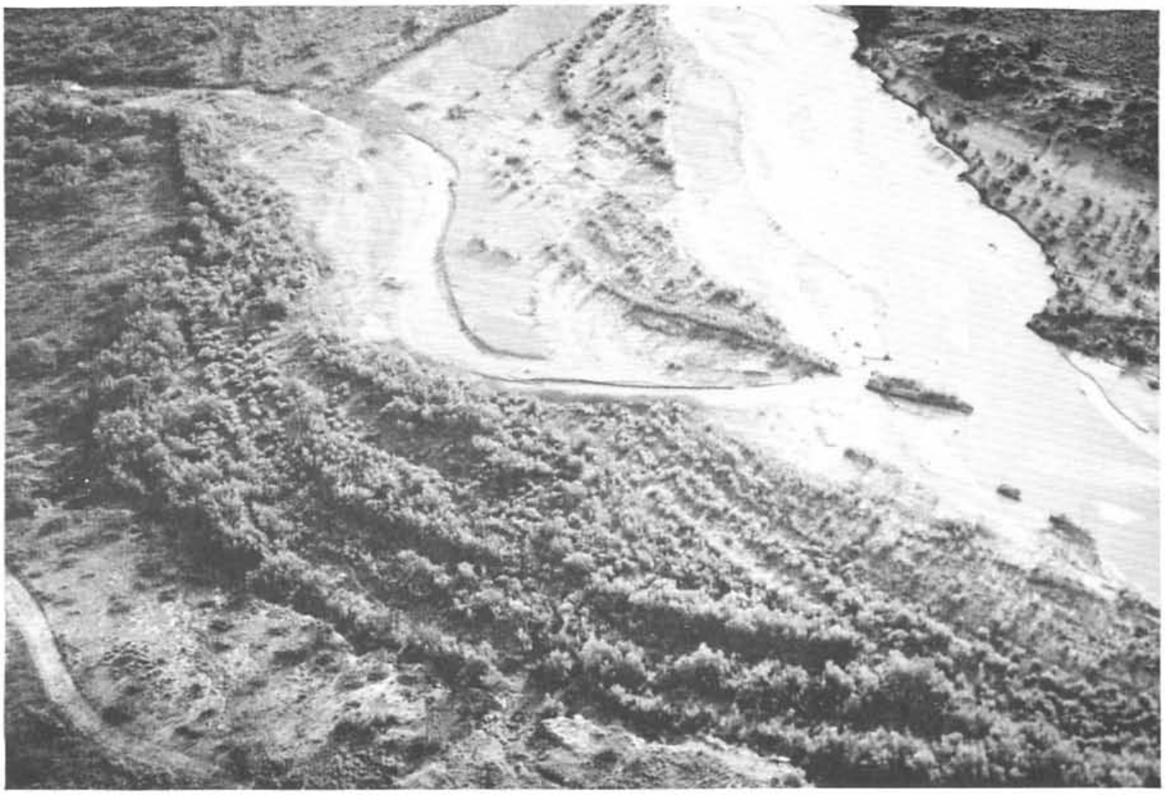


Figure 5.—Extensive Saltcedar on a Wide Flood Plain With a Shallow Water Table. Additional Moisture Supplied by the Small Stream Joining the Salt Fork at the Upper Left of This Photograph Has Allowed Saltcedar to Form a Dense Stand. The Oldest Plants Occur on the Outer Flood Plain. Stratified Bands of Progressively Younger Stands Grow Closer to the River.

Table 5.—Average Species Composition of the Saltcedar Communities Along Major Streams

STREAM	TOTAL ALL SPECIES[a] (PERCENT)	VEGETATIVE COVER OF MAJOR SPECIES[b] SALTCEDAR (PERCENT)	BACCHARIS (PERCENT)	MESQUITE (PERCENT)	WILLOW (PERCENT)
White River	18.6	14.9	2.9	0.2	0.9
upper Salt Fork	12.1	10.9	.5	.7	–
lower Salt Fork	35.4	34.1	.3	.7	–
North Fork Double Mountain Fork	18.6	15.5	2.1	.9	–
upper Double Mountain Fork	22.3	20.5	1.0	.7	[c]
lower Double Mountain Fork	39.6	34.5	2.7	.7	.7

[a] Sum of individual cover may exceed "Total all species" because of layering.
[b] Minor species encountered in the saltcedar communities were elm, cottonwood, sand sagebrush, and hackberry.
[c] Less than 0.1 percent cover.

The percentages of mesquite crown cover and vertical density varied between the six stream reaches. The calculation of equivalent acreage at 100 percent volume density is given in Table 8. The computed 3,034 equivalent acres at full crown cover and maximum foliage depth will theoretically use water at the maximum rate for the species.

Table 3.—Acreages of Phreatophyte Communities Occurring Along the Salt and Double Mountain Forks Brazos River and Major Tributaries

PHREATOPHYTES	SALT FORK[1]	DOUBLE MOUNTAIN FORK[2]	TOTAL
Saltcedar dominated	9,429	8,638	18,067
Saltcedar alone	8,706	7,045	15,751
Saltcedar-baccharis	723	1,593	2,316
Mesquite dominated	5,675	5,448	11,123
Mesquite alone	5,471	4,706	10,177
Mesquite-saltcedar	94	73	167
Mesquite-sand sagebrush	110	669	779
Cottonwood	203	2,293	2,496
Cottonwood alone	177	924	1,101
Cottonwood-saltcedar	21	1,107	1,128
Cottonwood-mesquite	5	262	267
Sand sagebrush	184	61	245
Juniper, willow, hackberry	—	20	20
TOTAL	15,491	16,460	31,951

1/ Includes the White River, as well as the Salt Fork.
2/ Includes the North Fork Double Mountain Fork, as well as the Double Mountain Fork.

Table 4.—Major Species and Average Vegetative Cover Determined From Transects Along Major Streams

STREAM	TOTAL ALL SPECIES[a] PERCENT	VEGETATIVE COVER OF MAJOR SPECIES[b]				
		SALTCEDAR (PERCENT)	MESQUITE (PERCENT)	COTTONWOOD (PERCENT)	SAND SAGEBRUSH (PERCENT)	BACCHARIS (PERCENT)
White River	14	5	5	1	1	2
upper Salt Fork	15	8	5	—	c/	2
lower Salt Fork	33	23	9	c/	c/	c/
North Fork Double Mountain Fork	20	11	2	2	c/	5
upper Double Mountain Fork	18	13	4	—	c/	1
lower Double Mountain Fork	40	16	14	4	—	3

a/ "Total all species" may exceed sum of individual species due to inclusion of some minor species.
b/ Minor species intercepted by the line transects were willow, hackberry, and elm.
c/ Less than 0.5 percent cover.

growing along the main streams are larger and more luxuriant than others on the surrounding uplands, indicating increased available moisture on the flood plain.

Line transects extending through the mesquite communities indicate a gradual increase in total plant and mesquite crown cover in the downstream direction. This trend corresponds to the increasing precipitation eastward. Sand sagebrush, willow, saltcedar, baccharis, and hackberry occur in the mesquite community. Average composition of the mesquite community is given in Table 7.

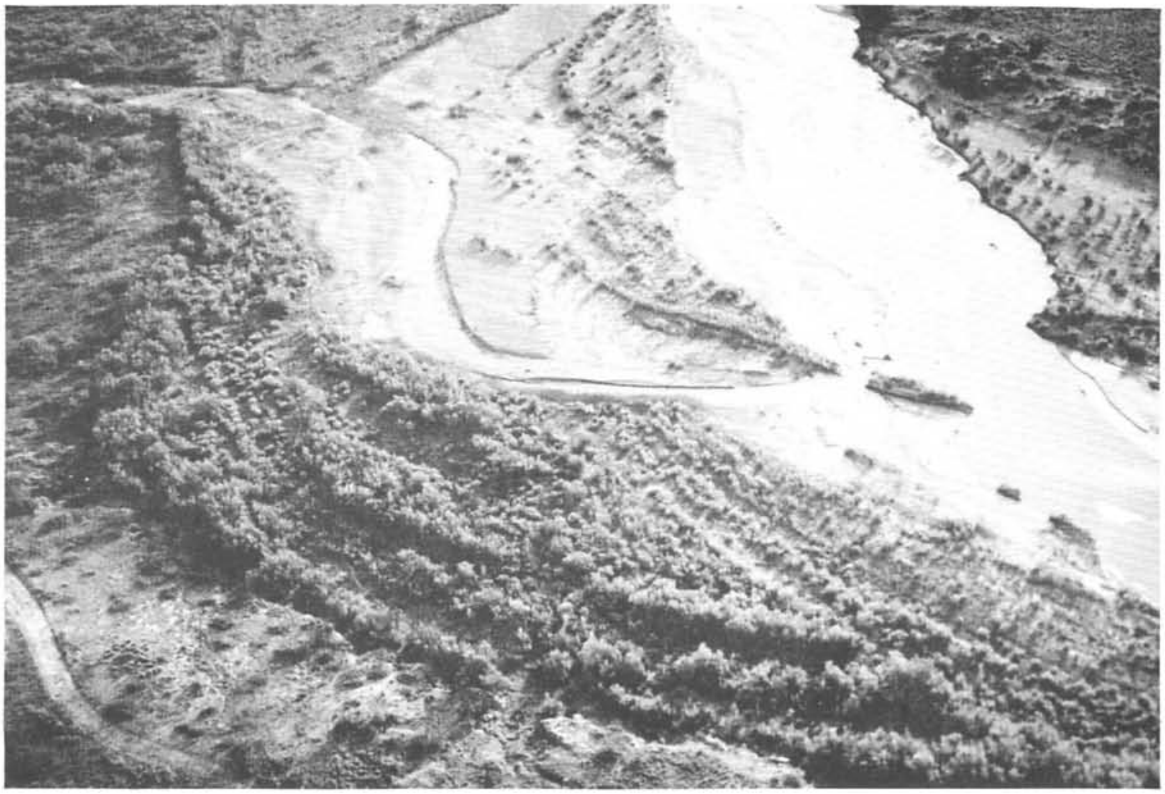


Figure 5.—Extensive Saltcedar on a Wide Flood Plain With a Shallow Water Table. Additional Moisture Supplied by the Small Stream Joining the Salt Fork at the Upper Left of This Photograph Has Allowed Saltcedar to Form a Dense Stand. The Oldest Plants Occur on the Outer Flood Plain. Stratified Bands of Progressively Younger Stands Grow Closer to the River.

Table 5.—Average Species Composition of the Saltcedar Communities Along Major Streams

STREAM	TOTAL ALL SPECIES[a] (PERCENT)	VEGETATIVE COVER OF MAJOR SPECIES[b] SALTCEDAR (PERCENT)	BACCHARIS (PERCENT)	MESQUITE (PERCENT)	WILLOW (PERCENT)
White River	18.6	14.9	2.9	0.2	0.9
upper Salt Fork	12.1	10.9	.5	.7	—
lower Salt Fork	35.4	34.1	.3	.7	—
North Fork Double Mountain Fork	18.6	15.5	2.1	.9	—
upper Double Mountain Fork	22.3	20.5	1.0	.7	[c]
lower Double Mountain Fork	39.6	34.5	2.7	.7	.7

[a] Sum of individual cover may exceed "Total all species" because of layering.
[b] Minor species encountered in the saltcedar communities were elm, cottonwood, sand sagebrush, and hackberry.
[c] Less than 0.1 percent cover.

The percentages of mesquite crown cover and vertical density varied between the six stream reaches. The calculation of equivalent acreage at 100 percent volume density is given in Table 8. The computed 3,034 equivalent acres at full crown cover and maximum foliage depth will theoretically use water at the maximum rate for the species.

Table 6.—Equivalent Acreage of Saltcedar at 100 Percent Volume Density

STREAM	CROWN COVER (PERCENT)	X	VERTICAL DENSITY (PERCENT)	X	ACREAGE	=	EQUIVALENT ACREAGE AT 100 PERCENT VOLUME DENSITY
White River	14.9		51.8		671		52
upper Salt Fork	10.9		68.4		797		59
lower Salt Fork	34.1		93.3		7,238		2,303
North Fork Double Mountain Fork	15.5		80.7		1,128		141
upper Double Mountain Fork	20.5		89.6		1,415		260
lower Double Mountain Fork	34.5		100.0		4,502		1,553
TOTAL	—		—		—		4,368

Mesquite-saltcedar mixtures occur along the boundaries between pure stands of the two species. Mesquite plants usually dominate, but mixtures with saltcedar dominating are included. Mesquite-sand sagebrush mixtures occupy sandy, dry soils on the upper tributaries. Mesquites in these areas are probably not true phreatophytes because the plants are small and scattered.

Cottonwood communities occur throughout the flood-plain area, but dominate only 5 percent of the acreage. Pure stands occur on 2 percent, cottonwood-saltcedar mixtures on 2.2 percent, and cottonwood-mesquite on 0.8 percent. The most extensive areas of cottonwood occurrence were on the Double Mountain Fork near its confluence with the Salt Fork.

Figure 6.—Mesquite on the Outer Flood Plain. In This View, a Distinct Boundary is Visible Between the Mesquite Community on the Left and the Saltcedar on the Right. This Clear Separation of the Two Communities is Common.

Table 7.—Average Species Composition of the Mesquite Communities on Major Streams

STREAM	TOTAL ALL SPECIES [a] (PERCENT)	VEGETATIVE COVER OF SPECIES					
		MESQUITE (PERCENT)	SAND SAGEBRUSH (PERCENT)	SALTCEDAR (PERCENT)	BACCHARIS (PERCENT)	WILLOW (PERCENT)	HACKBERRY (PERCENT)
White River	26.8	23.5	1.8	1.1	—	—	—
upper Salt Fork	17.6	17.5	—	—	0.1	—	—
lower Salt Fork	35.6	33.4	.1	1.1	.5	[b]	0.5
North Fork Double Mountain Fork	28.9	28.5	.3	—	—	—	—
upper Double Mountain Fork	12.0	9.9	1.2	—	.9	—	—
lower Double Mountain Fork	42.0	41.1	—	—	—	.2	[b]

[a] "Total all species" may exceed sum of individual species due to inclusion of some minor species.
[b] Less than 0.1 percent cover.

Table 8.—Equivalent Acreage of Mesquite at 100 Percent Volume Density

STREAM	CROWN COVER (PERCENT)	X	VERTICAL DENSITY (PERCENT)	X	ACREAGE	=	EQUIVALENT ACREAGE AT 100 PERCENT VOLUME DENSITY
White River	23.5		100		352		83
upper Salt Fork	17.5		100		1,387		243
lower Salt Fork	33.4		100		3,732		1,246
North Fork Double Mountain Fork	28.5		100		1,706		486
upper Double Mountain Fork	9.9		100		824		82
lower Double Mountain Fork	41.1		100		2,176		894
TOTAL	—		—		—		3,034

Mature cottonwood stands grow along all major tributaries on areas protected from flooding (Figure 7). Small plants were observed growing near the channel along the upper tributaries but these probably exist temporarily in the cycles of wet and dry periods as previously discussed for mesquite. Cottonwood-saltcedar mixtures occur along the inner flood plain surrounded by pure saltcedar stands. Cottonwood-mesquite mixtures grow on the outer flood plain.

Sand sagebrush occurs in pure stands on 0.5 percent of the flood-plain acreage. These stands grow on dry, sandy soils along the upper tributaries (Figure 8). They are not considered to be phreatophytes because no evidence exists of luxuriant growth due to available flood-plain moisture.

An important factor causing differences in community composition and location within the study area is the amount of available moisture in each stream reach. Total vegetative cover increases in the downstream direction (Table 4). The extent of saltcedar, the most water-demanding species, also increases downstream. The appearance of mesquite and cottonwood near the river channel along the upper tributaries indicates a deeper water table in the upstream areas. These are indications that moisture does increase downstream and has a controlling effect on community composition and location.

SUMMARY AND CONCLUSIONS

Saltcedar, mesquite, cottonwood, and sand sagebrush dominate the flood plain plant communities. Saltcedar and mesquite are the most widely distributed species, dominating 18,067 and 11,123 acres, respectively. Pure stands of saltcedar occur on the inner

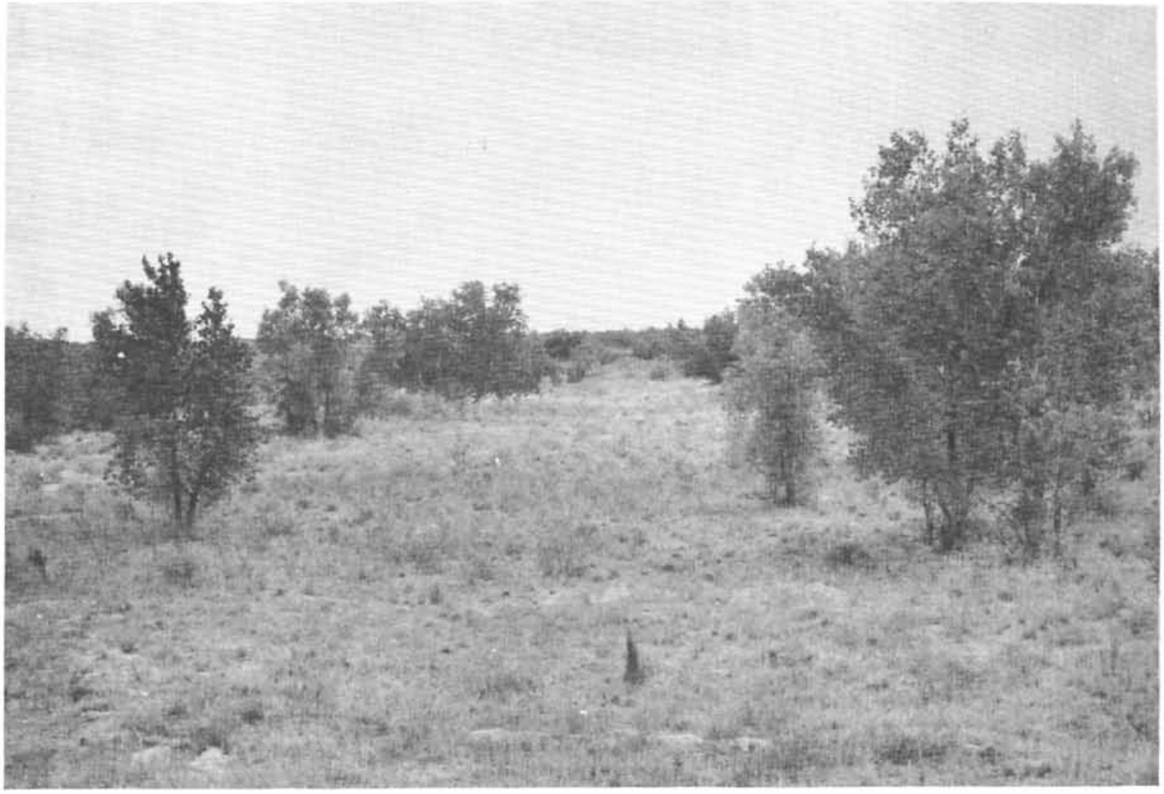


Figure 7.—Cottonwood on an Area Protected From Flooding. The Cottonwood Community Usually Forms a Narrow Band Parallel to the River Channel. Cottonwoods Dominate Areas Alone as in This View, or Occur in Mixtures With Mesquite, or in Mixtures With Saltcedar.

flood plain, forming dense stands adjacent to the channel. Along the upper tributaries, these stands are composed of small plants with occasional clumps of large, mature plants. On the Salt and Double Mountain Forks Brazos River extensive areas are occupied by large, mature saltcedars. Mesquite occurs on the outer flood plain where flooding rarely occurs. On the upper tributaries, some stands are composed of small plants, indicating they are not phreatophytic in those areas. Downstream, dense stands of large mesquite occur on the outer flood plain. Cottonwood communities occur throughout the study area, but are not as extensive as saltcedar and mesquite. The largest area of cottonwood dominance is along the Double Mountain Fork above its confluence with the Salt Fork. Sand sagebrush dominance is restricted to the upper tributaries. It occurs on dry, sandy areas and is not considered to be a phreatophyte.

The extent and percentage of vegetative cover of water-demanding saltcedar increases downstream. This trend corresponds to the increasing available moisture eastward.

The 15,751 acres of saltcedar in the flood plain is equivalent to 4,368 acres at 100 percent volume density. Mesquite acreage is equal to 3,034 acres at 100 percent volume density.

No research has been conducted on the water use of phreatophytes in Texas, but Gatewood and others (1950), working in Arizona, reported that saltcedar and mesquite (growing at 100 percent volume density) respectively used 7.2 and 3.3 acre-feet of water per acre annually. Class A pan and lake evaporation in the Safford, Arizona area and the tributaries of the Brazos River covered by this study are similar (Kohler and others, 1959). Since the climatic conditions affecting evaporation also influence transpiration (Penman, 1963), water use in the study area should be comparable with that in Arizona. Therefore, the 4,368 equivalent acres of saltcedar at 100 percent volume density in the study area should use approximately 31,450 acre-feet of water annually. Similarly, water use by mesquite in this area should be approximately 10,000 acre-feet annually.

Besides consuming large quantities of water that would be available for other uses, these plants on the flood plain compete with valuable grazing plants for water, nutrients, space, and sunlight, and are generally successful in this competition. Further study is needed on the present and potential impact these plants have on the area's economy and water supply and the feasibility of control. Any control program, however, must consider the effects that a change in vegetation would have on the wildlife and the esthetic values in the area as well as the effects on the water regime.

Figure 8.—Sand Sagebrush in a Sandy, Dry Area on an Upper Tributary. It is Not Considered to be a Phreatophyte, But Limits Grazing Capacity on Areas it Dominates.

LITERATURE CITED

Babcock, H. M., 1968, The phreatophyte problem in Arizona, *in* Arizona watershed symposium: Arizona Water Resources Comm. and Watershed and Forestry Div. State Land Dept., p. 34-36.

Blank, H. R., 1956, Salt flats of Kent and Stonewall Counties, Texas: Texas Jour. Sci., v. 8, p. 25-32.

Bogusch, E. R., 1951, Climatic limits affecting distribution of mesquite (*Prosopis juliflora*) in Texas: Texas Jour. Sci., v. 4, p. 554-558.

Carr, J. T., Jr., 1967, The climate and physiography of Texas: Texas Water Devel. Board Rept. 53, 27 p.

Cronin, J. G., Follett, C. R., Shafer, G. H., and Rettman, P. L., 1963, Reconnaissance investigation of the ground-water resources of the Brazos River basin, Texas: Texas Water Comm. Bull. 6310, 152 p.

Dallas Morning News, 1969, Texas almanac and state industrial guide, 1970-1971: A. H. Belo Corp., Dallas, Texas, 704 p.

Fletcher, H. C., and Elmendorf, H. B., 1955, Phreatophytes—a serious problem in the west *in* U.S. Department of Agriculture Yearbook—Water: U.S. Dept. Agr., p. 423-429.

Gatewood, J. S., Robinson, T. W., Colby, B. R., Hem, J. D., and Halpenny, L. C., 1950, Use of water by bottom-land and vegetation in lower Safford Valley, Arizona: U.S. Geol. Survey Water-Supply Paper 1103, 210 p.

Gould, F. W., 1969, Texas plants—a checklist and ecological summary: Texas Agr. Exp. Sta. MP-585 (revised), 121 p.

Horton, J. S., Robinson, T. W., McDonald, H. R., 1964, Guide for surveying phreatophyte vegetation: U.S. Dept. Agr. Handbook 266, 37 p.

Kane, J. W., 1967, Monthly reservoir evaporation rates for Texas, 1940 through 1965: Texas Water Devel. Board Rept. 64, 111 p.

Kohler, M. A., Nordenson, T. J., and Baker, D. R., 1959, Evaporation maps for the United States: U.S. Weather Bureau Tech. Paper 37, 18 p.

Meinzer, O. E., 1923, Outline of ground-water hydrology, with definitions: U.S. Geol. Survey Water-Supply Paper 494, 71 p.

Penman, H. L., 1963, Vegetation and hydrology: Commonwealth Bur. of Soils, Tech. Commun. 53, Farnham Royal, Bucks, England, 124 p.

Rechenthin, C. A., and Smith, H. N., 1967, Grassland restoration, Part V, Effects on water yield and supply: U.S. Soil Conservation Service, Temple, Texas, 46 p.

Robinson, T. W., 1958, The phreatophyte problem, *in* Symposium on phreatophytes, Pacific southwest regional meeting: Amer. Geophys. Union, p. 1-11.

Texas Agricultural Extension Service, 1968, Rolling plains economic program report: Texas A&M Univ., 196 p.

Texas Water Development Board, 1968, The Texas water plan: Texas Water Devel. Board planning rept.

APPENDICES

Appendix A
Common and Scientific Names of Plants Referred to in the Report (Gould, 1969)

COMMON NAME	SCIENTIFIC NAME
Saltcedar	*Tamarix gallica* L.
Mesquite	*Prosopis glandulosa* var. *glandulosa* Torr.
Baccharis	*Baccharis salicina* T. & G.
Cottonwood	*Populus deltoides* Marsh.
Sand sagebrush	*Artemisia filifolia* Torr.
Willow	*Salix nigra* Marsh.
Hackberry	*Celtis reticulata* Torr.
Elm	*Ulmus americana* L.
Juniper	*Juniperus pinchoti* Sudw.

Appendix B
List of Aerial Photographs Used in the Survey

Stream symbols are as follows:

WR — White River

SS — upper Salt Fork Brazos River

S — lower Salt Fork Brazos River

NDM — North Fork Double Mountain Fork Brazos River

SDM — upper Double Mountain Fork Brazos River

DM — lower Double Mountain Fork Brazos River

The number following the stream symbol refers to the survey position. Survey positions are numbered downstream to upstream, i.e., from confluences to headwaters.

SURVEY POSITION NUMBER	DATE OF FLIGHT	PHOTOGRAPH FLIGHT NUMBER
WR-1	November 10, 1963	DMT-1EE-155
WR-2	do.	156
WR-3	do.	105
WR-4	do.	28
WR-5	do.	29
WR-6	December 16, 1962	CVC-2DD-248
WR-7	do.	237
WR-8	do.	239
WR-9	do.	240
WR-10	January 8, 1963	CGP-2DD-65
SS-1	November 10, 1963	DMT-1EE-153
SS-2	do.	109
SS-3	do.	23
SS-4	December 16, 1962	CVC-2DD-228
SS-5	do.	183
SS-6	do.	182
SS-7	do.	180
SS-8	do.	163
SS-9	do.	110
SS-10	do.	95
SS-11	do.	43
SS-12	do.	27
SS-13	December 15, 1962	CVC-1DD-232
SS-14	do.	243
SS-15	do.	241
SS-16	January 21, 1963	CGP-3DD-94
SS-17	do.	95
S-1	December 3, 1963	CON-3EE-192
S-2	do.	166
S-3	do.	121
S-4	do.	123
S-5	do.	91
S-6	do.	50
S-7	do.	48
S-8	do.	23
S-9	do.	24
S-10	December 2, 1963	CON-1EE-275
S-11	do.	276
S-12	do.	277
S-13	do.	220
S-14	do.	209
S-15	do.	148
S-16	do.	150
S-17	do.	152
S-18	do.	134
S-19	do.	84
S-20	do.	85
S-21	do.	61
S-22	do.	60
S-23	do.	58
S-24	do.	56
S-25	do.	55
S-26	do.	22
S-27	November 30, 1963	DMT-2EE-15
S-28	do.	110
S-29	do.	139
S-30	do.	240
S-31	do.	238
S-32	do.	237
S-33	do.	275
S-34	December 2, 1963	DMT-4EE-83
S-35	do.	127
S-36	do.	218
S-37	November 10, 1963	DMT-3EE-217
S-38	do.	126
S-39	do.	82
S-40	do.	81
S-41	do.	DMT-1EE-284
S-42	do.	239
NDM-1	December 16, 1962	CVC-2DD-261
NDM-2	do.	263
NDM-3	do.	222
NDM-4	do.	192
NDM-5	do.	152
NDM-6	do.	123
NDM-7	do.	85
NDM-8	do.	87
NDM-9	do.	50
NDM-10	do.	20
NDM-11	December 15, 1962	CVC-1DD-224
NDM-12	do.	251
NDM-13	do.	250
NDM-14	do.	180
NDM-15	do.	179
NDM-16	do.	164
NDM-17	do.	165

SURVEY POSITION NUMBER	DATE OF FLIGHT	PHOTOGRAPH FLIGHT NUMBER	SURVEY POSITION NUMBER	DATE OF FLIGHT	PHOTOGRAPH FLIGHT NUMBER
NDM-18	December 15, 1962	CVC-1DD-106	DM-9	December 3, 1963	CON-3EE-204
NDM-19	do.	104	DM-10	do.	152
NDM-20	January 21, 1963	CGP-3DD-229	DM-11	do.	136
NDM-21	do.	227	DM-12	do.	78
			DM-13	do.	66
SDM-1	December 16, 1962	CVC-2DD-265	DM-14	do.	6
SDM-2	do.	267	DM-15	December 2, 1963	CON-1EE-255
SDM-3	do.	215	DM-16	do.	244
SDM-4	do.	198	DM-17	do.	185
SDM-5	do.	144	DM-18	do.	173
SDM-6	do.	130	DM-19	do.	174
SDM-7	do.	76	DM-20	do.	113
SDM-8	do.	61	DM-21	do.	105
SDM-9	do.	8	DM-22	do.	41
SDM-10	do.	7	DM-23	do.	35
SDM-11	December 15, 1962	CVC-1DD-209	DM-24	January 2, 1964	CRD-1EE-271
SDM-12	do.	268	DM-25	January 13, 1964	CRD-3EE-30
SDM-13	do.	200	DM-26	do.	41
SDM-14	do.	199	DM-27	do.	40
SDM-15	do.	142	DM-28	do.	107
SDM-16	do.	129	DM-29	do.	115
SDM-17	do.	76	DM-30	do.	114
SDM-18	do.	77	DM-31	do.	183
SDM-19	do.	59	DM-32	November 30, 1963	DMT-4EE-101
			DM-33	December 2, 1963	112
DM-1	February 5, 1963	CGS-1DD-22	DM-34	do.	231
DM-2	do.	46	DM-35	do.	230
DM-3	do.	47	DM-36	November 10, 1963	DMT-3EE-228
DM-4	do.	49	DM-37	do.	115
DM-5	do.	51	DM-38	do.	94
DM-6	do.	53	DM-39	do.	DMT-1EE-271
DM-7	do.	12	DM-40	do.	250
DM-8	do.	10	DM-41	do.	143
			DM-42	do.	118

Appendix C
Acreages of the Total Area, River Bed, Flood Plain, Cleared Areas, and Area of Phreatophyte Occurrence Along Major Streams

STREAM	TOTAL AREA	-	RIVER BED	=	FLOOD PLAIN	-	AREA CLEARED	=	AREA OF PHREATOPHYTE OCCURRENCE
White River	2,516		865		1,651		99		1,552
upper Salt Fork	3,658		1,300		2,358		6		2,352
lower Salt Fork	16,191		4,023		12,168		581		11,587
SUBTOTAL	22,365		6,188		16,177		686		15,491
upper Double Mountain Fork	5,265		1,960		3,305		117		3,188
North Fork Double Mountain Fork	5,764		2,299		3,465		81		3,384
lower Double Mountain Fork	16,622		5,056		11,566		1,678		9,888
SUBTOTAL	27,651		9,315		18,336		1,876		16,460
TOTAL	50,016		15,503		34,513		2,562		31,951

Appendix D
Acreages of Phreatophytes Along the Salt Fork Brazos River and Major Tributaries

PHREATOPHYTES	WHITE RIVER	UPPER SALT FORK	LOWER SALT FORK	TOTAL
Saltcedar dominated	792	916	7,721	9,429
Saltcedar alone	671	797	7,238	8,706
Saltcedar-baccharis	121	119	483	723
Mesquite dominated	448	1,411	3,816	5,675
Mesquite alone	352	1,387	3,732	5,471
Mesquite-saltcedar	10	–	84	94
Mesquite-sand sagebrush	86	24	–	110
Cottonwood dominated	128	25	50	203
Cottonwood alone	107	25	45	177
Cottonwood-saltcedar	21	–	–	21
Cottonwood-mesquite	–	–	5	5
Sand sagebrush	184	–	–	184
TOTAL	1,552	2,352	11,587	15,491

Appendix E
Acreages of Phreatophytes Along the Double Mountain Fork Brazos River and Major Tributaries

PHREATOPHYTES	UPPER DOUBLE MOUNTAIN FORK	NORTH FORK DOUBLE MOUNTAIN FORK	LOWER DOUBLE MOUNTAIN FORK	TOTAL
Saltcedar dominated	1,660	1,508	5,470	8,638
Saltcedar alone	1,415	1,128	4,502	7,045
Saltcedar-baccharis	245	380	968	1,593
Mesquite dominated	1,528	1,744	2,176	5,448
Mesquite alone	824	1,706	2,176	4,706
Mesquite-saltcedar	73	–	–	73
Mesquite-sand sagebrush	631	38	–	669
Cottonwood dominated	–	71	2,222	2,293
Cottonwood alone	–	46	878	924
Cottonwood-saltcedar	–	–	1,107	1,107
Cottonwood-mesquite	–	25	237	262
Sand sagebrush	–	61	–	61
Other	–	–	20	20
TOTAL	3,188	3,384	9,888	16,460