A STUDY OF PHREATOPHYTE GROWTH IN THE LOWER ARKANSAS RIVER VALLEY OF COLORADO

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INTRODUCTION

The study reported herein is a part of a larger research investigation concerned with the interrelationships of surface water and ground water in the lower Arkansas River Valley of Colorado. This larger investigation, sponsored by the Colorado Department of Natural Resources, is being conducted jointly by the U. S. Geological Survey and Colorado State University.

Reason for Study

Initial studies of the interrelationships of surface water and ground water were centered in the reach of the Arkansas River Valley between La Junta and Las Animas, Colorado. This reach of the Valley is referred to as the "study area" in this report.

Preliminary analyses of hydrologic records from the study area revealed (1) an increasing amount of water has been consumptively used over the years, and (2) the consumption of water by phreatophytes represents an economically important portion of the water used.

Because of these indications, it was decided to obtain additional information to help evaluate the influence of phreatophyte growth on water consumption.

Scope

The scope of this report is limited to the following:

1. Presentation of the results of a field survey conducted to determine the areal extent, the species, and the density of phreatophyte growth in the study area.
2. Estimation of the change in phreatophyte growth in the study area with time, using aerial photographs taken in 1936, 1947 and 1957.
3. Estimation of the annual volume of water consumed by phreatophytes in the study area.
4. Extension of field survey results within the study area to the entire Arkansas River Valley between Pueblo and the Colorado-Kansas State Line.

Acknowledgements

Several individuals and agencies were helpful in conducting the field work and in reviewing the results. Those active in planning and assisting the field work include Robert A. Longenbaugh, George Palos and Edmund Schulz, all of the Civil Engineering Section at Colorado State University. The excellent cooperation given by landowners, for the entrance of the surveyors upon their land, was sincerely appreciated. County Agents, and personnel of the Soil Conservation Service, Agricultural Stabilization and Conservation Committee and Bureau of Reclamation were all helpful in providing information.

Several members of the Pacific Southwest Inter-Agency Committee, Phreatophyte Subcommittee, have critically reviewed and provided comments on a preliminary report of this work. These include J. S. Horton (USDA Forest Service), T. W. Robinson (USDI Geological Survey), Harry S. Blaney (retired, USDA Agricultural Research Service) and Leonard Kuiper (Colorado Water Conservation Board). In addition, Floyd Brown, Norman Evans and Bernard Frank of Colorado State University have reviewed the earlier report and provided many helpful comments.

DESCRIPTION OF AREA

For the purpose of this report, the Lower Arkansas River Valley of Colorado is defined as the main-stem valley between the City of Pueblo and the Colorado-Kansas state line. This represents a distance of approximately 150 miles. The valley ranges generally from two to four miles in width. Agriculture is the largest water user, however industry and municipal water requirements are rapidly increasing.

Surface Water Development

Diversion of surface flows of the Arkansas River for irrigation began in the 1860's and increased rapidly through 1890. As in many similar cases in the West, appropriated water rights soon totaled more than the average flow of the river.

The valley is generally underlain with alluvial sands and gravels which have filled an erosion channel in the bedrock. This serves as an effective ground-water reservoir. During the years of initial irrigation development significant amounts of water reached this reservoir from overlying irrigation operations. As the water table built up to and above the stream-bed level, the Arkansas River became a "gaining" stream throughout most of its length. Additional appropriators in the lower valley diverted this "return flow" and put it to use. Thus the over-all efficiency of use of water in the Arkansas Valley is relatively high, made possible by the permeable materials underlying the valley.

Ground-Water Development

With the advent of better well-drilling methods, efficient pumps and the availability of electrical power, the development of ground-water to supplement surface-water supplies increased rapidly, particularly in the drouth period of the early 1950's. Today approximately 1400 large-capacity wells are pumped in the Lower Arkansas Valley, nearly all of which are below irrigation canals and are used to supplement canal deliveries. Development of the ground-water reservoir has resulted in increased beneficial use of water by supplying late season needs in all years, as well as major needs during low-runoff years.

Study Area Hydrology

Stream-flow records are available from 1939 to date for the Arkansas River at Las Animas. Records for La Junta are available for a longer period. Two irrigation ditches divert water from the river between La Junta and Las Animas--the Las Animas Town Ditch and the Las Animas Consolidated Ditch.

River Gain

River gain, as defined in this study, is the net difference between measured inflows and measured outflows of a river reach. For the study area, river gain has been computed by the following:

River gain = River outflow at Las Animas
+ Diversions by the Las Animas Town Ditch
+ Diversions by the Las Animas Consolidated Ditch
- River inflow at La Junta.

During the 22-years from 1940 through 1961 the average annual gain in the river as it passed through the study area was 22,100 acre-feet. The average for the first half of this period (1940 through 1948) was 29,800 acre-feet, whereas the average gain for 1949 through 1961 was only 14,500 acre-feet.

The reduction in river gain indicates an increasing amount of water is being used in the study area. Some of the increased use is going into the production of crops but undoubtedly a portion is being used by phreatophyte growth. This study is concerned with evaluating the suspected increased use of water by phreatophytes.

FIELD SURVEY - LA JUNTA TO LAS ANIMAS

The procedure for mapping phreatophytes as outlined by Horton et.al. (1962) was followed in this study. In brief, this procedure requires the following steps:

1. Classification of vegetative types on aerial photographs.

2. Checking of these types by reconnaissance survey on the ground and from the air.

3. Determination of the number of samples required from each vegatative type to obtain statistically accurate estimates of density and species.

4. Establishment of access lines through the phreatophyte growth.

5. Selection of sampling points.

6. Collection of data.

Delineation of Vegetative Types

Five classifications of woody phreatophyte growth, based upon density and type of vegetation, were delineated on aerial photographs* of the study

* Aerial photographs taken in 1957 for the U. S. Department of Agriculture.

area. A field check and flight over the area was made prior to sampling, with a few changes being made to improve conformation with the situation as of 1962. No further changes in types or boundaries were made after the sampling began, although minor inaccuracies were found. Table 1 summarizes the five classifications and gives the acreage of each type area.

Two classifications of herbaceous growth were delineated. These, along with acreages, are also shown in Table 1. Admittedly, it is somewhat arbitrary to limit the extent of Type VII to areas having a depth to water table of less than five feet, but it was not practical to attempt to classify into finer subdivisions at this time.

As shown in Table 1, the total area of tree and shrub growth is over 3600 acres.

Field Sampling Procedure

Access lines were cut through the phreatophyte growth on each north-south section line lying across the study area. For convenience these were assigned identification numbers, starting from the west end. Thus line one is the boundary between sections one and two, Township 24 North, Range 55 West, lying just east of the Highway 194 bridge over the Arkansas River at La Junta. Location of each access line (or transect line as they are referred to herein) is given in Appendix II.

Number of Samples

The lineal feet of transect line traversing each vegetative type was scaled from aerial photographs. These distances are shown in Appendix II. It was assumed that samples could be taken at 10-foot intervals. Therefore, the total possible samples were as follows:

Type I -----	155
Type II -----	372
Type III -----	1,066
Type IV -----	729
Type V -----	424

The range of variation of density within each vegetative type was estimated in the field. Using this information, the estimated number of samples in each type required to obtain an accuracy of $\pm$ 10% was determined using the nomograph presented by Horton et.al. (1962).

Method of Sampling

Sample locations were chosen using a random-number table. The locations of the samples for each vegetative type are shown in Appendix IV.

Table 1

Vegetative Type Classifications, Arkansas Valley Study Area

Tree and Shrub Growth			
Type I - Dense brush, few trees ----	458 Acres		
Type II - Medium brush, few trees ----	432 Acres		
Type III - Dense brush and trees ------	1,280 Acres		
Type IV - Medium brush and trees -----	646 Acres		
Type V - Trees, light brush ---------	841 Acres		
Subtotal, trees and shrubs -----		3,657 Acres	
Herbaceous Growth			
Type VI - Reeds, cattails, etc., generally growing in recently cutoff meanders of the river channel -	115 Acres		
Type VII - Saltgrass, weeds and other herbaceous vegetation growing outside of Tree-Shrub areas but where depth to the water table averages less than five feet* ---------------------	2,000 Acres		
Subtotal, herbaceous growth ----		2,115 Acres	
Total, phreatophyte growth -----		5,772 Acres	

* Water table information furnished by the Ground Water Branch of the U. S. Geological Survey, Denver.

At each sample location a 100-foot tape was laid out perpendicular to the transect line. The samples were taken consistently to the west of the transect line unless either a distance of 100-feet was not obtainable to the west because of the river, or several samples fell in successive 10-foot intervals. In the latter situation, one of the lines was taken eastward, with the others to the west as usual.

The amount of vegetative cover extending over the 100-foot tape was recorded for each sampling station. In addition, each species of phreatophyte providing canopy cover over the tape along with its total height and crown depth (vertical thickness of foliage) was determined. Because the canopy of larger trees often extended over smaller growth, instances of more than 100% cover occurred.

Results of Field Sampling

Field sampling disclosed that the trees identified on the aerial photographs were predominantly cottonwoods, with an occasional willow of sufficient size to be identified as a tree. The over-all area of willows is small, and in gneral the growth is young and occurs in dense thickets where it was identified as brush on the aerial photographs. The predominant shrub or brush was saltcedar (Tamarisk).

A summary of information obtained in the field sampling is given in Tables 2, 3, 4 and 5. The following paragraphs explain items in these tables.

Cover Intercepts

The cover intercept for each of the three species (cottonwoods, saltcedar and willow) was computed by dividing their respective total intercept distances by the number of samples. Since each sample length was 100 feet, this calculation results directly in the per cent of cover. The sum for each type area is larger than the net cover (actual shaded area) because of overlap.

Net Cover Intercept or Shaded Area

The net cover intercept or shaded area takes into account the overlapping of foliage, i.e., tree canopy over brush canopy. The overlapping was not large, ranging from an average of 2.0% in Type II up to 5.6% in Type V.

Open Area

The open area is the net unshaded area and was computed by subtracting the percentage of net cover intercept from 100.

Density Calculations

Data for each of the species of woody phreatophytes are summarized separately in Tables 3, 4 and 5. In addition to data on cover intercepts, these tables present information on total height and on depth of crown. The crown depth was used to compute the foliage volume, vertical density and area at 100% volume density as follows:

Foliage Volume--The summation of crown depth times cover intercept for each tree and shrub, divided by the total intercept distance for each species provides a weighted average crown depth for each species in each type area. This weighted average multiplied by the area of each species adjusted, to a 100% cover basis, provides an estimate of the volume of foliage.

Vertical Density--Each species growing in a particular soil-water-climate relationship will tend to develop a characteristic or standard height and crown depth. For calculations of vertical density, the average weighted crown depth is compared to this standard. For the study area, a standard crown depth for cottonwood was assumed at 35 feet and for saltcedar, 7 feet. The standard crown depth for willows was assumed at 20 feet in Type I (trees), but only 9 feet in the other type areas.

Area at 100% Volume Density--The calculated vertical density for each species in each type area was multiplied by the area of each adjusted to 100% cover intercept to obtain the equivalent area at 100% density.

Reliability of Data

In general, estimates of the range of cover intercept in the five vegetative types made prior to sampling were too low. The principal reason for the wide range found during sampling lies in the fact that the vegetation has developed in bands corresponding to old river channels (see fig. 2) which lie approximately perpendicular to the north-south section lines. Thus the sample line often fell wholly within a band containing no trees or within a band of high density. Less variation would have been encountered had the sampling lines been run north and south rather than east and west.

Figure 1 graphically shows the means, standard errors and 95% confidence intervals of cottonwood and saltcedar cover intercepts. It will be noted that Vegetative Types I and III were similar in both saltcedar and cottonwood cover. Additional samples may have more clearly identified the differences, but for the purposes of this study the two classifications could have been combined into one.

The differences in Types III, IV and V show up well in Figure 1. The classifications originally made from the aerial photographs anticipated an increase in tree cover and decrease in brush or shrub cover as one goes from Type III to Type V. This was borne out by the measurements as indicated in the Figure.

Table 2

Summary of Sampling Results

	Vegetative Type Classification					
	I	II	III	IV	V	Total
Gross Area, (acres)-----	458	432	1280	646	841	3657
Number of Samples-------	35	33	35	68	40	211
Number of Samples With Tree or Shrub Cover---	33	27	34	66	34	194
Cover Intercepts, (%):						
Cottonwood------	13.91	4.85	8.80	19.38	29.98	15.71
Saltcedar-------	38.37	17.48	46.46	25.00	13.42	30.63
Willow----------	1.40	2.21	0.29	3.53	5.10	2.33
Total*	53.68	24.54	55.55	47.91	48.50	48.67
Net Cover Intercept, (%)-	51.00	22.54	53.46	43.54	42.92	45.31
Overlap of Layers, (%)---	2.68	2.00	2.09	4.37	5.58	3.36
Net Open Area, (%)-------	49.00	77.46	46.54	56.46	57.08	54.69
Net Canopy Cover, (acres)	234	97	684	281	361	1657
Net Open Area, (acres)---	224	335	596	365	480	2000

* Total cover intercept includes overlap of canopy layers.

Table 3

Cottonwood Summary

	Vegetative Type Classification I	II	III	IV	V	Total or Overall Av.
Gross Area, (acres)	458	432	1280	646	841	3657
Number of Samples	35	33	35	68	40	211
Cottonwoods:						
No. of Samples Containing Cottonwoods	18	6	11	42	25	101
Cover Intercept:						
(1) Range, (%)	0-68	0-57	0-100	0-87	0-80	0-100
(2) Average, (%)	13.91	4.85	8.80	19.38	29.98	15.71
(3) Area at 100% (ac)	64	21	113	125	252	575
Height:						
(1) Range, (ft)	15-55	4-36	12-45	8-61	13-56	4-56
(2) Av. Height, (ft)	35.6	21.5	30.9	37.2	38.7	35.87
Crown Depth:						
(1) Range, (ft)	10-50	4-26	9-35	3-51	8-50	3-51
(2) Av. Depth, (ft)	29.2	15.5	21.9	31.2	30.7	28.4
Foliage Volume, (ac-ft)	1860	326	2466	3906	7739	16,297
Vertical Density* (%)	83.4	44.3	62.6	89.1	87.7	81.1
Area at 100% Vol. Density, (acres)	53	9	71	112	221	466

* Assuming 35-foot crown depth as 100% vertical density.

Table 4

Saltcedar Summary

	Vegetative Type Classification					
	I	II	III	IV	V	Total or Overall Av.
Gross Area, (acres)----------	458	432	1280	646	841	3657
Number of Samples------------	35	33	35	68	40	211
Saltcedars:						
No. of Samples Containing Saltcedars--------	31	25	33	60	20	169
Cover Intercept:						
(1) Range, (%)-----	0-100	0-52	0-100	0-66	0-52	0-100
(2) Average, (%)---	38.37	17.48	46.46	25.00	13.42	30.63
(3) Area at 100%--- (ac)	176	75	595	161	113	1120
Height:						
(1) Range, (ft)----	1-12	1-10	2-15	1-12	1-12	1-15
(2) Av., (ft)------	6.9	5.0	6.6	6.9	5.1	6.4
Crown Depth:						
(1) Range, (ft)----	1-12	1-10	2-15	1-12	1-12	1-15
(2) Av. (ft)-------	6.9	4.8	6.6	6.9	5.1	6.4
Foliage Vol., (ac-ft)-	1212	362	3925	1114	576	7189
Vertical Density*, (%)	98.7	68.6	94.3	98.7	72.8	91.6
Area at 100% Vol. Density, (acres)-------	173	52	561	159	82	1027

* Assuming 7 ft crown depth as 100% veartical density.

Table 5

Willow Summary

	Vegetative Type Classification					
	I	II	III	IV	V	Total or Overall Av.
Gross Area, (acres)----------	458	432	1280	646	841	3657
Number of Samples------------	35	33	35	68	40	211
Willows:						
No. of Samples Containing Willows-----------	5	6	2	21	8	42
Cover Intercept:						
(1) Range, (%)-----	0-27	0-23	0-8	0-31	0-100	0-100
(2) Average, (%)---	1.40	2.21	0.29	3.53	5.10	2.33
(3) Area, (ac)-----	6	9	4	23	43	85
Height:						
(1) Range, (ft)----	3-35	2-14	3-10	1-11	1-25	1-35
(2) Av., (ft)------	23.6	6.0	8.6	6.6	7.7	10.7
Crown Depth:						
(1) Range, (ft)----	1-27	2-14	3-10	1-11	1-20	1-27
(2) Av., (ft)------	19.6	6.0	8.6	6.3	7.6	8.0
Foliage Volume, (ac-ft)	125	57	32	144	326	684
Vertical Density*, (%)	98.0	67.7	95.6	70.0	84.4	80.2
Area at 100% Vol. Density-----------	6	6	4	16	36	68

* Assuming 20 ft and 9 ft as 100% vertical density for Type I and II-IV, respectively.

Phreatophyte Growth in Relation to Depth to Ground Water

A comparison of phreatophyte growth in relation to the depth to ground water is shown in Table 6. Using a preliminary depth-to-ground-water map prepared by the U. S. Geological Survey it was found that about 83% of the tree and shrub growth occurs in areas where the water table is within five feet of the ground surface. The ground water level fluctuates approximately one foot during the period of a year, therefore the area having a depth to water table of less than five feet varies. Records available from the U. S. Geological Survey indicate this area is at its largest during the summer, probably due to losses from irrigation activities. Observation during 1962 indicated a significant amount of irrigation tail water draining from irrigated fields into the phreatophyte growth along the river.

Table 6

Relationship of Phreatophyte Growth to Water Table Depth

Vegetative Type	Acreage	Percent of Acreage at Water Table Depths of:		
		0-5'	5-10'	>10'
I - Dense brush, few trees	458	74.3	24.0	1.7
II - Med. dense brush, few trees	432	85.4	11.6	3.0
III - Dense brush and trees	1280	80.7	18.6	0.7
IV - Med. brush and trees	646	89.0	10.0	1.0
V - Trees, light brush	841	84.9	14.9	0.2
All Types	3657	82.8	16.2	1.0

CHANGE IN PHREATOPHYTE GROWTH, 1936-1957

Aerial photographs of the study area taken in 1936, 1947 and 1957* were used to determine the change in area of phreatophyte growth with time. As shown in Table 7, an over-all increase of about 520 acres occurred between 1936 and 1947; an average of 47 acres per year. During the period from 1947 to 1957 an average increase of 57 acres per year occurred.

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* 1936 photos by SCS, USDA; 1947 photos by USGS, USDI; and 1957 photos by ASC, USDA.

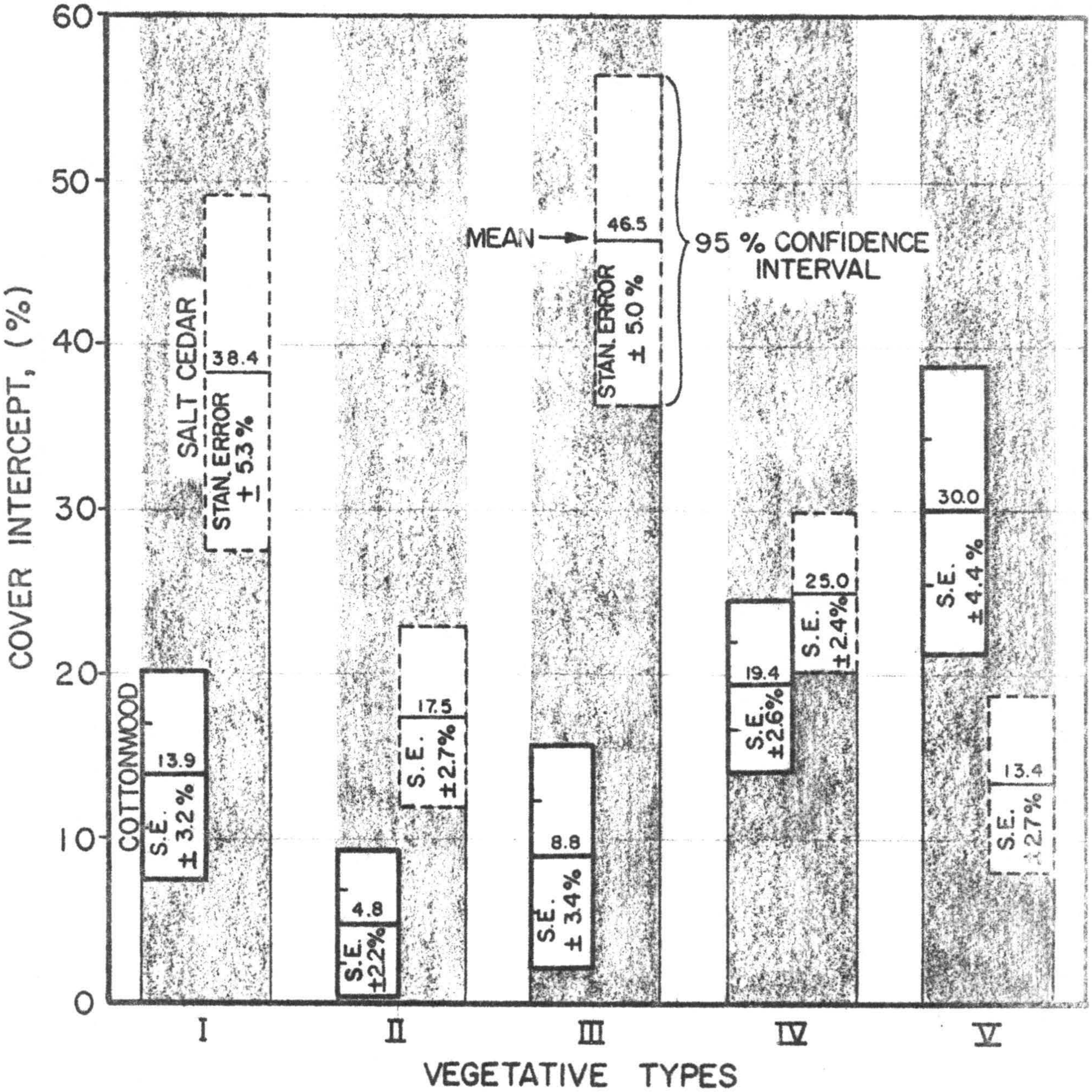

Fig. 1. Cover Intercept Sampling Statistics for Cottonwoods and Saltcedars in each Vegetative Type Classification in the Study Area.

Table 7

Acreages of Phreatophyte Growth in the Study Area, as Determined from 1936, 1947 and 1957 Aerial Photographs

Vegetative Type Classification	Area, Acres 1936	1947	1957
I	574	265	458
II	299	592	432
III	14	813	1280
IV	338	198	646
V	1340	1214	841
Total	2565	3082	3657

Density Changes

A change of possibly more significance than the change in area occurred in the density of cover. Although cover intercept is difficult to evaluate quantitatively from aerial photographs, it was apparent that many areas which contained only a scattered growth of cottonwood trees in 1936, experienced significant encroachment of saltcedar by 1957. Comparative photographs illustrating this encroachment are shown in Figure 2.

It will be noted in Table 7 that classification V (trees, light brush) was the predominant type in 1936, whereas in 1957 classification III (dense brush and trees) was the largest. Classification III increased by 1266 acres,while classification V decreased by about 500 acres during the 21-year period.

Effects of Stream Meandering and Floods

A reason for the increase in phreatophyte acreage can be deduced from a study of the meandering of the Arkansas River between 1936 and 1957. During this period the meander loops have extended noticeably into new land, leaving the insides of the loops available for the establishment of additional phreatophyte growth.

Because saltcedar seedlings require abundant moisture for a critical two or three week period immediately following sprouting, the increased growth during the 1936-1957 period is probably associated with high-water periods. Records of discharge from the La Junta and Las Animas gaging stations indicate some overflow occurs nearly every spring. Major flooding occurred principally in the years 1942, 1944, 1947 and 1955. It is likely that these floods were instrumental in spreading and propagating additional saltcedar growth.

SCS Photo No. AG 317 58

ASC Photo No. DMU-1T-18

Fig. 2. Comparison of 1936 and 1957 Phreatophyte Growth from Aerial Photographs.

WATER CONSUMPTION BY PHREATOPHYTES

Many field determinations and estimates of water consumption by phreatophytes have been made, principally in the Southwestern United States. Blaney (1961) has reviewed and summarized many of the important studies. Gatewood, et. al., (1950) determined that saltcedar growing in tanks in Arizona at 100% volume density (based on a standard canopy depth of 13 feet) consumed between 7 and 9 feet of water when the water table was 4 to 8 feet below the ground surface. In the same study, cottonwoods at 100% volume density used an average of 6 feet of water annually. Other studies reported by Blaney (1961) and Robinson (1958) in New Mexico and California indicate approximately the same range of values.

Temperatures in the Arkansas Valley are lower and the growing season shorter than those areas further to the southwest. Blaney and Criddle (1949), correcting for temperature and percent of daylight hours, have made the following estimates of consumptive use of water by native vegetation in this section of the Arkansas Valley:

Dense native vegetation-----------42.0 inches (3.5 ft)
Medium native vegetation----------35.0 inches (2.92 ft)
Light native vegetation-----------28.0 inches (2.33 ft).

Estimated Current Annual Consumptive Use

Annual water consumptive use by phreatophytes in the study area is estimated in Table 8. The consumptive use values for individual species are not defensible within plus or minus 10%. Therefore in view of possible inaccuracies in areas and in the percent of cover, the total estimated consumptive use carries an accuracy of about plus or minus 20%, or 3000 acre-feet.

Table 8

Estimated Annual Consumptive Use by Phreatophytes in the La Junta - Las Animas Reach of the Arkansas River Valley

Tree and Shrub Growth*	Estimated Annual Consumptive Use
Cottonwoods, (575 acres at 5.5 ft)	3,162 acre-feet
Saltcedars, (1120 acres at 6.5 ft)	7,280 acre-feet
Willows, (85 acres at 5.5 ft)	468 acre-feet
Subtotal	10,910 acre-feet
Herbaceous Growth	
Type VI (115 acres at 6 ft)	690 acre-feet
Type VII (2000 acres at 1.5 ft)	3,000 acre-feet
Total	14,600 acre-feet

* Acreages converted to equivalent acreage at 100% cover intercept.

Estimated Change in Consumptive Use, 1936-1957

The changes in area and in vegetative types, as determined from 1936 and 1957 aerial photographs, was discussed in an earlier section. Conversion of this information to changes in consumptive use is hazardous, but nevertheless, of considerable interest. To arrive at the approximate annual consumptive use of water by trees and shrubs in 1936 the following procedure was used:

1. The estimated water use by each vegetative type classification in 1957 was computed. For instance, in Type I; 63.7 acres of cottonwoods at 5.5 feet, 175.7 acres of saltcedars at 6.5 feet, and 6.4 acres of willows at 5.5 feet gives 1528 acre-feet of water use.

2. The depth of consumptive use for each classification was determined by dividing the estimated volume (from 1) by the 1957 gross area. These depths are:

Type	I	3.34 feet
Type	II	1.52 feet
Type	III	3.52 feet
Type	IV	2.88 feet
Type	V	2.80 feet

3. Using areas determined from 1936 aerial photographs and the above figures, estimates were made for 1936. These are:

Type	I	1,583 acre-feet
Type	II	454 acre-feet
Type	III	49 acre-feet
Type	IV	973 acre-feet
Type	V	3,752 acre-feet
Total (rounded to nearest 100 acre-foot)		6,800 acre-feet

Therefore, using the above procedure, the increased annual consumptive use by phreatophyte trees and shrubs during 1936-1957 in the study area was approximately 4,100 acre-feet. Because of the difficulty in classifying the type of growth and densities from the 1936 aerial photographs, it should be emphasized this figure is subject to considerable error. However, it is felt the figure is on the conservative side in that it is unlikely that the average cover intercept and vertical density within each classification was as high in 1936 as in 1957.

Extension to Entire Arkansas River Valley, Pueblo - State Line

Aerial photographs taken in 1956 and 1957 on file at County Agricultural Stabilization and Conservation offices were consulted to determine the acreage of woody phreatophytes between Pueblo and the Colorado-Kansas Line. Only those trees and shrubs occupying the valley immediately adjacent to the river were considered. Classification into the five vegetative types was made and areas were planimetered. The gross-area consumptive use factors determined for the La Junta to Las Animas reach were then applied to the rest of the valley. Table 9 shows a summary of this analysis.

An approximation of the degree of encroachment of saltcedar can be deduced from Table 9. For instance, Types I and III represent the areas having the most dense shrub growth and Type II and V the least dense. The percentage of the total phreatophyte area taken up by Types I and III are as follows:

Pueblo to Nepesta--------	13.0%
Nepesta to La Junta------	23.6%
La Junta to Las Animas---	47.5%
Las Animas to John Martin Dam--------------	58.4%
John Martin Dam to Colorado-Kansas Line-----	18.0%

This analysis indicates an increasing density of saltcedar as one goes from Pueblo to the John Martin Reservoir, with a significant reduction below the reservoir. The reasons for the reduction below the reservoir are uncertain, but the control of floods since completion of the dam in 1948 is undoubtedly a factor. In addition it appears the river channel may be in more resistant material in this section since meandering is much less pronounced.

SUMMARY AND CONCLUSIONS

A field survey of phreatophyte growth in the bottomland area of the Arkansas River Valley between La Junta and Las Animas, Colorado, was conducted in 1962. Tree and shrub growth was classified into five vegetative types, determined from 1957 aerial photographs. The following points summarize the results and the conclusions obtained:

1. Approximately 3660 acres of phreatophyte trees and shrubs were growing in the study area in 1957. This compares with 3082 and 2565 acres, respectively, in 1947 and 1936. (Note this does not include phreatophyte growth along tributaries to the Arkansas, such as Horse Creek.)

Table 9

Estimated Consumptive Use of Water By
Woody Phreatophytes, Arkansas River Bottom
Pueblo to State Line

Vegetative Type	Pueblo to Nepesta		Nepesta to La Junta		La Junta to Las Animas		Las Animas to John Martin Dam		John Martin Dam to Colo. Kans. Line	
	(Acres)	(Ac-Ft)	(Acres)	(Ac-Ft)	(Acres)	(Ac-Ft)	(Acres)	(Ac-Ft)	(Acres)	(Ac-Ft)
I	12	40	202	674	458	1,530	439	1,467	890	2,973
II	1,144	1,738	684	1,040	432	657	432	657	4,269	6,498
III	650	2,287	1,285	4,523	1,280	4,506	384	1,351	662	2,329
IV	551	1,587	879	2,533	646	1,861	73	210	1,318	3,796
V	2,809	7,866	3,258	9,122	841	2,355	80	224	1,479	4,142
Total*	5,170	13,500	6,310	17,900	3,660	10,900	1,410	3,900	8,620	19,700

Total Area = 25,170 acres

Total Estimated Consumptive Use = 65,900 acre-feet

* Totals are rounded to the nearest 10 acres and 100 acre-feet.

2. At least 83 percent of the tree and shrub growth enjoys a water table at less than five feet below the surface during the growing season.

3. Cottonwoods are the predominant species of trees, whereas saltcedar is the predominant shrub. Willows constitute a small part of the total tree and shrub growth.

4. An increase in area of tree and shrub growth between 1936 and 1957 has occurred, averaging approximately 50 acres per year. An increase in density has also occurred, primarily due to encroachment of saltcedar into areas formerly occupied by only cottonwood growth.

5. An estimated 15,000 ± 3000 acre-feet of water is now consumed annually by phreatophytes along the Arkansas River between La Junta and Las Animas. Of this total, approximately 11,000 acre-feet is due to tree and shrub growth.

6. Increase in water use by tree and shrub growth amounted to at least 4000 acre-feet between 1936 and 1957, or an average of about 200 acre-feet per year.

7. Extension of study area results to the entire Arkansas Valley from Pueblo to the Colorado-Kansas line indicates slightly over 25,000 acres of tree and shrub growth using about 66,000 acre-feet of water annually. (These figures do not include growth along tributaries to the Arkansas River).

8. Aerial photographs taken in 1956 and 1957 indicate a decided increase in saltcedar growth as one goes from Pueblo to the John Martin Reservoir. From the reservoir to the Colorado-Kansas boundary saltcedar density becomes less again.

It appears certain that the increasing phreatophyte growth is a factor in the deterioration of the value of junior surface water rights on the Arkansas River. Although it was not the purpose of this study to evaluate the water salvage potential within the study area, a few comments in this regard are in order:

1. Studies should be initiated to determine the economic feasibility and benefits of clearing tree and shrub growth and substituting vegetation which would be of beneficial use.

2. New water rights should not necessarily be acquired by the action of clearing phreatophyte growth, but should accrue to the benefit of present junior rights being injured.

3. Additional benefits could be obtained by lowering the water table, but since this would also cause a reduction in return flow, compensation to lower ditches from ground water sources would be needed. This possibility should have further study. The possibility of a low-flow lined channel for the river should also be explored.

4. Benefits from the phreatophyte growth in stabilizing the stream channel should not be overlooked. Also it is recognized that scattered cottonwood growth is of value as livestock shade and bird nesting. Beneficial use of saltcedar growth is minor, however, and it constitutes a menace which overshadows any possible benefit to the area.

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(3) Gatewood, J. S., Robinson, T. W., Colby, B. R., and others, 1950. Use of Water by Bottom Land Vegetation in Lower Safford Valley, Ariz., U. S. Geological Survey Water Supply Paper 1103.

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(5) Phreatophyte Subcommittee, PSIAC, 1962. Glossary of Terms Relating to the Phreatophyte Problem, Prepared by Task Force on Glossary of Terms, T. W. Robinson, Chairman. Mimeo, 7 p.

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APPENDICES

APPENDIX I

GLOSSARY OF TERMS

(Adapted from References 3 and 5)

Canopy--The cover or crown formed by the green leaves, needles and branches of trees or shrubs.

Consumptive Use--The quantity of water transpired by plants, retained in plant tissue, and evaporated from the plants and surrounding surfaces in a given period.

Cover Intercept--The amount or percent of ground covered or shaded by the vegetation foliage.

Crown Depth--The depth or thickness of the green canopy of leaves, twigs and branches of a tree or shrub.

Herbs--Plants whose stems develop very little wood but consist mostly of soft tissue which generally die each year. Perennial herbs are those whose tops generally die each year but whose roots survive from year to year.

Phreatophyte--A plant that habitually obtains its water supply from the zone of saturation, either directly or through the capillary fringe.

Shrubs--Woody plants more freely branched than trees and frequently having, even at the base, no single main stem. Used herein interchangeably with "brush". The principal distinction between trees and shrubs is one of size.

Stream, Effluent--A stream or stretch of stream which receives water from ground water in the zone of saturation. The water surface of such a stream stands at a lower level than the water table or piezometric surface of the ground-water body from which it receives water.

Trees--Woody plants generally having a single main stem or trunk for some distance above the ground.

APPENDIX II

LOCATION OF TRANSECT LINES

Transect Line Number	Location Between Sections	Township	Range
1	2 │ 1	24S	55W
2	1 │ 6	24S	54-55W
3	31 │ 32	23S	54W
4	29 │ 28 / 32 │ 33	23S	54W
5	21 │ 22 / 28 │ 27	23S	54W
6	22 │ 23	23S	54W
7	14 │ 13	23S	54W
8	13 │ 18 / 24 │ 19	23S	54W
9	18 │ 17	23S	53W
10	8 │ 9	23S	53W
11	9 │ 10	23S	53W
12	3 │ 2 / 10 │ 11	23S	53W
13	2 │ 1	23S	53W
14	1 │ 6	23S	52-53W
15	6 │ 5	23S	52W
16	5 │ 4 / 8 │ 9	23S	52W
17	4 │ 3	23S	52W
18	3 │ 2	23S	52W

APPENDIX III

Length* of each transect line lying across each vegetative type, La Junta to Las Animas

Transect Line Number	Vegetative Type					
	I	II	III	IV	V	Total
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
1	0	350	0	0	106	456
2	0	0	0	0	429	429
3	0	1,220	0	398	0	1,618
4	0	0	264	398	0	662
5	398	0	297	0	132	429
6	264	0	132	725	0	1,021
7	0	0	2,042	0	0	2,042
8	0	0	791	1,482	0	2,273
9	0	1,056	705	0	1,065	2,826
10	0	0	0	176	528	704
11	0	0	295	0	880	1,175
12	0	0	1,320	1,409	705	3,434
13	0	194	827	721	0	1,742
14	528	0	0	1,980	0	2,508
15	0	311	1,351	0	0	1,662
16	0	0	1,582	0	0	1,582
17	363	594	1,056	0	264	2,277
18	0	0	0	0	132	132
Totals	1,553	3,725	10,662	7,289	4,241	

* Measured on 1957 aerial photographs.

APPENDIX IV

A. Location of Samples Obtained From Vegetative Type I

(Dense Brush, few trees)

Transect Line No.	Beginning and Ending* Stations, Type I		Number of Samples	Sampling Stations	
5	0 + 00	2 + 54	3	1 + 80	2 + 20
				2 + 10	
	2 + 54	3 + 98	7	2 + 80	3 + 40
				3 + 00	3 + 80
				3 + 20	3 + 90
				3 + 30	
6	3 + 98	6 + 62	6	4 + 00	4 + 70
				4 + 40	5 + 90
				4 + 50	6 + 50
14	6 + 62	11 + 90	11	7 + 80	10 + 40
				8 + 70	10 + 80
				8 + 80	10 + 90
				8 + 90	11 + 20
				9 + 50	11 + 30
				10 + 30	
17	11 + 90	15 + 53	8	12 + 70	14 + 50
				13 + 60	14 + 90
				14 + 00	15 + 10
				14 + 30	15 + 40

Total, Type I---------------------------------1553 feet, 35 samples.

APPENDIX IV

B. Location of Samples Obtained From Vegetative Type II

(Med. Brush, few trees)

Transect Line No.	Beginning and Ending* Stations, Type II		Number of Samples	Sampling Stations	
1	0 + 00	3 + 50	3	0 + 90 1 + 50	3 + 20
3	3 + 50	8 + 20	3	5 + 70 6 + 20	6 + 50
	8 + 20	15 + 70	7	8 + 50 9 + 90 10 + 00 10 + 30	10 + 70 13 + 10 13 + 90
9	15 + 70	26 + 26	16	16 + 60 16 + 80 17 + 10 17 + 40 17 + 60 19 + 10 19 + 20 19 + 60	20 + 70 22 + 10 22 + 20 22 + 50 23 + 40 24 + 80 25 + 10 25 + 20
13	26 + 26	28 + 20	0	---	
15	28 + 20	31 + 31	0	---	---
17	31 + 31	37 + 25	4	33 + 90 34 + 20	35 + 00 35 + 10

Total Type II ----------------------------------3,725 feet, 33 samples.

APPENDIX IV

C. Location of Samples Obtained From Vegetative Type III (Dense Brush and Trees)

Transect Line No.	Beginning and Ending* Stations, Type III		Number of Samples	Sampling Stations	
4	0 + 00	2 + 64	0	---	
5	2 + 64	5 + 60	0	---	
6	5 + 60	6 + 93	0	---	
7	6 + 93	17 + 63	4	8 + 30 15 + 80	13 + 10 16 + 20
	17 + 63	27 + 35	3	21 + 80 24 + 50	24 + 80
8	27 + 35	35 + 26	5	28 + 10 28 + 30 28 + 80	29 + 10 31 + 60
9	35 + 26	42 + 31	1	40 + 80	
11	42 + 31	45 + 26	1	43 + 70	
12	45 + 26	58 + 46	6	46 + 70 48 + 20 48 + 70	52 + 40 55 + 60 56 + 60
13	58 + 46	61 + 62	0	---	
	61 + 62	66 + 73	1	64 + 90	
15	66 + 73	80 + 24	3	67 + 40 68 + 00	77 + 30
16	80 + 24	96 + 06	4	88 + 10 88 + 40	93 + 00 95 + 10
17	96 + 06	106 + 62	7	99 + 10 99 + 20 99 + 60 101 + 80	101 + 90 102 + 20 106 + 00

Total Type III----------------------------------10,662 feet, 35 samples.

APPENDIX IV

D. Location of Samples Obtained From Vegetative Type IV (Medium Brush and Trees)

Transect Line No.	Beginning and Ending* Stations, Type IV		Number of Samples	Sampling Stations	
3	0 + 00	3 + 98	3	1 + 80	3 + 30
				3 + 20	
4	3 + 98	7 + 96	6	4 + 00	5 + 90
				4 + 40	6 + 50
				4 + 50	7 + 80
6	7 + 96	15 + 21	9	9 + 50	14 + 00
				10 + 30	14 + 30
				10 + 80	14 + 50
				11 + 20	15 + 10
				13 + 60	
8	15 + 21	30 + 03	10	15 + 40	19 + 00
				16 + 90	19 + 60
				17 + 20	25 + 30
				18 + 00	26 + 50
				18 + 20	28 + 50
10	30 + 03	31 + 79	3	30 + 80	31 + 00
				30 + 90	
12	31 + 79	45 + 88	13	33 + 30	40 + 70
				36 + 60	41 + 30
				38 + 10	41 + 40
				38 + 50	42 + 30
				39 + 40	42 + 60
				44 + 70	44 + 80
				45 + 40	
13	45 + 88	53 + 09	8	47 + 20	49 + 50
				48 + 90	50 + 90
				49 + 00	51 + 40
				49 + 30	52 + 30
14	53 + 09	72 + 89	16	55 + 00	60 + 00
				55 + 20	60 + 40
				56 + 00	60 + 50
				56 + 20	62 + 90
				56 + 30	63 + 60
				57 + 50	67 + 00
				58 + 80	68 + 10
				59 + 30	71 + 70

Total Type IV------------------------------7,289 feet, 68 samples.

APPENDIX IV

E. Location of Samples Obtained From Vegetative Type V

(Trees, light brush)

Transect Line No.	Beginning and Ending* Stations, Type V		Number of Samples	Sampling Stations	
1	0 + 00	1 + 06	1	0 + 80	
2	1 + 06	5 + 35	3	1 + 90 2 + 60	2+ 80
5	5 + 35	6 + 67	2	5 + 60	5 + 90
9	6 + 67	17 + 32	12	8 + 30 8 + 70 10 + 90 11 + 40 11 + 50 12 + 10	13 + 00 13 + 70 14 + 20 15 + 10 15 + 30 15 + 50
10	17 + 32	22 + 60	2	17 + 90	21 + 20
11	22 + 60	31 + 40	11	22 + 70 23 + 80 23 + 90 25 + 10 25 + 20 26 + 20	28 + 10 28 + 30 28 + 70 29 + 60 30 + 80
12	31 + 40	38 + 45	6	31 + 70 32 + 00 33 + 40	33 + 90 35 + 40 38 + 00
17	38 + 45	41 + 09	3	38 + 80 39 + 00	40 + 90
18	41 + 09	42 + 41	0	------	

Totals Type V,----------------------------4,241 feet, 40 samples.

* Stationing is from north to south, and consecutive within each classification. For example, in Type V the south edge of that type traversed by transect line one is station 1 + 06, and likewise the north edge of Type V on transect line two begins with 1 + 06.