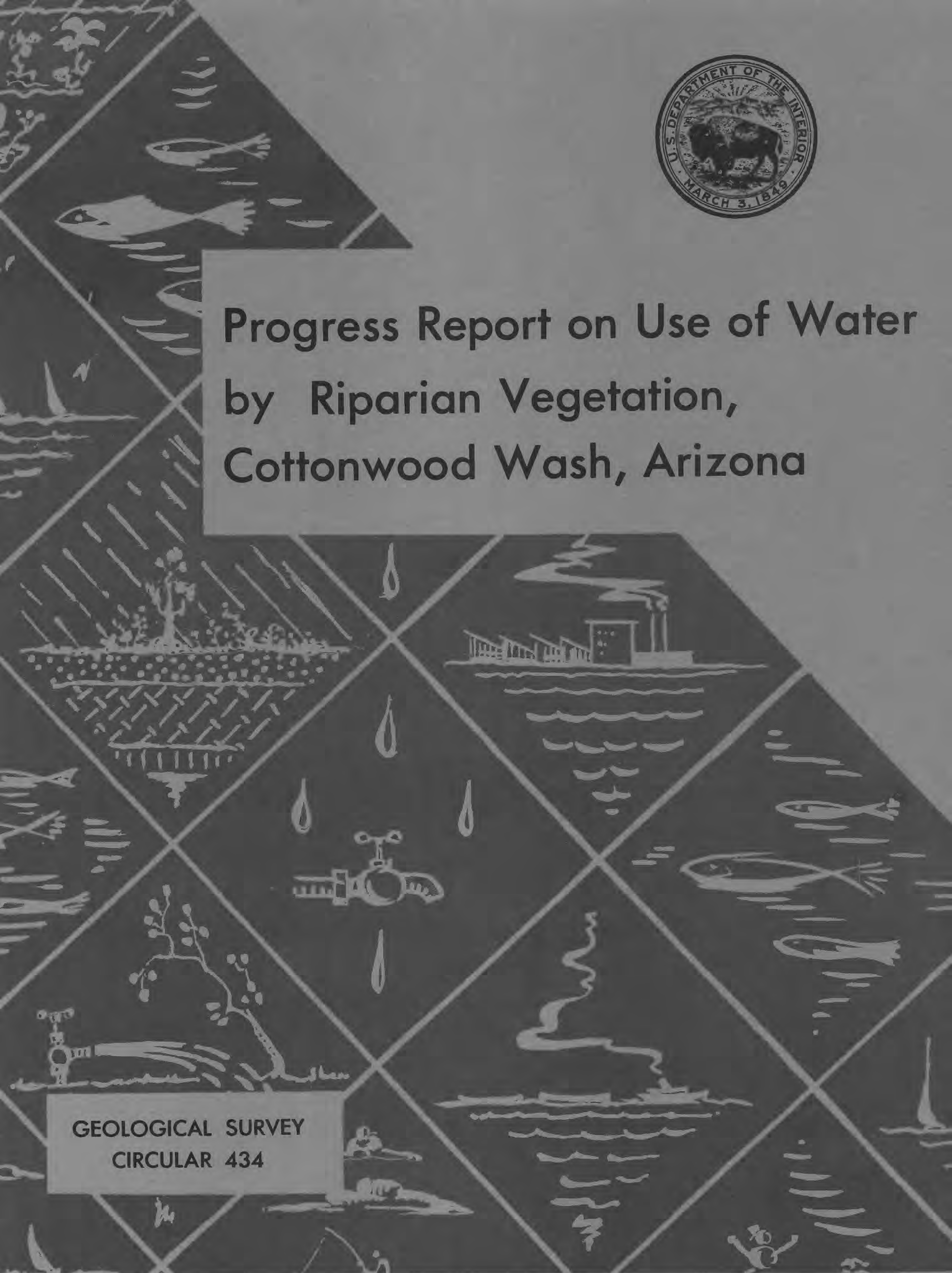
Progress Report on Use of Water by Riparian Vegetation, Cottonwood Wash, Arizona



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PREPARED IN COOPERATION WITH ARIZONA STATE LAND DEPARTMENT AND SALT RIVER VALLEY WATER USERS' ASSOCIATION

Progress Report on Use of Water by Riparian Vegetation, Cottonwood Wash, Arizona

By E. L. Hendricks, William Kam, and James E. Bowie

Prepared in cooperation with Arizona State Land Department and Salt River Valley Water Users' Association

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ABSTRACT

Measurements of streamflow, ground-water levels, and meterological data obtained in a 4.1-mile reach of the flood plain of Cottonwood Wash, Mohave County, Ariz., define the use of water by riparian vegetation in that part of the stream valley. The computed evapotranspiration loss during the growing season of 1959 was 175 acre-feet, which represented about 33 percent of the water that entered the reach. The maximum rate of loss during the season was slightly more than 8 acre-feet per week, or about 60 percent of the inflow.

The project reach is divided into two parts: An upstream subreach of 2.6 miles and a downstream subreach of 1.5 miles. Seasonal losses in the upstream and downstream subreaches were 75 and 100 acre-feet respectively. Losses in the shorter downstream subreach were larger because of the greater plant population.

During the summer of 1960 the vegetation in the lower subreach will be chemically defoliated as a part of the experiment to determine the savings in water losses that can be effected by modifying riparian vegetation. Tests on chemical defoliants indicate that a single spraying eliminates the leaves on cottonwood trees for 7 or 8 days and that no permanent damage results.

INTRODUCTION

Arizona has many thousands of miles of stream channels. Wherever channels carry a sufficient flow of water, their banks are lined with willow, cottonwood, saltcedar, and other water-loving plants. These plants, known as phreatophytes, pump water from the stream or from ground water tributary to the stream as effectively as if man had installed his mechanical pumps to divert water for his use. Thus the flow of many streams is greatly depleted as it travels from where it originates to the points where it can be used beneficially.

The transpiration of water by phreatophytes that line the banks of streams or draw from the water in the flood-plain sediments and the accompanying direct evaporation from water and soil surfaces are known as riparian losses. The losses involve two processes: (a) transpiration, which is the discharge of water vapor through the stomata of the plant leaves; and, (b) evaporation from the water and soil surfaces. These two processes, together, are called evapotranspiration.

Inasmuch as riparian losses by evapotranspiration aggregate large volumes of water, it is natural to inquire whether some of the water dissipated in this manner can be conserved for beneficial use. The most logical direction of inquiry into this question is to investigate the possibility of effecting this conservation by reducing the transpiration of the riparian vegetation. The project on Cottonwood Wash, Ariz., currently in progress, is designed to determine whether a water savings for beneficial use can be accomplished by modifying the vegetation to reduce transpiration losses. The purpose of this report is to describe the progress to date on this project and to indicate the direction that the project will take in future phases of the investigation.

Riparian vegetation, may be modified in two ways; by eradication and by chemical defoliation. Eradication of the vegetation is an extreme measure, for costs are necessarily high and the values of the vegetation would be destroyed. Thus, for these and other reasons any proposal to remove riparian vegetation in large-scale operations would likely meet with strenuous objections from many people. On the other hand, chemical defoliation of vegetation removes the leaves for a very limited time. However, the water savings, if any, would be effective for only a short time. Both methods of vegetation modification may be used in this project.

It is important that the role of the Cottonwood Wash project in relation to the basic question of water conservation by riparian-vegetation modification be seen in proper perspective. For example, the quantitative answers obtained from this project will apply strictly to the reach of Cottonwood Wash selected for study. Also, the present investigation is a pilot study in that it will furnish

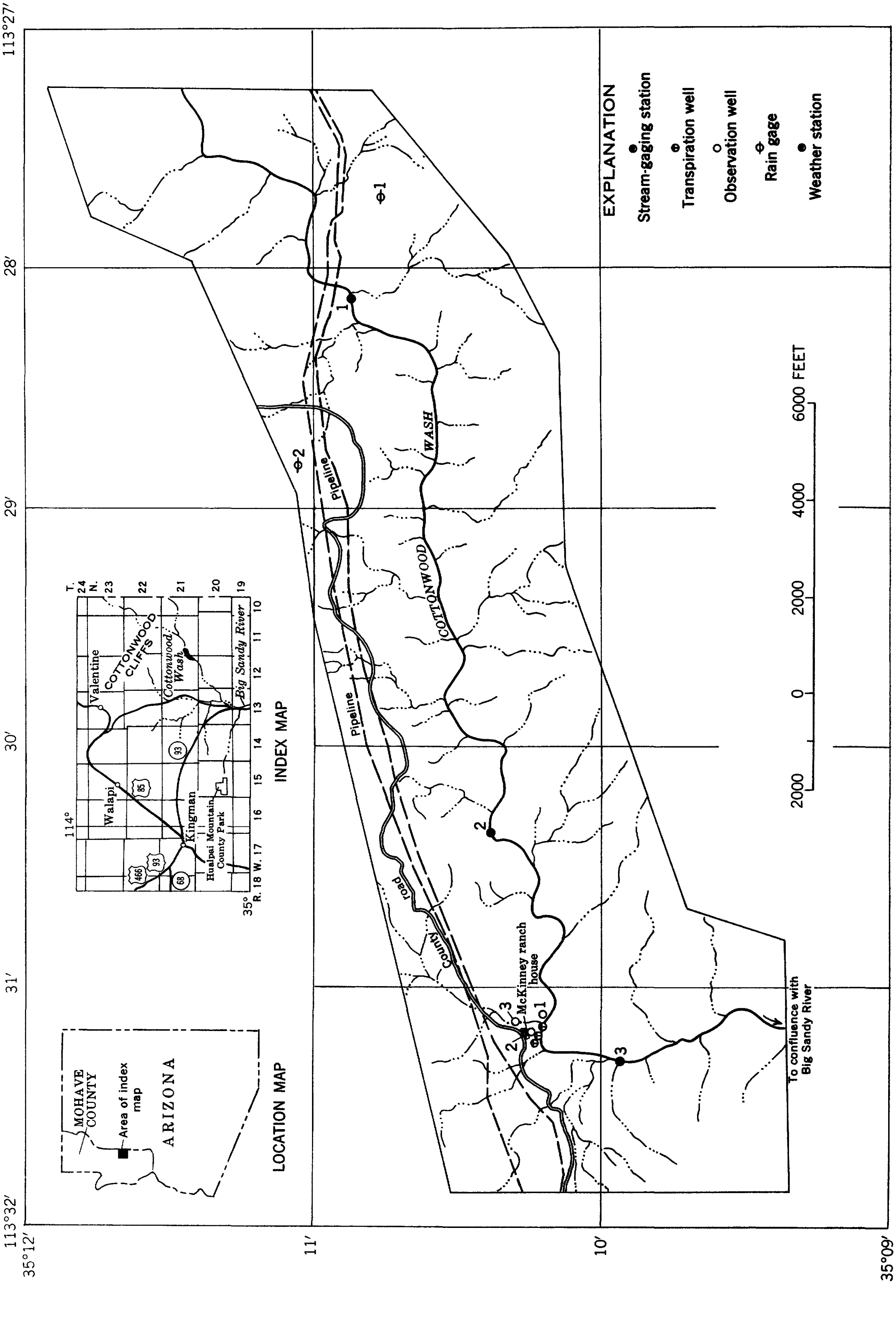

Figure 1.—Map of Cottonwood Wash project area, Mohave County, Ariz.

an answer for one type of environment and in that it is being used as a means to explore the techniques for conducting such studies. Experience is lacking on the kinds of data needed and the techniques to be used for analysis of the data. Similar studies in other environments will be needed before generalizations can be made.

The Cottonwood Wash project is sponsored by the Arizona Water Resources Committee. Installation of the gaging stations and ground-water wells was made possible by financial support of Arizona State Land Department and the Salt River Valley Water Users' Association. The project has subsequently been carried on in cooperation with the Arizona State Land Department.

PROJECT PLAN

A 4.1-mile reach of Cottonwood Wash, beginning at a point about 10 miles upstream from the Big Sandy River, is being used as the study area (fig. 1). For experimental purposes the reach is divided into two subreaches; an upstream subreach 2.6 miles long and a downstream subreach 1.5 miles long. A stream-gaging station at each end of the study reach and one at the dividing point between the upper and lower subreaches, a total of three gaging stations, permit analysis of the changes in streamflow that occur in each of the two subreaches.

The general plan of the experiment is to maintain the upper subreach unchanged throughout the study. Vegetation modifications will be made in the lower subreach to test for water savings. In the first phase of the study, which is now complete, the natural losses in the two subreaches were measured.

In the second phase of the study, which will be started in the spring of 1960, the vegetation on the flood plain of the lower subreach will be chemically defoliated and the duration of the defoliation will be controlled. The water savings, if any, resulting from the reduction in transpiration will be determined by analysis of the streamflow, ground-water, and meteorological records collected during the test period.

If it is shown in the second phase that sensible quantities of streamflow can be conserved by reducing transpiration losses, a third phase of the study will be started later in the summer of 1960. The vegetation in the lower subreach will be permitted to return to its original state and then a large grove of cottonwood and willow trees close above the upstream end of the study reach will be defoliated to determine whether the gain in streamflow obtained therefrom persists unabated through the three measuring points or is partly or completely lost through increased evapotranspiration as the water is being transported downstream.

In a final phase of the study, probably during the winter of 1960–61, it is planned that the flood-plain vegetation in the lower subreach will be removed by cutting. Records will be continued long enough, at least through the following summer and thereafter, to evaluate the effects of the regrowth of vegetation on the streamflow. It cannot, of course, be said at this time precisely how the study will proceed. Decision to conduct any one of the phases of work as outlined will depend on the results of the antecedent work.

GEOLOGY OF THE PROJECT AREA

The geologic environment is a major factor to be considered in the study of the surface-water and ground-water relation in the Cottonwood Wash area. A geologic investigation will be made, therefore, of the immediate area of the pilot study to determine, primarily, whether significant gains or losses in streamflow or ground-water storage are attributable to effluent or influent seepage. Seepage of ground water from tributary valleys or terrace deposits along the canyon walls may contribute to streamflow, or seepage of streamflow into fault zones or joint systems may cause losses from the stream. The following paragraphs give a very brief, general description of the geologic environment of the pilot-study area.

The Cottonwood Wash canyon traverses the Cottonwood Cliffs in southeastern Mohave County, Ariz. That part of the canyon with which this investigation is concerned is located in secs. 25, and 26, T. 21 N., R. 12 W., and secs. 29 and 30, T. 21 N., R. 11 W.

The canyon of Cottonwood Wash is a youthful valley in which the stream has excavated a narrow and relatively steep-walled trench in crystalline rocks. The bedrock floor of the canyon is irregular, resulting in rapids and falls along the stream course, and is covered discontinuously with gravel, sand, and silt. The walls of the canyon, within the area, rise to maximum altitude of about 5,000 feet above sea level and the maximum relief is about 1,000 feet. The average gradient of the stream within the area of study is about 125 feet per mile.

The rocks in the area are principally granite and gneiss of Precambrian age in which the Cottonwood Wash canyon has been cut. Extrusive and intrusive rocks of probable Tertiary age are present in the eastern part of the area. These consist primarily of andesite, tuff, and basalt. Unconsolidated to poorly consolidated sediments of Quaternary age form terrace remnants along the steep slopes of the canyon walls and in small basins, and thin lenticular mantles along the course of the stream. The terrace lies about 20 feet above the bed of the stream in the lower subreach and indicates the upper level of an older phase of aggradation in the canyon. The terrace deposits, consisting of silt, sand, and gravel, have been cut through in most places, to the crystalline-rock floor of the channel. It is, apparent, therefore that a recent change in the local base level has occurred in the area. The valley fill that has accumulated in the present channel of Cottonwood Wash consists of unconsolidated lenticular deposits of boulders, sand, and clay. These sediments lap up against the base of the terrace deposits except where they abut the crystalline rocks in the more deeply excavated parts of the channel.

METHOD OF INVESTIGATION

The basic method to be used for determining the riparian water losses in each subreach, and in the total study reach, is the water-budget method. This method requires that the outflow from the reach be subtracted from the inflow to the reach and that the difference be adjusted for changes in ground-water storage and soil-moisture storage in the valley fill. Either the outflow or inflow may occur by surface or subsurface means. The study reach of Cottonwood Wash was specifically chosen because a reconnaissance indicated that the subsurface inflow and outflow would be quite small if, indeed, it exists at all during the critical water-budget periods.

The three stream-gaging stations (fig. 1) are located at valley sections where the stream is flowing over bedrock. Concrete cutoff walls resting on the bedrock were constructed at each station to force all down-valley flow through the measuring flumes. If storm periods are omitted, the streamflow stations measure the principal inflow and outflow in each subreach under consideration. Thus, a first approximation of the water used by evaporation and transpiration in the reach is determined by subtracting the flow at the downstream gaging station from the flow of the upstream gaging station. The difference in streamflow thus computed should be adjusted for changes in ground-water storage and in soil-moisture storage. For example, if water levels fall during a period of observation, the water that came out of ground-water storage should be added to the loss in streamflow to obtain a corrected estimate of the evapotranspiration in a subreach. Preliminary estimates of the possible magnitude of the ground-water storage item were based on estimates of the volume of saturated valley-fill sediments, the probable rates of water-table recession, and the coefficient of drainage (storage coefficient). These estimates indicated that, in comparison to the volumes of water consumed by transpiration in the study reach, the quantities of water drawn from ground-water storage are small.

Although three wells are located in the valley fill in the vicinity of McKinney's ranch house to indicate changes in ground-water storage and for use as transpiration wells (see discussion that follows), it has been decided that it would not be feasible to install enough observation wells to define changes in water levels in all segments of the valley fill within the study reach. Too, the heterogeneity of the sediments would make it a difficult task to determine an average coefficient of drainage.

In this study water budgets for weekly periods will be computed. Weeks in which rainfall resulted in either storm runoff or recharge in the valley fill will be eliminated from consideration. Thus only weeks during which the water table was in continuous recession will be used. In this way, the necessity for evaluating quantitatively the changes in ground-water storage is minimized. Observed changes in ground-water levels during a water-budget period are used in this study only for qualitative evaluation of the computed evapotranspiration losses.

The evaluation of changes in soil-moisture storage is not being attempted in this study. As in the case of ground-water storage changes, it is estimated that changes in soil-moisture storage will be relatively small for the periods used in the study and that adjustments of the computed evapotranspiration for these changes would not appreciably improve the results.

Theoretically, of course, changes in storage in the stream channel should be considered in the water-budget method of measuring the evapotranspiration in the study reach. However, the water volumes involved in these changes are clearly inconsequential.

A second method for determining the evapotranspiration losses from the flood plain is known as the transpiration-well method. Although extensive work would be required to estimate the losses from all segments of the flood-plain vegetation by this method, a limited effort may yield estimates of evapotranspiration losses useful for comparison with those obtained by the water-budget method.

Records of the daily fluctuation of the water table in the vegetation covered parts of the flood plain are needed for computations by the transpiration-well method. For this purpose three wells were constructed in the downstream subreach in August 1958. The wells were dug by hand to about $1\frac{1}{2}$ feet below the water table. Samples of material in two wells were collected from within a foot above the water table. The physical properties of the samples from the zone of fluctuations of the water table were determined by laboratory procedures. A water-stage recorder was installed over each well.

The transpiration-well method involves obtaining continuous records of the daily water-table fluctuations and determining the coefficient of drainage of the material in which the daily fluctuations of the water table occur. From these data, transpiration volumes are computed and related to volume density of vegetation at the individual wells. The results are then applied to the larger area. No computation of losses by the transpiration-well method have been made for this progress report; however, before a final project report is prepared, this method will be explored further.

A limited observation-well network was established in the area in order to measure changes in storage in the ground-water reservoir and to determine the direction of movement of ground water. Two observation wells were dug and four were drilled in the terrace deposits, which occur generally above the level of the modern flood plain. One well was dug in the gravel and sand of the flood plain. Three of the wells intersected the water table, one in the flood plain and two in the terrace deposits; the others were dry. The altitude of the measuring point of each of the wells will be determined by instrument leveling. Thus, for any well it will be possible to compute the elevation of the water table above sea level and determine any gradients that are of interest. The location of both the transpiration and the observation wells is shown on figure 1.

Rates of evapotranspiration are related to the climatic factors that control the physical and physiological processes and to the density and types of vegetation. This project has been planned, therefore, to provide data on these factors in addition to the volumetric measurements of the quantities of water used in the evapotranspiration process in the study reach.

A partial weather station (fig. 1) is operated at McKinney's ranch. The group of instruments operated at this site include a recording rain gage, a hygrothermograph for measuring air temperature and relative humidity, a pyrheliograph for measuring radiation, and an anemometer to measure wind movement. Two other automatic rain gages are operated in the study area (fig. 1). The rain gages are used primarily to indicate the periods in which local recharge to the valley fill occurred and to indicate whether storm runoff measured at the gaging stations originated within the study area or above it.

A study of the flood-plain vegetation in the study reach is planned for sometime during the summer of 1960. In this part of the project the types and density of plants drawing water from the stream or from ground water in the valley fill will be described. The climatologic data and the quantitative vegetative descriptions being collected in the study area should provide the link between

Measuring site or instrument	*Location*	*Date of establishment*
Stream gage:		
1	At upstream end of 4.1-mile study reach	September 1958
2	2.6 miles downstream from stream gage 1, at junction of upstream and downstream subreaches.	Do.
3	4.1 miles downstream from stream gage 1, at downstream end of study reach.	Do.
Transpiration wells	In valley fill opposite McKinney ranch house	August 1958
Dug well 1	On flood plain about 0.10 mile southeast of McKinney ranch house.	June 1958
Drilled well:		
2	On terrace southeast of McKinney ranch house	November 1959
3	Bank of tributary wash and road junction northeast of McKinney ranch house.	Do.
Rain gage:		
1	2,200 feet southeast of stream gage 1	June 1959
2	3,600 feet northwest of stream gage 1	Do.
3	At McKinney ranch house	Do.
Anemometer	do	October 1959
Hygrothermograph	do	June 1959
Pyrheliograph	do	Do.
Water-temperature recorder:		
1	Attached to stream gage 1	Do.
3	Attached to stream gage 3	Do.

results obtained from this area and those from other areas when these studies have been extended. Also, it is probable that the climatic and vegetative factors may provide the basis for generalizing the answers obtained at several study sites for application to unmeasured areas.

In a pilot study such as this the possibility that the water quality may be altered owing to the evapotranspiration withdrawals as flow moves down the channel will not be overlooked. Water samples for chemical analysis were collected at each stream-gaging site in January 1960 during a base-flow period to provide an indication of the water quality unaffected by evapotranspiration. In the next phase of the study, on the effects of defoliating vegetation in the downstream subreach, sampling for water quality will be intensified and will include the periods before, during, and after treatment in order to evaluate possible changes in water quality. Inasmuch as the water transpired and evaporated in pure water, it is possible that during periods of high evapotranspiration losses the chemical quality of the streamflow may progressively deteriorate as the water that enters the project area proceeds downstream. Thus, reducing the evapotranspiration losses should improve the water quality, whether it will improve measurably remains to be determined.

In the defoliation phase of the study, the removal of the leaves from vegetation in the downstream subreach will be accomplished by the application of magnesium chlorate. This defoliant will be applied by crop-dusting methods. Magnesium chlorate was determined to be most feasible by preliminary field testing conducted on a one-quarter acre grove of cottonwood trees in a canal wasteway on the Salt River Indian Reservation in the vicinity of Scottsdale, Ariz. Magnesium chlorate was tested after consultation with several chemical companies[1] and the State universities. The recommended dosage used was 20 pounds of magnesium chlorate in 200 gallons of water per acre, which is the usual dosage for cotton. One quart of a wetting agent per acre was added to the mixture. This concentration of the defoliant is about one-tenth that commonly used to defoliate cotton but as indicated, the dosage used was twice that used for cotton. Magnesium chlorate is nontoxic to humans or animals. The

[1]Chemicals contributed by White Chemical Co. and Arizona Pest Control Co.

defoliant as made up is estimated to cost about $5.00 per acre. Application costs have not been estimated.

A summary of the instruments and data-collection sites being used in this study on the preceding page.

RESULTS

The losses of water in the 4.1-mile study reach and in the two subreaches were computed by subtracting the streamflow at the downstream end of the reach from that at the upstream end of the reach. No adjustments to the loss figures thus computed have been made. Error from this cause should be slight, however, for the reasons previously described. The water-budget period used in the computation is a week. Weeks in which there was significant storm runoff or groundwater recharge in the valley fill were eliminated from the computations.

The computed weekly loss rates are shown on figure 2. Although a smoothed line has been drawn on figure 2 to represent the changes in loss rate during the growing season, it is probable that the actual changes from week to week were somewhat more irregular than the smoothed line indicates. The air-temperature records show irregular weekly variations. Other climatological data collected to date have not been processed but when combined with the temperature record may provide the basis for a stricter interpretation of the week-to-week variations in evapotranspiration than has been made for this progress report.

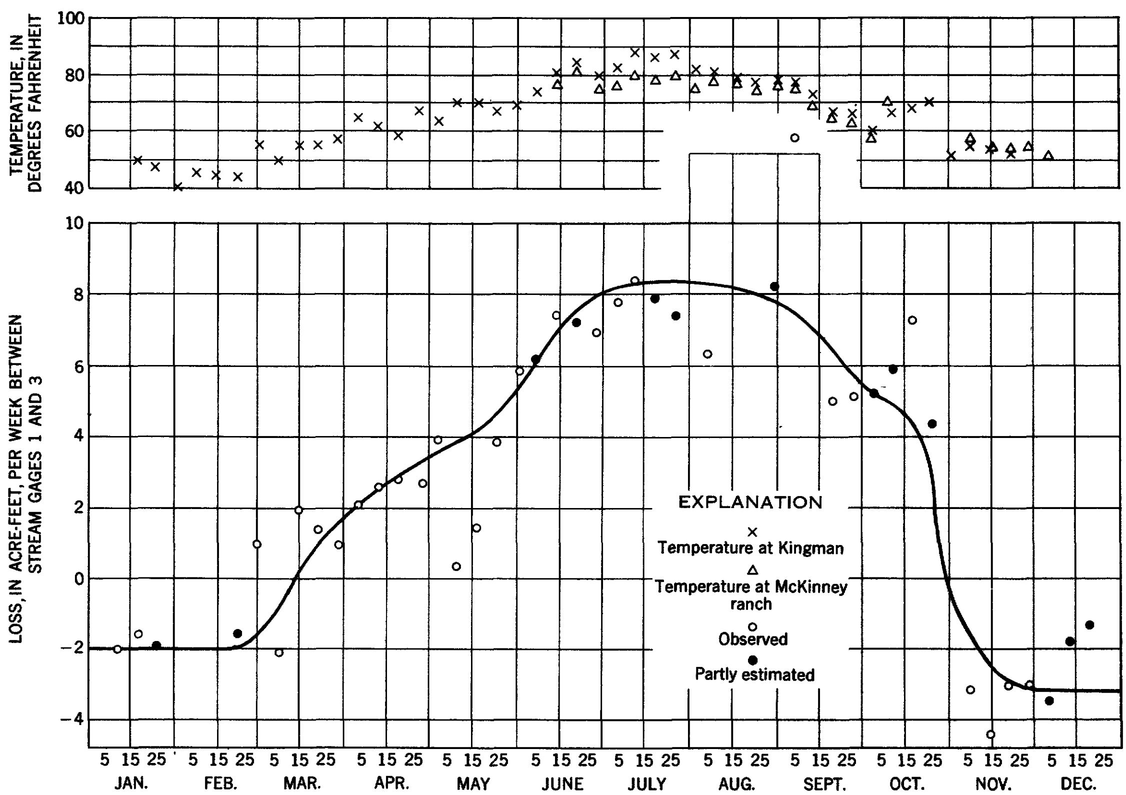

Figure 2.—Computed weekly use of water by riparian vegetation in 4.1-mile reach of Cottonwood Wash, Ariz., and weekly average air temperatures at Kingman and at McKinney ranch in the study area.

Additional scatter of the observed data above or below the smoothed loss curve is probably caused in large part by slight inaccuracies in the observed streamflow data. The loss figures computed by subtracting streamflow records contain all the error inherent in both records. Thus small errors in the streamflow records may cause much larger percentage errors in the computed losses. For example, although the departures of the observed data from the smoothed curve on figure 2 appear large, corrections to each of the streamflow records of as little as 3 percent in the right direction would account for all but about half a dozen of the departures. Failure to adjust the loss figures for changes in ground-water and soil-moisture storage may account for a small part of the scatter of the data plotted on figure 2.

The data plotted on figure 2 are for the loss in the 4.1-mile study reach, which includes the two subreaches. Similar diagrams have been prepared for each of the subreaches but are not reproduced in this report.

The computed evapotranspiration loss in the study reach for the growing season, March through October, is 175 acre-feet. This loss is 33 percent of the water that entered the reach, as measured at stream-gaging station 1. In the peak months of July and August the maximum weekly loss rate was 8.3 acre-feet, equivalent to slightly more than 60 percent of the water that entered the reach.

The computed season losses in the upstream (2.6 miles) and downstream (1.5 miles) subreaches were 75 and 100 acre-feet, respectively. It is noteworthy that, although the lower subreach is shorter, the losses are larger than in the upper subreach. The difference is due largely to a higher total population of phreatophytes in the lower reach.

The actual evapotranspiration losses may be somewhat greater than computed because of unmeasured inflow to the study reach. The data plotted on figure 2 show that there is a small gain in flow in the reach during the winter months. The gain in flow appears to be appreciably greater in the upstream subreach. Inasmuch as data for weeks having storm runoff have not been used, the conclusion is that the inflow occurs by subsurface routes. This is not totally unexpected, for several of the small tributary washes along the reach discharge onto or through the terrace remnants and thus there is opportunity for a limited amount of ground-water storage from storm runoff to provide the inflow. Evidence of this inflow from one tributary was detected during a reconnaissance in December prior to the start of the current project. Although inflow was not observed during the summer period it cannot be stated positively that none existed. There is a possibility, then, that both the total inflow to the reach (streamflow plus subsurface inflow) and the evapotranspiration losses are higher than have been computed. However, it is believed that the sources of subsurface inflow are largely depleted early in the summer and that error from this source is not large during the growing season. The subsurface-inflow factor will receive increased emphasis in the subsequent phases of the investigation.

The weekly changes in water levels in the three transpiration wells were computed. With few exceptions, the water table in the valley fill was in recession during the weeks for which evapotranspiration losses were computed. The weekly recession was usually less than 0.05 foot, confirming that the corrections for ground-water storage which could be applied to the computed losses were small.

During the spring of 1959 a series of weekly observations on the stage of leafage of the riparian vegetation was made. The graphs in figure 3 show the water-level fluctuations in the transpiration wells and the streamflow fluctuations.

Figure 3*B*, shows that as early as March 3 a pronounced pattern of diurnal fluctuations in streamflow rates had been established even though the vegetation was only starting to leaf out. Inasmuch as the water-table levels were showing only slight diurnal changes on this date (fig. 3*A*), there is indication that evaporation from the valley-fill surface preceded the onset of transpiration losses. Figure 3*C*—*H* demonstrates the increasing range of diurnal fluctuations as the vegetation leafted out and spring passed into summer.

The graphs of diurnal fluctuations in water-table levels and streamflow shown in figure 3 are typical and demonstrate the effects of variations in evapotranspiration rates during a day. The lowest water levels and streamflow rates occur during the afternoon when

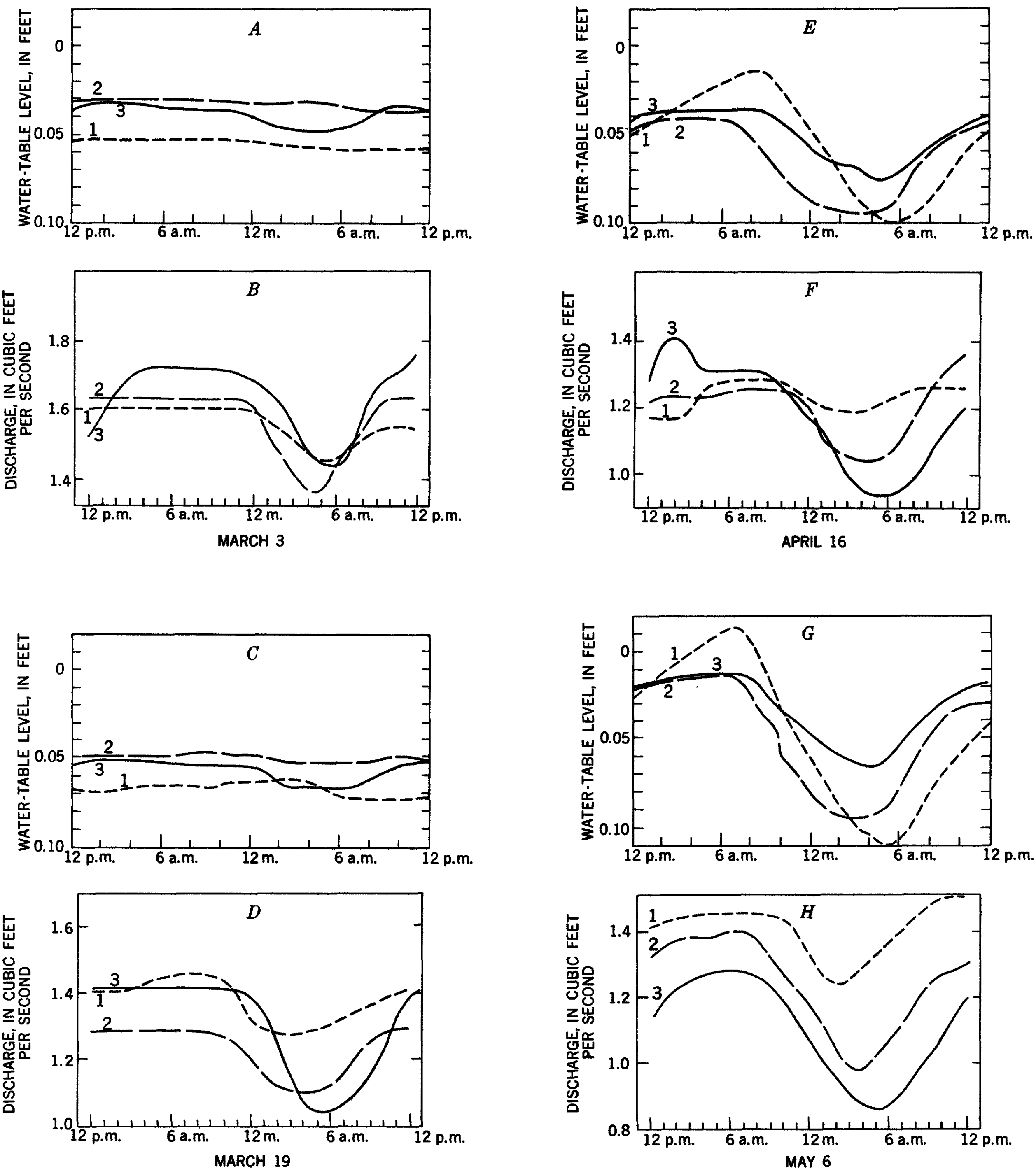

Figure 3.—Graphs of water-table and stream-discharge fluctuations on March 3, March 19, April 16, and May 6, 1959. Numbers refer to transpiration wells and stream gages, respectively.

the temperature and radiation are highest and the humidity is lowest. The highest water levels and streamflow rates occur during the night or early morning as solar radiation is reduced, temperature drops, and humidity rises.

During the season of highest evapotranspiration rates the maximum range in water levels in the transpiration wells during a day is about 0.15 foot. Typical of the diurnal fluctuations in streamflow is a variation in flow rate from 0.6 cfs to 0.85 cfs at stream gage 1 and a variation from about 0 to 0.5 cfs at stream gage 3.

In the defoliation experiment the defoliant tested is estimated to have been about 90 percent effective where reasonable spray coverage was attained. However, the period when transpiration was effectively eliminated was probably no longer than about 7 or 8 days, as shown by the chronology of observations as follows:

September	17	Cottonwood grove sprayed with defoliant.
	18	No effect observed.
	21	Leaves falling rapidly.
	24	All affected leaves either down or dry. Apparent that spray coverage not sufficient in densest parts of grove.
	28	New buds formed and leafing started.
October	2	Leafing well advanced. Some leaves completely open.
	6	Foliage nearly as dense as before spraying.
	12	Foliage back to normal density

The defoliant was not damaging to the vegetation, for foliage was observed to be back to normal density in about 3 weeks.

When the vegetation in the downstream subreach is defoliated in June as planned, it is expected that a first spraying will be followed by a second about 3 days later to insure complete defoliation. Supplementary hand spraying of the understory vegetation will probably be needed also. After the initial sprayings, other dosings at about weekly intervals may be necessary to effect a leaf-free period of about 3 weeks in which to observe the water-saving effects of the treatment.

SUMMARY AND CONCLUSIONS

1. Cottonwood Wash flows in a relatively steep-walled trench in massive crystalline rocks. Subsurface inflow or outflow from these rocks appears to be negligible; however, inflow from terrace deposits along parts of the canyon walls may contribute measurable quantities of seepage to the stream after periods of high rainfall.

2. Evapotranspiration losses along the stream valley computed by subtracting stream outflow from stream inflow are subject to only small errors from failure to adjust for ground-water and soil-moisture storage.

3. Results to date show that a measurable quantity of ground-water seepage enters the study reach during the winter periods. This seepage is believed to be very small, however, during the summer periods when water budgeting for computation of evapotranspiration losses is critical.

4. Computed evapotranspiration loss in the 4.1-mile project reach during the growing season, March through October, 1959, was 175 acre-feet. This loss is about 33 percent of the water that entered the reach. Maximum rate of loss during the season was slightly more than 8 acre-feet per week, or about 60 percent of the inflow.

5. Seasonal losses in the upstream and downstream subreaches were 75 and 100 acre-feet, respectively. Losses in the shorter downstream subreach were larger than in the upper subreach because of the greater plant population.

6. Net weekly changes in ground-water level measured in three transpiration wells was generally 0.05 foot or less during the water-budget weeks. Maximum diurnal range in stage in these wells was about 0.15 foot.

7. Typical maximum diurnal fluctuations in streamflow were as follows:

Stream gage 1	0.6 to 0.85 cfs
Stream gage 3	Nearly 0 to 0.6 cfs

8. During the spring of 1959 a pronounced diurnal pattern of streamflow was exhibited

prior to the leafing out of the vegetation. This suggests that direct evaporation of soil moisture from the valley-fill surface is an appreciable part of the losses observed in the project reach and leads to the speculation that the water savings that will be accomplished by modifying the riparian vegetation may not be as great as hoped.

9. A test to determine an effective defoliant to be used in the defoliating phase of the project indicates that magnesium chlorate is highly effective on cottonwood trees. However, a single spraying eliminates the leaves for an effective period of about 7 or 8 days. In project use, a multiple-spraying technique will be used to prolong the leaf-free period.

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