Infiltration of Wastewater Effluent in the Santa Cruz River Channel, Pima County, Arizona

By KEN GALYEAN

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CONVERSION FACTORS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter (L)
acre	0.4047	hectare
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

In this report, temperature is reported in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation:

$$°C = 5/9\ (°F) - 32$$

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Abstract

Infiltration of effluent into the Santa Cruz River channel from water-treatment plants near Tucson, Arizona was studied from March 23, 1990, to September 30, 1993. The study reach extended along a 23-mile stream reach from the water-treatment plants, about 5 miles northwest of central Tucson, downstream to Trico Road, about 5 miles west of Marana, Arizona. Data indicate that 88.4 to 90.2 percent of the effluent discharged from the two water-treatment plants infiltrated the Santa Cruz River channel. During 1991–93, the volume of effluent discharge that flowed out of the study area was 2,880, 4,120, and 3,320 acre-feet per year, respectively, and the volume of infiltration was 41,890, 43,640, and 45,670 acre-feet per year, respectively. Intermittent rainstorms resulted in high flows that altered the composition, structure, and geometry of the channel bed and may have caused the infiltration to increase to nearly 100 percent. In comparison, variations in evapotranspiration and open-channel evaporation had a minimal effect on the water budget. In the study reach, 3.2 to 3.9 percent of the effluent was lost to evapotranspiration and open-channel evaporation; 6.2 to 8.3 percent flowed through the reach.

INTRODUCTION

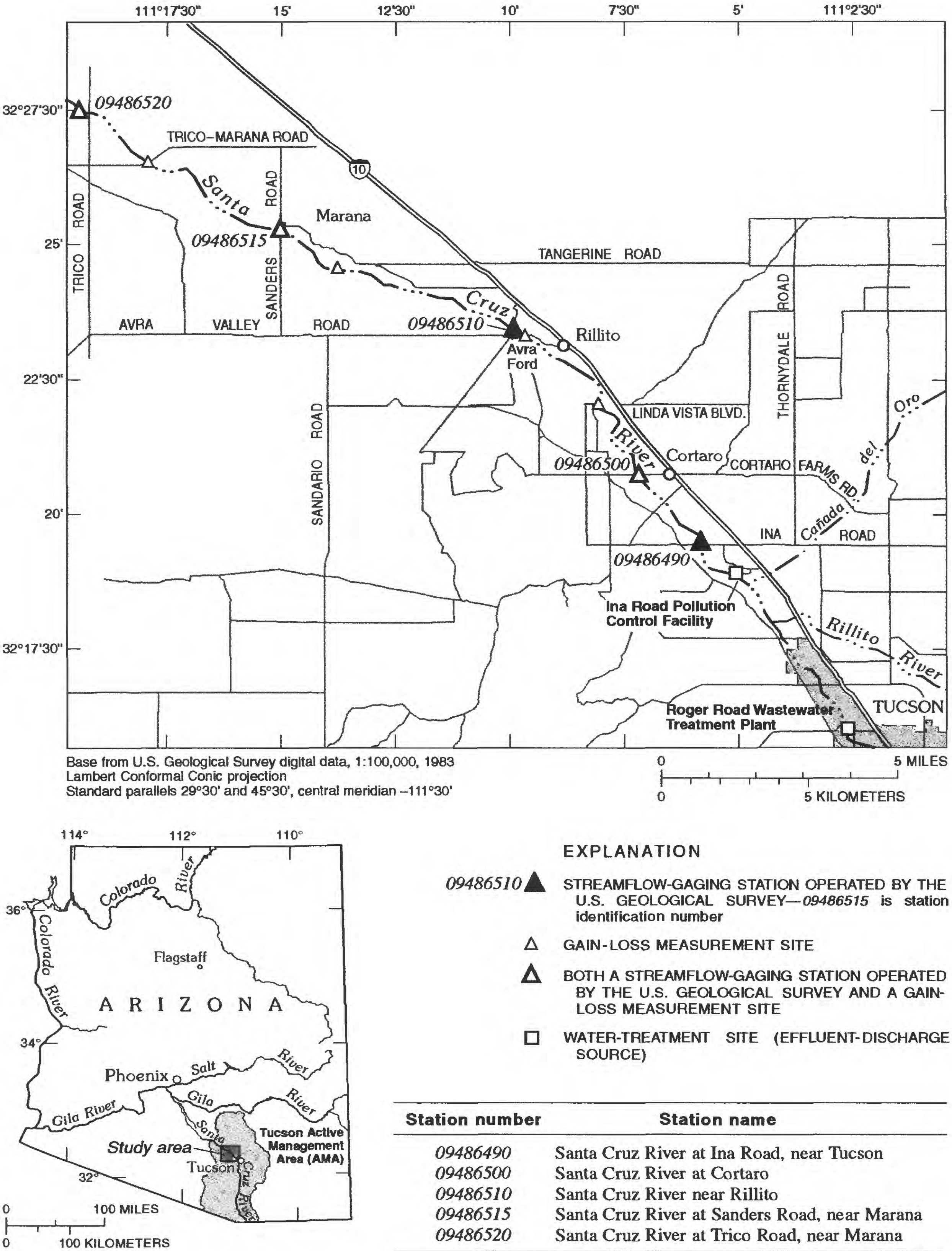
Effluent discharged to the Santa Cruz River from the Roger Road and Ina Road water-treatment plants (WTP's) northwest of Tucson, Arizona (fig. 1), is of concern to agencies charged with the conservation, management, and use of ground-water resources within the Tucson Active Management Area (AMA), which is defined by the Arizona Groundwater Management Act of 1980 (State of Arizona, 1980). The Act concerns areas where consumptive use of ground water exceeds recharge, establishes limits on ground-water withdrawals, and promotes conservation by mandating a balance between recharge and withdrawal by the year 2025.

Water is supplied to municipal, industrial, and agricultural users in the Tucson AMA from wells in the basin-fill alluvium. Most of the aquifer recharge occurs along the major stream channels in the basin by infiltration through the channel beds and percolation through the highly permeable alluvium. These streams are ephemeral, and runoff is generated by precipitation that occurs primarily during the monsoon season from July to September and, to a lesser degree, from the frontal-type storms that typically occur in December and January.

From March 23, 1990, to September 30, 1993, the U.S. Geological Survey (USGS), in cooperation with the City of Tucson, studied the amount of effluent discharged from the WTP's that infiltrates the channel bed of the Santa Cruz River. This study is important in meeting the goals of the Arizona Groundwater Management Act in the Tucson AMA and in the determination of recharge credits.

Purpose and Scope

This report presents the results of two gain-loss studies done from March 23, 1990, to October 24, 1990, and from October 25, 1990, to



Station number	Station name
09486490	Santa Cruz River at Ina Road, near Tucson
09486500	Santa Cruz River at Cortaro
09486510	Santa Cruz River near Rillito
09486515	Santa Cruz River at Sanders Road, near Marana
09486520	Santa Cruz River at Trico Road, near Marana

Figure 1. Study area and locations of gain-loss study sites and streamflow-gaging stations, Santa Cruz River, Arizona.

September 30, 1993, to determine the amount of effluent infiltration in the Santa Cruz River channel. The 23-mile study reach extends from the WTP's at Roger and Ina Roads, about 5 mi northwest of central Tucson to Trico Road, about 5 mi west of Marana (fig. 1). Data collected to determine the amount of sewage-treatment effluent infiltrated along this reach includes source discharge from water-treatment plants, flow at several points in the reach calculated from streamflow-gaging station records and discharge measurements, phreatophyte evapotranspiration estimated by applying meteorological data and riparian components to evapotranspiration estimation formula, and open-channel evaporation derived from analysis of channel and reach characteristics.

Precipitation data were not used because significant amounts of precipitation would produce high flows (storm flows), and the amount of precipitation would be insignificant when compared to the volume of water in the inundated channel. Inflows from tributaries were not considered because those tributaries are from minor drainage areas and had no flow except under storm conditions. There are no known outflows or diversion of surface waters in the study area, and the only known water right for diversion of surface water in the study area is held by a cement-processing plant. No diversions to the plant have been reported.

METHODS OF INVESTIGATIONS

Initial Gain-Loss Study

The initial gain-loss study of the infiltration of effluent discharged by the WTP's in the study reach was done on March 23, April 26, and October 24, 1990, at seven measurement sites downstream from the WTP's on the Santa Cruz River (fig. 1). Two existing continuous-record streamflow-gaging stations—Santa Cruz River at Cortaro, Arizona, and Santa Cruz River at Trico Road, near Marana, Arizona—were the end points of the study reach. Five additional sites were chosen on the basis of measurement conditions, ease of access, and distribution along the study reach.

The daily stage hydrographs at Cortaro and Trico Road usually displayed dual peaks (figs. 2–5) because of differing release and travel times of the peak discharges from the WTP's at Roger and Ina Roads. The peaks usually attenuated in a downstream direction, and neither peak was consistently higher. At times, one of the treatment plants reduced or diverted effluent discharge, and only a single peak was recorded. The stage rarely was constant and either rose or fell in the daily cycle. In an attempt to follow the same water as it progressed downstream through the reach, the diurnal low of the effluent discharge was chosen for measurement because the daily low was constant enough to be readily identified, predictable, and of adequate duration to obtain a discharge measurement. Results and calculations of the initial gain-loss study are presented in table 1, and measured discharges are shown in figure 6.

Results of the Initial Gain-Loss Study

The discharges measured in the initial gain-loss study declined at most sites during the study period (table 1 and fig. 6), and the point where the diurnal low of the effluent discharge was zero moved upstream. The differences in discharges between the studies of March and April 1990 could be attributed, in part, to seasonal increases in evapotranspiration and open-channel evaporation rates. The differences in measured discharges between April and October, however, probably were due to storm flows, particularly in early October. The storm flows disrupted and loosened the streambed, removed vegetation, and altered channel geometry and location, which may have resulted in increased losses of effluent flow through the study reach.

The discharge measurements at the diurnal low of the effluent discharge represented only a single point in the daily hydrograph and did not reflect daily mean discharges. It was uncertain if the general decrease in discharge downstream through the study reach represented absolute or proportional losses of effluent discharge or a combination of the two. A more comprehensive streamflow-gaging network, therefore, was installed to monitor the full diurnal range of the

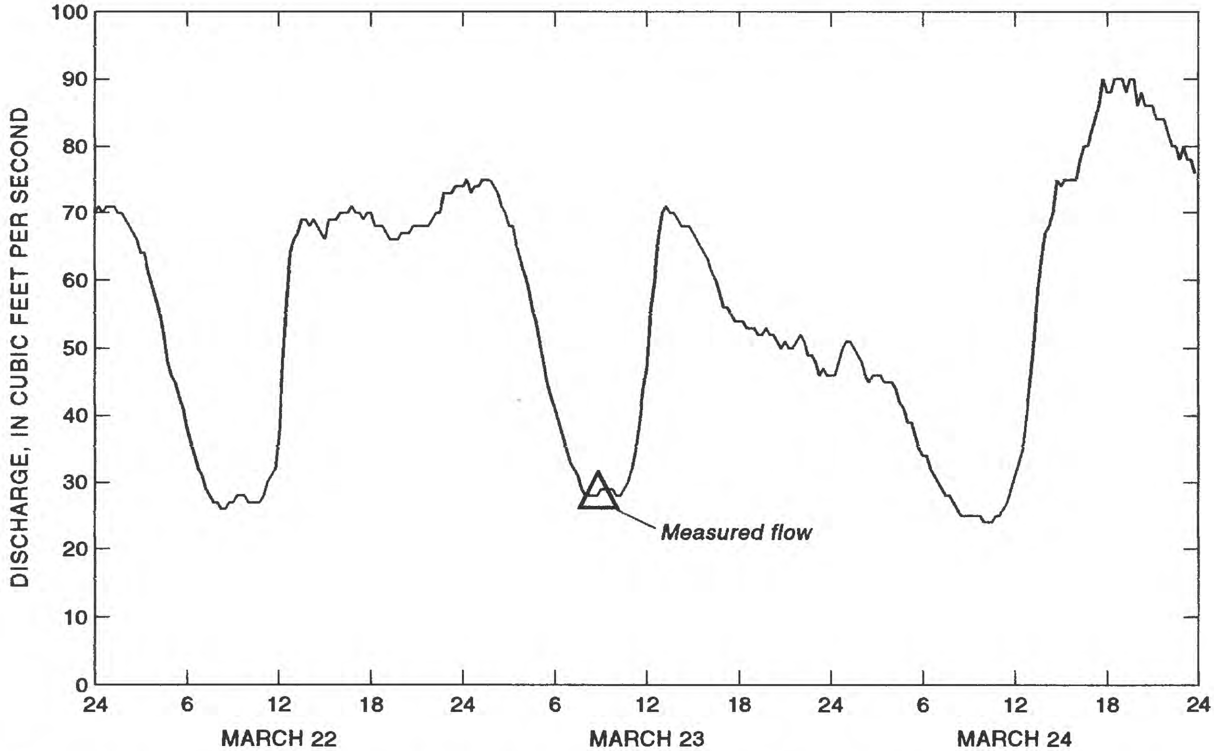


Figure 2. Instantaneous discharge of effluent, Santa Cruz River at Cortaro, Arizona, March 22–24, 1990.

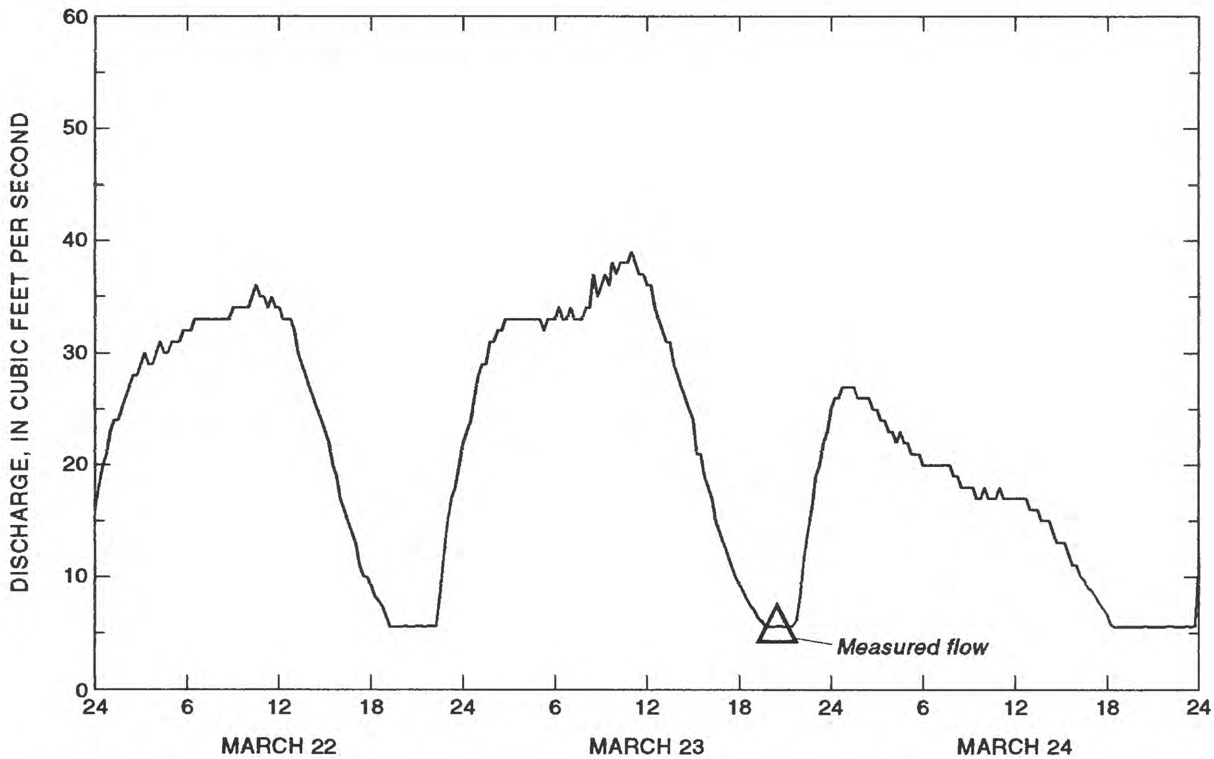


Figure 3. Instantaneous discharge of effluent, Santa Cruz River at Trico Road, near Marana, Arizona, March 22–24, 1990.

Table 1. Initial gain-loss study, Santa Cruz River, March 23, 1990, to October 24, 1990

[Dashes indicate no data]

Measurement site	Distance downstream from Cortaro, in miles	Measured effluent discharge, in cubic feet per second	Cumulative gain or loss in effluent discharge, in cubic feet per second	Measured effluent discharge, in percent, of discharge measured at Cortaro	Effluent discharge lost, in percent, of discharge measured at Cortaro
		March 23, 1990			
Cortaro	0	28.5	0	100	0
Linda Vista Boulevard	2.96	30	1.5	105.3	-5.3
Avra Ford	5.27	21	-7.5	73.7	26.3
Sandario Ford	9.71	19.3	-9.2	67.7	32.3
Sanders Road	10.95	12.8	-15.7	44.9	55.1
Trico-Marana Road	14.34	6.7	-21.8	23.5	76.5
Trico Road	16.34	5.2	-23.3	18.2	81.8
		April 26, 1990			
Cortaro	0	19.5	0	100	0
Linda Vista Boulevard	2.96	19.8	.3	101.5	-1.5
Avra Ford	5.27	9.9	-9.6	50.8	49.2
Sandario Ford	9.71	5.8	-13.7	29.7	70.3
Sanders Road	10.95	3.9	-15.6	20	80
Trico-Marana Road	14.34	.19	-19.31	1	99
Trico Road	16.34	.16	-19.34	.8	99.2
		October 24, 1990			
Cortaro	0	30.9	0	100	0
Linda Vista Boulevard	2.96	20.3	-10.6	65.7	34.3
Avra Ford	5.27	13	-17.9	42.1	57.9
Sandario Ford	9.71	([1])	---	---	---
Sanders Road	10.95	0	-30.9	0	100
Trico-Marana Road	14.34	0	-30.9	0	100
Trico Road	16.34	0	-30.9	0	100

[1]Site not measured because of channel displacement.

discharge in order to quantify discharge through the study reach.

Determination of Effluent Infiltration

Quantifying the amount of effluent discharge that infiltrated the channel bed required a water budget to determine the disposition of effluent discharged into the study reach. The water budget has five interdependent components—volume of effluent discharge, discharge through and past the reach, evapotranspiration, open-channel surface-water evaporation, and infiltration through the channel bed. Any one of the water-budget components may be derived as a residual by determining the other components. In this report, infiltration was derived using known or estimated values of the other water-budget components.

Determination of Discharge Through the Study Area

Field Methods

To determine the discharge at various points through the study area for the second, more comprehensive gain-loss study, three low-flow streamflow-gaging stations were installed in the

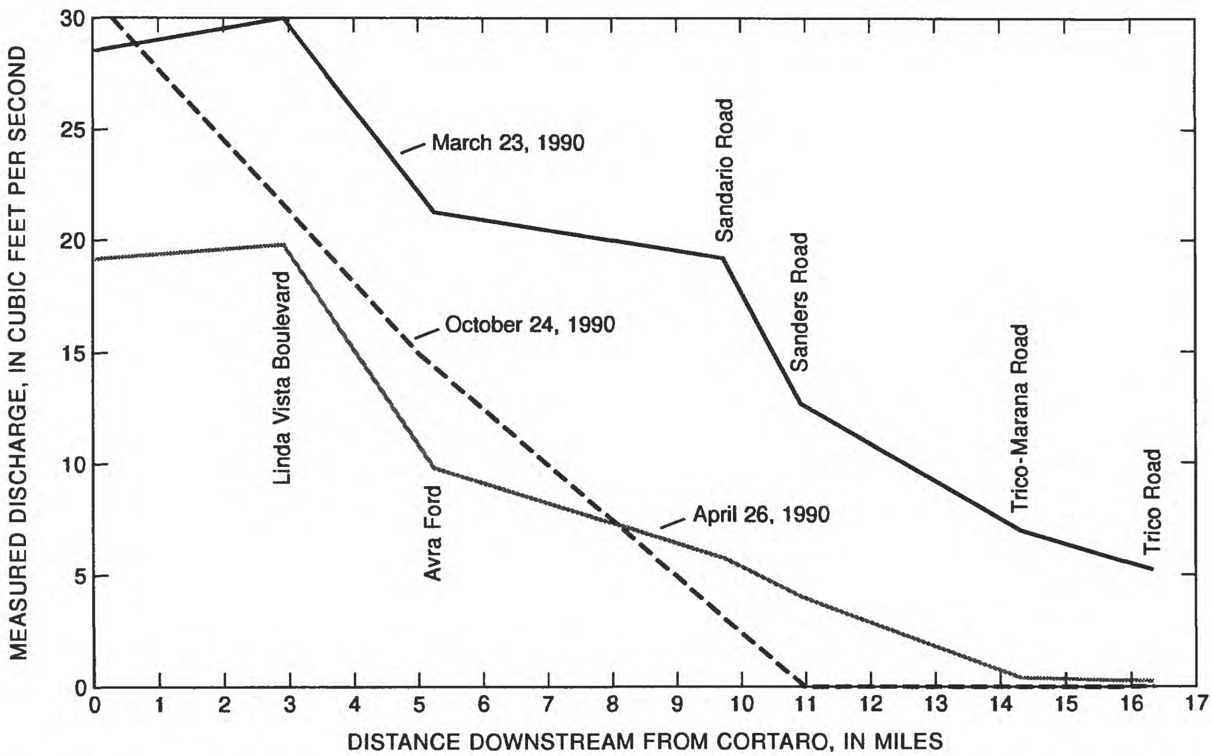


Figure 6. Measured discharge of effluent in relation to distance downstream from Cortaro during the initial gain-loss study, 1990.

spring of 1991 to complement the existing continuous-record streamflow-gaging stations at Cortaro and at Trico Road (fig. 1). A low-flow streamflow-gaging station was used for gage-height data collection and discharge-record production for low to moderate discharges only. Two of the low-flow stations were installed at gain-loss measurement sites used before this study—Santa Cruz River near Rillito, just below Avra Ford; and Santa Cruz River at Sanders Road, near Marana. The third low-flow station—Santa Cruz River at Ina Road—was installed upstream from the initial gain-loss reach and closer to the effluent source.

Discharge measurements (171), gaging-station inspections (126), and observations of no flow (38) were made at the 5 sites during the effluent-infiltration study in water years (WY) 1991–93. A water year begins October 1 of one year and ends September 30 the following year, and is named for the year in which it ends. WY 1991, therefore, began October 1, 1990, and ended September 30, 1991. The reaches between sites were inspected frequently, and characteristics and conditions of the channel were noted. Descriptions of the five streamflow-gaging stations are in the "Basic Data and Hydrologic Data-Collection Conditions" section (hereafter referred to as the basic-data section) at the back of the report.

Analytical Methods

Daily records of effluent discharged from the WTP's were converted from millions of gallons per day to daily mean cubic feet, monthly totals in cubic feet, and monthly totals in acre-feet (table 21 in the basic-data section; data from Donald Armstrong, superintendent, Pima County Wastewater Management Department, written commun., 1993). Discharges from the five streamflow-gaging stations were derived by applying standard techniques of the USGS (1977a, b) for discharge computation. Reported discharges for the three low-flow gaging stations were limited to a maximum of 140 ft^3/s to eliminate the effects of storm flow. The maximum value of 140 ft^3/s was selected because it is slightly greater than the maximum effluent discharge during the study period (table 21 in the basic-data section).

A correction was applied to monthly discharges at the streamflow-gaging stations for months in which high flows from storms occurred. The effects of the daily mean discharges of storm-flow days were removed by computing the average daily mean discharge for days of nonstorm flow in the month. The monthly discharge was reconstructed by multiplying the computed daily mean of the days of nonstorm flow by the full number of days in the month (equation 1). The record was reconstructed for months in which the daily mean discharges at the gaging stations exceeded the effluent daily discharge (table 2, figs. 7–10, and table 20 in the basic-data section).

$$Q_s = \left(\frac{Q_a - Q_e}{D_{ne}}\right) D_m, \qquad (1)$$

where

Q_s = reconstructed monthly discharge from the streamflow-gaging station,

Q_a = discharge for month including days of storm flow at streamflow-gaging station,

Q_e = sum of daily mean discharge for days of nonstorm flow at streamflow-gaging station,

D_{ne} = number of nonstorm days, and

D_m = number of days in complete month.

For example, the streamflow-gaging station at Ina Road had four daily mean discharges in March 1991 that exceeded the effluent daily mean discharge limit of 140 ft^3/s. The average daily mean discharge of the nonstorm days was 31.3 ft^3/s, which gives a 31-day month total of 84 million ft^3 or 1,920 acre-ft.

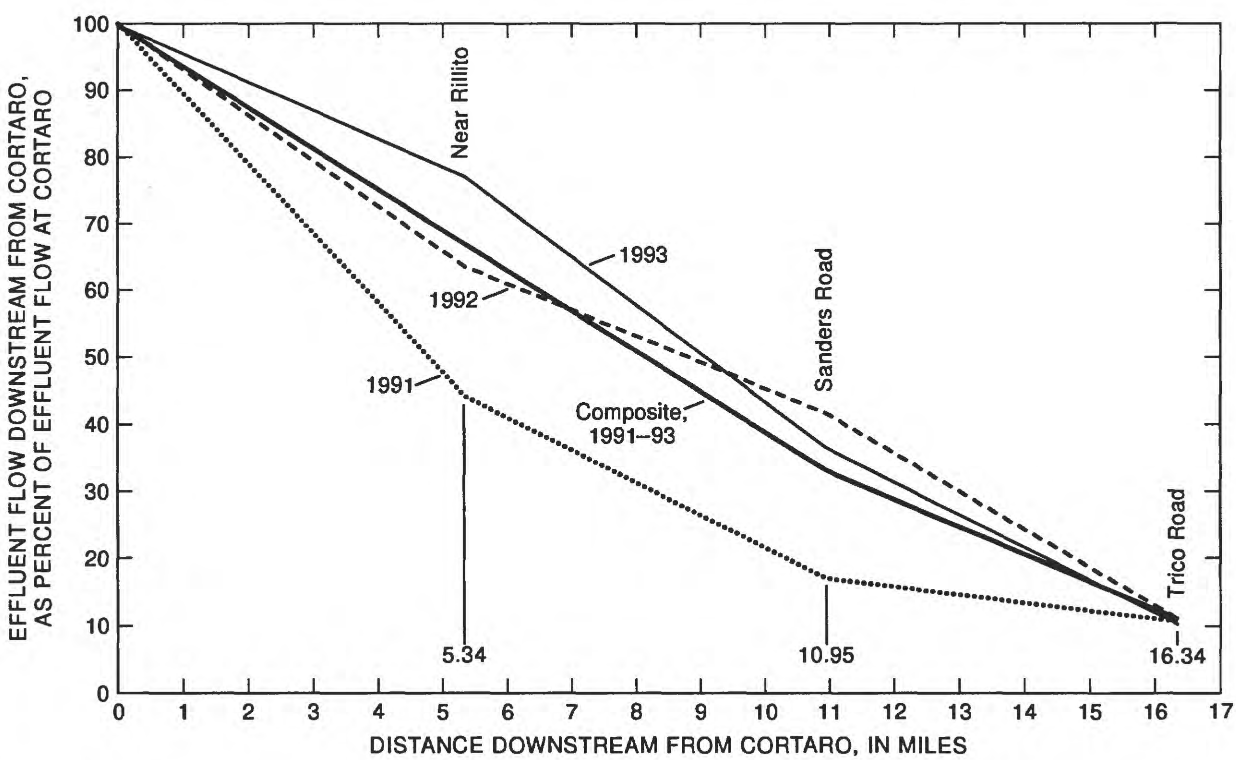


Figure 7. Effluent flow downstream from Cortaro in relation to effluent flow at Cortaro, Arizona, water years 1991–93.

Table 2. Reconstruction of monthly discharges, water years 1991–93

[Dashes indicate nonreconstructed month]

Month	Ina Road			Cortaro			Rillito			Sanders Road			Trico Road		
	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet
Water year 1991															
October	---	---	---	20	44.1	2,710	---	---	---	---	---	---	---	---	---
November	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
December	---	---	---	28	46	2,830	---	---	---	---	---	---	27	18.6	1,140
January	---	---	---	28	28.9	1,780	---	---	---	---	---	---	29	3	184
February	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
March	27	31.3	1,920	27	33.7	2,070	---	---	---	27	1.85	50	28	1.29	59.2
April	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May	---	---	---	---	---	---	---	---	---	---	---	---	28	1.29	---
June	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
July	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
August	15	56.7	3,490	26	47.4	2,910	29	13	799	---	---	---	---	---	---
September	28	64.5	3,840	29	58.9	3,500	---	---	---	---	---	---	---	---	---
Water year 1992															
October	---	---	3,550	---	---	---	26	51.6	3,170	---	---	---	---	---	---
November	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
December	24	68.7	4,220	30	63.8	3,920	24	43.2	2,660	---	---	---	---	---	---
January	24	66.9	4,110	25	62.4	3,840	21	52.4	3,220	---	---	---	---	---	---
February	22	49.8	2,860	15	30.1	1,730	24	28.4	1,630	27	21.6	1,240	25	10.5	604
March	23	50.7	3,120	23	42.8	2,630	21	32.5	2,000	25	12.5	769	27	5.16	317
April	26	54.6	3,250	27	48.3	2,870	26	42	2,500	---	---	---	---	---	---
May	---	---	---	---	---	---	29	42.6	2,620	---	---	---	---	---	---

Table 2. Reconstruction of monthly discharges, water years 1991–93—Continued

Month	Ina Road			Cortaro			Rillito			Sanders Road			Trico Road		
	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet	Number of non-storm days in the month	Average daily discharge of non-storm days, in cubic feet per second	Reconstructed monthly discharge, in acre-feet
Water year 1992—Continued															
June	---	---	---	---	---	---	22	45.2	2,690	---	---	---	---	---	---
July	28	51.4	3,160	27	55.7	2,600	29	6.87	422	29	14.4	885	---	---	259
August	22	52.8	3,250	26	67.9	2,870	19	14.7	904	26	16.4	1,010	28	3.25	200
September	27	63.7	3,790	29	71.8	3,550	28	25.2	1,500	27	10.4	619	---	---	---
Water year 1993															
October	22	52.5	3,230	19	55.9	3,440	30	39.2	2,410	---	---	---	---	---	---
November	14	53.5	3,180	18	60.8	3,620	---	---	---	---	---	---	---	---	---
December	25	51	3,140	25	67.9	3,140	---	---	---	27	23.7	1,460	28	16.4	1,010
January	---	---	---	5	55.8	3,430	---	---	---	---	---	---	12	15.1	360
February	---	---	---	20	45.8	2,540	---	---	---	---	---	---	---	---	---
March	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
April	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
May	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
June	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
July	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
August	---	---	---	---	---	---	---	---	---	---	---	---	---	---	123
September	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

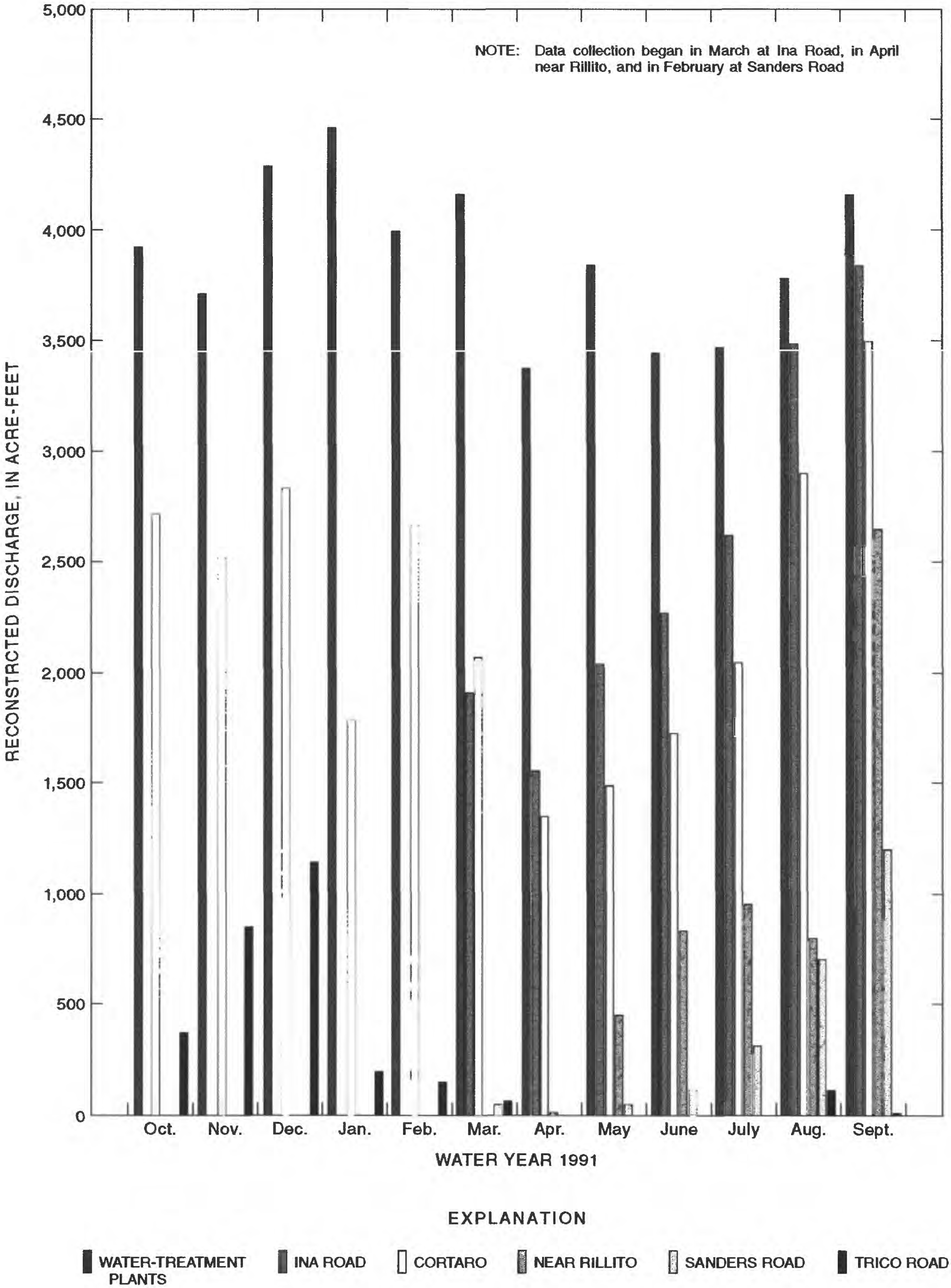


Figure 8. Reconstructed monthly discharge at measurement sites, water year 1991.

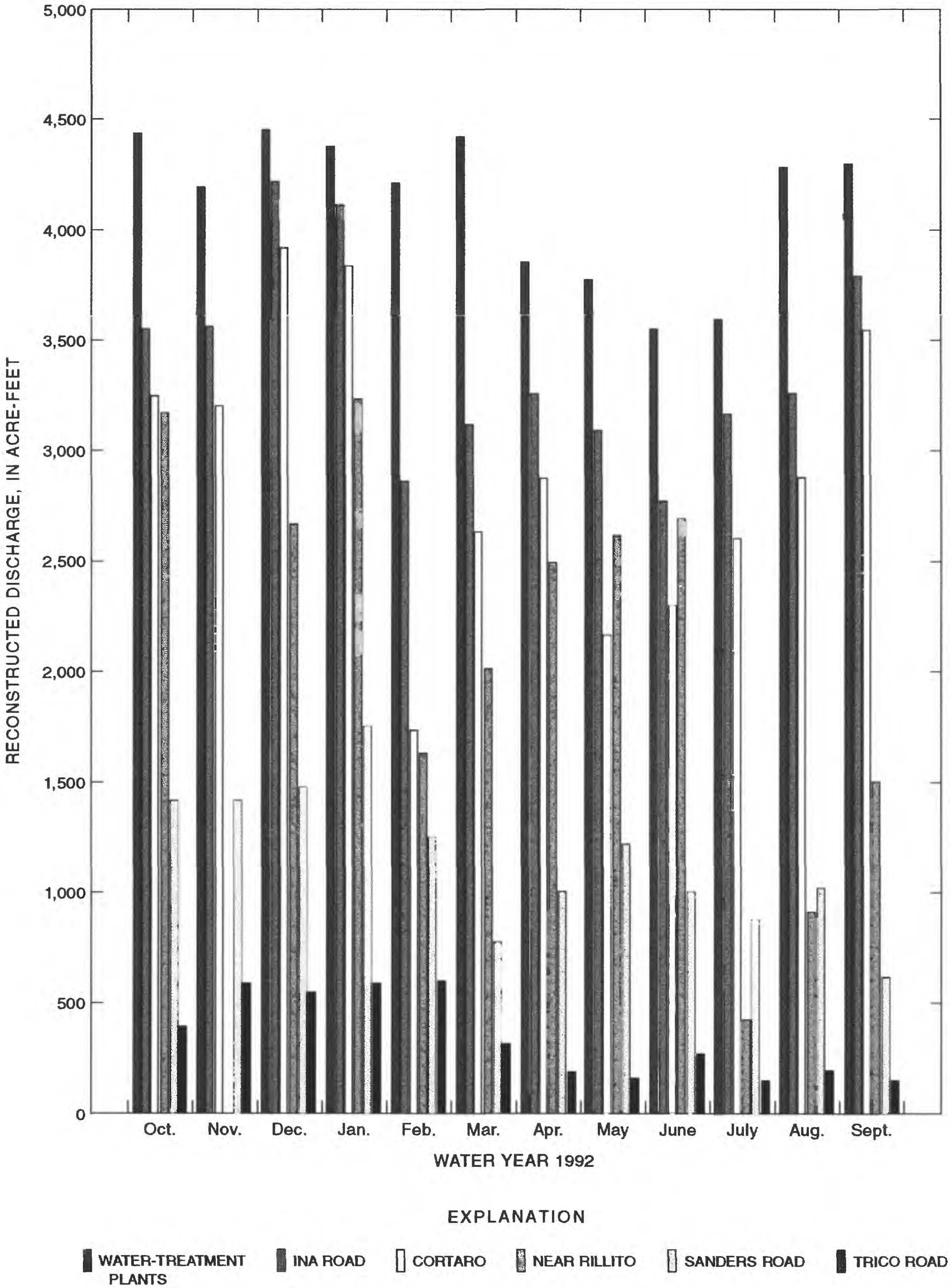


Figure 9. Reconstructed monthly discharge at measurement sites, water year 1992.

Assumptions and Uncertainties Associated with Streamflow Data

Reconstruction of the monthly average of daily mean discharge was assumed to produce values similar to the record in which only effluent discharge flowed in the channel. As a test, this method was applied to the discharge data for several of the gaging stations during months with nonstorm flow. Daily mean discharges were randomly deleted, and monthly total discharge was recalculated. The reconstructed monthly discharges varied from the known monthly discharges by less than 5 percent and were considered verification of the method.

The continuous record of discharge at each gaging station was computed by measuring discharge at several stage heights, developing a stage-discharge relation, and applying the continuously recorded stage data to the relation. The potential margin of errors in the 171 discharge measurements generally ranged from about 2 to 8 percent using standard techniques of the USGS (Rantz and others, 1982). Accordingly, these margins of error would be incorporated in the stage-discharge relation and subsequent discharge-record computations.

Additional uncertainties in the discharge record correspond to periods of time when there were vertical fluctuations in the channel geometry and gage-pool control (see stream-gage histories in the basic-data section). These fluctuations are mainly attributed to the effect of storms and human activities on the channel conditions and made for difficult correlation of stage to discharge for certain periods between discharge measurements.

The data from gaging stations indicate that discharge generally decreases in a downstream direction (fig. 6 and tables 14–27 in the basic-data section). The reduction in discharge usually is far greater than can be attributed to errors associated with discharge estimates. However, there were periods of time when individual sites varied from this trend, and discharge appeared to increase downstream between adjacent sites. This deviation from the general trend may be attributed to the inherent inaccuracies associated with the collection and computation of streamflow data on alluvial channels. During these periods, there were no known inflows or diversions between stations that were significant enough to account for these deviations.

Estimation of Evapotranspiration and Evaporation

Estimation of evapotranspiration through the study reach required the determination of phreatophyte area, open-channel area, and proportion and density of vegetation types as well as weighted water-consumption coefficients of phreatophyte and riparian species. Additional data required to adequately estimate losses include annual daytime hours, temperature, and humidity data. These data are used in the Blaney-Morin equation to estimate evapotranspiration in the study area.

Estimation of Total Phreatophyte and Open-Channel Areas

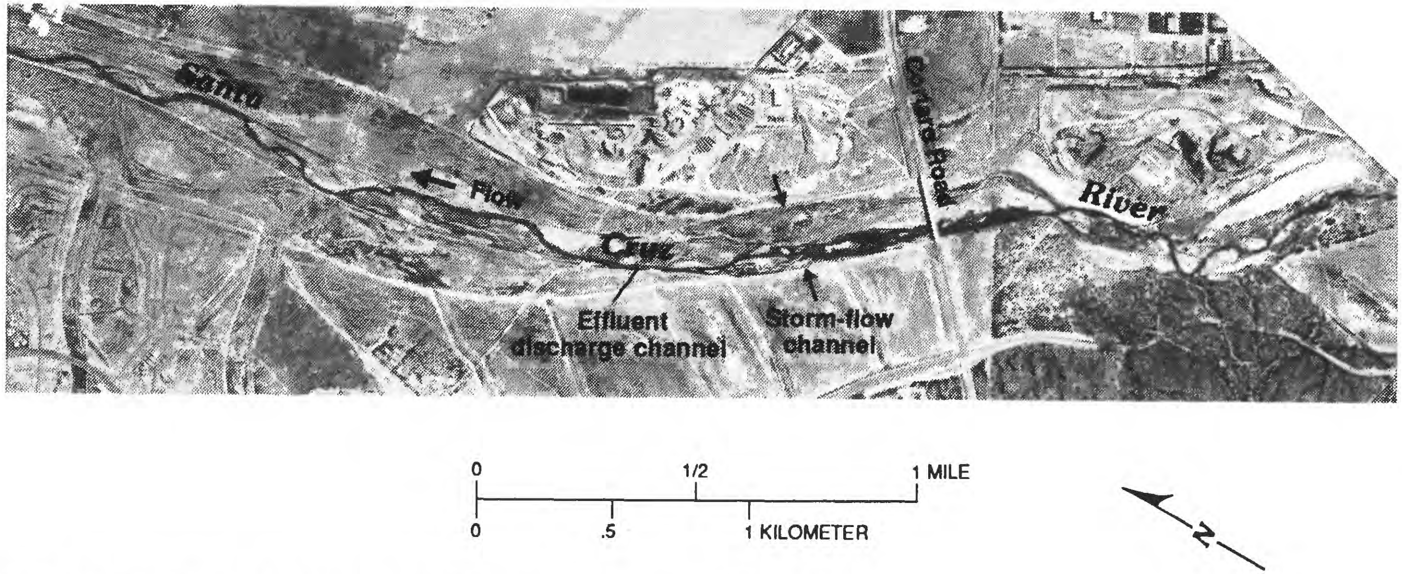
The phreatophyte-zone area was evaluated using aerial photographs of the study reach for March 19, 1990, and June 20 and 23, 1993 (figs. 11 and 12 and table 3; Cooper Aerial Survey Company, 1990–93). Photographs for March 19, 1990, represented channel and vegetation status before storms and reflect conditions when vegetation approached maximum coverage after a lengthy recovery period (figs. 11 and 12). The photographs for June 20 and 23, 1993, were taken following the flood of January 1993 and represent the status of vegetation as observed after storm flows during the study period (figs. 11 and 12).

The total phreatophyte and open-channel area for each stream reach (the portion of the study area between streamflow-gaging stations) were classified by vegetation and channel conditions and segmented accordingly. The delineation of phreatophyte boundaries often was difficult in some reaches, and consideration was given to the maximum possible zone area of vegetation functioning as phreatophytes. Phreatophyte acreage in each reach segment was measured by computer digitization (tables 4 and 5). A reach segment is a subreach between study points (table 3).

Estimation of Open-Channel Area

To differentiate the evapotranspiration and evaporation components, the open-channel area was identified and separated from the phreatophyte area. The effluent discharge channel was examined

A, Channel conditions before storm flows. Photograph taken March 19, 1990.



B, Channel conditions after storm flows. Photograph taken June 20, 1993.

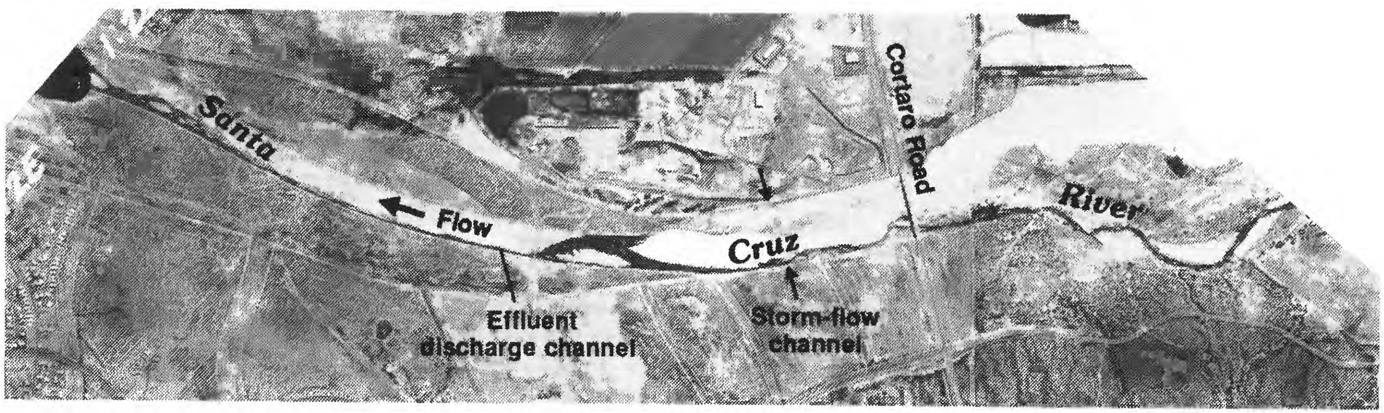
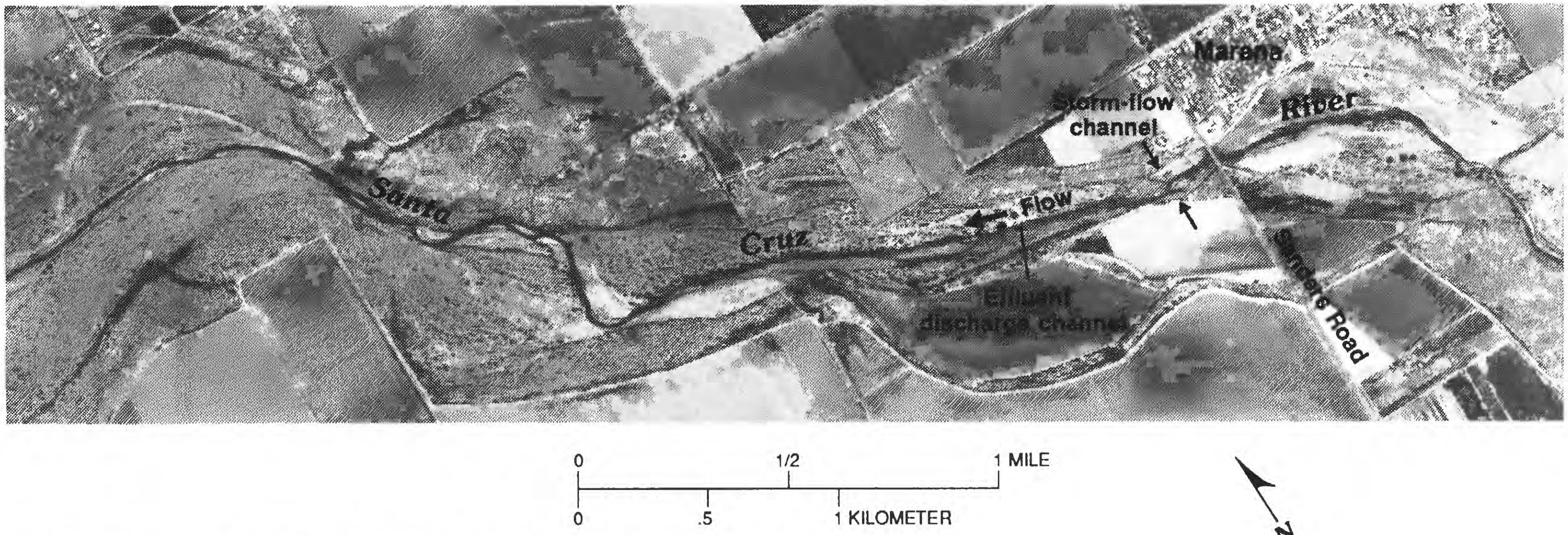


Figure 11. Channel conditions representative of periods before and after storm flows in the Santa Cruz River near Cortaro Road northwest of Tucson, Arizona. (Aerial photographs by Cooper Aerial Survey, 1990 and 1993)

A, Channel conditions before storm flows. Photograph taken March 19, 1990.



B, Channel conditions after storm flows. Photograph taken June 23, 1993.

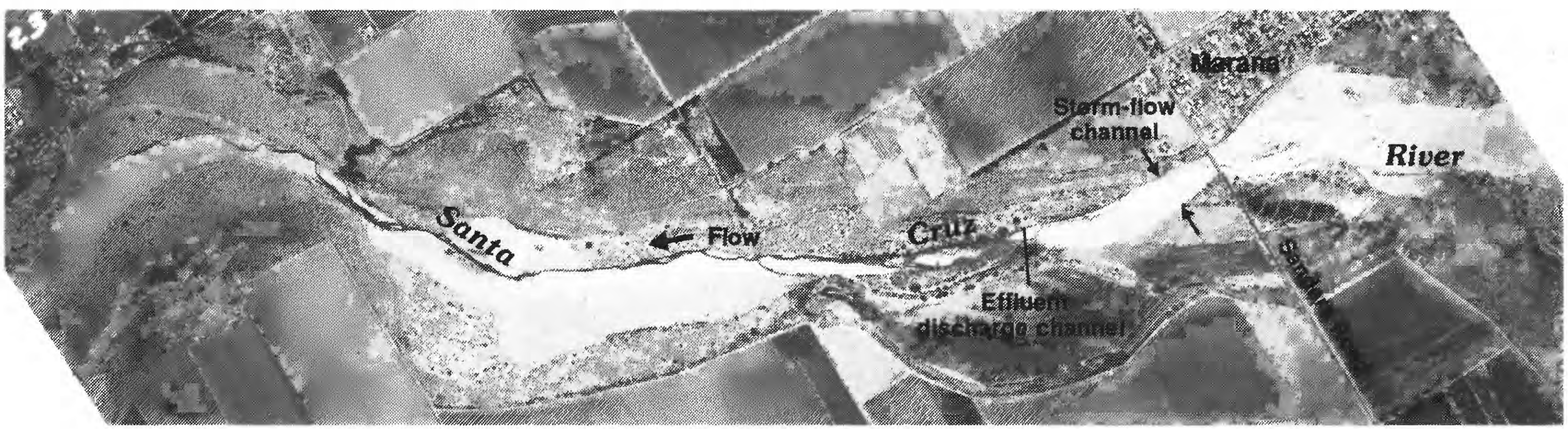


Figure 12. Channel conditions representative of periods before and after storm flows in the Santa Cruz River near Sanders Road at Marana, Arizona. (Aerial photographs by Cooper Aerial Survey, 1990 and 1993)

Table 3. Study points for estimation of evapotranspiration using aerial photographs, March 19, 1990, and June 20 and 23, 1993

[X, indicates an evaluation was done at the study point; dashes indicate an evaluation was not done at the study point. EOF, end of flow]

Study point number	Study points	1990 study points	1993 study points
	Reach from Roger Road water-treatment plant to Ina Road		
1	Roger Road water-treatment plant	X	X
2	El Camino del Cerro	X	X
3	Rillito Creek	X	X
4	Cañada del Oro	X	X
5	Ina Road water-treatment plant	X	X
6	Confluence of effluent channels from Roger Road and Ina Road water-treatment plants	X	X
	Reach from Ina Road to Cortaro		
7	Dam below Ina Road	X	--
8	Miscellaneous point	--	X
9	Miscellaneous point	--	X
	Reach from Cortaro to near Rillito		
10	Linda Vista Boulevard	X	X
11	Miscellaneous point	X	X
12	Avra Ford	X	X
	Reach from near Rillito to Sanders Road		
13	Miscellaneous point	X	X
14	Channel divergence upstream from Sanders Road	X	X
15	Channel convergence upstream from Sanders Road	--	X
	Reach from Sanders Road to Trico Road		
16	Miscellaneous point	X	--
17	Miscellaneous point	--	X
18	Miscellaneous point	--	X
19	Miscellaneous point	--	X
20	Miscellaneous point	X	X
21	Miscellaneous point (EOF)	--	X

in the aerial photographs, and 4 to 14 sections were selected within each reach segment on the basis of channel complexity. To obtain an average width for the reach segment, the channel was examined and the edges of the high stage of the diurnal flow was identified. Each section width was measured by a graduated loupe, which is a desk-top magnifying scope.

Lengths of the reach segments then were measured by computer digitization. The average wetted-channel width and length of the segment were used to determine open-channel areas, which were converted to acres (tables 6 and 7). The calculated open-channel areas (A_{ch}) then were subtracted from their respective digitized total phreatophyte and open-channel area (A_t) to obtain the actual phreatophyte area (A_{ph}, equation 2, tables 6 and 7).

$$A_{ph} = A_t - A_{ch} . \qquad (2)$$

Phreatophyte Area and Water Consumptive-Use Coefficients

The phreatophyte area in each reach segment was evaluated with respect to vegetation and was classified into four types—honey mesquite, cottonwood/willow, cattail/grass, and arrow weed. The water consumptive-use coefficients (k; Owen-Joyce and Raymond, 1996) were used for evapotranspiration calculations. A water consumptive-use coefficient is used to rank vegetation by the amount of water consumed. The coefficient is derived empirically and is unitless.

Several species of mesquite, palo verde, and other small trees were present but were indistinguishable by aerial photography. The consumptive-use coefficient for honey mesquite (k=0.7) represented the water consumptive-use coefficient of various mesquite and other small trees and was used for evapotranspiration calculations. Cottonwood trees and willows (combined k_t=1.2) occurred sporadically in the study area and usually along the edges of the phreatophyte area. Cattails and grasses (combined k_t=1.2) were prevalent in the upper parts of the study area, given sufficient time for revegetation after storm flows, and were intermittently present downstream. The consumptive-use coefficient (k_t=0.9) for arrow weed, which is common throughout the study area, was selected because it

Table 4. Open-channel area, March 19, 1990

Reach segments (See table 3 for explanation of study point)	Number of sections	Width, in feet	Length, in miles	Open-channel area, in acres
Reach from Roger Road water-treatment plant to Ina Road				
1–2	6	26	0.93	2.93
2–3	14	31.6	1.81	6.93
3–4	10	32	1.22	4.73
4–6	8	34	.65	2.68
5–6	6	21.5	.42	1.09
6–Ina Road	4	29.2	.38	1.34
SUM				19.70
Reach from Ina Road to Cortaro				
Ina Road –7	8	34.5	1.28	5.35
7–Cortaro	5	24.4	.29	.86
SUM				6.21
Reach from Cortaro to near Rillito				
Cortaro–10	8	28.9	2.00	7.01
10–11	6	27.8	1.39	4.68
11–12	8	65.6	1.88	14.95
12–near Rillito	11	16.7	.07	.14
SUM				26.78
Reach from near Rillito to Sanders Road				
Near Rillito–13	8	26.8	.99	3.22
13–14	11	56.8	2.65	18.24
14–Sanders Road	8	50.9	1.97	12.15
SUM				33.61
Reach from Sanders Road to Trico Road				
Sanders Road–16	10	42.5	2.33	12.00
16–20	8	64.2	2.49	19.38
20–Trico Road	6	58.2	.57	4.02
SUM				35.40

Table 5. Open-channel area, June 23–24, 1993

Reach segments (See table 3 for explanation of study point)	Number of sections	Width, in feet	Length, in miles	Open-channel area, in acres
Reach from Roger Road water-treatment plant to Ina Road				
1–2	7	39.3	1.00	4.76
2–3	10	67.5	1.97	16.12
3–4	7	70	1.18	10.01
4–6	6	86.7	.64	6.73
5–6	5	26.7	.42	1.36
6–Ina Road	7	116	.40	5.62
SUM				44.60
Reach from Ina Road to Cortaro				
Ina Road–8	5	381	.13	6.00
8–9	9	51.7	.88	5.51
9–Cortaro	4	29.5	.44	1.57
SUM				13.08
Reach from Cortaro to near Rillito				
Cortaro–10	11	61	2.09	15.45
10–11	7	86.1	1.43	14.92
11–12	7	108	1.96	25.66
12–near Rillito	3	16.7	.07	.14
SUM				56.17
Reach from near Rillito to Sanders Road				
Near Rillito–13	7	23.7	1.12	3.22
13–14	9	54.4	2.72	17.94
14–15	10	26.7	1.46	4.73
15–Sanders Road	8	21.6	.60	1.57
SUM				27.46
Reach from Sanders Road to Miscellaneous Point 21				
Sanders Road–17	5	45.8	.21	1.17
17–18	9	40.4	.75	3.67
18–19	6	26.7	.72	2.33
19–20	5	29.4	.76	2.71
20–21 (End of flow)	6	9.2	.66	.74
SUM				10.62

Table 6. Consumptive-use coefficient determination, March 19, 1990

[K_t=Blaney-Criddle consumptive-use coefficient for type(s) of vegetation]

Reach segments (See table 3 for explanation of study point)	Total phreatophyte and open-channel areas, in acres	Open-channel area, in acres	Phreatophyte area, in acres	Fraction of total area covered by vegetation type				Coefficient weighted by proportion (K_{tp})	Density coefficient (K_d)	Coefficient weighted by proportion and density (K_{tpd})	Weighted coefficient multiplied by phreatophyte area, in acres	Weighted coefficient with respect to segment areas (K_{tpda})
				Cottonwood/ Willow $K_t = 1.2$	Honey Mesquite $K_t = 0.7$	Arrow-weed $K_t = 0.9$	Cattail/ Grass $K_t = 1.2$					
Reach from Roger Road water-treatment plant to Ina Road												
1–2	10.2	2.93	7.27	0.1	0.1	0.5	0.3	1.00	0.85	0.850	6.18	
2–3	65.3	6.93	58.37	.2	.2	.4	.2	.98	.7	.686	40.04	
3–4	47.4	4.73	42.67	.2	.1	.4	.3	1.03	.85	.876	37.38	
4–6	19.2	2.68	16.52	.1	.2	.3	.4	1.01	.7	.707	11.68	0.769
5–6	7.0	1.09	5.91	.25	.25	.25	.25	1.00	.85	.850	5.02	
6–Ina Road	3.2	1.34	1.86	.1	.1	.4	.4	1.03	.85	.876	1.63	
SUM		19.70	132.63								101.93	
Reach from Ina Road to Cortaro												
Ina Road–7	6.4	5.35	1.05	.05	.1	.55	.3	.99	.85	.842	.88	
7–Cortaro	3.2	.86	2.34	.15	.1	.35	.4	1.05	1.00	1.05	2.46	.985
SUM		6.21	3.39								3.34	
Reach from Cortaro to near Rillito												
Cortaro–10	35.2	7.01	28.19	.1	.1	.5	.3	1.00	.85	.850	23.96	
10–11	12.2	4.68	7.52	.05	.2	.6	.15	.92	.85	.782	5.88	
11–12	57	14.95	42.05	.2	.5	.1	.2	.92	1.00	.920	38.69	.879
12–near Rillito	.64	.14	.50	0	.05	.4	.55	1.06	.55	.583	.29	
SUM		26.78	78.26								68.82	
Reach from near Rillito to Sanders Road												
Near Rillito–13	5.1	3.22	1.88	.2	.2	.4	.2	.98	.85	.833	1.57	
13–14	47.4	18.24	29.16	.25	.25	.25	.25	1.00	.85	.850	24.79	.843
14–Sanders Road	14.7	12.15	2.55	.05	.2	.65	.1	.91	.85	.774	1.97	
SUM		33.61	33.59								28.33	
Reach from Sanders Road to Trico Road												
Sanders Road–16	43.5	12.00	31.50	.2	.2	.4	.2	.98	.85	.833	26.24	
16–20	40.3	19.38	20.92	.05	.60	.03	.05	.81	.85	.688	14.39	.786
20–Trico Road	9.6	4.02	5.58	.3	.2	.2	.3	1.04	.85	.884	4.93	
SUM		35.40	58.00								45.56	

Table 7. Consumptive-use coefficient determination, June 23–24, 1993

[K_t=Blaney-Criddle consumptive-use coefficient for type(s) of vegetation]

Reach segments (See table 3 for explanation of study point)	Total phreatophyte and open-channel areas, in acres	Open-channel area, in acres	Phreatophyte area, in acres	Fraction of total area covered by vegetation type				Coefficient weighted by proportion (K_{tp})	Density coefficient (K_d)	Coefficient weighted by proportion and density (K_{tpd})	Weighted coefficient multiplied by phreatophyte area, in acres	Weighted coefficient with respect to segment areas (K_{tpda})
				Cottonwood/ Willow K_t = 1.2	Honey Mesquite K_t = 0.7	Arrow-weed K_t = 0.9	Cattail/ Grass K_t = 1.2					
Reach from Roger Road water-treatment plant to Ina Road												
1–2	19.2	4.76	14.44	0.2	0.2	0.2	0.4	1.04	0.7	0.728	10.51	
2–3	80.6	16.12	64.48	.1	.1	.3	.5	1.06	.7	.742	47.84	
3–4	40.3	10.01	30.29	0	.1	.2	.7	1.09	.55	.600	18.17	
4–6	14.1	6.73	7.37	.05	.05	.1	.8	1.15	.55	.632	4.66	0.694
5–6	3.9	1.36	2.54	0	.1	.7	.2	.94	.7	.658	1.67	
6–Ina Road	9.6	5.62	3.98	0	.05	.8	.15	.94	.7	.658	2.62	
SUM		44.60	123.10								85.47	
Reach from Ina Road to Cortaro												
Ina Road–8	8.4	6.00	2.40	.05	.05	.7	.2	.97	.7	.679	1.63	
8–9	10.2	5.51	4.69	.05	.1	.55	.3	.99	.85	.842	3.95	.791
9–Cortaro	1.9	1.57	.33	.15	.1	.4	.35	1.03	.85	.876	.29	
SUM		13.08	7.42								5.87	
Reach from Cortaro to near Rillito												
Cortaro–10	22.4	15.45	6.95	0	0	.8	.2	.96	.7	.672	4.67	
10–11	24.3	14.92	9.38	0	.05	.8	.15	.94	.55	.517	4.85	
11–12	57	25.66	31.34	.25	.4	.2	.15	.94	.85	.799	25.04	.725
12–Rillito	.6	.14	.46	0	0	.7	.3	.99	.7	.693	.32	
SUM		56.17	48.13								34.88	
Reach from near Rillito to Sanders Road												
Near Rillito–13	10.9	3.22	7.68	.1	.05	.5	.35	1.03	.7	.721	5.54	
13–14	34.6	17.94	16.66	.1	.05	.55	.3	1.01	.7	.707	11.78	
14–15	43.5	4.73	38.77	.15	.5	.2	.15	.89	.85	.756	29.31	.744
15–16	3.8	1.57	2.23	0	0	.5	.5	1.05	.85	.892	1.99	
SUM		27.46	65.44								48.62	
Reach from Sanders Road to Miscellaneous Point 21												
Sanders Road–17	1.3	1.17	0.13	0	0	.9	.1	.93	.55	.512	.07	
17–18	21.8	3.67	18.13	.15	.15	.4	.3	1.01	.7	.707	12.82	
18–19	3.5	2.33	1.17	0	0	.7	.3	.99	.55	.544	.64	.683
19–20	6.4	2.71	3.69	0	.2	.6	.2	.92	.7	.644	2.38	
20–21	3.2	.74	2.46	0	.05	.7	.2	.91	.7	.637	1.57	
SUM		10.62	25.58								17.48	

represents consumptive-use coefficients of other herbaceous plants.

Weighting Consumptive Use by Vegetation Type and Proportion—Each vegetation type in each reach segment was considered as a fraction of all vegetation in the reach segment and assigned a proportional coefficient. Then each type proportion coefficient (P) was multiplied by the consumptive-use coefficient types (k_t) to obtain a type- and proportion-weighted consumptive-use coefficient (K_{tp}; equation 3; and tables 6 and 7).

$$K_{tp} = \Sigma (P) K_t . \qquad (3)$$

Weighting Consumptive-Use Coefficient by Vegetation Type, Proportion, and Density—Using the aerial photographs, each reach segment was rated for vegetation density (D) using a scale of 1.0 for dense, 0.85 for medium, and 0.70 for sparse distribution (Owen-Joyce and Raymond, 1996). An additional density coefficient of 0.55 was used for extremely sparse areas where plants were nearly nonexistent or the extremely narrow shoreline vegetation was widely separated from phreatophyte-area edge vegetation by expanses of barren sand (table 6 and 7). Each segment (K_{tp}) then was multiplied by the relative density coefficient to produce a consumptive-use coefficient weighted by type, proportion, and density (K_{tpd}; equation 4; tables 6 and 7).

$$K_{tpd} = (K_{tp}) D . \qquad (4)$$

Weighting Consumptive-Use Coefficient by Vegetation Type, Proportion, Density, and Area—The consumptive-use coefficient weighted by type, proportion, density, and area (K_{tpda}) then was calculated by summing the products of K_{tpd} and A_{ph} and then dividing that sum by the total A_{ph} as in equation 5. This calculation provides the K_{tpda} for the entire reach that is weighted by vegetation type, proportion, and density for the reach with consideration of the magnitude of the reach-segment areas (tables 6 and 7).

$$K_{tpda} = \frac{\Sigma ((K_{tpd}) A_{ph})}{\Sigma A_{ph}} . \qquad (5)$$

Weighting Consumptive-Use Coefficient by Vegetation Type, Proportion, Density, Area, and Channel Conditions—The K_{tpda} was calculated for each reach segment from the data derived from aerial photographic data sets (Cooper Aerial Survey Company, 1990–93). The results for each month for each reach then were averaged (table 8).

Table 8. Weighted consumptive-use coefficients, March 1990 and June 1993

Reach	March 1990	June 1993	Average
Roger Road water-treatment plant to Ina Road	0.769	0.694	0.732
Ina Road to Cortaro	.985	.791	.888
Cortaro to near Rillito	.879	.725	.802
Near Rillito to Sanders Road	.843	.744	.794
Sanders Road to Trico Road	.786	.683	.734

As mentioned previously during storm periods, vegetation was stripped, and channel geometry was altered (figs. 10 and 11). If the channel changes were severe enough that the channel characteristics approached the postflood conditions of June 1993, the weighted consumptive-use coefficient that was based on the 1993 data was used. During the study period when revegetation and channel stabilization progressed downstream, the average of the March 1990 preflow and the June 1993 postflow weighted consumptive-use coefficients was used. When vegetation returned to a condition approximating the near maximum vegetated state of March 1990, the consumptive-use coefficient that was based on the March 1990 data was used. The coefficient was selected and applied on a month-by-month basis for each reach to reflect changing vegetation and channel conditions. The choice of a consumptive-use coefficient was based on site visits, measurement record, hydrographic record, and observations of vegetation and channel conditions.

Estimation of Monthly Percent of Annual Daytime Hours

Evapotranspiration by vegetation is responsive to temperature, solar radiation, humidity, and wind speed. Monthly percent of annual daytime hours was interpolated from published daylight hours (Cruff and Thompson, 1967) for a latitude of 32°24' (table 9), which is about the mean latitude of the study area (table 26 in the basic-data section). The mean monthly temperature and mean monthly humidity were recorded at the University of Arizona experimental farm at Marana, Arizona (University of Arizona, 1990–93), which was the meteorological recording site nearest the study area.

The phreatophyte-zone areas (A_{phr}) for each reach for 1990 and 1993 were averaged (table 10). Of these three values, the one corresponding to the weighted consumptive-use coefficient selected for evaporation (*ET*) calculations was selected to reflect the condition of the vegetation in the channel in that reach for the month (tables 14, 16, and 18 in the basic-data section).

Table 9. Annual percentage of daylight hours for each month in any year for the mean latitude of the study area

[Data modified from Cruff and Thompson (1967)]

Month	Latitude 32°	Latitude 34°	Latitude 32°24'	Month	Latitude 32°	Latitude 34°	Latitude 32°24'
October	7.93	7.90	7.92	April	8.75	8.80	8.76
November	7.11	7.02	7.09	May	9.63	9.72	9.65
December	7.05	6.92	7.02	June	9.60	9.70	9.62
January	7.20	7.10	7.18	July	9.77	9.88	9.79
February	6.97	6.91	6.96	August	9.28	9.33	9.29
March	8.37	8.36	8.37	September	8.34	8.36	8.34

Table 10. Phreatophyte area and open-channel area, March 19, 1990, and June 20, 23, and 24, 1993

Reach	Phreatophyte area, in acres (A_{ph}) 03–19–90	06–20, 23 and 06–24–93	Average	Reach	Open-channel area, in acres (A_{ch}) 03–19–90	06–20, 23 and 06–24–93	Average
Roger Road water-treatment plant to Ina Road	132.60	123.10	127.85	Roger Road water-treatment plants to Ina Road	19.70	44.60	32.15
Ina Road to Cortaro	3.39	7.42	5.40	Ina Road to Cortaro	6.21	13.08	9.64
Cortaro to near Rillito	78.26	48.13	63.20	Cortaro to near Rillito	26.78	56.17	41.48
Near Rillito to Sanders Road	33.59	65.44	49.51	Near Rillito to Sanders Road	33.61	27.46	30.54
Sanders Road to Trico Road	58.00	25.58	41.79	Sanders Road to Trico Road	35.40	10.62	23.01

Blaney-Morin Equation for Estimation of Evapotranspiration

Several equations of varying complexity are available to estimate evapotranspiration. The data available determine the equation used. The Blaney-Morin equation for estimating evapotranspiration was selected for two reasons: (1) the formula complexity matched the available meteorological data (table 27 in basic-data section) and (2) consumptive water-use coefficients of native vegetation could be transferred from the Blaney-Criddle formula (Owen-Joyce and Raymond, 1996).

The rate of water consumption by some plants is indexed for the various formulas for computing evapotranspiration (Chow, 1964). Saltcedar (*Tamarisk*) was used to cross reference the water-consumption coefficients by Blaney and Morin (1942) and Blaney and Criddle (1950). The winter and summer consumptive-use coefficients (0.0075 and 0.0216) of Blaney and Morin (1942) were averaged for an annual consumption of 0.0146. The consumption value for saltcedar (1.4) of Blaney and Criddle (Owen-Joyce and Raymond, 1996) must be adjusted by a factor of 0.0104 to produce the Blaney and Morin annual consumption constant (0.0146). All reach-weighted consumption values were developed from coefficients developed by Blaney and Criddle (1950), and the following equations by Blaney and Morin (1942) utilize the 0.0104 correction factor. The original Blaney and Morin formula is shown in equation 6 and is modified with respect to the cross-reference correction to the *k* values of Blaney-Criddle (tables 11–13).

$$ET = (C)\,(K)\,(P)\,(T)\,(114-H)\,, \qquad (6)$$

where

ET = evapotranspiration, in inches per month;

C = correction factor, Blaney-Criddle to Blaney-Morin (0.0104);

K = consumptive-use coefficient weighted by phreatophyte type, proportion, density, and phreatophyte area (K_{tpda});

P = monthly percent of annual daytime hours times 0.01;

T = temperature, monthly mean in degrees Fahrenheit; and

H = relative humidity, average monthly percent.

Estimation of Evapotranspiration in Channel Reach

The evapotranspiration per reach per month (ET_r), in acre-feet, was calculated as in equation 7 using the chosen A_{ph}, in acres and calculated potential evapotranspiration (ET), in feet per month (tables 14, 16, and 18 in the basic-data section).

$$ET_r = A_{ph}(ET)\,. \qquad (7)$$

Estimation of Open-Channel Evaporation in Channel Reach

Monthly class A pan-evaporation values (E_p), in inches per month (tables 14, 16, 18, and 27 in the basic-data section; University of Arizona, 1990–93), were corrected for open-channel evaporation (E_c), in inches per month, by applying a 0.69 correction factor (E_{ow}) obtained by comparing values from the class A pan to free water-ratio maps (Farnsworth, Thompson, and Peck, 1992). These values then were converted to open-channel evaporation (E_c), in feet per month, as in equation 8.

$$E_c = \frac{(E_p)\,0.69}{12}\,. \qquad (8)$$

The open-channel areas (A_{ch}) of March 1990 and June 1993 were averaged for each reach (table 13). Of the three values, the one that corresponds to K_{tpda} and A_{ph}, already selected for use for that month, was used to determine open-channel evaporation. Open-channel evaporation for each reach (E_r), in acre-feet per month, was obtained, as in equation 9, as the product of E_c, in feet per month, and A_{ch}, in acres (tables 14, 16, and 18 in the basic-data section).

$$E_r = E_c(A_{ch})\,. \qquad (9)$$

Table 11. Evapotranspiration by reach, water year 1991

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (P)	Temperature, monthly mean, in degrees Fahrenheit (T)	Relative humidity, monthly average, in percent (H)	Evapotranspiration (ET)	
					Inches	Feet
Reach from Roger Road water-treatment plant to Ina Road						
October 1990	0.769	0.0792	68	41	3.14	0.26
November	.769	.0709	57	47	2.16	.18
December	.732	.0702	47	62	1.31	.11
January 1991	.732	.0718	49	68	1.23	.10
February	.732	.0696	58	40	2.27	.19
March	.732	.0837	54	51	2.17	.18
April	.732	.0876	64	24	3.84	.32
May	.769	.0965	73	16	5.52	.46
June	.769	.0962	80	17	5.97	.50
July	.769	.0979	86	29	5.72	.48
August	.732	.0929	84	51	3.74	.31
September	.732	.0834	79	54	3.01	.25
Reach from Ina Road to Cortaro						
October 1990	.888	.0792	68	41	3.63	.30
November	.888	.0709	57	47	2.50	.21
December	.791	.0702	47	62	1.41	.12
January 1991	.791	.0718	49	68	1.33	.11
February	.888	.0696	58	40	2.76	.23
March	.791	.0837	54	51	2.34	.20
April	.791	.0876	64	24	4.15	.35
May	.791	.0965	73	16	5.65	.47
June	.791	.0962	80	17	6.11	.51
July	.791	.0979	86	29	5.86	.49
August	.791	.0929	84	51	4.02	.34
September	.888	.0834	79	54	3.65	.30
Reach from Cortaro to near Rillito						
October 1990	.879	.0792	68	41	3.59	.30
November	.879	.0709	57	47	2.48	.21
December	.725	.0702	47	62	1.29	.11
January 1991	.725	.0718	49	68	1.22	.10
February	.802	.0696	58	40	2.49	.21
March	.725	.0837	54	51	2.15	.18

See footnote at end of table.

Table 11. Evapotranspiration by reach, water year 1991—Continued

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (*P*)	Temperature, monthly mean, in degrees Fahrenheit (*T*)	Relative humidity, monthly average, in percent (*H*)	Evapotranspiration (*ET*) Inches	Evapotranspiration (*ET*) Feet
Reach from Cortaro to near Rillito—Continued						
April	0.725	0.0876	64	24	3.80	0.32
May	.725	.0965	73	16	5.20	.43
June	.725	.0962	80	17	5.63	.47
July	.725	.0979	86	29	5.40	.45
August	.725	.0929	84	51	3.71	.31
September	.802	.0834	79	54	3.30	.27
Reach from near Rillito to Sanders Road						
October 1990	.794	.0792	68	41	3.25	.27
November	.794	.0709	57	47	2.24	.19
December	.794	.0702	47	62	1.41	.12
January 1991	.794	.0718	49	68	1.34	.11
February	.794	.0696	58	40	2.47	.21
March	.794	.0837	54	51	2.35	.20
April	.794	.0876	64	24	4.17	.35
May	.794	.0965	73	16	5.70	.48
June	.794	.0962	80	17	6.16	.51
July	.794	.0979	86	29	5.91	.49
August	.794	.0929	84	51	4.06	.34
September	.794	.0834	79	54	3.26	.27
Reach from Sanders Road to Trico Road						
October 1990	.734	.0792	68	41	3.00	.25
November	.734	.0709	57	47	2.07	.17
December	.734	.0702	47	62	1.31	.11
January 1991	.734	.0718	49	68	1.23	.10
February	.734	.0696	58	40	2.27	.19
March	.734	.0837	54	51	2.17	.18
April	.734	.0876	64	24	3.85	.32
May	.734	.0965	73	16	5.27	.44
June	.734	.0962	80	17	5.68	.47
July	.734	.0979	86	29	5.45	.45
August	.734	.0929	84	51	3.74	.31
September	.734	.0834	79	54	3.01	.25

[1]Weighted by vegetation type, proportion, density, and area.

Table 12. Evapotranspiration by reach, water year 1992

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (P)	Temperature, monthly mean, in degrees Fahrenheit (T)	Relative humidity, monthly average, in percent (H)	Evapotranspiration (ET) Inches	Evapotranspiration (ET) Feet
Reach from Roger Road water-treatment plant to Ina Road						
October 1991	0.732	0.0792	71	40	3.17	0.26
November	.732	.0707	55	54	1.78	.15
December	.732	.0702	51	79	.95	.08
January 1992	.732	.0718	49	69	1.21	.10
February	.732	.0696	54	70	1.26	.10
March	.732	.0837	57	68	1.67	.14
April	.769	.0876	68	40	3.52	.29
May	.769	.0965	75	37	4.46	.37
June	.732	.0962	83	17	5.90	.49
July	.732	.0979	85	39	4.75	.40
August	.732	.0929	83	60	3.17	.26
September	.732	.0834	81	46	3.50	.29
Reach from Ina Road to Cortaro						
October 1991	.884	.0792	71	40	3.83	.32
November	.884	.0707	55	54	2.15	.18
December	.884	.0702	51	79	1.15	.10
January 1992	.787	.0718	49	69	1.46	.12
February	.787	.0696	54	70	1.35	.11
March	.787	.0837	57	68	1.80	.15
April	.884	.0876	68	40	4.05	.34
May	.884	.0965	75	37	5.12	.43
June	.884	.0962	83	17	7.12	.59
July	.884	.0979	85	39	5.74	.48
August	.787	.0929	83	60	3.41	.28
September	.884	.0834	81	46	4.22	.35
Reach from Cortaro to near Rillito						
October 1991	.802	.0792	71	40	3.47	.29
November	.802	.0707	55	54	1.95	.16
December	.802	.0702	51	79	1.04	.09
January 1992	.802	.0718	49	69	1.32	.11
February	.802	.0696	54	70	1.38	.11
March	.725	.0837	57	68	1.65	.14
April	.725	.0876	68	40	3.32	.28

See footnote at end of table.

Table 12. Evapotranspiration by reach, water year 1992—Continued

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (*P*)	Temperature, monthly mean, in degrees Fahrenheit (*T*)	Relative humidity, monthly average, in percent (*H*)	Evapotranspiration (*ET*) Inches	Evapotranspiration (*ET*) Feet
Reach from Cortaro to near Rillito—Continued						
May	0.725	0.0965	75	37	4.20	0.35
June	.802	.0962	83	17	6.46	.54
July	.725	.0979	85	39	4.70	.39
August	.725	.0929	83	60	3.14	.26
September	.802	.0834	81	46	3.83	.32
Reach from near Rillito to Sanders Road						
October 1991	.843	.0792	71	40	3.65	.30
November	.843	.0707	55	54	2.05	.17
December	.843	.0702	51	79	1.10	.09
January 1992	.843	.0718	49	69	1.39	.12
February	.843	.0696	54	70	1.45	.12
March	.843	.0837	57	68	1.92	.16
April	.843	.0876	68	40	3.86	.32
May	.843	.0965	75	37	4.89	.41
June	.843	.0962	83	17	6.79	.57
July	.843	.0979	85	39	5.47	.46
August	.843	.0929	83	60	3.65	.30
September	.843	.0834	81	46	4.03	.34
Reach from Sanders Road to Trico Road						
October 1991	.734	.0792	71	40	3.18	.26
November	.734	.0707	55	54	1.79	.15
December	.734	.0702	51	79	.96	.08
January 1992	.734	.0718	49	69	1.21	.10
February	.734	.0696	54	70	1.26	.10
March	.734	.0837	57	68	1.68	.14
April	.734	.0876	68	40	3.36	.28
May	.734	.0965	75	37	4.27	.35
June	.734	.0962	83	17	5.91	.49
July	.734	.0979	85	39	4.76	.40
August	.734	.0929	83	60	3.18	.26
September	.734	.0834	81	46	3.51	.29

[1]Weighted by vegetation type, proportion, density, and area.

Table 13. Evapotranspiration by reach, water year 1993

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (*P*)	Temperature, monthly mean, in degrees Fahrenheit (*T*)	Relative humidity, monthly average, in percent (*H*)	Evapotranspiration (*ET*)	
					Inches	Feet
Reach from Roger Road water-treatment plant to Ina Road						
October 1992	0.769	0.0792	70	37	3.41	0.28
November	.769	.0707	53	32	2.46	.21
December	.769	.0702	48	82	.86	.07
January 1993	.694	.0718	53	84	.82	.07
February	.694	.0696	52	74	1.04	.09
March	.694	.0837	59	60	1.92	.16
April	.694	.0876	67	29	3.60	.30
May	.694	.0965	77	27	4.67	.39
June	.694	.0962	82	15	5.64	.47
July	.694	.0979	85	35	4.74	.40
August	.694	.0929	82	58	3.08	.26
September	.694	.0834	77	45	3.20	.27
Reach from Ina Road to Cortaro						
October 1992	.888	.0792	70	37	3.94	.33
November	.888	.0709	53	32	2.84	.24
December	.888	.0702	48	82	1.00	.08
January 1993	.791	.0718	53	84	.94	.08
February	.791	.0696	52	74	1.19	.10
March	.791	.0837	59	60	2.19	.18
April	.791	.0876	67	29	4.10	.34
May	.791	.0965	77	27	5.32	.44
June	.791	.0962	82	15	6.42	.54
July	.791	.0979	85	35	5.38	.45
August	.888	.0929	82	58	3.94	.33
September	.888	.0834	77	45	4.09	.34
Reach from Cortaro to near Rillito						
October 1992	.802	.0792	70	37	3.56	.30
November	.802	.0709	53	32	2.57	.21
December	.802	.0702	48	82	.90	.07
January 1993	.725	.0718	53	84	.86	.07
February	.725	.0696	52	74	1.09	.09

See footnote at end of table.

Table 13. Evapotranspiration by reach, water year 1993—Continued

Month	Consumptive-use coefficient (K_{tpda})[1]	Monthly percent of annual daylight hours x 0.01 (*P*)	Temperature, monthly mean, in degrees Fahrenheit (*T*)	Relative humidity, monthly average, in percent (*H*)	Evapotranspiration (*ET*) Inches	Evapotranspiration (*ET*) Feet
Reach from Cortaro to near Rillito—Continued						
March	0.725	0.0837	59	60	2.01	0.17
April	.725	.0876	67	29	3.76	.31
May	.725	.0965	77	27	4.87	.41
June	.725	.0962	82	15	5.87	.49
July	.725	.0979	85	35	4.96	.41
August	.802.	.0929	82	58	3.56	.30
September	.802	.0834	77	45	3.70	.31
Reach from near Rillito to Sanders Road						
October 1992	.843	.0792	70	37	3.74	.31
November	.843	.0709	53	32	2.70	.22
December	.843	.0702	48	82	.94	.08
January 1993	.744	.0718	53	84	.88	.07
February	.744	.0696	52	74	1.12	.09
March	.744	.0837	59	60	2.06	.17
April	.744	.0876	67	29	3.86	.32
May	.744	.0965	77	27	5.00	.42
June	.744	.0962	82	15	6.04	.50
July	.744	.0979	85	35	5.09	.42
August	.744	.0929	82	58	3.30	.28
September	.744	.0834	77	45	3.43	.29
Reach from Sanders Road to Trico Road						
October 1992	.734	.0792	70	37	3.26	.27
November	.734	.0709	53	32	2.35	.20
December	.734	.0702	48	82	.82	.07
January 1993	.683	.0718	53	84	.81	.07
February	.683	.0696	52	74	1.03	.09
March	.683	.0837	59	60	1.89	.16
April	.683	.0876	67	29	3.54	.30
May	.683	.0965	77	27	4.59	.38
June	.683	.0962	82	15	5.55	.46
July	.683	.0979	85	35	4.67	.39
August	.683	.0929	82	58	3.03	.25
September	.683	.0834	77	45	3.15	.26

[1]Weighted by vegetation type, proportion, density, and area.

Estimation of Effluent Infiltration

Estimation of Infiltration in Channel Reach

The total loss of discharge per reach (L_r) is obtained by subtraction of the discharge at the gaging station (Q_s) from the discharge of the nearest upstream gaging station (Q_s'). Subtracting the sum of evapotranspiration (ET_r) and evaporation (E_r) for each reach from the L_r as in equation 10 yields the infiltration occurring in the reach upstream from that gaging station (I_r), in acre-feet (tables 15, 17, and 19 in the basic-data section).

$$I_r = L_r - (ET_r + E_r),$$

or (10)

$$(Q_s' - Q_s) - (ET_r + E_r)\,.$$

Estimation of Infiltration From Water-Treatment Plants to a Gaging-Station Site

One method to determine the cumulative infiltration from the WTP's to a gaging-station site (I_s) in acre-feet, is to sum the infiltration amounts of the upstream reaches (ΣI_r), in acre-feet, as in equation 11.

$$I_s = \Sigma I_r\,. \qquad (11)$$

Infiltration along each reach was considered as a percent (I_{rp}) of the WTP's effluent discharge (Q_{wtp}) as in equation 12 or as accumulative infiltration percentage to each gaging-station site (I_{sp}) as a percent of Q_{wtp} (equation 13).

$$I_{rp} = \frac{I_r}{Q_{wtp}}(100), \qquad (12)$$

and

$$I_{sp} = \frac{I_s}{Q_{wtp}}(100). \qquad (13)$$

The rate of infiltration also was computed for each reach, in acre-feet per mile (I_r/mi; equation 14) and from the WTP's to the considered gaging-station site (I_s/mi; equation 15; tables 15, 17, and 19 in the basic-data section).

$$I_r/\text{mi} = \frac{I_r}{D_r/\text{mi}}, \qquad (14)$$

where

D_r/mi = length of reach, in miles.

$$I_s/\text{mi} = \frac{I_s}{D_{wtp}/\text{mi}}, \qquad (15)$$

where

D_{wtp}/mi = distance from WTP's to gaging-station site, in miles.

RESULTS OF THE COMPREHENSIVE GAIN-LOSS STUDY

The WY infiltration, as a percentage of discharge from the WTP's, ranged from 88.4 to 90.2 percent, and the average for 1991–93 was 89.5 percent. Total effluent discharges from the WTP's for WY 1991, 1992, and 1993 were 46,600, 49,380, and 50,620 acre-ft, respectively. Estimated infiltration for WY 1991, 1992, and 1993 were 41,890, 43,640, and 45,670 acre-ft, respectively. During the study period, the discharge from the WTP's increased 8.7 percent, and infiltration increased 8.9 percent. The monthly infiltration, as a percent of discharge from the WTP's, ranged from 72.1 percent in December 1990, after a period of channel stabilization, to 98.8 percent in February 1993, after severe channel disturbance caused by the floods of December 1992 through January 1993.

Large decreases in discharges in the downstream direction closely followed storm flows as shown in the hydrographs for the gaging stations at Cortaro, Arizona, and at Trico Road (figs. 13–15 and tables 22–26 in the basic-data section). The storm flows disrupted channel-bed integrity by altering channel geometry and placement and stripping the channel of phreatophyte and riparian vegetation. This disruption probably resulted in the greater-than-normal infiltration rates, and markedly diminished discharges were recorded

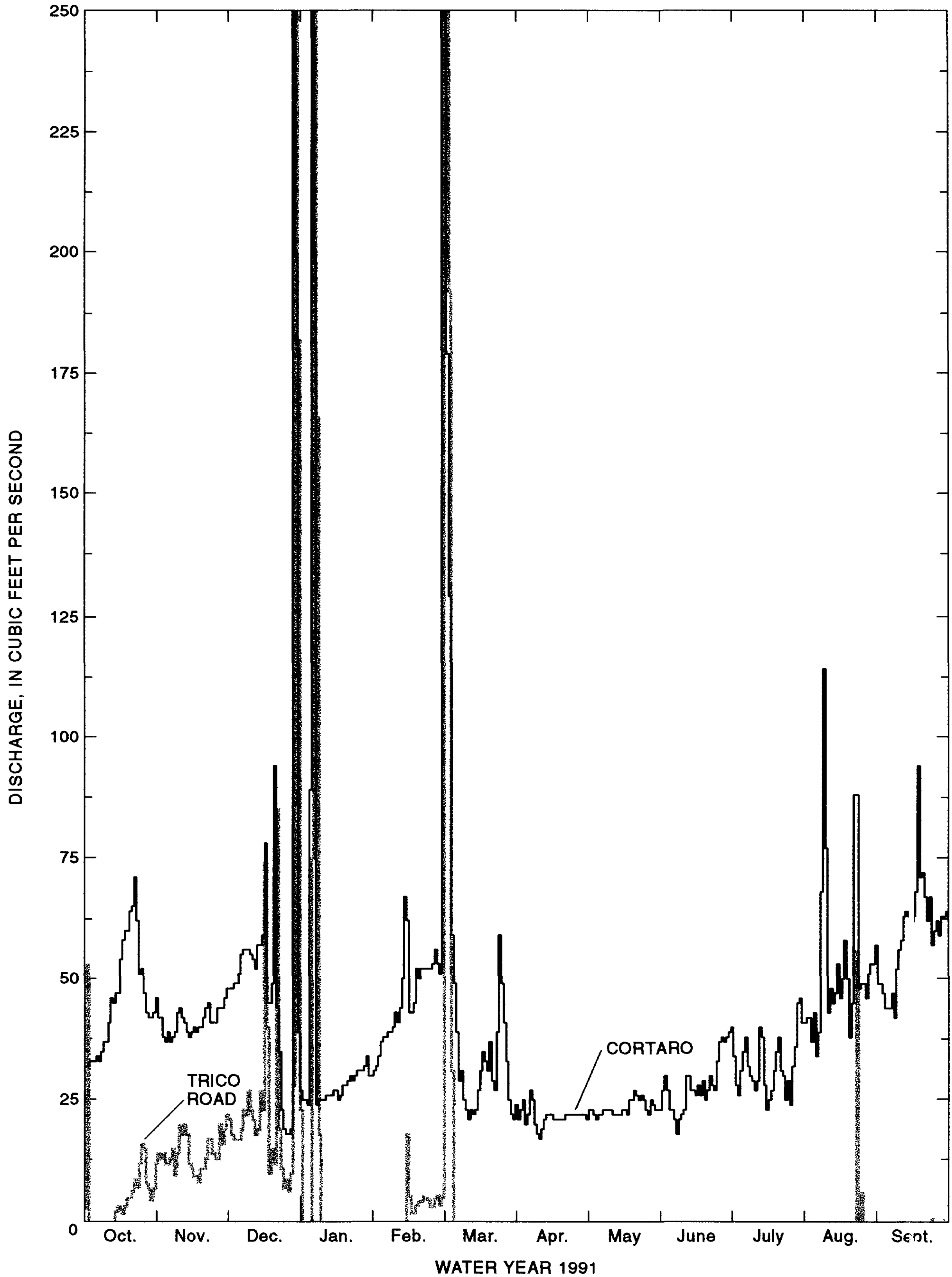


Figure 13. Daily mean discharges of the Santa Cruz River at Cortaro, Arizona, and at Trico Road, near Marana, Arizona, water year 1991 (not reconstructed, but limited to 250 cubic feet per second).

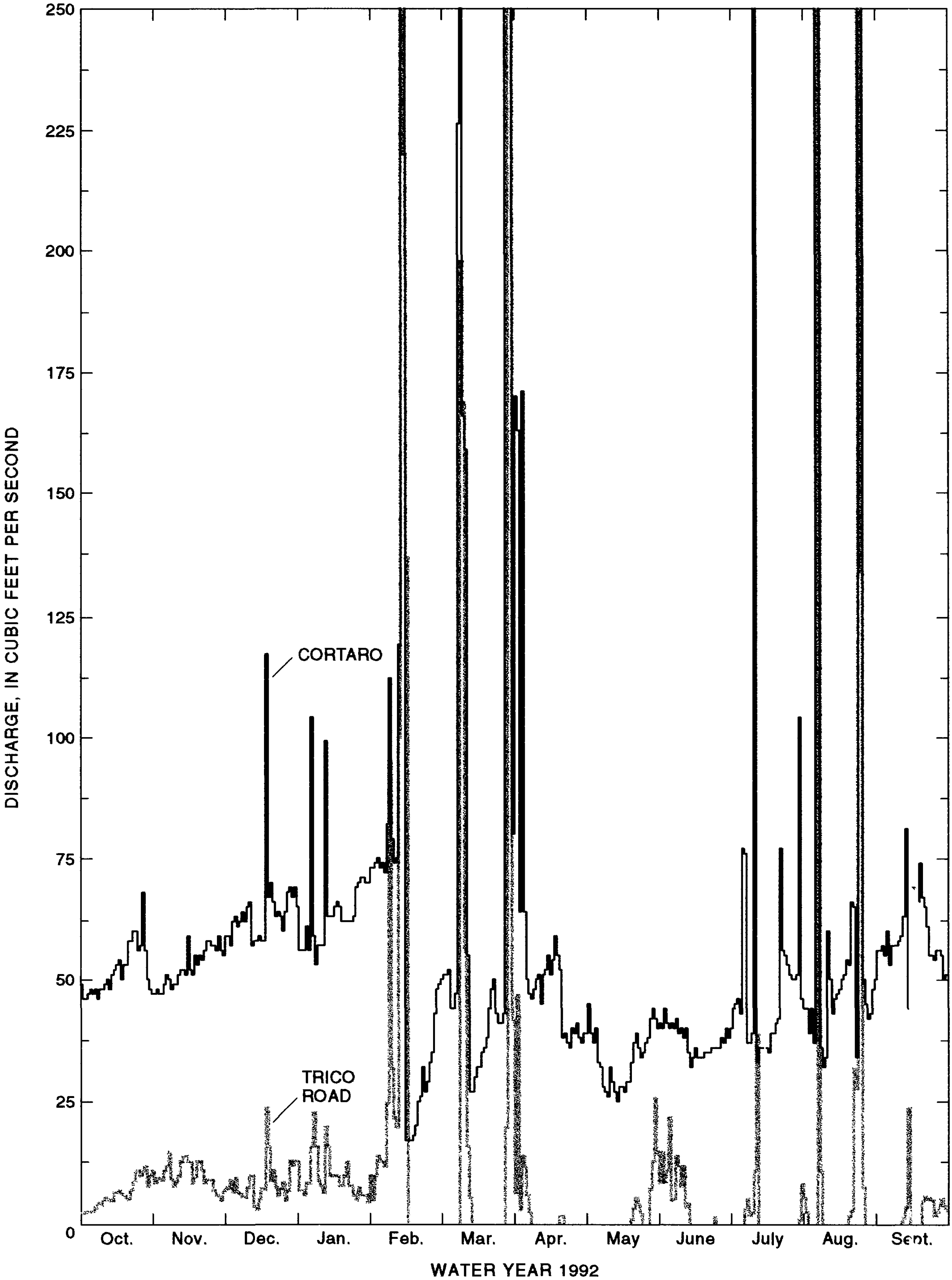


Figure 14. Daily mean discharges of the Santa Cruz River at Cortaro, Arizona, and at Trico Road, near Marana, Arizona, water year 1992 (not reconstructed, but limited to 250 cubic feet per second).

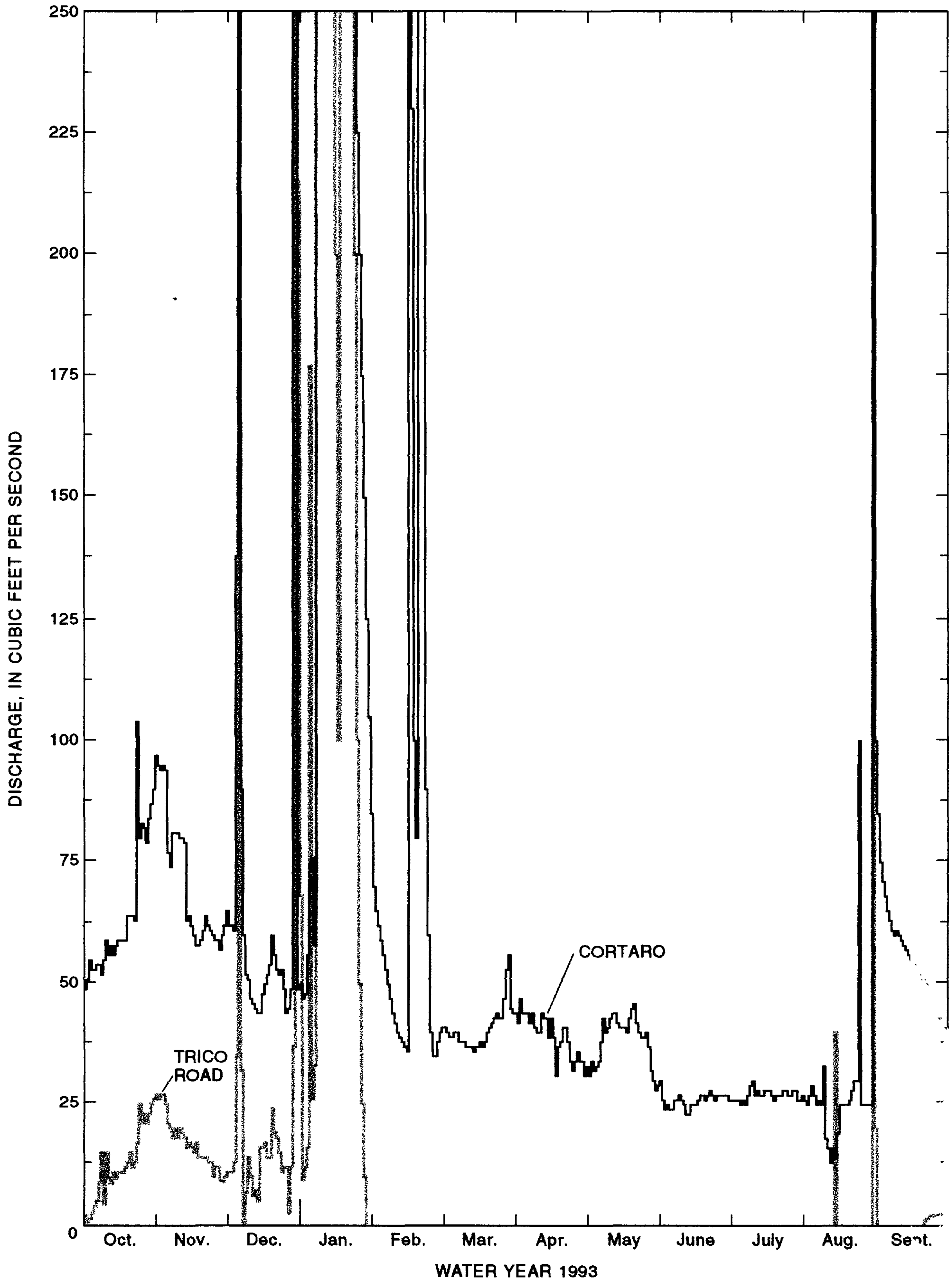


Figure 15. Daily mean discharges of the Santa Cruz River at Cortaro, Arizona, and at Trico Road, near Marana, Arizona, water year 1993 (not reconstructed, but limited to 250 cubic feet per second).

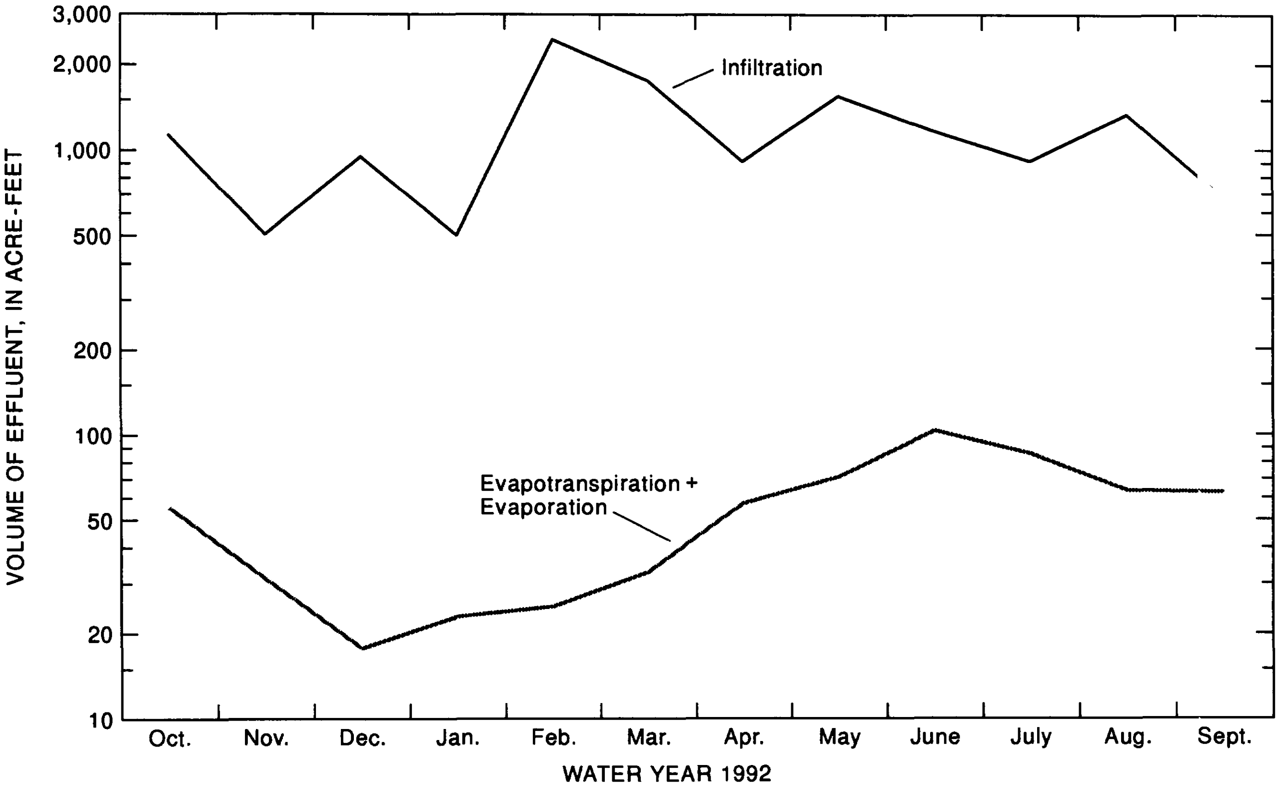


Figure 16. Infiltration and combined evapotranspiration and evaporation from points of effluent discharge to Cortaro, Arizona, water year 1992.

downstream. After storm flows, the gaging-station sites near Rillito, at Sanders Road, and at Trico Road often recorded long periods without effluent discharge.

After storm flows, discharge gradually increased and infiltration gradually decreased (figs. 8–10 and 13–15). The cycle of disruption was repeated with the next storm flow. The loss of discharge to evapotranspiration and open-channel evaporation was negligible when compared to infiltration, especially after storm flows (fig. 16).

The differing phreatophyte-zone and open-channel areas of each reach for March 1990 and June 1993 (tables 4–7) reflect channel alteration and displacement caused by storm flows. Because of the small water consumption and overall sparsity of vegetation through the study reach, the potential open-channel evaporation generally is greater than potential phreatophyte evapotranspiration (tables 15, 16, and 18 in the basic-data section). The combined water-year open-channel evaporation and phreatophyte evapotranspiration, as a percentage of discharge from the WTP's, ranged from 3.2 to 5.3 percent and averaged 3.9 percent for 1991–93.

For 1991–93, estimated open-channel evaporation was 899, 812, and 791 acre-ft/water year, respectively, and the estimated water-year evapotranspiration was 899, 805, and 831 acre-ft, respectively. During 1991–93, the volume of effluent discharge that flowed out of the study area was 2,880, 4,120, and 3,320 acre-ft/yr, respectively. Even though the total estimated phreatophyte area remained about 3,200 acres, the phreatophyte-zone area of individual gaging-station site reaches varied, especially in the lower reaches. During the study period, the phreatophyte-zone area between the gaging-station sites near Rillito and at Sanders Road increased 70 percent, and the phreatophyte-zone area between Sanders Road and Trico Road decreased 30 percent. The changes were caused by storm flows that altered the area and types of phreatophytes. After the floods of January 1993, the effluent flowed a shorter distance from the WTP's, and the available phreatophyte-zone area was reduced.

The potential evapotranspiration calculated from the Blaney-Morin equations reflects seasonal changes in the temperature and humidity components. The annual consumptive-use coefficient was used because of the lack of monthly or seasonal values for all vegetation types. This coefficient moderates the evapotranspiration extremes; the estimated winter values are larger, and summer values are smaller. The evapotranspiration sums, however, are probably representative when considered on an annual or study-period basis.

Trees often withered when the channel was shifted a distance of 30–40 ft. This may indicate a steep infiltration gradient because the root system of many types of trees extends laterally about as far as the trees are tall—in this instance, 20 ft.

SUMMARY

Infiltration into the channel bed of the Santa Cruz River constituted nearly the entire water budget for effluent discharged by the WTP's near Tucson, Arizona. During October 1, 1990, to September 30, 1993, the estimated water-year rate of infiltration through the 23-mile reach ranged from 88.4 to 90.2 percent of the discharges from the WTP's, and the average of the 3 years was 89.8 percent. Estimates of evapotranspiration and open-channel evaporation ranged from 3.2 to 3.9 percent of the discharges from the WTP's in the water year, and averaged 3.5 percent. For 1991–93, 6.2 to 8.3 percent of total effluent discharge flowed past the study reach, and the 3-year average was 7.0 percent. In 1991–93, estimated open-channel evaporation was 899, 812, and 791 acre-ft/water year, and the estimated water-year evapotranspiration was 899, 805, and 831 acre-ft, respectively. During 1991–93, the volume of effluent discharge that flowed out of the study area was 2,880, 4,120, and 3,320 acre-ft/yr, respectively, and the volume of infiltration was 41,890, 43,640, and 45,670 acre-ft/yr, respectively.

Storm flows stripped the channel of riparian and phreatophyte vegetation and altered channel geometry and location. Following storm flows, infiltration increased significantly, effluent discharge through the study reach decreased sharply, and the small amount of water lost to evaporation and evapotranspiration dropped slightly. After a period without storm flows, the channel geometry began stabilizing, and new growth of riparian and phreatophyte vegetation gradually appeared. Infiltration would gradually decrease, with a corresponding increase in discharge through the reach; evaporation and evapotranspiration would increase slightly.

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BASIC DATA AND CONDITIONS OF HYDROLOGIC DATA COLLECTION

— PAGE 39 FOLLOWS —

Table 14. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1991

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Area of phreatophytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation to the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Roger Road water-treatment plant to Ina Road										
October	132.6	0.26	34.5	19.7	7.68	8.70	43.2		43.2	
November	132.6	.18	23.9	19.7	5.14	5.82	29.7		29.7	
December	127.8	.11	14.1	32.2	2.69	4.98	19.1		19.1	
January	127.8	.10	12.8	32.2	2.78	5.15	18.0		18.0	
February	127.8	.19	24.3	32.2	4.86	9.00	33.3		33.3	
March	127.8	.18	23.0	32.2	6.09	11.3	34.3	0.8	34.3	.8
April	127.8	.32	40.9	32.2	11.26	20.8	61.7	1.8	61.7	1.8
May	132.6	.46	61.0	19.7	15.76	17.8	78.8	2.1	78.8	2.1
June	132.6	.50	66.3	19.7	14.73	16.7	83.0	2.4	83.0	2.4
July	132.6	.48	63.6	19.7	15.1	17.1	80.7	2.3	80.7	2.3
August	127.8	.31	39.6	32.2	13.55	25.1	64.7	1.7	64.7	1.7
September	127.8	.25	32.0	32.2	10.44	19.3	51.3	1.2	51.3	1.2
Subtotal	1,557.6		436	323.9		162	598		598	1.7
Reach from Ina Road to Cortaro										
October	5.4	.30	1.62	9.6	7.68	4.24	5.9	.2	49.1	1.3
November	5.4	.21	1.13	9.6	5.14	2.84	4.0	.1	33.7	.9
December	7.4	.12	0.89	13.1	2.69	2.03	2.9	.1	22.0	.5
January	7.4	.11	0.81	13.1	2.78	2.09	2.9	.1	20.9	.5
February	5.4	.23	1.24	9.6	4.86	2.68	3.9	.1	37.2	.9
March	7.4	.20	1.48	13.1	6.09	4.59	6.1	.1	40.5	1.0
April	7.4	.35	2.59	13.1	11.26	8.48	11.1	.3	72.8	2.2
May	7.4	.47	3.48	13.1	15.76	11.9	15.4	.4	94.2	2.5
June	7.4	.51	3.77	13.1	14.73	11.1	14.9	.4	97.5	2.8
July	7.4	.49	3.63	13.1	15.1	11.4	15.0	.4	95.3	2.7
August	7.4	.34	2.52	13.1	13.55	10.2	12.7	.3	77.6	2.1
September	5.4	.30	1.62	9.6	10.44	5.76	7.4	.2	58.5	1.4
Subtotal	80.8		25	143.2		77	102		699	1.5
Reach from Cortaro to near Rillito										
October	78.3	.30	23.5	26.8	7.68	11.8	35.3		84.4	
November	78.3	.21	16.4	26.8	5.14	7.92	24.3		58.0	

Table 14. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1991—Continued

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Cortaro to near Rillito—Continued										
December	48.1	0.11	5.29	56.2	2.69	8.69	14.0		35.8	
January	48.1	.10	4.81	56.2	2.78	8.98	13.8		35.0	
February	63.2	.21	13.3	41.5	4.86	11.6	24.9		62.0	
March	48.1	.18	8.66	56.2	6.09	19.7	28.4		68.9	
April	48.1	.32	15.4	56.2	11.26	36.4	51.8	1.5	125	3.7
May	48.1	.43	20.7	56.2	15.76	50.9	71.6	1.9	166	4.3
June	48.1	.47	22.8	56.2	14.73	47.6	70.4	2.0	168	4.9
July	48.1	.45	21.6	56.2	15.1	48.8	70.4	2.0	166	4.8
August	48.1	.31	14.9	56.2	13.55	43.8	58.7	1.6	136	3.6
September	63.2	.27	17.1	41.5	10.44	24.9	42.0	1.0	100	2.4
Subtotal	667.8		184	586.2		321	505		1,205	4.0
Reach from near Rillito to Sanders Road										
October	33.6	.27	9.07	30.5	7.68	13.5	22.6		107	
November	33.6	.19	6.38	30.5	5.14	9.01	15.4		73.0	
December	33.6	.12	4.03	30.5	2.69	4.72	8.8		44.3	
January	33.6	.11	3.70	30.5	2.78	4.88	8.6		43.7	
February	33.6	.21	7.06	30.5	4.86	8.52	15.6		77.3	
March	33.6	.20	6.72	30.5	6.09	10.7	17.4	0.4	86.3	2.1
April	33.6	.35	11.8	30.5	11.26	19.8	31.6	0.9	157	4.6
May	33.6	.48	16.1	30.5	15.76	27.6	43.7	1.1	210	5.5
June	33.6	.51	17.1	30.5	14.73	25.8	42.9	1.2	211	6.1
July	33.6	.49	16.5	30.5	15.1	26.5	43.0	1.2	209	6.0
August	33.6	.34	11.4	30.5	13.55	23.8	35.2	0.9	171	4.5
September	33.6	.27	9.07	30.5	10.44	18.3	27.4	0.7	127	3.1
Subtotal	403.2		119	366.6		193	312		1,171	4.5

Table 14. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1991—Continued

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Sanders Road to Trico Road										
October	41.8	0.25	10.4	23	7.68	10.2	20.6	0.5	128	3.3
November	41.8	.17	7.11	23	5.14	6.80	13.9	0.4	86.9	2.4
December	41.8	.11	4.60	23	2.69	3.56	8.2	0.2	52.5	1.2
January	41.8	.10	4.18	23	2.78	3.68	7.9	0.2	51.6	1.2
February	41.8	.19	7.94	23	4.86	6.43	14.4	0.4	91.7	2.3
March	41.8	.18	7.52	23	6.09	8.05	15.6	0.4	102	2.4
April	41.8	.32	13.4	23	11.26	14.9	28.3	0.8	185	5.4
May	41.8	.44	18.4	23	15.76	20.8	39.2	1.0	249	6.5
June	41.8	.47	19.6	23	14.73	19.5	39.1	1.1	250	7.2
July	41.8	.45	18.8	23	15.1	20.0	38.8	1.1	248	7.1
August	41.8	.31	13.0	23	13.55	17.9	30.9	0.8	202	5.4
September	41.8	.25	10.4	23	10.44	13.8	24.2	0.6	151	3.7
Subtotal	501.6		135	276		146	281		1,800	5.3
TOTAL	3,210		899	1,690		899				

Table 15. Computations of infiltration of effluent, Santa Cruz River, water year 1991

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Roger Road water-treatment plant to Ina Road											
October			3,920								
November			3,710								
December			4,280								
January			4,460								
February			3,980								
March	4,150	1,920	4,150	2,230	2,230	2,196	52.9	2,196	52.9	440	440
April	3,380	1,540	3,380	1,840	1,840	1,778	52.6	1,778	52.6	356	356
May	3,830	2,040	3,830	1790	1,790	1,711	44.7	1,711	44.7	343	343
June	3,450	2,260	3,450	1,190	1,190	1,107	32.1	1,107	32.1	222	222
July	3,480	2,620	3,480	860	860	779	22.4	779	22.4	156	156
August	3,780	3,490	3,780	290	290	225	6.0	225	6.0	45.1	45.1
September	4,160	3,840	4,160	320	320	269	6.5	269	6.5	53.9	53.9
Subtotal	26,230	17,710	46,660	8,520	8,520	8,065		8,065	30.7	1,620	1,620
Reach from Ina Road to Cortaro											
October	3,920	2,710			1,210			1,151	29.4		175
November	3,710	2,510			1,200			1,156	31.3		176
December	4,280	2,830			1,450			1,428	33.4		218
January	4,460	1,780			2,680			2,659	59.6		405
February	3,970	2,650			1,320			1,283	32.5		197
March	4,150	2,070	1,920	-150	2,080	-156	-3.8	2,040	49.1	-99.4	311
April	3,380	1,350	1,540	190	2,030	179	5.3	1,957	57.9	114	298
May	3,830	1,490	2,040	550	2,340	535	14.0	2,246	58.9	341	344
June	3,450	1,730	2,260	530	1,720	515	14.9	1,622	47.0	328	247

Table 15. Computations of infiltration of effluent, Santa Cruz River, water year 1991—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Ina Road to Cortaro—Continued											
July	3,480	2,050	2,620	570	1,430	555	15.9	1,334	38.1	354	203
August	3,780	2,910	3,490	580	870	567	15.0	792	21.0	361	121
September	4,160	3,500	3,840	340	660	333	8.0	602	14.5	212	91.8
Subtotal	46,570	27,580	17,710	2,610	19,000	2,528		18,270	39.3	1,610	2,790
Reach from Cortaro to near Rillito											
October			2,710								
November			2,510								
December			2,830								
January			1,780								
February			2,650								
March			2,070								
April	3,380	6.3	1,350	1,344	3,374	1,292	38.2	3,249	96.1	242	273
May	3,830	454	1,490	1,036	3,376	964	25.2	3,210	83.8	180	270
June	3,450	825	1,730	905	2,625	835	24.2	2,457	71.2	156	206
July	3,480	961	2,050	1,089	2,519	1,019	29.3	2,353	67.6	191	198
August	3,780	799	2,910	2,111	2,981	2,052	54.3	2,845	75.3	384	239
September	4,160	2,640	3,500	860	1,520	818	19.7	1,420	34.1	153	119
Subtotal	22,080	5,685	27,580	7,345	16,395	6,980		15,535	70.4	1,310	1,300
Reach from near Rillito to Sanders Road											
October											
November											
December											
January											

Table 15. Computations of infiltration of effluent, Santa Cruz River, water year 1991—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from near Rillito to Sanders Road—Continued											
February											
March	4,150	50			4,100			4,014	96.7		229
April	3,380	0	6.3	6.3	3,380	-25	-0.7	3,223	95.4	-4.5	184
May	3,830	57	454	397	3,773	353	9.2	3,563	93.0	62.9	203
June	3,450	128	825	697	3,322	654	19.0	3,111	90.2	117	178
July	3,480	310	961	651	3,170	608	17.5	2,961	85.1	108	169
August	3,780	706	799	93	3,074	58	1.5	2,903	76.8	10.3	166
September	4,160	1,190	2,640	1,450	2,970	1,423	34.2	2,843	68.3	254	162
Subtotal	26,230	2,441	5,685	3,294	23,789	3,071		22,619	86.2	547	1,290
Reach from Sanders Road to Trico Road											
October	3,920	356			3,564			3,436	87.6		150
November	3,710	850			2,860			2,773	74.7		121
December	4,280	1,140			3,140			3,088	72.1		135
January	4,460	184			4,276			4,224	94.7		184
February	3,970	142			3,828			3,736	94.1		164
March	4,150	79.2	50	-29.2	4,071	-45	-1.1	3,969	95.6	-8.3	173
April	3,380	0	0	0	3,380	-28	-0.8	3,195	94.6	-5.2	140
May	3,830	0	57	57	3,830	18	0.5	3,581	93.2	3.3	156
June	3,450	0	128	128	3,450	89	2.6	3,200	92.8	16.5	140
July	3,480	0	310	310	3,480	271	7.8	3,232	92.9	50.3	141
August	3,780	123	706	583	3,657	552	14.6	3,455	91.4	102	151
September	4,160	4.4	1,190	1,185.6	4,156	1,161	27.9	4,005	96.2	215	175
TOTAL	46,570	2,880	2,440	2,240	43,690	2,030		41,390	90.0	376	1,330

Table 16. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1992

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Area of phreatophytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Roger Road water-treatment plant to Ina Road										
October	127.8	0.26	33.2	32.2	8.56	15.8	49.0	1.1	49.0	1.1
November	127.8	.15	19.2	32.2	4.54	8.41	27.6	.7	27.6	.7
December	127.8	.08	10.2	32.2	2.92	5.41	15.6	.4	15.6	.4
January	127.8	.10	12.8	32.2	3.96	7.33	20.1	.5	20.1	.5
February	127.8	.10	12.8	32.2	4.11	7.61	20.4	.5	20.4	.5
March	127.8	.14	17.9	32.2	5.28	9.78	27.7	.6	27.6	.6
April	132.6	.29	38.4	19.7	9.98	11.3	49.7	1.3	49.7	1.3
May	132.6	.37	49.1	19.7	11.59	13.1	62.2	1.7	62.2	1.7
June	132.6	.49	65.0	32.2	14.47	26.8	91.8	2.6	91.8	2.5
July	127.8	.40	51.1	32.2	13.16	24.4	75.5	2.1	75.5	2.1
August	127.8	.26	33.2	32.2	10.83	20.0	53.2	1.3	53.2	1.3
September	127.8	.29	37.1	32.2	9.79	18.1	55.2	1.3	55.2	1.3
Subtotal	1,542.9		380	361.4		168	548		548	1.1
Reach from Ina Road to Cortaro										
October	5.4	.32	1.72	9.6	8.56	4.73	6.4	.1	55.4	1.2
November	5.4	.18	.97	9.6	4.54	2.51	3.5	.1	31.1	.7
December	5.4	.10	.54	9.6	2.92	1.61	2.2	.0	17.8	.4
January	5.4	.12	.65	9.6	3.96	2.19	2.8	.1	22.9	.5
February	7.4	.11	.81	13.1	4.11	3.10	3.9	.1	24.3	.6
March	7.4	.15	1.11	13.1	5.28	3.98	5.1	.1	32.7	.7
April	5.4	.34	1.84	9.6	9.98	5.51	7.4	.2	57.1	1.5
May	5.4	.43	2.32	9.6	11.59	6.40	8.7	.2	70.9	1.9
June	5.4	.59	3.19	9.6	14.47	7.99	11.2	.3	103	2.8
July	5.4	.48	2.59	9.6	13.16	7.26	9.8	.3	85.3	2.4
August	7.4	.28	2.07	13.1	10.83	8.16	10.2	.2	63.4	1.5
September	5.4	.35	1.89	9.6	9.79	5.40	7.3	.2	62.5	1.5
Subtotal	72.8		19.7	125.7		59	78.5		627	1.3

Table 16. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1992—Continued

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Cortaro to near Rillito										
October	63.2	0.29	18.3	41.5	8.56	20.4	38.7	0.9	94.1	2.1
November	63.2	.16	10.1	41.5	4.54	10.8	20.9	.5	52.0	1.2
December	63.2	.09	5.69	41.5	2.92	6.97	12.7	.3	30.5	.7
January	63.2	.11	6.95	41.5	3.97	9.45	16.4	.4	39.3	.9
February	63.2	.11	6.95	41.5	4.11	9.81	16.8	.4	41.1	1.0
March	48.1	.14	6.73	56.2	5.28	17.1	23.8	.5	56.6	1.3
April	48.1	.28	13.5	56.2	9.98	32.2	45.7	1.2	103	2.7
May	48.1	.35	16.8	56.2	11.59	37.4	54.2	1.4	125	3.3
June	63.2	.54	34.1	41.5	14.47	34.5	68.6	1.9	172	4.8
July	48.1	.39	18.8	56.2	13.16	42.5	61.3	1.7	147	4.1
August	48.1	.26	12.5	56.2	10.83	35.0	47.5	1.1	111	2.6
September	63.2	.32	20.2	41.5	9.79	23.4	43.6	1.0	106.	2.5
Subtotal	682.9		171	571.5		280	450		1,078	2.2
Reach from near Rillito to Sanders Road										
October	33.6	.30	10.1	30.5	8.56	15.0	25.1	.6	119	2.6
November	33.6	.17	5.71	30.5	4.54	7.96	13.7	.3	65.7	1.6
December	33.6	.09	3.02	30.5	2.92	5.12	8.14	.2	38.6	.9
January	33.6	.12	4.03	30.5	3.96	6.94	11.0	.2	50.3	1.2
February	33.6	.12	4.03	30.5	4.11	7.21	11.2	.3	53.3	1.3
March	33.6	.16	5.38	30.5	5.28	9.26	14.6	.3	71.0	1.6
April	33.6	.32	10.8	30.5	9.98	17.5	28.3	.6	132	3.4
May	33.6	.41	13.8	30.5	11.59	20.3	34.1	.9	160	4.2
June	33.6	.57	19.2	30.5	14.47	25.4	44.6	1.2	217	6.0
July	33.6	.46	15.4	30.5	13.16	23.1	38.5	1.1	186	5.1
August	33.6	.30	10.1	30.5	10.83	19.0	29.1	.7	140	3.3
September	33.6	.34	11.4	30.5	9.79	17.2	28.6	.7	135	3.1
Subtotal	403.2		113	366		174	287		1,368	2.8

Table 16. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1992—Continued

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Sanders Road to Trico Road										
October	41.8	0.26	10.9	23	8.56	11.3	22.2	0.5	141	3.1
November	41.8	.15	6.27	23	4.54	6.00	12.3	.3	78.0	1.9
December	41.8	.08	3.34	23	2.92	3.86	7.2	.2	45.8	1.1
January	41.8	.10	4.18	23	3.96	5.24	9.4	.2	59.7	1.4
February	41.8	.10	4.18	23	4.11	5.44	9.6	.2	62.9	1.5
March	41.8	.14	5.85	23	5.28	6.98	12.8	.3	83.8	1.9
April	41.8	.28	11.7	23	9.98	13.2	24.9	.6	157	4.0
May	41.8	.35	14.6	23	11.59	15.3	29.9	.8	190	4.8
June	41.8	.49	20.5	23	14.47	19.1	39.6	.9	257	6.7
July	41.8	.40	16.7	23	13.16	17.4	34.1	1.1	220	5.8
August	41.8	.26	10.9	23	10.83	14.3	25.2	0.6	165	3.9
September	41.8	.29	12.1	23	9.79	13.0	25.1	.6	160	3.6
Subtotal	501.6		121	276		131	252		1,620	3.3
TOTAL	3,200		805	1,700		812				

Table 17. Computations of infiltration of effluent, Santa Cruz River, water year 1992

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plant (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plant (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Roger Road water-treatment plant to Ina Road											
October	4,430	3,550	4,430	880	880	831	18.7	831	18.7	166	166
November	4,180	3,560	4,180	620	620	592	14.2	592	14.2	119	119
December	4,440	4,220	4,440	220	220	204	4.6	204	4.6	41.0	41.0
January	4,370	4,110	4,370	260	260	240	5.5	240	5.5	48.1	48.1
February	4,200	2,860	4,200	1,340	1,340	1,320	31.4	1,319	31.4	264	264
March	4,420	3,120	4,420	1,300	1,300	1,272	28.8	1,272	28.8	255	255
April	3,840	3,250	3,840	590	590	540	15.5	540	15.5	108	108
May	3,780	3,080	3,780	700	700	638	16.9	1638	16.9	128	128
June	3,560	2,770	3,560	790	790	698	19.6	700	19.6	140	140
July	3,600	3,160	3,600	440	440	364	10.1	365	10.1	73.2	73.2
August	4,270	3,250	4,270	1,020	1,020	967	22.6	967	22.6	194	194
September	4,290	3,790	4,290	500	500	445	10.4	445	10.4	89.1	89.1
Subtotal	49,380	40,720	49,380	8,660	8,660	8,111		8,110	16.4	1,620	1,620
Reach from Ina Road to Cortaro											
October	4,430	3,240	3,550	310	1,190	304	6.9	1,135	25.6	193	173
November	4,180	3,200	3,560	360	980	357	8.5	949	22.7	227	145
December	4,440	3,920	4,220	300	520	298	6.7	502	11.3	190	76.6
January	4,370	3,840	4,110	270	530	267	6.1	507	11.6	170	77.3
February	4,200	1,730	2,860	1,130	2,470	1,126	26.8	2,446	58.2	717	373
March	4,420	2,630	31,20	490	1,790	485	11.0	1,757	39.8	309	268
April	3,840	2,870	3,250	380	970	373	9.7	913	23.8	238	139
May	3,780	2,160	3,080	920	1,620	911	24.1	1,549	41.0	580	236
June	3,560	2,290	2,770	480	1,260	469	13.2	1,169	32.8	299	178
July	3,600	2,600	3,160	560	1,000	550	15.3	915	25.4	350	140
August	4,270	2,870	3,250	380	1,400	370	8.7	1,337	31.3	236	204
September	4,290	3,550	3,790	240	740	233	5.4	677	15.8	148	103
Subtotal	49,380	34,900	40,720	5,820	14,490	5,740		13,850	28.0	3,660	2,110

Table 17. Computations of infiltration of effluent, Santa Cruz River, water year 1992—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plant (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plant (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Cortaro to near Rillito											
October	4,430	3,170	3,240	70	1,260	31	0.7	1,166	26.3	5.8	98.0
November			3,200								
December	4,440	2,660	3,920	1,260	1,780	1,247	28.1	1,750	39.4	234	147
January	4,370	3,220	3,840	620	1,150	604	13.8	1,111	25.4	113	93.3
February	4,200	1,630	1,730	100	2,570	83	2.0	2,529	60.2	15.5	212
March	4,420	2,000	2,630	630	2,420	606	13.7	2,363	53.5	113	199
April	3,840	2,500	2,870	370	1,340	324	8.4	1,237	31.8	60.7	104
May	3,780	2,620	2,160	−460	1,160	−514	−13.6	1,035	27.4	−96.2	87.0
June	3,560	2,690	2,290	−400	870	−469	−13.2	698	19.6	−87.8	58.7
July	3,600	4221	2,600	2,178	3,178	2,117	58.8	3,031	84.2	396	255
August	4,270	904	2,870	1,966	3,366	1,918	44.8	3,255	76.2	359	274
September	4,290	1,500	3,550	2,050	2,790	2,006	46.8	2,684	62.6	376	226
Subtotal	45,200	23,316	34,900	8,384	21,884	7,955		20,806	46.0	1,490	1, 750
Reach from near Rillito to Sanders Road											
October	4,430	1,420	3,170	1,750	3,010	1,725	39.0	2,891	65.2	307	165
November	4,180	1,410	5,380	3,970	2,770	3,956	94.7	2,704	64.7	705	154
December	4,440	1,470	2,660	1,190	2,970	1,182	26.6	2,832	66.0	211	162
January	4,370	1,750	3,220	1,470	2,620	1,459	33.4	2,570	58.7	260	147
February	4,200	1,240	1,630	390	2,960	379	8.6	2,908	69.2	67.6	166
March	4,420	769	2,000	1,231	3,651	1,216	27.1	3,579	81.0	217	204
April	3,840	1,000	2,500	1,500	2,840	1,472	37.9	2,709	70.5	262	155
May	3,780	1,210	2,620	1,410	2,570	1,376	36.4	2,411	63.8	245	138
June	3,560	994	2,690	1,696	2,566	1,651	46.4	2,349	66.1	294	134
July	3,600	885	422	−463	2,715	−502	−13.9	2,529	70.3	−89.5	144
August	4,270	1,010	904	−106	3,260	−135	−3.2	3,120	73.1	−24.1	178
September	4,290	619	1,500	881	3,671	853	19.9	3,536	82.4	152	202
Subtotal	49,380	13,777	28,696	14,919	35,603	14,632		34,137	69.1	2,610	1,950

Table 17. Computations of infiltration of effluent, Santa Cruz River, water year 1992—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s')	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plant (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plant (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Sanders Road to Trico Road											
October	4,430	386	1,420	1,034	4,044	1,012	22.8	3,903	88.2	188	170
November	4,180	595	1,410	815	3,585	803	19.2	3,507	83.9	149	153
December	4,440	536	1,470	934	3,904	927	20.9	3,859	86.9	172	168
January	4,370	590	1,750	1,160	3,780	1,151	26.3	3,721	85.1	214	162
February	4,200	604	1,240	636	3,596	626	14.9	3,534	84.1	116	154
March	4,420	317	769	452	4,103	439	9.9	4,018	90.9	81.5	175
April	3,840	186	1,000	814	3,654	789	20.5	3,498	91.2	146	153
May	3,780	153	1,210	1,057	3,627	1,027	27.2	3,444	91.1	190	150
June	3,560	259	994	735	3,301	695	19.6	3,047	86.0	129	133
July	3,600	146	885	739	3,454	705	19.6	3,224	90.1	131	141
August	4,270	200	1,010	810	4,070	785	18.3	3,905	91.5	146	170
September	4,290	149	619	470	4,141	445	10.4	3,981	92.9	82.6	174
TOTAL	49,380	4,120	13,780	9,660	45,270	9,400		43,640	88.4	1,740	1,910

Table 18. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1993

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Roger Road water-treatment plant to Ina Road										
October	132.6	0.28	37.1	19.7	7.76	8.79	45.9	1.2	45.9	1.2
November	132.6	.21	27.8	19.7	4.9	5.55	33.4	.8	33.4	.8
December	132.6	.07	9.28	19.7	2.06	2.33	11.6	.3	11.6	.3
January	123.1	.07	8.62	44.6	2.08	5.33	14.0		14.0	
February	123.1	.09	11.1	44.6	2.90	7.44	18.5		18.5	
March	123.1	.16	19.7	44.6	6.53	16.8	36.5		36.5	
April	123.1	.30	36.9	44.6	9.52	24.4	61.3		61.3	
May	123.1	.39	48.0	44.6	12.41	31.8	79.8		79.8	
June	123.1	.47	57.9	44.6	14.66	37.6	95.5		95.5	
July	123.1	.40	49.2	44.6	13.41	34.4	83.6		83.6	
August	123.1	.26	32.0	44.6	9.55	24.5	56.5		56.5	
September	123.1	.27	33.2	44.6	9.73	25.0	58.2		58.2	—
Subtotal	1,505.7		371	460.5		224	595		595	1.2
Reach from Ina Road to Cortaro										
October	5.4	.33	1.78	9.6	7.76	4.28	6.1	.2	52.0	1.4
November	5.4	.24	1.30	9.6	4.9	2.70	4.0	.1	37.4	.9
December	5.4	.08	.43	9.6	2.06	1.14	1.6	.0	13.2	.3
January	5.4	.08	.43	13.1	2.08	1.57	2.0	.0	16.0	.3
February	7.4	.10	.74	13.1	2.90	2.18	2.9	.1	21.4	.5
March	7.4	.18	1.33	13.1	6.53	4.92	6.2	.1	42.7	.9
April	7.4	.34	2.52	13.1	9.52	7.17	9.7	.2	71.0	1.7
May	7.4	.44	3.26	13.1	12.41	9.35	12.6	.3	92.4	1.9
June	7.4	.54	4.00	13.1	14.66	11.1	15.1	.4	111.0	3.1
July	7.4	.45	3.33	13.1	13.41	10.1	13.4	.4	97.0	2.6

Table 18. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1993—Continued

Month	Area of phreato-phytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from Ina Road to Cortaro—Continued										
August	5.4	0.33	1.78	9.6	9.55	5.27	7.0	0.2	63.5	1.5
September	5.4	.34	1.84	9.6	9.73	5.37	7.2	.2	65.0	1.4
Subtotal	76.8		22.7	139.7		65.2	87.8		683	1.4
Reach from Cortaro to near Rillito										
October	63.2	.30	19.0	41.5	7.76	18.5	37.5	1.0	89.5	2.3
November	63.2	.21	13.3	41.5	4.9	11.7	25.0	.6	62.4	1.6
December	63.2	.07	4.42	41.5	2.06	4.92	9.3		22.5	
January	48.1	.07	3.37	56.2	2.08	6.72	10.1		26.1	
February	48.1	.09	4.33	56.2	2.90	9.37	13.7		35.1	
March	48.1	.17	8.18	56.2	6.53	21.1	29.3		72.0	
April	48.1	.31	14.9	56.2	9.52	30.8	45.7		117	
May	48.1	.41	19.7	56.2	12.41	40.1	59.8		152	
June	48.1	.49	23.6	56.2	14.68	47.4	71.0		182	
July	48.1	.41	19.7	56.2	13.41	43.3	63.0		160	
August	63.2	.30	19.0	41.5	9.55	22.8	41.8		105	
September	63.2	.31	19.6	41.5	9.73	23.2	42.8		108	—
Subtotal	652.7		169	600.9		280	449		7,131	2.2
Reach from near Rillito to Sanders Road										
October	33.6	.31	10.4	30.5	7.76	13.6	24.0	.6	114	3.0
November	33.6	.22	7.39	30.5	4.9	8.59	16.0	.4	78.4	2.0
December	33.6	.08	2.69	30.5	2.06	3.61	6.3	.1	28.8	.7
January	65.4	.07	4.58	27.4	2.08	3.28	7.9		34.0	
February	65.4	.09	5.89	27.4	2.90	4.57	10.5		45.6	
March	65.4	.17	11.1	27.4	6.53	10.3	21.4		93.4	

Table 18. Computations of evapotranspiration and evaporation, Santa Cruz River, water year 1993—Continued

Month	Area of phreatophytes, in acres (A_{ph})	Evapotranspiration (ET) in reach		Open-channel area of reach, in acres (A_{ch})	Pan evaporation, in inches per month (E_p)	Evaporation in reach, in acre-feet (E_r)	Evapotranspiration and evaporation (ET_r+E_r) in reach		Evapotranspiration and evaporation at the site (ET_s+E_s)	
		Feet	Acre-feet				Acre-feet	As percent of discharge from water-treatment plants	Acre-feet	As percent of discharge from water-treatment plants
Reach from near Rillito to Sanders Road—Continued										
April	65.4	.32	20.9	27.4	9.52	15.0	35.9		153	
May	65.4	.42	27.5	27.4	12.41	19.6	47.1		199	
June	65.4	.50	32.7	27.4	14.68	25.1	57.8		240	
July	65.4	.42	27.5	27.4	13.41	21.1	48.6		209	
August	65.4	.28	18.3	27.4	9.55	15.0	33.3		138	
September	65.4	.29	19.0	27.4	9.73	15.3	34.3		142	—
Subtotal	689.4		188	338.1		155	343		1,475	2.9
Reach from Sanders Road to Trico Road										
October	41.8	.27	11.3	23	7.76	10.3	21.6	0.6	136	3.5
November	41.8	.20	8.36	23	4.9	6.48	14.8	.4	93.2	2.4
December	41.8	.07	2.93	23	2.06	2.72	5.6	.1	34.4	.8
January	25.6	.07	1.79	10.6	2.08	1.27	3.1	.1	37.1	.8
February	25.6	.09	2.30	10.6	2.90	1.77	4.1	.1	49.7	1.2
March	25.6	.16	4.10	10.6	6.53	3.98	8.1	.2	102	2.1
April	25.6	.30	7.68	10.6	9.52	5.80	13.5	.3	166	4.0
May	25.6	.38	9.73	10.6	12.41	7.56	17.3	.4	216	4.8
June	25.6	.46	11.8	10.6	14.68	8.95	20.8	.6	261	7.2
July	25.6	.39	9.98	10.6	13.41	8.17	18.2	.5	227	6.1
August	25.6	.25	6.40	10.6	9.55	5.82	12.2	.3	150	3.6
September	25.6	.26	6.66	10.6	9.73	5.93	12.6	.3	155	3.4
Subtotal	355.8		83	164.4		69	152		1,630	3.2
TOTAL	3,280		831	1,700		791				

Table 19. Computations of infiltration of effluent, Santa Cruz River, water year 1993

[WTP's, water-treatment plants. Subtotals and totals have been rounded]

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site ($Q_{s'}$)	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Roger Road water-treatment plant to Ina Road											
October	3,860	3,230	3,860	630	630	584	15.1	584	15.1	117	117
November	3,900	3,180	3,900	720	720	687	17.6	687	17.6	138	138
December	4,330	3,140	4,330	1,190	1,190	1,178	27.2	1,178	27.2	236	236
January											
February											
March											
April											
May											
June											
July											
August											
September											
Subtotal	12,090	9,550	12,090	2,540	2,540	2,449		2,449	20.3	491	491
Reach from Ina Road to Cortaro											
October	3,860	3,440	3,230	-210	420	-262		322	8.3	-167	49.1
November	3,900	3,620	3,190	-430	290	-467		220	5.6	-283	33.5
December	4,330	3,140	3,140	0	1,190	-13.2		1,165	26.9	-1.0	178
January	4,800	3,430			1,370			1,354	28.2		
February	4,150	2,540			1,610			1,589	38.3		
March	4,840	2,520			2,320			2,277	47.0		
April	4,160	2,350			1,810			1,739	41.8		
May	4,460	2,350			2,110			2,018	45.2		
June	3,600	1,550			2,050			1,939	53.9		
July	3,710	1,660			2,050			1,953	52.7		

Table 19. Computations of infiltration of effluent, Santa Cruz River, water year 1993—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site (Q_s)	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from Ina Road to Cortaro—Continued											
August	4,210	2,230			1,680			1,616	38.4		
September	4,600	3,280	—	—	1,320	—		1,255	27.3		—
Subtotal	50,620	32,410	9,550	-640	18,210	-742		17,527	34.6		267
Reach from Cortaro to near Rillito											
October	3,860	2,410	3,440	1,030	1,450	992	25.7	1,360	35.2	186	114
November	3,900	3,010	3,620	610	890	585	15.0	829	21.3	110	69.7
December			3,140								
January			3,430								
February			2,540								
March			2,520								
April			2,350								
May			2,350								
June			1,550								
July			1,660								
August			2,230								
September	—	—	3,280	—	—	—		—	—	—	—
Subtotal	7,760	5,420	32,410	1,640	2,340	1,578		2,188	28.2	148	91.9
Reach from near Rillito to Sanders Road											
October	3,860	1,090	2,410	1,320	2,770	1,296	33.6	2,746	71.1	235	157
November	3,900	1,170	3,010	1,840	2,730	1,824	46.8	2,652	68.0	328	151
December	4,330	1,460	3,140	1,680	2,870	1,674	38.7	2,841	65.6	299	162
January											
February											
March											
April											

Table 19. Computations of infiltration of effluent, Santa Cruz River, water year 1993—Continued

Month	Discharge, in acre-feet			Loss, in acre-feet		Infiltration in reach		Infiltration to site		Infiltration per mile, in acre-feet	
	From WTP's (Q_{wtp})	At site (Q_s)	From upstream site ($Q_{s'}$)	In reach, (L_r)	Total loss to site (L_s)	Acre-feet (I_r)	As percent of discharge from water-treatment plants (I_{rp})	Acre-feet (I_s)	As percent of discharge from water-treatment plants (I_{sp})	In reach (I_r/mi)	To site (I_s/mi)
Reach from near Rillito to Sanders Road—Continued											
May											
June											
July											
August											
September											
Subtotal	12,090	3,720	8,560	4,840	8,370	4,793		8,323	68.8	285	159
Reach from Sanders Road to Trico Road											
October	3,860	803	1,090	287	3,057	265	6.9	2,921	75.7	49.1	126
November	3,900	982	1,170	188	2,918	173	4.4	2,825	72.4	32.1	123
December	4,330	1,010	1,460	450	3,320	444	10.3	3,286	75.9	82.3	143
January	4,800	360			4,440			4,403	91.7		
February	4,150	0			4,150			4,100	98.8		
March	4,840	0			4,840			4,738	97.9		
April	4,160	0			4,160			3,994	96.0		
May	4,460	0			4,460			4,244	95.2		
June	3,600	0			3,600			3,339	92.8		
July	3,710	0			3,710			3,483	93.9		
August	4,210	123			4,087			3,937	93.5		
September	4,600	41			4,559			4,404	95.8		
TOTAL	50,620	3,320			47,300			45,670	90.2	54.5	131

Table 20. Reconstructed monthly discharge at the streamflow-gaging stations at Cortaro, near Rillito, at Sanders Road, and at Trico Road, Arizona, 1991–93

[Dashes indicate no data. N/A, not applicable]

Measurement site	Discharge, in acre feet												Effluent discharge at site, in percent, of effluent discharge at Cortaro, Arizona	
	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Per year	1991–93
1991														
Cortaro	2,710	2,510	2,830	1,780	2,650	2,070	1,350	1,490	1,730	2,050	2,910	3,500	N/A	N/A
Rillito	---	---	---	---	---	---	6.3	454	825	961	799	2,640	43.6	66.5
Sanders Road	---	---	---	---	---	50	0	57	128	310	706	1,190	16.2	33.1
Trico Road	356	850	1,140	184	142	71.5	0	0	0	0	123	4.4	10.4	10.2
1992														
Cortaro	3,240	3,200	3,920	3,840	1,730	2,630	2,870	2,160	2,290	2,600	2,870	3,550	N/A	
Rillito	3,170	---	2,660	3,220	1,630	2,000	2,500	2,620	2,690	422	904	1,500	63.7	
Sanders Road	1,420	1,410	1,470	1,750	1,240	769	1,000	1,210	994	885	1,010	619	42.0	
Trico Road	386	595	536	590	604	317	186	153	259	146	200	149	11.8	
1993														
Cortaro	3,440	3,620	3,140	3,430	2,540	2,520	2,350	1,550	1,660	2,530	3,280	---	N/A	
Rillito	2,410	3,010	---	---	---	---	---	---	---	---	---	---	76.8	
Sanders Road	1,090	1,170	1,460	---	---	---	---	---	---	---	---	---	36.5	
Trico Road	803	982	1,010	360	0	0	0	0	0	123	41	---	10.2	

Table 21. Total daily mean discharges of Roger Road and Ina Road water-treatments plants, water years 1991–93

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	73	62	65	73	71	73	62	53	50	57	61	65
2	72	62	63	67	74	82	58	59	58	53	60	67
3	69	63	62	67	73	74	57	64	64	50	62	64
4	67	59	62	69	70	73	63	64	66	54	55	64
5	64	61	63	90	72	70	59	65	60	55	56	62
6	67	59	66	78	68	69	63	66	62	60	55	61
7	65	58	65	74	68	68	67	62	59	60	54	65
8	64	59	70	77	67	68	60	66	63	60	57	64
9	64	62	69	74	70	71	55	62	61	56	62	63
10	63	61	67	77	68	73	53	65	62	53	61	66
11	62	63	64	75	70	72	57	65	61	57	60	66
12	63	68	61	79	70	67	53	62	61	57	59	72
13	66	64	70	78	71	57	68	66	70	60	58	72
14	61	61	68	79	69	66	58	67	64	55	56	70
15	61	63	73	76	70	68	61	64	62	53	60	69
16	58	60	87	70	75	72	56	62	60	52	59	68
17	63	57	74	72	76	70	55	63	56	56	63	69
18	65	60	72	69	79	66	55	65	52	55	62	74
19	62	59	72	72	77	63	53	65	54	54	63	79
20	62	62	72	69	76	65	54	65	53	61	60	76
21	66	65	77	72	76	78	54	64	54	58	58	75
22	64	67	73	68	74	65	52	63	58	54	63	74
23	60	60	65	69	70	61	54	63	53	57	67	79
24	66	62	71	67	67	62	54	64	52	54	71	71
25	65	63	60	66	70	61	54	63	55	54	70	71
26	62	66	68	71	74	63	54	57	53	54	69	75
27	61	62	70	71	68	67	55	61	50	60	62	69
28	61	64	82	72	66	66	53	64	53	58	65	75
29	59	67	75	68	---	60	54	58	59	55	66	77
30	60	69	76	69	---	63	54	53	56	68	65	74
31	60	---	78	73	---	59	---	52	---	63	69	---
TOTAL	1,975	1,868	2,160	2,251	1,999	2,092	1,705	1,932	1,741	1,753	1,908	2,096
MEAN	63.7	62.3	69.7	72.6	71.4	67.5	56.8	62.3	58.0	56.5	61.5	69.9
AC-FT	3,920	3,710	4,280	4,460	3,970	4,150	3,380	3,830	3,450	3,480	3,780	4,160

WATER YEAR 1991 TOTAL 23,480 MEAN 64.3 ACRE-FT 46,570

Table 21. Total daily mean discharge of Roger Road and Ina Road water-treatments plants, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	72	65	72	68	71	70	78	57	69	54	60	74
2	71	69	72	69	70	76	69	62	67	56	60	71
3	71	71	68	64	71	79	70	58	70	54	57	70
4	71	68	71	77	69	72	72	58	69	57	60	69
5	73	70	71	70	69	72	70	58	66	52	58	74
6	72	72	70	80	69	71	72	55	68	57	70	64
7	73	66	69	68	76	77	70	55	65	58	74	72
8	68	64	72	71	80	82	68	56	67	60	70	69
9	73	68	70	74	73	76	68	58	63	56	67	68
10	72	70	74	72	71	73	69	56	66	58	68	68
11	68	75	77	69	73	72	67	63	62	74	63	68
12	72	73	69	76	72	72	62	59	64	65	64	74
13	69	74	68	74	98	72	67	60	58	61	64	82
14	74	72	72	75	72	70	66	57	54	55	67	77
15	72	74	73	74	76	68	67	57	54	55	66	75
16	70	76	69	72	77	68	65	60	54	55	66	73
17	66	69	68	71	77	64	69	55	54	57	68	76
18	68	77	82	74	74	65	73	61	55	58	68	71
19	72	74	75	71	73	65	69	58	56	56	68	76
20	70	70	77	73	72	66	66	60	57	57	66	78
21	72	68	76	67	74	68	57	66	57	57	66	80
22	72	69	72	67	72	71	58	66	56	62	73	79
23	73	71	74	68	74	76	56	65	60	60	84	71
24	75	71	68	70	73	66	56	63	54	62	100	70
25	74	70	65	74	71	66	56	65	55	64	80	70
26	78	68	69	72	68	68	58	65	56	59	78	74
27	85	67	76	71	66	75	58	69	57	58	73	72
28	80	70	76	72	68	90	52	72	53	57	74	69
29	72	66	75	67	70	74	54	70	55	60	74	66
30	68	72	74	68	---	73	56	73	52	62	75	64
31	66	---	74	64	---	69	---	69	---	60	74	---
TOTAL	2,232	2,109	2,238	2,202	2,119	2,226	1,938	1,906	1,793	1,816	2,155	2,164
MEAN	72.0	703	72.2	71.0	73.1	71.8	64.6	61.5	59.8	58.6	69.5	72.1
AC-FT	4,430	4,180	4,440	4,370	4,200	4,420	3,840	3,780	3,560	3,600	4,270	4,290

WATER YEAR 1992 TOTAL 24,898 MEAN 68.0 ACRE-FEET 49,390

Table 21. Total daily mean discharge of Roger Road and Ina Road water-treatments plants, water years 1991-93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	58	65	61	64	73	82	78	63	74	60	63	83
2	60	65	65	66	70	81	76	61	62	61	56	82
3	63	66	72	71	70	79	82	63	58	59	52	81
4	62	68	91	70	70	78	79	61	62	58	65	82
5	61	65	93	67	73	78	80	61	61	58	65	74
6	62	61	72	77	79	80	81	60	59	58	59	77
7	64	67	73	100	74	81	78	71	60	60	68	76
8	59	67	77	100	73	78	80	80	61	60	66	75
9	61	68	73	78	76	77	76	78	60	64	73	82
10	61	68	67	82	71	78	74	76	61	64	63	77
11	61	66	68	80	73	77	72	79	58	60	63	84
12	64	63	57	75	73	77	77	79	60	61	60	86
13	63	64	68	97	78	78	76	78	61	63	66	84
14	63	66	66	76	84	77	76	74	62	64	68	80
15	60	67	68	74	82	78	70	79	60	64	63	75
16	61	67	67	79	73	76	72	72	60	64	59	72
17	62	62	66	79	74	76	66	74	61	63	62	76
18	63	64	71	100	76	73	61	71	62	63	65	74
19	64	64	73	83	85	74	65	77	59	58	60	74
20	61	66	68	78	78	76	62	77	62	57	60	72
21	61	70	64	78	77	78	64	79	58	57	66	75
22	62	69	66	78	78	78	64	77	59	58	68	77
23	66	65	69	77	76	80	59	77	57	59	66	78
24	66	64	68	73	70	80	59	76	59	60	73	75
25	67	64	61	75	70	80	64	75	60	59	76	78
26	65	63	65	72	65	79	64	75	58	55	84	75
27	61	64	65	71	71	84	59	73	62	59	87	75
28	64	65	92	72	80	83	62	74	59	58	87	72
29	65	65	76	72	---	90	60	72	58	60	85	74
30	66	70	69	77	---	78	62	68	62	61	90	73
31	68	---	71	77	---	78	---	68	---	63	82	---
TOTAL	1,944	1,968	2,182	2,418	2,092	2,442	2,098	2,248	1,815	1,868	2,120	2,318
MEAN	62.7	65.6	70.4	78.0	74.7	78.8	69.9	72.5	60.5	60.3	68.4	77.3
AC-FT	3,860	3,900	4,330	4,800	4,150	4,840	4,160	4,460	3,600	3,710	4,210	4,600

WATER YEAR 1993 TOTAL 25,513 MEAN 69.9 ACRE-FT 56,610

Table 22. Daily mean discharges, Santa Cruz River at Ina Road, water years 1991–93

[Dashes indicate no data]

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	---	---	---	---	---	([1])	16	24	27	46	54	65
2	---	---	---	---	---	([1])	19	28	33	43	58	62
3	---	---	---	---	---	([1])	20	26	39	47	63	59
4	---	---	---	---	---	([1])	23	37	40	50	56	60
5	---	---	---	---	---	[2]60	23	34	44	49	58	55
6	---	---	---	---	---	[2]50	23	35	46	52	49	51
7	---	---	---	---	---	[2]35	27	33	39	42	52	56
8	---	---	---	---	---	37	23	36	32	41	57	50
9	---	---	---	---	---	38	22	31	44	39	242	59
10	---	---	---	---	---	36	23	37	36	35	184	61
11	---	---	---	---	---	37	30	34	37	39	94	60
12	---	---	---	---	---	40	29	30	47	51	98	65
13	---	---	---	---	---	30	35	35	40	53	68	69
14	---	---	---	---	---	39	33	35	33	53	54	67
15	---	---	---	---	---	39	34	34	29	35	60	69
16	---	---	---	---	---	43	30	34	28	36	66	66
17	---	---	---	---	---	34	31	34	34	33	73	69
18	---	---	---	---	---	32	30	34	35	32	97	113
19	---	---	---	---	---	24	27	35	37	37	78	79
20	---	---	---	---	---	27	27	34	38	54	49	73
21	---	---	---	---	---	34	24	32	41	50	49	72
22	---	---	---	---	---	14	28	31	42	39	216	71
23	---	---	---	---	---	27	25	33	38	40	161	73
24	---	---	---	---	---	30	25	34	36	30	53	59
25	---	---	---	---	---	26	27	33	41	36	62	60
26	---	---	---	---	---	10	24	31	41	35	59	63
27	---	---	---	---	---	24	25	35	37	34	57	68
28	---	---	---	---	---	23	22	38	39	37	63	72
29	---	---	---	---	---	26	25	34	43	39	62	72
30	---	---	---	---	---	18	25	32	44	59	60	68
31	---	---	---	---	---	13	---	33	---	56	69	---
TOTAL	---	---	---	---	---	3,790	775	1,026	1,140	1,322	2,521	1,986
MEAN	---	---	---	---	---	122	25.8	33.1	38.0	42.6	81.3	66.2
MAX	---	---	---	---	---	1,320	35	38	47	59	242	113
MIN	---	---	---	---	---	10	6	24	27	30	49	50
AC-FT	---	---	---	---	---	7,520	1,540	2,040	2,260	2,620	5,000	3.940

See footnotes at end of table.

Table 22. Daily mean discharges, Santa Cruz River at Ina Road, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	56	55	67	62	67	[3]58	([4])	[3]52	[3]54	[3]48	59	[2]60
2	51	56	67	63	68	[3]60	([4])	[3]57	[3]51	[3]50	59	[2]62
3	52	55	65	62	70	[3]62	[3]70	[3]55	[3]54	[3]49	59	125
4	52	55	70	68	68	[3]60	([4])	[3]55	[3]53	[3]51	61	[2]60
5	53	57	71	63	67	[3]50	[3]70	[3]56	[3]52	[3]48	60	[2]6
6	53	59	67	118	67	[3]50	[3]60	[3]55	[3]50	[3]51	([1])	[2]60
7	53	57	68	67	75	[3]54	[3]55	[3]54	[3]49	[3]52	([1])	[2]62
8	53	55	71	60	111	([4])	[3]53	[3]55	[3]50	[3]54	46	[2]64
9	54	56	69	67	78	([4])	[3]54	[3]54	[3]47	[3]51	47	[2]63
10	54	56	72	67	76	([4])	[3]55	[3]8	[3]48	[3]52	52	[2]64
11	54	58	85	68	76	([4])	[3]56	[3]50	[3]48	([4])	106	[2]64
12	56	59	71	107	119	[3]80	[3]52	[3]48	[3]49	[3]44	45	[2]67
13	56	59	68	71	([1])	[3]40	[3]56	[3]44	[3]46	[3]48	45	[2]86
14	57	58	69	73	([1])	[3]42	[3]57	[3]44	[3]43	[3]49	50	[2]68
15	58	69	71	73	24	[3]44	[3]58	[3]42	[3]42	[3]50	52	[2]68
16	58	61	68	72	[3]26	[3]46	[3]56	[3]43	[3]42	[3]52	51	[2]72
17	59	58	68	75	[3]28	[3]46	[3]59	[3]48	[3]43	[3]52	53	[2]69
18	58	63	139	75	[3]29	[3]47	[3]67	[3]52	[3]43	[3]51	54	[2]69
19	60	61	71	71	[3]32	[3]47	[3]64	[3]48	[3]44	[3]50	55	[2]77
20	59	62	75	71	[3]34	[3]48	[3]52	[3]46	[3]45	[3]51	56	[2]70
21	61	60	76	67	[3]38	[3]52	[3]49	[3]44	[3]45	[3]50	65	[2]68
22	61	60	69	68	[3]43	[3]56	[3]50	[3]46	[3]44	[3]80	123	[2]65
23	63	62	74	66	[3]46	[3]57	[3]49	[3]44	[3]43	[3]56	57	[2]60
24	64	64	67	66	[3]46	[3]50	[3]49	[3]42	[3]41	[3]56	([1])	[2]60
25	65	63	62	67	[3]48	[3]48	[3]50	[3]53	[3]42	[3]55	([1])	[2]59
26	65	63	66	68	[3]52	[3]48	[3]49	[3]50	[3]43	[3]54	[2]50	[2]62
27	83	61	70	69	[3]54	[3]50	[3]48	[3]50	344	[3]52	[2]52	[2]62
28	56	65	70	67	[3]56	[3]52	[3]49	[3]54	[3]47	[3]51	[2]50	[2]60
29	54	61	68	66	[3]57	([4])	[3]51	[3]56	[3]48	53	[2]52	[2]58
30	55	67	69	63	---	([4])	[3]52	[3]55	[3]46	99	[2]54	[2]59
31	56	---	69	66	---	[2]100	---	[3]54	---	59	[2]58	---
TOTAL	1,789	1,795	2,232	2,186	2,529	3,597	2,050	1,554	1,396	1,988	4,160	2.009
MEAN	57.7	59.8	72.0	70.5	87.2	116	68.3	50.1	46.5	64.1	134	67.0
MAX	83	69	139	118	831	750	190	57	54	370	1,600	125
MIN	51	55	62	60	24	40	48	42	41	44	45	58
AC-FT	3,550	3,560	4,430	4,340	5,020	7,130	4,070	3,080	2,770	3,940	8,250	3.980

See footnotes at end of table.

Table 22. Daily mean discharges, Santa Cruz River at Ina Road, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	42	107	42	([1])	---	---	---	---	---	---	---	---
2	43	115	41	([1])	---	---	---	---	---	---	---	---
3	49	114	49	([1])	---	---	---	---	---	---	---	---
4	48	112	([1])	([1])	---	---	---	---	---	---	---	---
5	51	93	([1])	([1])	---	---	---	---	---	---	---	---
6	54	88	33	([1])	---	---	---	---	---	---	---	---
7	[2]54	89	35	([1])	---	---	---	---	---	---	---	---
8	[2]55	87	45	([1])	---	---	---	---	---	---	---	---
9	56	88	43	([1])	---	---	---	---	---	---	---	---
10	56	83	41	---	---	---	---	---	---	---	---	---
11	56	80	45	---	---	---	---	---	---	---	---	---
12	59	74	43	---	---	---	---	---	---	---	---	---
13	57	76	50	---	---	---	---	---	---	---	---	---
14	56	75	50	---	---	---	---	---	---	---	---	---
15	53	72	52	---	---	---	---	---	---	---	---	---
16	53	69	51	---	---	---	---	---	---	---	---	---
17	53	62	54	---	---	---	---	---	---	---	---	---
18	53	60	59	---	---	---	---	---	---	---	---	---
19	53	58	65	---	---	---	---	---	---	---	---	---
20	52	59	59	---	---	---	---	---	---	---	---	---
21	52	62	55	---	---	---	---	---	---	---	---	---
22	51	58	54	---	---	---	---	---	---	---	---	---
23	([1])	53	65	---	---	---	---	---	---	---	---	---
24	76	51	65	---	---	---	---	---	---	---	---	---
25	84	50	56	---	---	---	---	---	---	---	---	---
26	85	51	57	---	---	---	---	---	---	---	---	---
27	85	44	65	---	---	---	---	---	---	---	---	---
28	96	48	([1])	---	---	---	---	---	---	---	---	---
29	101	47	([1])	---	---	---	---	---	---	---	---	---
30	105	46	([1])	---	---	---	---	---	---	---	---	---
31	110	---	([1])	---	---	---	---	---	---	---	---	---
TOTAL	---	2,171	---	---	---	---	---	---	---	---	---	---
MEAN	---	72.4	---	---	---	---	---	---	---	---	---	---
MAX	---	115	---	---	---	---	---	---	---	---	---	---
MIN	---	44	---	---	---	---	---	---	---	---	---	---
AC-FT	---	4,310	---	---	---	---	---	---	---	---	---	---

[1]Discharge above 140 cubic feet per second.

[2]Estimated.

[3]Estimated, recorder removed.

[4]Estimated above 140 cubic feet per second, recorder removed.

Table 23. Daily mean discharges, Santa Cruz River at Cortaro, Arizona, water years 1991–93

[A continuous-record station; published data is not limited to ceiling of 140 cubic feet per second. Dashes indicate no data]

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	[1]33	43	49	[1]26	33	580	[1]25	22	24	41	42	50
2	[1]33	43	49	[1]26	35	[1]300	[1]22	24	28	35	43	50
3	[1]34	39	50	[1]25	38	[1]180	[1]24	24	31	29	43	48
4	[1]34	38	50	[1]90	39	[1]130	[1]26	23	28	27	38	45
5	[1]34	40	52	[1]480	39	[1]60	[1]21	22	24	32	44	45
6	[1]35	38	56	[1]200	40	[1]50	[1]23	23	24	36	35	45
7	[1]34	39	57	[1]25	40	[1]40	[1]28	23	22	39	40	48
8	[1]36	40	57	[1]26	41	[1]30	[1]26	24	19	33	69	43
9	[1]38	44	57	[1]26	44	[1]32	[1]21	24	22	31	115	53
10	[1]38	45	56	[1]26	42	[1]26	[1]19	24	23	30	78	57
11	[1]42	43	55	[1]27	45	[1]24	18	24	24	28	44	59
12	[1]47	42	53	[1]27	51	[1]22	20	23	31	30	49	64
13	[1]46	40	58	[1]27	68	[1]24	22	23	31	41	46	65
14	[1]48	39	58	[1]28	63	[1]23	23	23	28	39	48	64
15	[1]48	40	60	[1]28	44	[1]24	23	[1]23	28	29	54	63
16	[1]55	41	79	[1]26	44	[1]28	23	[1]24	27	24	47	61
17	[1]59	40	46	[1]27	46	[1]32	22	[1]24	29	26	51	69
18	[1]61	41	46	[1]29	53	[1]36	22	23	27	28	59	95
19	[1]61	41	50	[1]29	51	[1]34	22	26	30	32	51	72
20	65	43	[1]95	[1]30	53	[1]32	22	26	26	36	39	73
21	66	45	[1]45	[1]31	53	[1]38	22	28	28	39	46	68
22	72	46	[1]36	[1]30	53	[1]30	23	27	31	32	89	63
23	63	42	[1]24	[1]31	53	[1]28	23	26	29	31	89	68
24	52	42	[1]20	[1]32	53	[1]40	23	27	28	26	49	58
25	53	42	[1]19	[1]32	54	[1]60	23	26	34	30	50	61
26	48	45	[1]19	[1]32	57	[1]50	23	24	38	25	50	63
27	44	45	[1]20	33	54	[1]42	23	23	39	33	47	60
28	43	45	[1]280	35	52	[1]34	23	26	38	37	52	64
29	43	47	[1]200	31	---	[1]26	23	25	39	46	54	64
30	44	49	[1]40	31	---	[1]23	23	24	40	47	54	65
31	47	---	[1]28	32	---	[1]22	---	24	---	42	58	---
TOTAL	1,456	1,267	1,864	1,578	1,338	2,100	681	752	870	1,034	1,673	1,803
MEAN	47.0	42.2	60.1	50.9	47.8	67.7	22.7	24.3	29.0	33.4	54.0	60.1
MAX	72	49	280	480	68	580	28	28	40	47	115	95
MIN	33	38	19	25	33	22	18	22	19	24	35	43
AC-FT	2,890	2,510	3,700	3,130	2,650	4,170	1,350	1,490	1,730	2,050	3,320	3,580

WY 1991 TOTAL: 16,416 MEAN: 45.0 MAX: 580 MIN: 18 ACRE-FT: 32,560

See footnote at the end of the table.

Table 23. Daily mean discharges, Santa Cruz River at Cortaro, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	50	48	[1]60	[1]57	74	[1]51	171	40	42	41	45	57
2	47	[1]49	[1]60	[1]57	75	[1]52	164	46	41	45	45	57
3	47	[1]48	[1]58	[1]57	76	[1]52	65	40	45	46	40	58
4	48	[1]48	[1]63	[1]62	74	53	172	38	42	47	45	56
5	49	[1]50	[1]64	[1]57	75	45	65	41	41	44	38	61
6	48	[1]52	[1]62	[1]105	73	45	51	34	42	78	263	54
7	49	[1]51	[1]63	[1]60	83	48	48	33	41	77	320	58
8	47	[1]49	[1]65	[1]54	113	227	47	29	43	38	37	58
9	49	[1]50	[1]63	[1]58	80	355	49	28	40	38	33	58
10	49	[1]50	[1]66	[1]58	75	167	51	27	41	40	35	59
11	50	[1]52	67	[1]58	76	160	52	33	39	346	61	60
12	51	[1]53	58	[1]100	120	56	46	30	41	34	51	64
13	49	[1]53	59	[1]64	[1]1,000	28	52	28	36	37	44	82
14	52	[1]52	59	[1]64	[1]550	28	53	26	33	37	47	45
15	53	[1]60	60	[1]64	[1]18	31	56	29	35	37	48	68
16	54	[1]53	59	[1]66	[1]18	33	52	29	37	37	49	70
17	55	[1]52	59	[1]67	[1]18	33	55	28	35	36	51	67
18	51	[1]56	118	[1]66	[1]19	36	60	30	35	40	52	67
19	54	[1]54	68	[1]63	21	37	56	30	35	40	55	75
20	54	[1]56	71	[1]63	26	39	53	34	36	42	54	68
21	59	[1]55	67	[1]63	27	45	39	38	36	43	67	66
22	59	[1]57	64	[1]63	33	49	40	40	36	78	66	62
23	61	[1]59	65	[1]63	28	51	38	37	37	57	35	56
24	61	[1]59	64	[1]64	30	44	37	35	37	56	1,710	56
25	57	[1]58	61	70	34	42	41	36	37	54	507	55
26	58	[1]58	65	71	36	42	40	38	37	52	51	57
27	69	[1]57	69	72	44	[1]44	42	39	39	51	46	57
28	57	[1]60	70	72	49	[1]290	39	43	38	51	43	56
29	51	[1]57	68	71	[1]50	699	38	45	41	52	44	51
30	49	[1]56	70	71	---	410	40	43	39	105	49	52
31	48	---	[1]66	74	---	81	---	41	---	47	51	---
TOTAL	1,635	1,612	2,031	2,054	2,995	3,373	1,812	1,088	1,157	1,826	4,082	1,810
MEAN	52.7	53.7	65.5	66.3	103	109	60.4	35.1	38.6	58.9	132	60.3
MAX	69	60	118	105	1,000	699	172	46	45	346	1,710	82
MIN	47	48	58	54	18	28	37	26	33	34	33	45
AC-FT	3,240	3,200	4,030	4,070	5,940	6,690	3,590	2,160	2,290	3,620	8,100	3,590

WY 1992 TOTAL: 25,475 MEAN: 69.6 MAX: 1,710 MIN: 18 ACRE-FT: 50,530

See footnote at the end of the table.

Table 23. Daily mean discharges, Santa Cruz River at Cortaro, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	49	95	[1]62	[1]47	[1]65	[1]41	[1]44	33	30	26	[1]26	[1]85
2	51	94	[1]62	[1]48	[1]62	[1]41	[1]42	31	26	26	[1]25	[1]75
3	55	95	61	[1]56	[1]59	[1]40	[1]47	34	24	26	[1]27	[1]71
4	53	94	138	[1]75	[1]56	[1]39	[1]44	32	25	26	29	[1]68
5	53	77	[1]400	[1]76	[1]53	[1]39	[1]44	33	24	25	27	[1]65
6	54	74	[1]90	[1]58	[1]50	[1]40	[1]44	34	24	26	25	[1]63
7	54	81	[1]60	[1]1,000	[1]47	[1]40	[1]42	38	26	[1]25	26	[1]61
8	52	81	52	[1]4,000	[1]44	[1]38	[1]44	43	26	[1]27	25	[1]60
9	55	81	51	[1]2,500	[1]42	[1]38	[1]41	40	27	[1]29	33	[11]61
10	59	80	47	[1]700	[1]40	[1]38	[1]40	41	26	30	18	[1]60
11	56	80	[1]46	[1]8,800	[1]39	[1]37	[1]40	43	25	27	16	[1]59
12	58	79	[1]45	[1]3,600	[1]38	[1]37	[1]44	44	23	28	13	[1]58
13	56	63	[1]44	[1]4,200	[1]37	[1]37	[1]43	44	23	27	[1]16	[1]57
14	58	[1]64	[1]44	[1]1,500	[1]36	[1]36	43	42	25	27	14	[1]56
15	59	[1]62	[1]48	[1]600	[1]400	[1]37	39	41	25	28	19	[1]55
16	59	[1]60	[1]50	[1]275	[1]230	[1]37	43	41	25	28	25	54
17	59	[1]58	[1]52	[1]1,500	[1]100	[1]38	39	41	26	28	[1]25	53
18	59	[1]58	[1]54	[1]9,000	[1]80	[1]37	31	40	27	27	[1]25	52
19	64	[1]59	[1]60	[1]25,000	[1]550	[1]38	37	43	27	26	25	49
20	64	[1]61	[1]56	[1]8,800	[1]1150	[1]40	38	45	26	27	26	51
21	64	[1]64	[1]53	[1]2,500	[1]270	[1]41	41	46	27	27	28	50
22	63	[1]62	[1]52	[1]1,300	[1]90	[1]42	41	42	28	27	30	48
23	104	[1]61	53	[1]275	[1]60	[1]43	38	40	27	28	30	47
24	80	[1]60	49	[1]225	[1]40	[1]44	34	39	26	28	[1]100	46
25	83	[1]59	44	[1]200	[1]35	[1]43	32	39	27	27	[1]25	45
26	82	[1]59	45	[1]175	[1]35	[1]43	34	40	27	27	[1]25	42
27	79	[1]57	49	[1]150	[1]38	[1]47	36	37	27	28	[1]25	43
28	84	[1]60	318	[1]125	[1]40	[1]53	34	32	27	28	[1]25	41
29	87	[1]62	280	[1]105	---	[1]56	34	30	27	26	[1]25	41
30	90	[1]65	[1]49	[1]85	---	[1]45	31	28	26	26	[1]400	40
31	97	---	[1]50	[1]70	---	[1]44	---	29	---	[1]27	[1]100	---
TOTAL	2,040	2,105	2,564	77,045	3,786	1,269	1,184	1,185	779	838	1,278	1,656
MEAN	65.8	70.2	82.7	2,485	135	40.9	39.5	38.2	26.0	27.0	41.2	55.2
MAX	104	95	400	25,000	1,150	56	47	46	30	30	400	85
MIN	49	57	44	47	35	36	31	28	23	25	13	40
AC-FT	4,050	4,180	5,090	152,800	7,510	2,520	2,350	2,350	1,550	1,660	2,530	3,280

WY 1993 TOTAL: 95,729 MEAN: 262 MAX: 25,000 MIN: 13 ACRE-FT: 189,900

[1]Estimated

Table 24. Daily mean discharges, Santa Cruz River near Rillito, water years 1991–93

[Dashes indicate no data]

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	---	---	---	---	---	---	[1].00	[2]1.0	[2]10	9.6	19	25
2	---	---	---	---	---	---	[1].00	[2]1.0	[2]12	7.0	18	45
3	---	---	---	---	---	---	[1].00	[2]1.5	[2]15	14	15	46
4	---	---	---	---	---	---	[1].00	[2]2.0	[2]12	10	13	43
5	---	---	---	---	---	---	[1].00	[2]2.0	[2]10	14	14	34
6	---	---	---	---	---	[1]0	[1].00	[2]3.0	[2]10	18	11	34
7	---	---	---	---	---	[1]0	[1].00	[2]2.5	[2]9.0	23	9.3	32
8	---	---	---	---	---	[1]0	[1].00	[2]3.0	[2]10	20	13	37
9	---	---	---	---	---	[1]0	[1].00	[2]3.0	[2]12	15	15	38
10	---	---	---	---	---	[1]0	[1].00	[2]7.0	[2]13	13	68	45
11	---	---	---	---	---	[1]0	[1].00	[2]7.0	[2]14	13	5.4	47
12	---	---	---	---	---	[1]0	[1].00	[2]8.0	[2]14	12	9.1	48
13	---	---	---	---	---	[1]0	[1].00	[2]9.0	[2]16	19	7.5	38
14	---	---	---	---	---	[1]0	[1].00	[2]9.0	[2]17	15	8.9	43
15	---	---	---	---	---	[1]0	[1].00	[2]7.0	20	15	10	49
16	---	---	---	---	---	[1]0	[1].00	[2]7.0	16	15	9.2	42
17	---	---	---	---	---	[1]0	[1].00	[2]8.0	16	14	9.2	80
18	---	---	---	---	---	[1]0	[1].00	[2]9.0	19	14	7.3	31
19	---	---	---	---	---	[1]0	[1].00	[2]10	19	12	27	42
20	---	---	---	---	---	[1]0	[1].00	[2]11	11	14	17	46
21	---	---	---	---	---	[1]0	[1].00	[2]12	15	20	18	45
22	---	---	---	---	---	[1]0	[1].00	[2]12	17	18	29	45
23	---	---	---	---	---	[1]0	[1].00	[2]12	23	17	201	57
24	---	---	---	---	---	[1]0	[1].00	[2]11	14	16	8.0	41
25	---	---	---	---	---	[1]0	[1].00	[2]10	12	15	8.3	43
26	---	---	---	---	---	[1]0	[2].20	[2]9.0	14	15	6.0	46
27	---	---	---	---	---	[1]0	[2].50	[2]11	12	14	6.4	45
28	---	---	---	---	---	[1]0	[2].50	[2]12	15	18	9.0	49
29	---	---	---	---	---	[1]0	[2]1.0	[2]10	11	22	13	51
30	---	---	---	---	---	[1]0	[2]1.0	[2]10	7.8	24	20	61
31	---	---	---	---	---	[1]0	---	[2]9.0	---	19	21	---
TOTAL	---	---	---	---	---	---	3.20	229.0	415.8	484.6	645.6	1,328
MEAN	---	---	---	---	---	---	.11	7.39	13.9	15.6	20.8	44.3
MAX	---	---	---	---	---	---	1.0	12	23	24	201	80
MIN	---	---	---	---	---	---	.00	1.0	7.8	7.0	5.4	25
AC-FT	---	---	---	---	---	---	6.3	454	825	961	1,280	2,630

See footnotes at the end of the table.

Table 24. Daily mean discharges, Santa Cruz River near Rillito, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	46	69	84	39	29	32	(3)	49	69	19	(4)	50
2	46	80	99	41	36	60	(3)	54	67	17	(4)	36
3	43	81	82	39	43	63	61	37	61	18	(4)	31
4	42	87	91	55	38	26	(3)	38	61	19	(4)	28
5	45	88	98	52	35	30	133	46	57	16	(4)	33
6	49	89	93	138	36	36	52	53	57	19	(3)	29
7	52	85	68	119	51	(3)	34	47	83	67	(3)	31
8	48	77	58	53	101	(3)	34	33	76	15	.00	30
9	46	74	52	60	59	(3)	33	28	73	15	.00	29
10	45	84	44	58	47	(3)	38	30	67	16	.00	27
11	46	105	68	58	50	(3)	38	44	71	(3)	2.5	26
12	45	109	38	(3)	134	91	33	35	61	34	9.8	29
13	50	97	28	95	(3)	9.5	50	26	56	7.2	11	(4)
14	50	103	25	75	(3)	6.0	48	24	52	3.9	(3)	(4)
15	55	125	37	70	105	7.8	47	31	44	(4)	(3)	25
16	48	105	39	81	.00	11	45	29	46	(4)	11	21
17	52	96	30	77	.00	11	51	32	51	(4)	(4)	17
18	45	108	(3)	85	.00	18	62	40	46	(4)	(4)	18
19	52	95	39	78	.70	24	62	40	49	(4)	(4)	29
20	49	108	37	84	6.2	26	58	39	50	(4)	(4)	25
21	58	83	36	78	13	32	38	42	52	(4)	(4)	28
22	58	85	37	61	18	42	38	50	53	(4)	(4)	25
23	63	88	47	62	25	49	37	55	55	(4)	(4)	21
24	64	87	49	60	34	47	41	52	(4)	(4)	(4)	20
25	68	96	34	62	38	40	38	49	(4)	(4)	(4)	20
26	76	82	34	65	33	48	35	57	15	(4)	(4)	20
27	128	85	48	58	28	65	34	62	16	(4)	46	19
28	130	76	50	44	32	(3)	28	(4)	15	(4)	39	17
29	85	70	46	36	31	(3)	24	78	18	(4)	51	11
30	71	95	45	26	---	(3)	33	70	13	(4)	57	9.9
31	71	---	47	27	---	142	---	71	---	(4)	52	---
TOTAL	1,826	2,712	1,729	2,095	---	---	---	---	---	---	---	---
MEAN	58.9	90.4	55.8	67.6	---	---	---	---	---	---	---	---
MAX	130	125	146	159	---	---	---	---	---	---	---	---
MIN	42	69	25	26	---	---	---	---	---	---	---	---
AC-FT	3,620	5,380	3,430	4,160	---	---	---	---	---	---	---	---

See footnotes at the end of the table.

Table 24. Daily mean discharges, Santa Cruz River near Rillito, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	29	54	55	---	---	---	---	---	---	---	---	---
2	29	57	---	---	---	---	---	---	---	---	---	---
3	30	58	---	---	---	---	---	---	---	---	---	---
4	30	57	---	---	---	---	---	---	---	---	---	---
5	32	39	---	---	---	---	---	---	---	---	---	---
6	32	35	---	---	---	---	---	---	---	---	---	---
7	34	47	---	---	---	---	---	---	---	---	---	---
8	35	49	---	---	---	---	---	---	---	---	---	---
9	35	49	---	---	---	---	---	---	---	---	---	---
10	35	47	---	---	---	---	---	---	---	---	---	---
11	36	46	---	---	---	---	---	---	---	---	---	---
12	40	46	---	---	---	---	---	---	---	---	---	---
13	41	46	---	---	---	---	---	---	---	---	---	---
14	41	50	---	---	---	---	---	---	---	---	---	---
15	40	49	---	---	---	---	---	---	---	---	---	---
16	39	49	---	---	---	---	---	---	---	---	---	---
17	41	44	---	---	---	---	---	---	---	---	---	---
18	42	47	---	---	---	---	---	---	---	---	---	---
19	55	49	---	---	---	---	---	---	---	---	---	---
20	57	52	---	---	---	---	---	---	---	---	---	---
21	58	64	---	---	---	---	---	---	---	---	---	---
22	55	61	---	---	---	---	---	---	---	---	---	---
23	93	56	---	---	---	---	---	---	---	---	---	---
24	22	50	---	---	---	---	---	---	---	---	---	---
25	29	51	---	---	---	---	---	---	---	---	---	---
26	33	52	---	---	---	---	---	---	---	---	---	---
27	32	45	---	---	---	---	---	---	---	---	---	---
28	41	52	---	---	---	---	---	---	---	---	---	---
29	47	54	---	---	---	---	---	---	---	---	---	---
30	50	61	---	---	---	---	---	---	---	---	---	---
31	56	---	---	---	---	---	---	---	---	---	---	---
TOTAL	1,269	1,516	---	---	---	---	---	---	---	---	---	---
MEAN	40.9	50.5	---	---	---	---	---	---	---	---	---	---
MAX	93	64	---	---	---	---	---	---	---	---	---	---
MIN	22	35	---	---	---	---	---	---	---	---	---	---
AC-FT	2,520	3,010	---	---	---	---	---	---	---	---	---	---

[1]Observed no-flow period.

[2]Estimated.

[3]Discharge exceeded 140 cubic feet per second.

[4]Incomplete data.

Table 25. Daily mean discharges, Santa Cruz River at Sanders Road, near Marana, Arizona, water years 1991–93

[Dashes indicate no data]

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991 DAILY MEAN VALUES												
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	---	---	---	---	---	([1])	0.00	0.00	[2]0.80	0.16	6.3	14
2	---	---	---	---	---	([1])	.00	.00	[2]1.0	.00	5.7	14
3	---	---	---	---	---	([1])	.00	.00	[2]1.5	.21	5.6	17
4	---	---	---	---	---	([1])	.00	.00	[2]1.8	.63	5.2	12
5	---	---	---	---	---	50	.00	.00	[2]2.8	1.4	3.6	11
6	---	---	---	---	---	.00	.00	.00	[2].50	.34	4.6	10
7	---	---	---	---	---	.00	.00	.00	[2]1.0	6.6	2.3	12
8	---	---	---	---	---	.00	.00	.00	[2]1.5	5.3	5.3	16
9	---	---	---	---	---	.00	.00	.00	[2]2.0	2.1	6.5	14
10	---	---	---	---	---	.00	.00	.00	[2]2.5	3.4	33	17
11	---	---	---	---	---	.00	.00	.00	[2]3.0	3.3	1.1	19
12	---	---	---	---	---	.00	.00	.00	[2]6.0	2.8	.27	22
13	---	---	---	---	---	.00	.00	.00	17	2.6	.14	23
14	---	---	---	---	---	.00	.00	[2]1.8	7.6	4.9	2.2	22
15	---	---	---	---	---	.00	.00	[2]1.5	4.0	2.9	3.7	21
16	---	---	---	---	---	.00	.00	[2]1.8	1.3	9.5	4.5	19
17	---	---	---	---	---	.00	.00	[2].50	1.9	9.8	4.6	18
18	---	---	---	---	[2]10	.00	.00	[2].70	1.7	13	4.8	37
19	---	---	---	---	17	.00	.00	[2]1.0	.05	13	9.8	20
20	---	---	---	---	18	.00	.00	[2]1.5	.00	11	10	22
21	---	---	---	---	15	.00	.00	[2]2.0	.00	16	8.9	19
22	---	---	---	---	14	.00	.00	[2]2.2	.10	11	10	21
23	---	---	---	---	13	.00	.00	[2]2.5	.56	2.8	65	26
24	---	---	---	---	16	.00	.00	[2]2.5	.14	3.6	33	22
25	---	---	---	---	15	.00	.00	[2]1.8	1.1	2.4	32	25
26	---	---	---	---	18	.00	.00	[2]1.3	1.6	3.9	18	24
27	---	---	---	---	21	.00	.00	[2]1.0	1.3	4.4	16	27
28	---	---	---	---	18	.00	.00	[2]1.5	1.2	2.1	12	21
29	---	---	---	---	---	.00	.00	[2]1.8	.26	3.5	13	24
30	---	---	---	---	---	.00	.00	[2]2.2	.16	5.8	14	33
31	---	---	---	---	---	.00	.00	[2]1.4	---	7.6	15	---
TOTAL	---	---	---	---	---	3,303.00	.00	28.70	64.37	156.04	356.11	602
MEAN	---	---	---	---	---	107	.00	.93	2.15	5.03	11.5	20.1
MAX	---	---	---	---	---	2,370	.00	2.5	17	16	65	37
MIN	---	---	---	---	---	.00	.00	.00	.00	.00	.14	10
AC-FT	---	---	---	---	---	6,550	.00	57	128	310	706	11,190

See footnotes at the end of the table.

Table 25. Daily mean discharges, Santa Cruz River at Sanders Road, near Marana, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	18	18	19	24	24	[2]7.0	11	12	33	10	[2]18	3.8
2	19	21	24	24	29	[2]7.5	93	13	26	11	[2]17	5.3
3	18	23	17	23	34	[2]8.0	4.5	26	25	12	[2]16	6.7
4	20	25	20	26	31	[2]8.0	34	16	26	12	[2]20	8.8
5	18	28	21	25	31	[2]10	27	18	27	9.1	[2]15	9.2
6	20	28	20	35	30	[2]12	11	23	19	10	([1])	7.7
7	21	25	14	44	45	[2]15	21	20	27	16	([1])	7.5
8	19	23	15	23	61	([1])	15	[2]19	33	11	[2]23	12
9	19	17	20	27	47	([1])	11	[2]17	27	12	[2]16	11
10	21	23	21	26	44	([1])	11	[2]16	23	16	[2]13	13
11	19	29	30	24	42	([1])	8.4	[2]20	19	([1])	[2]20	12
12	18	32	24	40	70	67	7.2	[2]18	20	116	[2]15	13
13	21	27	22	36	([1])	11	6.4	[2]17	12	1.8	[2]11	17
14	21	30	17	30	([1])	.00	9.1	[2]14	16	3.5	[2]11	113
15	25	31	19	28	[2]10	.53	14	[2]16	15	[2]6.0	[2]12	3.1
16	20	31	24	30	[2]5.5	6.9	15	[2]16	17	[2]7.0	[2]14	4.2
17	21	26	19	30	[2]5.5	7.6	17	[2]13	17	[2]7.0	[2]15	5.9
18	22	29	61	28	[2]5.5	7.6	13	[2]18	14	[2]10	15	8.1
19	21	27	24	28	[2]5.8	6.7	21	[2]17	6.9	[2]10	11	13
20	19	27	28	30	[2]5.8	7.9	15	[2]21	6.9	[2]12	15	14
21	25	21	25	34	[2]5.8	10	12	[2]23	7.7	[2]14	22	16
22	27	22	24	27	[2]6.0	7.5	13	25	8.9	[2]40	87	14
23	30	21	24	28	[2]6.0	9.5	13	25	9.2	[2]20	30	12
24	29	21	25	26	[2]6.0	5.6	16	16	8.6	[2]20	([1])	13
25	29	24	24	25	[2]6.0	4.5	12	15	9.0	[2]18	([1])	11
26	27	21	21	27	[2]6.5	1.8	11	19	9.2	[2]16	([1])	11
27	32	16	26	29	[2]6.5	10	19	25	8.2	[2]15	3.1	11
28	42	15	28	26	[2]6.5	39	19	31	9.4	[2]13	1.4	14
29	27	13	29	26	[2]7.0	([1])	14	23	10	[2]15	.68	11
30	24	18	29	23	---	([1])	12	31	11	[2]49	1.1	13
31	22	---	29	28	---	42	---	29	---	[2]20	3.2	---
TOTAL	714	712	743	880	---	---	505.6	612	501.0	---	---	414.3
MEAN	23.0	23.7	24.0	28.4	---	---	16.9	19.7	16.7	---	---	13.8
MAX	42	32	61	44	---	---	93	31	33	---	---	113
MIN	18	13	14	23	---	---	4.5	12	6.9	---	---	3.1
AC-FT	1,420	1,410	1,470	1,750	---	---	1,000	1,210	994	---	---	822

See footnotes at the end of the table.

Table 25. Daily mean discharges, Santa Cruz River at Sanders Road, near Marana, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	10	33	18	---	---	---	---	---	---	---	---	---
2	8.2	34	14	---	---	---	---	---	---	---	---	---
3	8.7	33	17	---	---	---	---	---	---	---	---	---
4	9.8	32	49	---	---	---	---	---	---	---	---	---
5	11	24	([1])	---	---	---	---	---	---	---	---	---
6	11	22	20	---	---	---	---	---	---	---	---	---
7	12	20	6.4	---	---	---	---	---	---	---	---	---
8	12	20	22	---	---	---	---	---	---	---	---	---
9	12	23	23	---	---	---	---	---	---	---	---	---
10	12	23	24	---	---	---	---	---	---	---	---	---
11	12	18	26	---	---	---	---	---	---	---	---	---
12	13	21	15	---	---	---	---	---	---	---	---	---
13	13	16	19	---	---	---	---	---	---	---	---	---
14	13	15	26	---	---	---	---	---	---	---	---	---
15	12	17	24	---	---	---	---	---	---	---	---	---
16	11	21	24	---	---	---	---	---	---	---	---	---
17	12	18	25	---	---	---	---	---	---	---	---	---
18	11	16	27	---	---	---	---	---	---	---	---	---
19	15	14	35	---	---	---	---	---	---	---	---	---
20	13	16	31	---	---	---	---	---	---	---	---	---
21	12	16	30	---	---	---	---	---	---	---	---	---
22	12	18	28	---	---	---	---	---	---	---	---	---
23	20	18	31	---	---	---	---	---	---	---	---	---
24	35	13	26	---	---	---	---	---	---	---	---	---
25	32	14	22	---	---	---	---	---	---	---	---	---
26	38	12	21	---	---	---	---	---	---	---	---	---
27	33	14	31	---	---	---	---	---	---	---	---	---
28	35	13	([1])	---	---	---	---	---	---	---	---	---
29	34	15	([1])	---	---	---	---	---	---	---	---	---
30	35	19	([1])	---	---	---	---	---	---	---	---	---
31	33	---	5.8	---	---	---	---	---	---	---	---	---
TOTAL	550.7	588	---	---	---	---	---	---	---	---	---	---
MEAN	17.8	19.6	---	---	---	---	---	---	---	---	---	---
MAX	38	34	---	---	---	---	---	---	---	---	---	---
MIN	8.2	12	---	---	---	---	---	---	---	---	---	---
AC-FT	1,090	1,170	---	---	---	---	---	---	---	---	---	---

[1]Discharge above 140 cubic feet per second. [2]Estimated.

Table 26. Daily mean discharges, Santa Cruz River at Trico Road, near Marana, Arizona, water years 1991–93

[A continuous-record station; published data is not limited to ceiling of 140 cubic feet per second. Dashes indicate no data]

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1991
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	2.1	14	21	0.00	0.00	5.0	0.00	0.00	0.00	0.00	0.00	.00
2	53	13	18	.00	.00	1,660	.00	.00	.00	.00	.00	.00
3	.00	14	17	.00	.00	656	.00	.00	.00	.00	.00	.00
4	.00	12	17	.00	.00	192	.00	.00	.00	.00	.00	.00
5	.00	12	17	75	.00	31	.00	.00	.00	.00	.00	.00
6	.00	13	19	532	.00	.03	.00	.00	.00	.00	.00	.00
7	.00	15	23	166	.00	.00	.00	.00	.00	.00	.00	.00
8	.00	9.6	22	18	.00	.00	.00	.00	.00	.00	.00	.00
9	.00	14	27	.00	.00	.00	.00	.00	.00	.00	.00	.00
10	.00	20	23	.00	.00	.00	.00	.00	.00	.00	.00	.00
11	.00	18	21	.00	.00	.00	.00	.00	.00	.00	.00	.00
12	.00	20	18	.00	.00	.00	.00	.00	.00	.00	.00	.00
13	.03	18	19	.00	.00	.00	.00	.00	.00	.00	.00	.00
14	2.0	12	27	.00	18	.00	.00	.00	.00	.00	.00	.00
15	3.0	11	23	.00	5.2	.00	.00	.00	.00	.00	.00	.00
16	2.4	9.3	74	.00	1.7	.00	.00	.00	.00	.00	.00	.00
17	1.6	9.5	40	.00	1.8	.00	.00	.00	.00	.00	.00	.00
18	3.2	8.2	10	.00	3.3	.00	.00	.00	.00	.00	.00	.00
19	4.6	11	15	.00	3.9	.00	.00	.00	.00	.00	.00	.00
20	5.0	11	12	.00	4.1	.00	.00	.00	.00	.00	.00	.00
21	6.2	13	85	.00	5.2	.00	.00	.00	.00	.00	.00	.00
22	8.6	17	19	.00	4.8	.00	.00	.00	.00	.00	.00	.00
23	7.1	17	11	.00	4.4	.00	.00	.00	.00	.00	56	.00
24	12	14	6.9	.00	3.0	.00	.00	.00	.00	.00	.00	.57
25	16	13	8.6	.00	3.0	.00	.00	.00	.00	.00	5.9	.00
26	15	13	6.2	.00	4.5	.00	.00	.00	.00	.00	.00	.00
27	7.7	20	10	.00	5.4	.00	.00	.00	.00	.00	.00	.00
28	6.6	16	28	.00	3.3	.00	.00	.00	.00	.00	.00	.00
29	4.4	19	293	.00	---	.00	.00	.00	.00	.00	.00	.42
30	6.8	22	182	.00	---	.00	.00	.00	.00	.00	.00	1.1
31	12	---	23	.00	---	.00	---	.00	---	.00	.00	----
TOTAL	179.33	428.6	1,135.7	791.00	71.60	2,544.03	.00	.00	.00	.00	61.90	2.22
MEAN	5.78	14.3	36.6	25.5	2.56	82.1	.00	.00	.00	.00	2.00	.074
MAX	53	22	293	532	18	1,660	.00	.00	.00	.00	56	1.1
MIN	.00	8.2	6.2	.00	.00	.00	.00	.00	.00	.00	.00	.00
AC-FT	356	850	2,250	1,570	142	5,050	.00	.00	.00	.00	123	4.4

CAL YR 1992	TOTAL: 18,670.58	MEAN: 51.2	MAX: 4,310	MIN: 0.00	ACRE-FT: 37,030
WY 1993	TOTAL: 5,214.38	MEAN: 14.3	MAX: 1,660	MIN: 0.00	ACRE-FT: 10,340

See footnote at the end of the table.

Table 26. Daily mean discharges, Santa Cruz River at Trico Road, near Marana, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1992
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	2.3	8.6	7.6	[1]7.0	[1]5.0	0.00	[1]6.5	.00	8.7	0.00	[1]5.5	[1]0.00
2	2.2	9.6	7.3	[1]7.0	[1]10	.00	[1]47	.00	15	.00	[1]2.5	.00
3	2.5	9.3	9.1	[1]6.0	[1]14	.00	[1]3.0	.00	8.7	1.2	.0C	.00
4	2.5	9.2	6.7	[1]8.5	[1]13	.00	[1]14	.00	11	.65	.0C	.00
5	2.6	11	9.5	[1]8.5	[1]13	.00	[1]12	.00	22	.00	.0C	.00
6	2.7	12	6.6	[1]16	[1]12	.00	[1]6.0	.00	5.0	.00	.0C	.00
7	3.4	15	6.3	[1]23	[1]25	.00	2.3	.00	5.3	3.0	323	.00
8	4.3	9.4	5.7	[1]16	[1]95	.00	.00	.00	14	5.2	11	.00
9	4.0	8.0	5.5	[1]9.0	[1]32	198	[1].00	[1].00	12	1.9	.0C	.00
10	4.9	8.8	7.5	[1]8.0	[1]22	169	.00	.00	7.9	2.4	.0C	.00
11	5.5	10	10	[1]6.5	[1]20	56	.00	.00	12	11	.0C	.41
12	5.0	13	10	[1]20	[1]100	16	.00	.00	3.5	39	.0C	1.2
13	5.2	14	3.6	[1]16	554	5.4	.00	.00	4.2	.00	.0C	3.4
14	4.9	14	3.0	[1]10	[1]220	.00	.00	.00	.00	.00	.0C	24
15	6.6	13	5.1	[1]10	137	.00	.00	.00	.00	.00	.0C	.08
16	6.6	13	7.3	[1]10	.52	[1].00	.00	.00	.00	.00	[1].0C	.00
17	6.9	8.6	7.2	[1]10	.00	[1].00	.00	.00	.00	.00	.0C	.00
18	6.2	9.7	24	[1]8.0	.00	[1].00	.00	.00	.00	[1].00	.0C	.00
19	6.0	13	16	[1]8.0	.00	[1].00	.00	.00	.00	.00	.0C	.00
20	5.1	13	9.0	[1]10	.00	[1].00	1.5	.95	.00	.00	1.6	4.9
21	5.2	11	11	[1]13	.00	[1].00	1.6	3.2	.00	.00	2.8	5.7
22	7.1	8.6	7.6	[1]8.0	.00	[1].00	.00	5.5	.00	.00	32	5.2
23	9.0	9.2	5.9	[1]8.0	.00	[1].00	.00	4.0	.00	.00	28	5.4
24	[1]11	9.0	7.3	[1]6.0	.00	[1].00	[1].00	[1]2.0	1.3	.00	373	4.8
25	11	9.2	8.6	[1]5.0	.00	[1].00	.00	.00	.00	.00	134	1.8
26	10	7.0	4.8	[1]7.5	.00	[1].00	.00	.00	.00	.00	7.6	2.5
27	11	6.1	7.0	[1]6.0	.00	[1].00	.00	.00	.00	.00	.0C	3.8
28	12	5.8	13	[1]6.0	.00	[1]20	.00	7.3	.00	.00	.0C	5.3
29	7.8	5.0	12	[1]6.0	.00	[1]500	.00	13	.00	.00	.0C	3.7
30	10	6.9	13	[1]4.5	---	[1]300	.00	26	.00	.80	.0C	2.8
31	11	---	[1]13	[1]10	---	[1]42	---	15	---	8.3	[1].0C	---
TOTAL	194.5	300.0	270.2	297.5	1,272.52	1,306.40	93.90	76.95	130.60	73.45	921.0C	74.99
MEAN	6.27	10.0	8.72	9.60	43.9	42.1	3.13	2.48	4.35	2.37	29.7	2.50
MAX	12	15	24	23	554	500	47	26	22	39	373	24
MIN	2.2	5.0	3.0	4.5	.00	.00	.00	.00	.00	.00	.00	.00
AC-FT	386	595	536	590	2,520	2,590	186	153	259	146	1,830	149

CAL YR 1992 TOTAL: 4,235.40 MEAN: 11.6 MAX: 1,660 MIN: 0.00 ACRE-FT: 8,400
WY 1993 TOTAL: 5,012.01 MEAN: 13.7 MAX: 554 MIN: 0.00 ACRE-FT: 9,940

See footnote at the end of the table.

Table 26. Daily mean discharges, Santa Cruz River at Trico Road, near Marana, Arizona, water years 1991–93—Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR 1993
DAILY MEAN VALUES

Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	2.2	26	11	9.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.00
2	.72	27	11	12	.00	.00	.00	.00	.00	.00	.00	.00
3	1.4	27	13	16	.00	.00	.00	.00	.00	.00	.00	.00
4	2.7	25	35	[1]177	.00	.00	.00	.00	.00	.00	.00	.00
5	3.9	21	159	[1]26	.00	.00	.00	.00	.00	.00	.00	.00
6	5.1	20	32	33	.00	.00	.00	.00	.00	.00	.00	.00
7	8.9	18	.12	508	.00	.00	.00	.00	.00	.00	.00	.00
8	15	20	6.9	1,350	.00	.00	.00	.00	.00	.00	.00	.00
9	4.5	18	14	1,490	.00	.00	.00	.00	.00	.00	.00	.00
10	15	20	10	566	.00	.00	.00	.00	.00	.00	.00	.00
11	9.8	19	6.2	[1]7,000	.00	.00	.00	.00	.00	.00	.00	.00
12	8.7	18	7.3	[1]3,000	.00	.00	.00	.00	.00	.00	.00	.00
13	11	16	5.1	[1]3,500	.00	.00	.00	.00	.00	.00	.00	.00
14	9.8	17	16	[1]500	.00	.00	.00	.00	.00	.00	[1]40.0	.00
15	11	16	16	[1]200	.00	.00	.00	.00	.00	.00	.00	.00
16	11	15	17	[1]100	.00	.00	.00	.00	.00	.00	.00	[1].00
17	11	17	14	[1]500	.00	.00	.00	.00	.00	.00	.00	[1].00
18	12	14	14	[1]4,000	.00	.00	.00	.00	.00	.00	.00	[1].00
19	13	14	24	[1]15,000	.00	.00	.00	.00	.00	.00	.00	[1].00
20	15	14	19	[1]7,000	.00	.00	.00	.00	.00	.00	.00	[1].00
21	12	14	18	[1]1,000	.00	.00	.00	.00	.00	.00	.00	[1]1.0
22	13	13	15	[1]400	.00	.00	.00	.00	.00	.00	.00	[1]1.5
23	17	13	11	[1]200	.00	.00	.00	.00	.00	.00	.00	[1]2.0
24	25	10	12	[1]100	.00	.00	.00	.00	.00	.00	.00	[1]2.1
25	21	12	12	[1]50.0	.00	.00	.00	.00	.00	.00	.00	[1]2.2
26	23	12	2.5	[1]25.0	.00	.00	.00	.00	.00	.00	.00	[1]2.3
27	21	9.3	12	[1]10.0	.00	.00	.00	.00	.00	.00	.00	[1]2.4
28	23	9.0	37	[1].00	.00	.00	.00	.00	.00	.00	.00	2.4
29	25	10	401	[1].00	---	.00	.00	.00	.00	.00	.00	[1]2.4
30	26	11	215	[1].00	---	.00	.00	.00	.00	.00	[1]130	[1]2.5
31	27	---	68	[1].00	---	.00	---	.00	---	.00	[1]20	---
TOTAL	404.72	495.3	1,234.12	46,772.40	0.00	0.00	0.00	0.00	0.00	0.00	190.00	20.80
MEAN	13.1	16.5	39.8	1,509	.00	.00	.00	.00	.00	.00	6.13	.69
MAX	27	27	401	15,000	.00	.00	.00	.00	.00	.00	130	2.5
MIN	.72	9.0	.12	.00	.00	.00	.00	.00	.00	.00	.00	.00
AC-FT	803	982	2,450	92,770	.00	.00	.00	.00	.00	.00	377	41
CAL YR 1992		TOTAL:	6,381.45	MEAN: 17.4		MAX: 554		MIN: 0.00		ACRE-FT:	12,660	
WY 1993		TOTAL:	49,117.34	MEAN: 135		MAX: 15,000		MIN: 0.00		ACRE-FT:	97,420	

[1]Estimated

Table 27. Meteorological data for the study area, water years 1991–93

Month	Monthly percent of annual daytime hours for lat. 32°24' (from table 11)	Temperature, monthly mean, in degrees Fahrenheit	Relative humidity, monthly average, in percent	Class A pan evaporation, in inches per month
		Water year 1991		
October 1991	0.0793	68	41	7.68
November	.0708	57	47	5.14
December	.0701	47	62	2.69
January 1992	.0718	49	68	2.78
February	.0696	58	40	4.86
March	.0838	54	51	6.09
April	.0877	64	24	11.26
May	.0964	73	16	15.76
June	.0962	80	17	14.73
July	.0979	86	29	15.1
August	.0929	84	51	13.55
September	.0834	79	54	10.44
		Water year 1992		
October 1992	0.0793	71	40	8.56
November	.0708	55	54	4.54
December	.0701	51	79	2.92
January 1993	.0718	49	69	3.96
February	.0696	54	70	4.11
March	.0838	57	68	5.28
April	.0877	68	40	9.98
May	.0964	75	37	11.59
June	.0962	83	17	14.47
July	.0979	85	39	13.16
August	.0929	83	60	10.83
September	.0834	81	46	9.79
		Water year 1993		
October 1993	0.0793	70	37	7.76
November	.0708	53	32	4.9
December	.0701	48	82	2.06
January 1994	.0718	53	84	2.08
February	.0696	52	74	2.90
March	.0838	59	60	6.53
April	.0877	67	29	9.52
May	.0964	77	27	12.41
June	.0962	82	15	14.68
July	.0979	85	35	13.41
August	.0929	82	58	9.55
September	.0834	77	45	9.73

09486490 Santa Cruz River at Ina Road, near Tucson, Arizona

Location—The gaging station was at lat. 32°20'17"N, long. 111°04'50"W, in the SE1/4 SE1/4 of sec. 35, T.12 S., R.12 E., in Pima County, Arizona. The gaging station was 10 ft downstream from the left abutment of the Ina Road bridge.

Gage—The gage-height data were collected by a PSS2 stage-sensing and recording unit, including a Setra transducer, a Campbell CR10 datalogger, and a Campbell SM192 electronic data-storage module. The equipment was in a 2x2x4-foot metal shelter. The reference gage was a wire-weight gage mounted on the upstream handrail of the bridge. The equipment was installed and operational on January 27, 1991, and was deactivated January 9, 1993, because of flood damage to the bridge abutment.

History—The WTP channel was 30–60 ft wide and against the left bank of the flood channel. The left bank was steep soil cement, and the right bank had a shallow slope and was edged by grasses, cattails, and shrubs. The channel was straight for 200 yards downstream at which point the channel made a shallow left bend. The upstream channel was straight for about 0.25 mi and then turned east. Upstream, the WTP channel moved to the center of the flood channel, and the banks were highly vegetated.

The channel bed was composed initially of sand and gravel through the reach and had cobbles at the gaging station. Channel control normally existed through the effluent diurnal discharge. The reach filled with sand after the high flows of early March 1991. The channel bed shifted constantly, was sensitive in the diurnal range of the WTP's discharge, and was affected significantly by high flows caused by storm runoff.

An earthen dam was constructed by a landowner on June 14, 1991. The dam, which had two culverts, was installed about 600 ft downstream from the gage. The dam became the gage-pool control for the higher part of the diurnal range of the discharge from the WTP's when discharge exceeded the capacity of the lower part of the culvert section. A large gage pool resulted and was subject to storage at the high of the diurnal discharge. The pool was about 2 acres in area, extended about 200 ft above the gage, and left the gage in backwater. As the pool filled with sand, braided sand riffles became the gage-pool control for lower stages of the diurnal discharge. These riffles were highly sensitive, and the gage-pool control changed daily.

The construction of the dam significantly affected the data collection of stage data and the development of stage-discharge relations. The stage-discharge relation was poor because of the combination of a large gage pool that was affected by storage at the high of the diurnal discharge, subsequent pool fill, and the constantly changing low-stage control.

During WY 1992, high flows breached the dam and caused severe scour through the gage reach that was followed by fill when the dam was repaired. From October 1, 1991, to February 13, 1992, the channel bed filled with sand. High flows during February 13–14, 1992, breached the dam and scoured the reach. The gage orifice was isolated at the low of the diurnal discharge from the WTP's. The site was declared unsuitable for stream gaging, and the stage recorder was removed on February 21, 1992, and replaced on July 27, 1992.

The damage and repair cycle was repeated as a result of storm flows on August 7, 11, and 24, 1992, and September 3, 1992. Channel geometry constantly changed, channel-bed stability was degraded, and the stage record and stage-discharge relation deteriorated.

During the fall of 1992, the channel and the channel bed through the reach filled and regained stability until the high flows of December 27–28, 1992, which caused another dam breach and more channel-bed scour. Discharge from the WTP's bypassed the gage orifice. The flood of January 1993 caused significant channel changes, collapsed the bridge abutment that supported the gage shelter, and weakened the gage. The stage-recording equipment was removed, and the site was abandoned on January 9, 1993. After the flood recession and abutment repair, the site was re-evaluated and was deemed unsatisfactory for data collection. Initially, the site had potential for good quantification of discharge from the WTP's; however, cyclic construction and breaching of the dam downstream and the corresponding excessive channel reach and control fluctuations resulted in a poor record.

09486500 Santa Cruz River at Cortaro, Arizona

Location—The streamflow-gaging station was at lat. 32°21'04"N, long. 111°05'38"W, in the NW1/4 NW1/4 NW1/4 of sec. 35, T.12 S., R.12 E., in Pima County, Arizona. The gaging station was on the center pier under the Cortaro Road bridge on the left bank.

Gage—The gage-height data were collected by a PSS2 transducer unit including a Setra transducer, a Campbell CR10 datalogger, and a Campbell SM192 electronic data-storage module. The equipment was housed in a 2x4x4-foot metal shelter. The original low-stage reference gage was a staff plate mounted to the bridge pier. A wire-weight gage on the left bank and on the downstream guard rail was the high-stage reference gage. The gage was installed on February 21, 1990, and the datalogger was operational on March 2, 1990.

During August 1 to October 19, 1990, the gage was about 600 ft downstream from the bridge on the right bank in a 3x3x4-foot steel shelter. The reference gage was a steel fence post driven into the channel. The gage was reinstalled at the original left-bank site on October 19, 1990. On April 10, 1991, the gage was moved to the downstream side of the bridge about 200 ft from the left bank and adjacent to the Pima County stilling well. A steel fence post driven in the channel was used as a reference gage. The gage was returned to the left bank on May 17, 1991, where it remained for the duration of the study period.

History—The flood channel at the gage was about 800 ft wide and had high, steeply sloping soil-cement banks. The effluent discharge channel, which tended to shift after flows, was 30–60 ft wide and had a sand, gravel, and cobble bed. Initially, storm flows at gage heights of about 7.5 ft would approach full flood-channel width; however, subsequent scouring reduced the gage height of the floodflow by several feet.

If sufficient time occurred after high flows, the effluent discharge channel had significant growth of grasses, cattails, brush, and trees. The vegetation extended beyond the channel edge by 1 to 1.5 times the channel width at the high of the diurnal discharge from the WTP's. High flows caused by rainstorms stripped the channel of vegetation, disrupted the entire 800-foot-wide flood channel, and often left multiple, meandering, recessional channels. The gage was activated on February 21, 1990, on the left bank. The effluent discharge channel moved to the right bank on August 1, 1990, after the high flows on July 24, 1990. Although multiple channels of flow were present for several days, the flow did not extend more than about 150 ft past the gage site. The gage was moved to the right bank in September 1990. The flow from the WTP's, however, abruptly moved back to the left bank, and the gage was returned to the left bank.

In July 1990, the high flows stripped the channel of most vegetation and caused the channel bed to become sensitive in the range of diurnal discharge from the WTP's. The earthen dam that was alternately built, breached, and rebuilt below the gaging station at Ina Road was detrimental and complicated the streamflow-gaging work at Cortaro. The normal channel of the effluent at Cortaro followed the left bank. High storm flows breached the dam on the right side, entered a gravel pit, and exited the pit about 0.25 mi upstream from Cortaro on the right bank, often in multiple channels. The effluent from the WTP's effectively bypassed the gage. When the dam was repaired, the effluent channel returned to the usual left-bank position. This pattern would be repeated many times.

After high flows in March of 1991, the dam at Ina Road was breached. Multiple channels at Cortaro converged toward the right bank in April, and the gage was moved on April 10 in order to include the new channel. Following more high flows, the dam at Ina Road was rebuilt, and the normal effluent channel returned to the left bank. The gage was returned to the left bank on May 17, 1991, where it remained throughout the study period despite subsequent temporary channel displacement. Because the channels were unstable and unpredictable, attempts to move the gaging equipment in order to follow temporary channels did not yield acceptable results.

After high flows in early February 1992, flow again was diverted to the gravel pit and exited on the right bank of the flood channel upstream from Cortaro. Multiple channels were present, and the gage was isolated. The gage was operable again in March when the discharge from the WTP's returned to the left bank after reconstruction of the dam at Ina Road. High flows in August 1992 again breached the dam. Most of the flow moved to the right, and a small portion of flow remained in the channel. By late August, the gaged channel again contained all the effluent from the WTP's, and the channel had begun to stabilize.

The flood of January 1993 scoured 4–6 ft through the reach, left the gage channel dry, and created multiple channels near the right bank. This condition remained until April 1993. After high flows, especially the January floods, the channel bed was stripped of vegetation and was scoured and loosened. Regrowth required several consecutive months without high flows. Following channel displacement of 30–40 ft, vegetation adjacent to the former channel, which included trees, often withered and died. The channel had significant vertical and horizontal movement and shifting with normal diurnal changes in the effluent discharge. High flow in August 1993 scoured an additional 3 ft at the gage, and multiple channels and lack of flow in the gaged channel made the gage unusable until September 1993. High flows caused severe damage to the channel bed and caused channel displacement, which resulted in poor quality of the discharge record. If adequate time occurred to allow stabilization of the channel and channel bed, the record quality was fair to good.

09486510 Santa Cruz River near Rillito, Arizona

Location—The streamflow-gaging station was at lat. 32°23'46"N, long. 111°08'58"W, in SE1/4 NE1/4 of sec. 7, T.12 S., R.11 E., in Pima County, Arizona. The gaging station was on top of the Portland Cement Company conveyor bridge, near the right bank, and about 600 yards downstream from the bridge at Avra Valley Road.

Gage—The gage-height data-recording equipment was a PSS2 unit, and included a Setra transducer, a Campbell CR10 datalogger, and a Campbell SM192 electronic data-storage module. The equipment was enclosed in a 2x3x4-foot metal shelter. The low-stage reference gage was a steel fence post driven into the channel and a point on the gage shelter was established for determining stage during high flow by taping down to the water level.

The original streamflow-gaging station was installed on February 23, 1991, 500 ft downstream and 60 ft shoreward from the left bank. The streamflow-gaging equipment was the same, but was in a 4-foot-diameter corrugated pipe with a steel lid that was set in the ground. This site was destroyed by high flows on March 1–2, 1991, and subsequently was abandoned. After the flood, the channel was dry, and effluent from the WTP's did not reach the gage site until May 8, 1991. When discharge at the site resumed, the gage was relocated to the conveyor bridge.

History—The normal effluent channel was 10–30 ft wide, and moderate flows occupied a channel about 100 ft wide. The flood channel generally was straight for 200 yards upstream and 300 yards downstream where it began a modest right bend. Both upstream banks and the right downstream banks were low and sloping and consisted of sand, gravel, and cobbles. The downstream left bank was nearly vertical and was predominantly sand and cobbles. Grasses occupied the wetted-channel edges when time between high flows was sufficient, and cottonwood, mesquite, palo verde, and various weeds were sporadic in and on the edges of the flood channel.

The channel bed through the reach was composed almost entirely of sand, and was highly sensitive in the normal range of the discharge from the WTP's. The gage-pool control varied from a single channel at the high of the diurnal range of the WTP's discharge to braided sand riffles at lower discharges.

Varying periods at the Rillito gaging station that had no discharge or partial-day discharge from the WTP's followed high flows from storms during which the upstream reach of the channel bed was disturbed. After high flows, there were periods when large quantities of sand were transported through the reach, which was most noticeable after the removal of an earthen dam about 150 yards upstream. The dam protected a ford immediately downstream and effectively stored sand for several hundred yards upstream. A vast quantity of sand was released and moved slowly past the gage when the dam was removed. Sand transport also was evident after several high flows disturbed the upstream reach by severe scour and fill. High flows appeared to produce a residual cyclical movement of bedload sand.

The channel bed was transient sand, unstable, sensitive and responsive in the diurnal range of the discharge from the WTP's. The channel bed at the gage site frequently fluctuated vertically nearly a foot on a day-to-day basis. Horizontal displacement of the channel occurred with any moderately high flow. The constantly shifting sand riffles that were the low gage-pool control and frequent fill-scour cycle of the streambed made the gage-height record poor.

09486515 Santa Cruz River at Sanders Road, near Marana, Arizona

Location—The streamflow-gaging station was at lat. 32°26'06"N, long. 111°14'00"W, in the SW1/4 NE1/4 of sec. 32, T.11 S., R.11 E., in Pima County, Arizona. The gaging station was situated on the downstream side of the bridge at Sanders Road.

Gage—The gage-height data-recording equipment was a PSS2 unit, which included a Setra transducer, a Campbell CR10 datalogger, and a Campbell SM192 electronic data-storage module. The equipment was housed in a 1-1/2x2x4-foot steel shelter attached to the outside of the downstream guard rail, closer to the right bank. The reference gage was a staff plate attached to the left-bank abutment. A reference point was established on the downstream right corner of the shelter for determining stage at high flows by taping down to the water level.

The gage was installed and operational on February 18, 1991. The gage orifice was attached to the pier under the shelter until June 10, 1991. The orifice was moved to the left-bank abutment when the WTP's effluent channel moved after the high flows during March 1–2, 1991. The gaging conditions were too poor to yield reliable data after the flood of January 1993, and the station was discontinued on June 14, 1993.

History—The flood channel at the gage was about 400 ft wide and had a steep soil-cement bank on the upstream right side. The left upstream bank and both downstream banks were sand and gravel of varying slope. The approach to the gage was fairly straight for about 100 yards and then began a shallow bend to the right. The downstream channel was straight for about 300 yards and then turned right.

The high-flow channel diverged about 3 mi upstream and then converged about 300 yards upstream from the gage. Either fork contained the flow from the WTP's after periods of high flow. The WTP's effluent channel was 20–50 ft wide and originally was right of center; however, it moved to the left bank after high flows in May 1991, where it remained for the duration of the gaging period.

The gage-pool control at the high of the diurnal range of the WTP's discharge was the channel, and at the low stages of the diurnal discharge, the control was indeterminate because of a mixture of braided, meandering, shallow channels. The channel bed was predominantly sand. When time between high flows was sufficient, grasses lined the edges of the channel, and hydrophytes, such as filamentous algae and milfoil, were present. The flood-plain channel, which was about 300 ft wide, was sparsely populated with assorted weeds and grasses that were removed by high flows. Multiple, meandering, and receding channels were common after moderate or higher flows, and long periods without flow from the WTP's usually followed high flows.

Shortly after the gage was installed, the high flows of March 1–2, 1990, deposited about 2 ft of sand through the reach. The upstream channel and channel bed were disturbed, and effluent from the WTP's did not reach the gage until about May 11, 1990, when flow reappeared near the left bank in intermittent, partial-day spurts. The gage shelter was left in place, and the orifice line was extended to the channel of the left bank where flow from the WTP's remained through the study period. Throughout the remainder of WY 1991, the discharge from the WTP's dropped to zero at the low of the diurnal range and gradually increased as the channel stabilized. A fill process continued throughout the water year.

Minor inflow was observed on two occasions 100 ft upstream from the gage on the left bank, and may have been irrigation drainage. Sporadic, brief "spiking" of the gage-height record was noted, and may be attributed to additional instances of irrigation-water inflow.

During WY 1992, storm flows continued to be followed by severely reduced, then slowly increasing flows from the WTP's. The abnormal "spikes" in the gage-height record that were observed the previous water year were not present. The cycle of high storm flow followed by zero discharge followed by slowly increasing partial-day flow of WTP's effluent continued into WY 1993. Flooding in December 1992, and January 1993 severely disrupted channel geometry and structure. When the gage was discontinued on June 14, 1993, flow from the WTP's had not consistently reached the gage.

09486520 Santa Cruz River at Trico Road, near Marana, Arizona

Location—The streamflow-gaging station was at lat. 32°28'17"N, long. 111°18'25"W, in the NE1/4 SE1/4 of sec. 15, T.11 S., R.10 E., in Pima County, Arizona. The gaging station was on the left bank 350 ft downstream from the bridge at Trico Road and 50 ft shoreward.

Gage—The original streamflow-gaging equipment was installed and operational on January 23, 1989, and included a water-stage sensing manometer, graphic recorder, encoder, interface, and a Synergetic data-collection platform for satellite communication. Additional equipment included pressure transducers, a Campbell CR21 datalogger, and a Campbell SM192 electronic data-storage module. The manometer, graphic recorder, and data-collection platform eventually were removed, and the transducer and electronic-recording devices were used for stage-data collection. The equipment was in a 4x4x6-foot steel shelter. The low-stage reference gage was a staff plate anchored in the channel, and a high-stage reference point was established on the bridge. Continuous fill in the reach required establishment of a series of low-stage reference points.

History—The flood channel was 150 ft wide and had sloping sand banks when the gage was originally installed. The downstream channel was straight for 300 ft and angled to the right after a steep banked constriction narrowed the channel to 75 ft. Two channels contained the flow from the WTP's during the high part of the diurnal discharge. One channel was 20 ft wide with short, vertical banks, and a second channel was slightly perched towards the right bank at daily peak flow. Before several high flows in March 1991 deposited fill and when stage was above about 2 ft, the two channels overflowed and merged.

The flood-channel bed was composed of sand and gravel, and the channel bed and gage-pool control of the effluent channel contained shifting, unconsolidated sand. The high-flow gage-pool control was the channel that had some edge effect because of vegetation. Grasses and herbaceous plants lined the effluent channels, and mesquite and palo verde trees were sporadically distributed in the flood channel. All grass, weeds, brush, and most trees were stripped from the flood channel by high flows on July 24, 1990, which left a flat and barren bed of sand. The high flow deposited approximately 1.5 to 2 ft of sand. Following subsequent high flows in August 1990, effluent from the WTP's did not reach the site until the beginning of the study period in October 1990.

When effluent from the WTP's returned in October 1990, the gage-sensing lines were reconfigured to adjust for the earlier fill. An experimental, temporary weir was installed in November to direct the flow from the WTP's to the gage-sensor orifice at the low of the diurnal discharge for more complete data collection. The weir functioned well, and the channel bed was stabilized until the high flows and subsequent fill in March 1991.

After flows in March 1991, effluent from the WTP's was not consistently present until late September 1991. After effluent from the WTP's returned, any moderate to large streamflow was followed by periods when the effluent from the WTP's did not reach Trico Road. The channel had no vegetation; however, the channel bed slowly stabilized until storm runoff occurred in February 1992, after which only moderate to high flows from storms flowed down the Santa Cruz River as far as Trico Road. Generally, a fill condition existed throughout WY 1992.

Effluent from the WTP's reached the gage again in October 1992, and sensor lines were raised to accommodate the sand fill through the reach. Storm flows in December again destabilized the channel bed. The channel was filled with more sand that nearly reached the bottom of the bridge. Large volumes of sand were deposited by the floods of January 1993, and filled the channel over the bridge. The high flows spread out from the filled channel on both banks by 0.25 to 0.5 mi, and 1 to 3 ft of fill was deposited in the surrounding area. The recession channel was observed 200 yards north of the bridge.

After the January floods, effluent from the WTP's did not reach the gage until late September 1993. During the spring and summer, construction crews excavated the channel to a depth of about 10 ft and for a distance of 3,000 ft downstream to 4,000 ft upstream from the gage. The resulting channel was about 10 ft deep, 150 ft wide, and had high, steep, erodible banks of sand. The channel bed was loose sand and was flat. The conditions were conducive to channel meandering and a high rate of effluent infiltration. The gage was moved upstream to the left downstream side of the bridge on September 29, 1993, when effluent from the WTP's again reached the site.