WATER RESOURCES AGENCY

M E M O R A N D U M

Monterey County

September 20, 2023

2023 Salinas River Discharge Measurement Series Results

Background

The Salinas River Discharge Measurement Series (River Series) is a streamflow measurement event, conducted annually when conditions allow, that provides information essential to understanding the hydrologic conditions under which reservoir releases and flows in the Salinas River are managed. During the River Series, discharge (streamflow) measurements are collected at multiple locations along the Salinas River in a discreet time period and changes in discharge rates between locations are analyzed to inform the nature of the groundwater-surface water interaction along the channel.

2023 River Series Overview

The 2023 River Series occurred from August 8-10, 2023. Ten discharge measurements were performed by Monterey County Water Resources Agency (Agency) and U.S. Geological Survey (USGS) staff. Overall, the 2023 River Series documented an entirely losing stream (Figure 1) system with a total of 499 cubic feet per second (cfs), or 990 acre-feet per day, leaving the surface water system across the ninety-one sampled river miles. The 2023 River Series recorded less reduction in discharge than in the 2021 River Series, following the overall decreasing trend in the discharge losses[1] since the 2012-2016 drought. Further analysis of the reach-to-reach variations in rates of discharge loss, comparison to historical and recent River Series events, and discussion of factors that may have influenced the 2023 River Series are provided below.

[1] Discharge "loss" refers to discharge (streamflow) rates that decrease with distance from the reservoirs, indicating that surface water is moving into the groundwater system or moving from the land surface to the atmosphere through evapotranspiration.

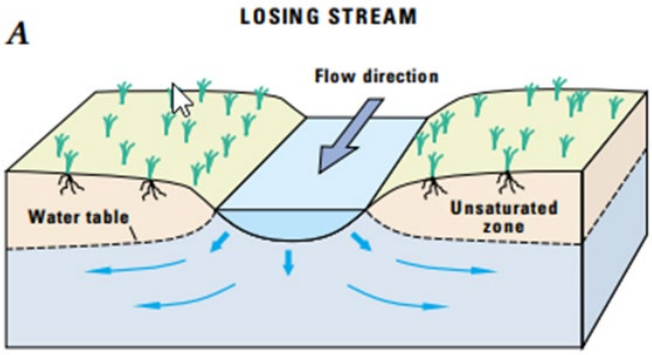


Figure 1. Illustration of a losing stream. (From Oklahoma-Texas Water Science Center https://www.usgs.gov/media/images/illustration-a-losing-stream)

Procedures and Methods

Sample sites were located downstream of Nacimiento and San Antonio Reservoirs, within the lower one hundred miles of the Salinas River watershed (Figure 2). Combined reservoir releases were held approximately constant at 564 cfs for five days prior to, and during, the River Series (Figure 3). This allowed for any variations in discharge to move through the system prior to sampling so that measured changes in flow during the River Series would not be an artifact of changes in reservoir releases.

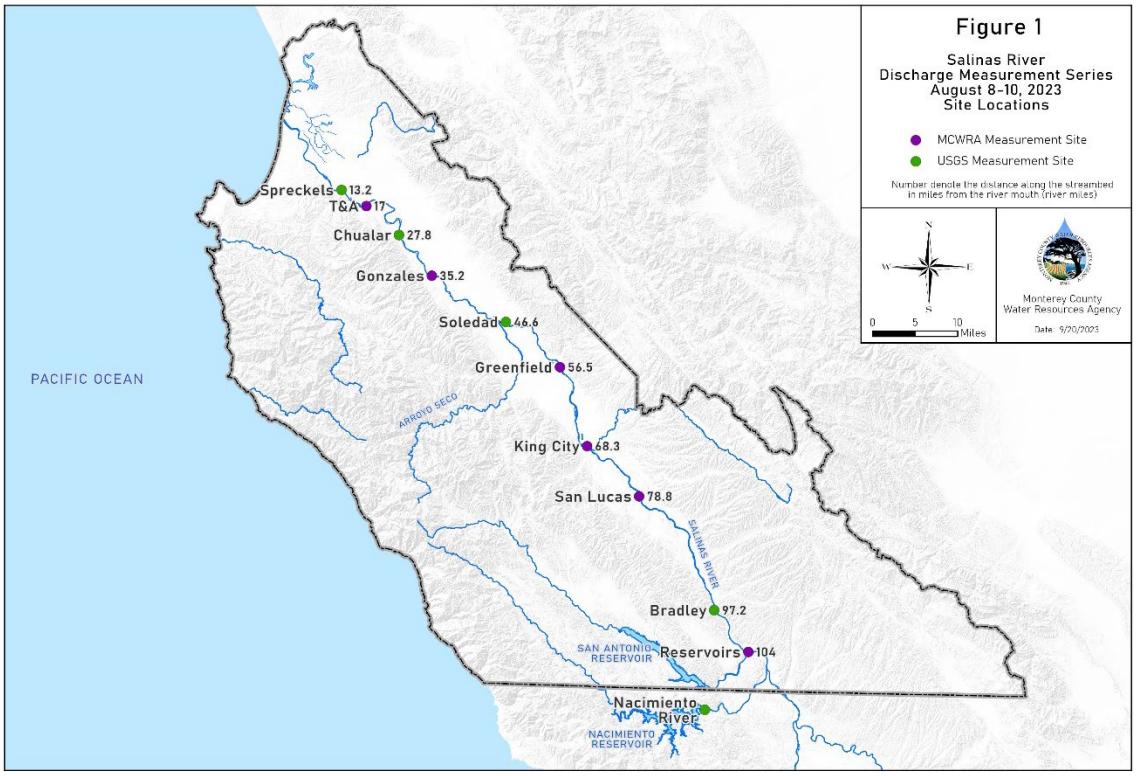


Figure 2. Salinas River Discharge Measurement Series Site Locations

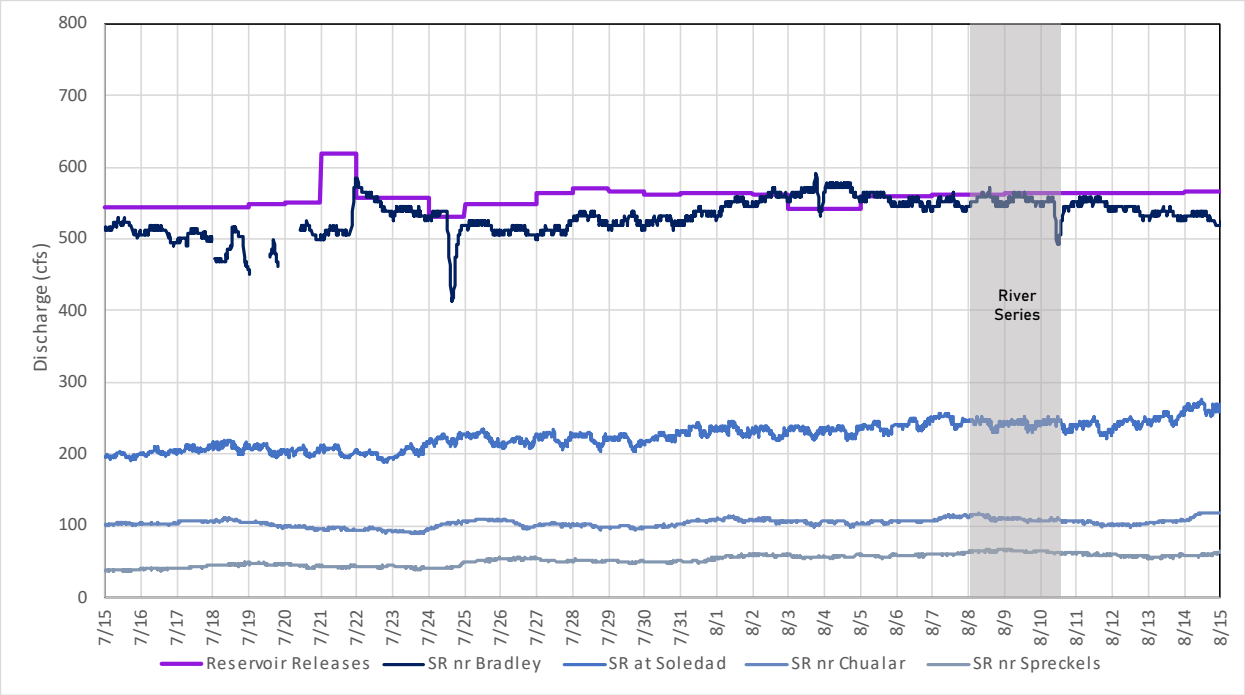


Figure 3. Reservoir Releases and Salinas River Discharge at USGS Gages

River Series measurements were coordinated with USGS staff to coincide with their routine monthly calibration measurements at the five USGS automated gage stations on the Salinas River. USGS staff performed measurements at established USGS gages. Agency staff performed measurements at the following sites: San Lucas (river mile 78.8), King City (river mile 68.3), Greenfield (river mile 56.5), Gonzales (river mile 35.2) and T&A, a site approximately two miles south of the town of Spreckels (river mile 17.0). All Agency measurements were collected using an acoustic doppler velocimeter. USGS measurements were collected using either an acoustic doppler velocimeter or an acoustic doppler current profiler.

Discharge Observations and Analysis

Discharge (Q) results for each site are summarized in Table 1 and graphed by river mile (RM) in Figure 4. The changes in discharge (ΔQ) between measurement sites, referred to as a 'river reach' and reach-to-reach loss rates (ΔQ/RM) are summarized in Table 2.

Table 1. Discharge Measurement Results for 2023 River Series					
Measurement Site Name	River Mile (RM)	Measurement			Discharge Q (cfs)
		Date	Time	Source	
San Antonio Reservoir		8/9/2023	7:00	MCWRA	10*
Nacimiento Reservoir		8/9/2023	7:00	USGS	554**
Combined Reservoirs	104	8/9/2023	7:00	MCWRA	564***
Bradley	97.5	8/8/2023	12:45	USGS	563
San Lucas	78.8	8/8/2023	13:20	MCWRA	479
King City	68.3	8/9/2023	10:13	MCWRA	379
Greenfield	56.5	8/9/2023	14:50	MCWRA	274
Soledad	46.7	8/8/2023	9:50	USGS	247
Gonzales	35.2	8/9/2023	10:11	MCWRA	159.7
Chualar	27.8	8/9/2023	9:50	USGS	114.0
T&A	17	8/10/2023	9:41	MCWRA	62.6
Spreckels	13	8/9/2023	12:12	USGS	64.7

* Reservoir releases as reported by the Agency
** Nacimiento USGS Gage Station
***Combined release from San Antonio releases and Nacimiento USGS Station

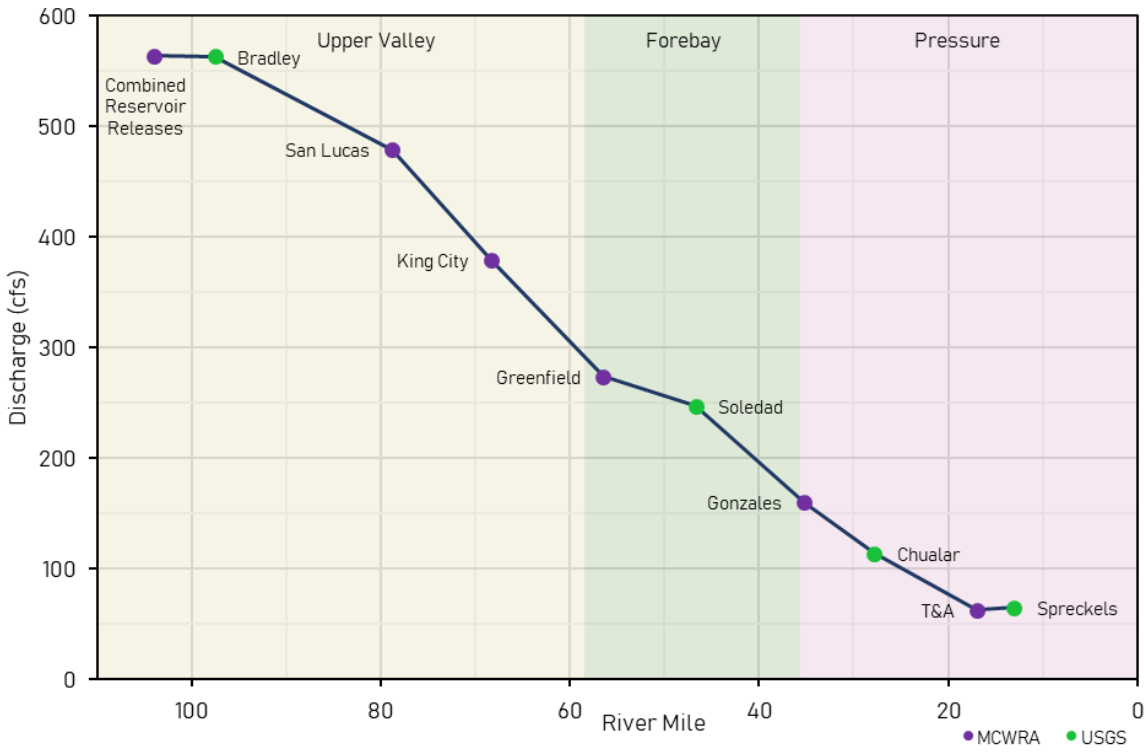


Figure 4. Discharge Measurement Series Results for the 2023 Salinas River Series

Table 2. 2023 Discharge Loss Rates by River Reach					
River Reach	Upstream River Mile	Downstream River Mile	Length of Reach (miles)	ΔQ (cfs)	ΔQ/RM (cfs/mile)
Reservoirs- Bradley	104	97.5	6.5	1	0.2
Bradley- San Lucas	97.5	78.8	18.7	84.1	4.5
San Lucas- King City	78.8	68.3	10.5	100.05	9.5
King City- Greenfield	68.3	56.5	11.8	105.25	8.9
Greenfield- Soledad	56.5	46.7	9.8	26.6	2.7
Soledad- Gonzales	46.7	35.2	11.5	87.3	7.6
Gonzales- Chualar	35.2	27.8	7.4	45.7	6.2
Chualar- T&A	27.8	17	10.8	51.4	4.8
T&A- Spreckels	17	13	4	-2.1	-0.5
Chualar- Spreckels *	27.8	13	14.8	49.3	3.3

* Included for comparison of loss rates discussed in text

During the April through October conservation season, Salinas River flows are maintained by the modulated release of accumulated winter and spring inflow stored in Nacimiento and San Antonio Reservoirs. The Salinas River is predominantly a losing stream, meaning the amount of discharge decreases downstream as water from the river recharges the underlying aquifers, evaporates, or is taken up by riparian vegetation. By contrast, a gaining stream would show an increase in the amount of discharge downstream as groundwater was discharged to the surface water system. Table 1 and Figure 4 show that most of the 2023 measurements decreased downstream, with the exception of the river reach between the T&A and the Spreckels sites. This small increase in discharge is likely due to the measurement uncertainties that the instruments have (± 10%). The 2023 data indicate that the Salinas River is an entirely losing stream for the sampled portion of the river. Taking the difference between the combined reservoir releases and the flow at the furthest downstream Spreckels site, the total discharge lost over the 91 miles of the River Series is:

$$564 \text{ cfs} - 64.7 \text{ cfs} = 499.3 \text{ cfs}$$

Assuming that reservoir releases remained constant over a twenty-four-hour period, this loss rate can be converted to a daily volume for comparison to water stored in the reservoirs. Using a conversion factor of 1 cfs to 1.983 acre-feet/day, this loss rate would equate to 990.4 acre-feet per day between the two sites.

$$1{,}118.7 \text{ acre-feet/day} - 128.3 \text{ acre-feet/day} = 990.4 \text{ acre-feet/day}$$

A total discharge loss of 499 cfs suggests that, on average, 5.49 cfs are lost every river mile. However, discharge does not decrease uniformly throughout the measured system. Variations in loss rates across the different reaches are evident in loss rate hydrographs (Figure 5). These hydrographs compare 2023 discharge loss rates per river mile (ΔQ/RM) to the mean loss rates for each reach. Mean loss rates are calculated using a reference period of 1995-2021, excluding the years in which there was no River Series such as the 2012-2016 drought.

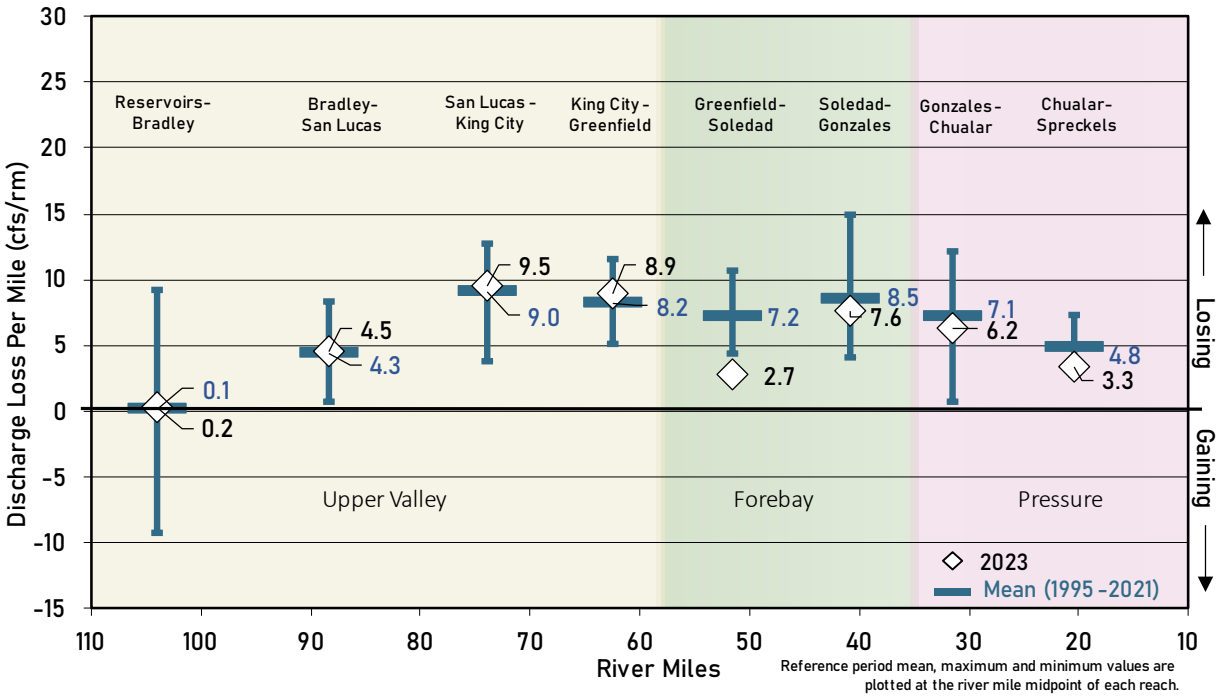


Figure 5. Comparison of 2023 Reach-to-Reach Discharge Loss Rates to 1995-2021 Loss Rate Ranges

Reach-to-Reach Analysis

This section discusses the reach-by-reach discharge losses. Data are also provided in Table 3.

Reservoirs-to-Bradley reach: The reach between the confluence of the Reservoirs and Bradley in the Upper Valley is the only section of the Salinas River that has historically recorded gains in flow, meaning a loss rate less than zero is observed; this was considered to be a gaining reach before the 2012-2016 drought. River Series data collected since the end of the 2012-2016 drought shows that this reach has shifted to a losing reach, including a loss of 0.2 cfs/rm recorded during the 2023 River Series. This reach had the smallest loss rate observed during the 2023 series.

Bradley-to-San Lucas reach: This reach had a loss rate of 4.5 cfs/rm, which is slightly greater than its reference period average of 4.3 cfs/rm.

San Lucas-to-King City reach: Historically, this reach has the highest loss rates in the system (9.0 cfs/rm on average) and it again had the highest loss rate in the 2023 River Series (9.5 cfs/rm). This loss rate was greater than in 2021 (8.6 cfs/rm) but smaller compared to other years (10.6 cfs/rm in 2020, 12.7 cfs/rm in 2019). This reach contains galleries of agricultural production wells in direct hydraulic communication with the Salinas River.

King City-to-Greenfield reach: The 2023 loss rates (8.9 cfs/rm) were greater than the reference period average 8.2 cfs/rm through this reach.

Greenfield-to-Soledad reach: This reach had a loss rate in 2023 (2.7 cfs/rm) that was smaller than the minimum value previously recorded during the reference period (4.4 cfs/rm), and which is the second lowest loss rate recorded during the 2023 event. This phenomenon is likely a consequence of the continuous and relatively large flows recorded during the first five months of 2023 in the Arroyo Seco River, which converges with the Salinas River just south of Soledad, saturating the soil where the Salinas Valley and the Arroyo Seco Cone meet.

Soledad-to-Gonzales reach: The loss rate recorded in the 2023 River Series (7.6 cfs/rm) was lower than the average for the reference period (8.5 cfs/rm).

Gonzales-to-Chualar reach: The loss rate recorded in the 2023 River Series (6.2 cfs/rm) was lower than the reference period average (7.1 cfs/rm).

Chualar-to-Spreckels reach: This is the furthest downstream reach. It had a loss rate of 3.3 cfs/rm in 2023 which is below its reference period average (4.8 cfs/rm), and which is the third lowest loss rate recorded during the 2023 River Series. This reach is located over strata dominated by low permeability clay layers of the 180/400-Foot Aquifer Subbasin.

Overall, during the 2023 River Series, all of the reaches upstream of Greenfield showed loss rates slightly above their reference period averages; most of the reaches downstream of Greenfield showed loss rates slightly below their reference period averages, and the Greenfield-Soledad reach showed a considerably lower loss rate than its reference.

Table 3. 2023 Discharge Loss Rates by River Reach compared to the 1995-2021 Loss Rate Ranges

River Reach	2023 Loss (cfs/rm)	Average Loss (cfs/rm)	Maximum Loss (cfs/rm)	Minimum Loss (cfs/rm)
Reservoirs- Bradley	0.2	0.1	-9.4	9.3
Bradley- San Lucas	4.5	4.3	-0.6	8.3
San Lucas- King City	9.5	9	3.8	12.7
King City- Greenfield	8.9	8.2	5.1	11.5
Greenfield- Soledad	2.7	7.2	4.4	10.7
Soledad- Gonzales	7.6	8.5	4.1	15
Gonzales- Chualar	6.2	7.1	-0.7	12.2
Chualar- Spreckels	3.3	4.8	2.8	7.3

Total System Discharge Losses Discussion

The overall discharge lost during the 2023 River Series can also be compared with the other River Series measurement events since 2017. Figure 6 shows the variability in hydrologic conditions and water year types under which reservoir releases and Salinas River flows have been managed in order to achieve similar discharge rates at Spreckels. For example, water year 2017 was a wet year, followed by a dry-normal year in 2018, a wet year in 2019, a dry-normal year in 2020 and a dry year in 2021. Water year 2022 was also a dry year with no conservation releases and the River Series measurement event was not able to be completed. Overall, there has been a decreasing trend in the amount of total flow lost between the reservoirs and Spreckels since the end of the 2012-2016 drought. Even though there were no reservoir releases apart from conservation releases

during 2022 due to the low levels at both reservoirs that were the direct effect of the scarce precipitation between 2020 and 2022, 2023 has the lowest flow lost between the reservoirs and Spreckels since 2017. This is due to fact the high precipitation received during the January and March storms.

Several factors can impact flows and flow losses in the Salinas River including weather, riparian vegetation, groundwater extractions, surface diversions, the degree of aquifer depletion and antecedent moisture conditions which reflect the degree of saturation in the subsurface. The decrease in flow lost during 2023 is the result of the intense and prolonged periods of rainfall caused by the January and March storms events that saturated the soils beneath the channel, making the infiltration of surface water into underlying aquifers a slower process.

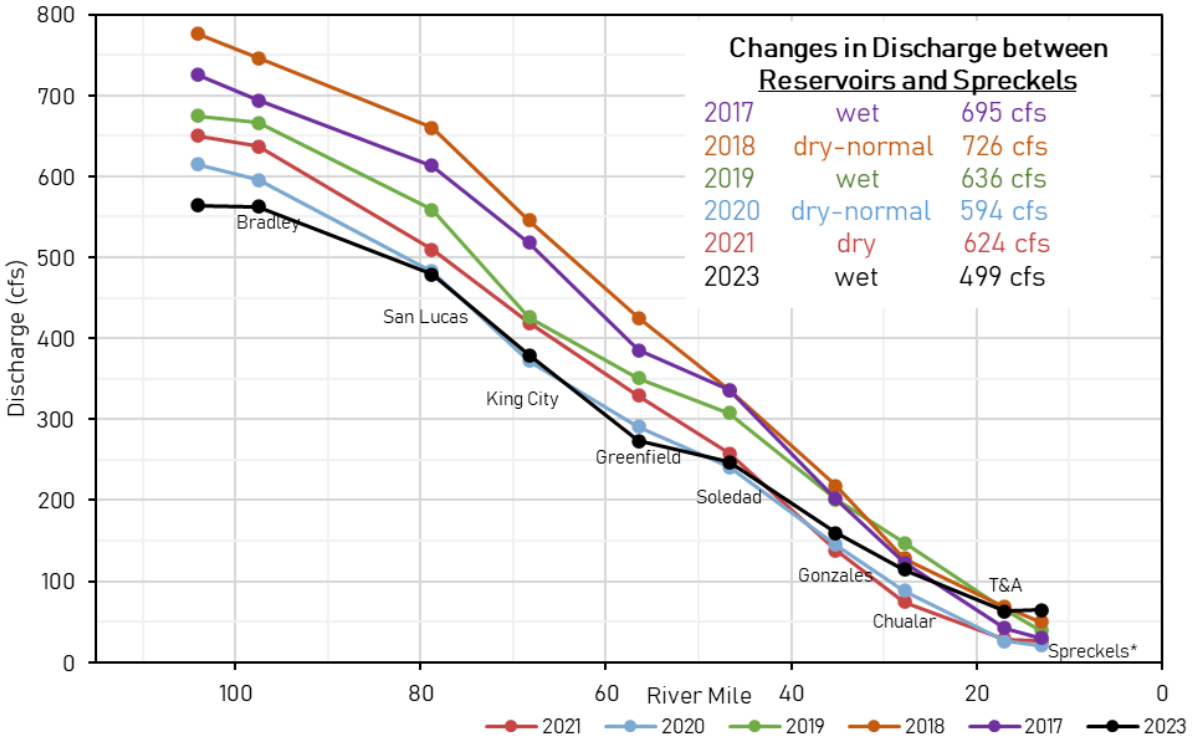
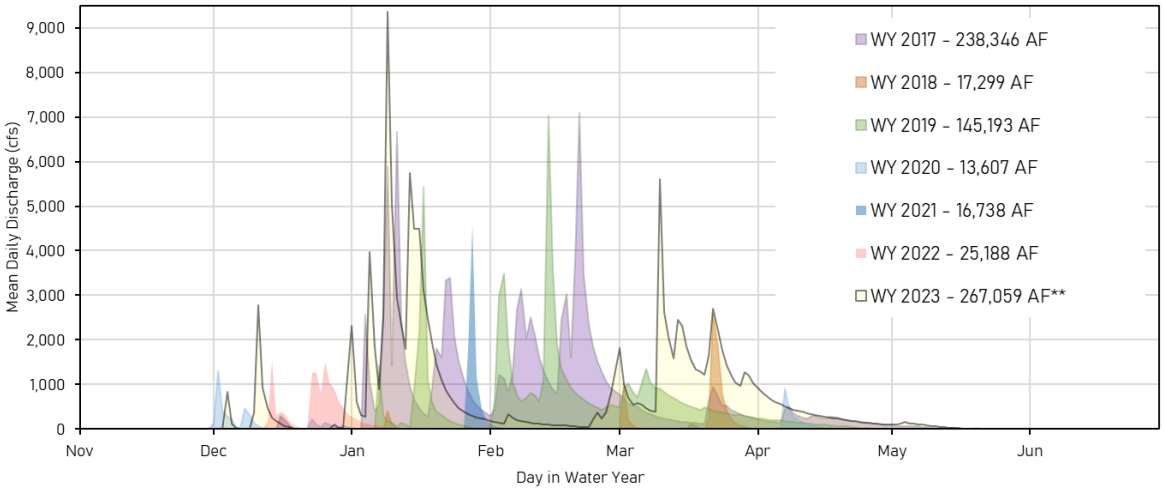


Figure 6. Changes in Discharge between Reservoirs and Spreckels.

One way to evaluate antecedent groundwater conditions is by looking at the water year type and timing of natural discharge in the system. While the River Series occurs in late summer, usually after several months of conservation releases, natural discharge can indicate the amount of groundwater recharge that occurred during the winter and spring recharge period. For example, frequent rainfall over an extended period of time allows for the subsurface to become saturated, which promotes groundwater recharge, while times with episodic storms may only penetrate the top portion of the subsurface and potentially dry out before recharging the aquifers.

There has been a range in the frequency and intensity of natural discharge in the years since the 2012-2016 drought, as illustrated by the mean daily discharge at the USGS Arroyo Seco near Reliz stream gage (Figure 7). This gage is often used to represent unimpaired, natural discharge in the

Salinas Valley watershed. In some years the Arroyo Seco had continuous discharge throughout the winter and spring, while other years only saw a few rain events that resulted in short periodic discharge. Even though each of the 2017-2023 annual River Series events all documented an entirely losing system, the frequency, duration, or intensity of natural discharge was not strongly correlated to the amount of discharge lost during the River Series; an example of this phenomenon is water year 2021. Water year 2023 not only shows an almost continuous discharge between January and May, and had the highest discharge recorded since water year 2017.



*Legend values represent the Total Annual Discharge Volume (in acre-feet) by Water Year at the Arroyo Seco near Reliz gage.
**At the time of this report, WY 2023 data was still being collected. WY 2023 discharge is based on preliminary USGS data and the assumption that there will not be flow in the Arroyo Seco for the remainder of the water year

Figure 7. Mean Daily Discharge by Water Year at the USGS Arroyo Seco near Reliz Gage

Another factor that can influence discharge losses in the river is the degree of aquifer depletion, which can be thought of as the long-term decline in groundwater levels and the decreased amount of groundwater in storage due to pumping. If groundwater levels are lower than average, there is more aquifer storage available to accept recharge from the river system, compared to when groundwater levels are higher. Figure 8 shows the average groundwater elevations in the Forebay subarea over the last decade. The first year of the 2012-2016 drought seems to have had little impact on groundwater levels, but from 2013 to 2016 groundwater levels saw a steep basin-wide decline. In water year 2017, the first wet year following the 2012-2016 drought, groundwater levels showed a rapid recovery, followed by a slower but continual recovery through 2019. By water year 2020, groundwater levels started to stabilize or slow in their recovery compared to the pre-drought levels. The return of groundwater levels to pre-drought levels, except for the Deep Aquifers and the East Side Subarea[2], indicated a lessening in the degree of aquifer depletion by water year 2020. By water year 2021, groundwater levels in the Forebay Subarea started to decline again and by water year 2022 the groundwater levels had dramatically decreased. This declining trend in groundwater levels within the Forebay Subarea shifted at the beginning of water year 2023

[2] The Quarterly Conditions Report shows groundwater elevations for the major aquifers and subareas in the Salinas Valley and is updated every quarter of the water year. These reports can be accessed at: https://www.co.monterey.ca.us/government/government-links/water-resources-agency/documents/quarterly-salinas-valley-water-conditions

coinciding with the previously mentioned high precipitation events, which may explain the lower amount of discharge lost in the 2023 River Series compared to previous years.

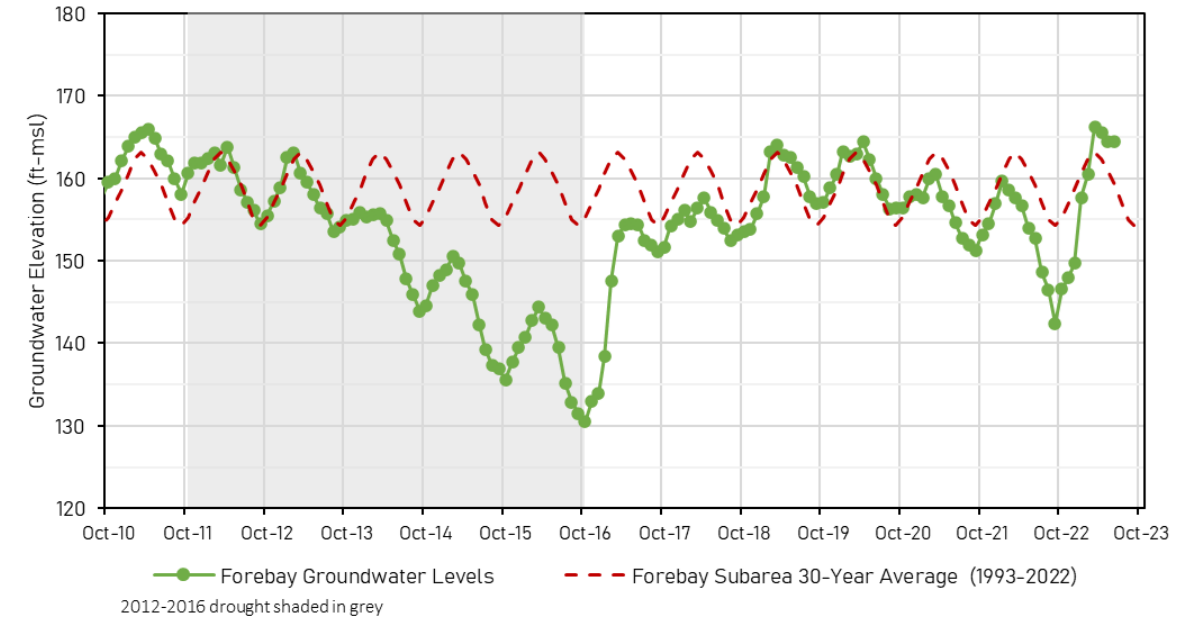


Figure 8. Groundwater Level Trends in the Forebay Subarea

It should be noted that other variables besides natural discharge and the degree of aquifer depletion may need to be considered to better represent antecedent groundwater conditions and their impact on discharge in the Salinas River. The extent to which these variables may contribute to reach-to-reach loss rates in the Salinas River is beyond the scope of this memorandum but warrants further investigation. These variables may be better quantified in the future using tools such as the Salinas Valley Integrated Hydrologic Model (SVIHM).

Conclusion

Overall, the 2023 River Series documented an entirely losing system with 499 cfs, or 990 acre-feet per day, lost across the ninety-one sampled river miles. Most of the reaches saw loss rates similar to their reference period averages except for one reach (Greenfield-to-Soledad) that saw a significant decrease in loss rate. The 2023 River Series recorded less discharge lost than in the previous year, following the overall decreasing trend observed in the River Series since the 2012-2016 drought. This comes as the Salinas Valley had its first wet year after three consecutive water years with dry or dry-normal water conditions, and following the 2023 January and March storm events.